Decision making in environmental management projects is usually complex because of heterogeneous stakeholder interests, multiple objectives, long planning processes and uncertain outcomes. Multiple criteria decision analysis (MCDA) methods are potentially helpful to support decision making in such complex decision situations. However, there are few studies that have systematically evaluated the strengths of MCDA methods in multiple stakeholder settings.

The aim of this study is to analyze the possible contribution of MCDA methods for decision making and conflict resolution in environmental management projects. Thereby, MCDA methods were applied to two river rehabilitation projects: the Thur River in Switzerland and the Alpine Rhine River basin in Central Europe. The principle advantage of the MCDA methods was not in the original setting of a single decision maker, but rather to enhance conflict resolution among stakeholder groups as a result of individual and social learning of stakeholders.

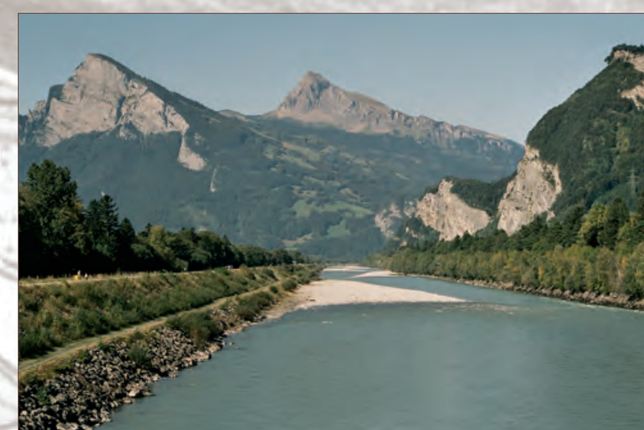
The results of this study indicate that increased application of MCDA methods in multiple stakeholder settings could contribute to conflict resolution and ultimately to more effective and efficient environmental projects.

Decision Support for River Rehabilitation

Hostmann

DISS. ETH No. 16136

# Decision Support for River Rehabilitation

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# Decision Support for River Rehabilitation

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presented by

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# Summary

Decision making in environmental management projects is usually complex because of heterogeneous stakeholder interests, multiple objectives, long planning and implementation processes, and uncertain outcomes. Conflicting stakeholder interests in particular are often an important impediment to the realization and success of a project. Multiple criteria decision analysis (MCDA) methods are potentially helpful to support decision making in complex decision situations. They were originally developed to support the individual decision makers to take decisions in a rational manner. However, studies that have applied MCDA methods indicate that users are often skeptical about the value of MCDA methods to support their individual decisions and prefer the freedom of unaided decision making. In addition, there is a lack of studies that have systematically evaluated the strengths of MCDA methods in multiple stakeholder settings.

The aim of this study is to analyze the possible contribution of MCDA methods for decision making and conflict resolution in environmental management projects. Thereby, we tested the following hypotheses: (1) MCDA methods have a high validity to predict the final preferences of stakeholders and decision makers, (2) the implementation of the MCDA method in the multiple stakeholder setting supports the negotiation and consensus finding process, and (3) the stakeholders and decision makers show a high acceptance of the method mainly due to fact that it helps to support learning and negotiation processes and not because it helps to predict their final preferences. To test these hypotheses, we applied MCDA methods to two real-world rehabilitation projects. First, we applied the multi-attribute value theory (MAVT) method in the multiple stakeholder setting at the Thur River to evaluate stakeholder preferences for different rehabilitation alternatives. Thereby, we conducted three interview phases with a total number of 26 stakeholder representatives testing the three mentioned hypotheses. Second, we implemented the analytical hierarchy process (AHP) focusing on a small group of decision makers to compare and prioritize different rehabilitation sites within the Alpine Rhine River basin.

The results obtained testing the first hypothesis revealed that the MAVT method has a limited validity to predict the final preferences of stakeholders for different rehabilitation alternatives. This is shown by the limited correlation of the MAVT ranking of alternatives and stakeholder final preferences stated for alternatives directly. Hence, one can conclude that the normative model of the MAVT method does not hold for the individual stakeholder. There are several reasons for this finding. First, stakeholders might have difficulties to express and quantify their preferences in such a consistent way as is required by the MAVT method. Second, the rational framework of the MAVT methodology does not include further determinants of stakeholder preferences, such as emotional aspects of stakeholder decisions. In contrast to the multiple stakeholder setting, method’s validity to predict final preferences was slightly better in the decision maker setting at the Alpine Rhine River. This might be due to the fact that decision makers are trained to evaluate the various locations in quite a rational manner and that therefore emotional aspects seem to play a minor role in this decision situation.

The second hypothesis analyzes the question whether the MAVT method can facilitate the negotiation process among conflicting stakeholder groups. The results showed that the majority of stakeholders reconsidered and changed their preferences towards more balanced and consensus-oriented decisions after they had been confronted with the MAVT results. This was mainly due to the fact that the MAVT method supported stakeholders' understanding and social learning. Based on the structured discussion of all objectives, stakeholders became aware of a larger amount of objectives which influence the decision. Since the emphasis of the MAVT method is first to focus on values and later on alternatives that might achieve them, discussions among stakeholders could be carried out in an objective and comprehensive manner. As a result, stakeholders learned more about other stakeholder objectives and preferences and improved their acceptance of other stakeholder opinions (social learning).

The third hypothesis looks for possible reasons for the high acceptance of the MAVT method among stakeholders and decision makers. The results showed that the high acceptance is mainly due to the contribution of the method to support the learning and negotiation process, rather than the prediction of stakeholder final preferences. We arrive at this conclusion through the final discussion with all stakeholders. Thereby, all stakeholders emphasized that the support of learning and elaboration of consensus-oriented solutions is an important result of the method. In contrast, only 23% of the respondents considered the ranking of the alternatives based on the MAVT method to be important for the decision process. This finding might be due to the fact that stakeholders generally prefer the freedom of unaided decision making for their individual decision, but approve the contribution of the method in the multiple stakeholder setting.

This is one of the first studies that conducted an extensive post-evaluation of stakeholders to assess the contribution of the method in real conflict situations. We found that the principle advantage of the MAVT method is not in the original setting of a single decision maker, but rather to enhance conflict resolution among stakeholder groups as a result of individual and social learning of stakeholders. Hence, we conclude that increased application of MCDA methods in multiple stakeholder settings would contribute to conflict resolutions and ultimately to more effective and efficient environmental projects. Furthermore, important conclusions can be drawn for the further methodological development of MCDA methods.

# Zusammenfassung

Die Entscheidungsfindung bei Umweltprojekten ist schwierig wegen unterschiedlichen Interessenspositionen der beteiligten Akteure, sich gegenseitig beeinträchtigenden Zielen, langen Planungs- und Umsetzungsphasen und grossen Unsicherheiten in den Auswirkungen. Besonders unterschiedliche Interessenspositionen verzögern oder verhindern oftmals ein Planungsprojekt. Multikriterienmethoden können bei komplexen Entscheidungssituationen eine mögliche Unterstützung bieten. Ursprünglich wurden diese Methoden für einen einzelnen Entscheidungsträgers entwickelt, um aufzuzeigen, wie rationale Entscheide getroffen werden können. Verschiedene Studien haben jedoch gezeigt, dass die Entscheidungsträger gegenüber den Multikriterienmethoden kritisch eingestellt sind, und ihre individuellen Entscheidungen lieber ohne formale Entscheidungshilfe treffen. Hingegen wurden bisher nur sehr wenige Studien durchgeführt, welche den Nutzen der Methoden für die Konfliktlösung systematisch untersucht haben.

Diese Arbeit hat deshalb das Ziel, den Nutzen der Multikriterienmethoden für die Entscheidungsfindung und Konfliktlösung bei Umweltprojekten zu untersuchen. Dabei wurden die drei folgenden Hypothesen getestet: (1) die Multikriterienmethode kann die realen Entscheidungen der Interessensvertreter gut voraussagen, (2) die Anwendung der Multikriterienmethode unterstützt die Konsensfindung zwischen unterschiedlichen Interessenspositionen, und (3) die Interessensvertreter und Entscheidungsträger akzeptieren die Methode vor allem wegen der Unterstützung bei der Konfliktlösung, und nicht weil die Methode ihre realen Entscheidungen gut voraussagen kann. Diese Hypothesen wurden an ausgewählten Fallbeispielen im Themenbereich Flussrevitalisierungen getestet. Der Fokus im ersten Fallbeispiel (Thur) lag auf dem Einbezug verschiedener Interessenspositionen. Basierend auf der multiattributiven Wertfunktion (MAVT) haben wir die Präferenzen von 26 Interessensvertretern ermittelt und verschiedene Revitalisierungsalternativen für einen Standort verglichen. In zwei weiteren Interviewphasen haben wir die Resultate den Interessensvertretern vorgestellt und deren Feedback erhoben. Im zweiten Fallbeispiel haben wir uns auf eine kleine Gruppe von Entscheidungsträgern fokussiert und eine Priorisierung möglicher Standorte innerhalb des Einzugsgebietes Alpenrhein durchgeführt. Dazu haben wir die AHP Methode (Analytic Hierarchy Process) verwendet.

Die Resultate bezüglich der ersten Hypothese zeigten, dass die realen Entscheidungen der Interessensvertreter durch die MAVT Methode nur begrenzt vorausgesagt werden können. Es resultierte nämlich nur eine begrenzte Übereinstimmung zwischen den Resultaten der MAVT Methode und den realen Entscheidungen der Interessensvertreter. Daraus kann man folgern, dass das normative Modell der MAVT Methode für den Einzelentscheid der Personen nicht haltbar ist. Dafür sind verschiedene Gründe verantwortlich: erstens sollten die Interessensvertreter für die MAVT Methode ihre Werthaltungen genau kennen und quantifizieren können, was oftmals nicht möglich ist. Zweitens werden Entscheidungen vielfach durch Aspekte beeinflusst, welche im rationalen Modell der MAVT Methode nicht abgebildet werden, wie beispielsweise emotionale Aspekte. Beim zweiten Fallbeispiel war die Übereinstimmung der Resultate der Methode mit den realen Entscheidungen leicht besser. Ein Grund dafür ist, dass die Entscheidungsträger die Standorte auch ohne Hilfe der Multikriterienmethode nach

rationalen Kriterien verglichen haben. Zudem haben emotionale Aspekte bei der Entscheidung eine geringere Rolle gespielt.

Die zweite Hypothese untersuchte die Frage, ob die Konsensfindung zwischen unterschiedlichen Interessenspositionen durch die Multikriterienmethode unterstützen werden kann. Hier waren die Resultate positiv, da die meisten Interessensvertreter nach Anwendung der Methode ihre Werthaltungen zugunsten von ausgewogenen und konsensorientierten Alternativen geändert haben. Der Hauptgrund dafür ist, dass die MAVT Methode den individuellen Lerneffekt wie auch den Lerneffekt zwischen den Interessensvertretern gefördert hat. So haben die Interessensvertreter eine grössere Anzahl von Zielen in ihren Entscheidungen berücksichtigt. Zudem diente die Methode als objektive und sachliche Diskussionsgrundlage, da man zuerst über die Ziele und erst in einem zweiten Schritt über Alternativen diskutiert hat. Dadurch konnten die Interessensvertreter die Ziele und Werthaltungen der anderen Gruppen besser verstehen und nachvollziehen.

Die dritte Hypothese untersuchte mögliche Gründe für eine hohe Akzeptanz der Multikriterienmethode bei den Interessensgruppen und Entscheidungsträgern. Die Resultate zeigten, dass die grosse Akzeptanz vor allem auf den Nutzen der Methode für die Konsensfindung zurückzuführen ist, und nicht auf die Voraussage der realen Entscheidungen auf individueller Ebene. So haben in der Schlussdiskussion alle Interessensvertreter betont, dass die Unterstützung der Konsensfindung ein wichtiges Resultat der Methode ist. Im Gegensatz dazu haben nur 23% der befragten Personen angegeben, dass die Rangierung der Alternativen basierend auf der Methode für den weiteren Entscheidungsprozess wichtig sei. Ein möglicher Grund für dieses Ergebnis ist die Tatsache, dass die Interessensvertreter ihre individuellen Entscheidungen lieber ohne formale Entscheidungshilfe treffen, jedoch den Nutzen der Methoden für die Konsensfindung anerkennen und schätzen.

Diese Studie ist eine der Einzigen, welche den Nutzen der Multikriterienmethoden bei realen Konfliktsituationen systematisch und auf Hypothesen basierend untersucht hat, indem die betroffenen Interessensvertreter und Entscheidungsträger direkt befragt wurden. Die Resultate zeigen, dass die Stärke der Methoden nicht in der Unterstützung der individuellen Entscheidungen liegt (obwohl die Methoden ursprünglich dafür entwickelt wurden), sondern in der Konfliktlösung und Konsensfindung zwischen unterschiedlichen Interessenspositionen. Durch eine verstärkte Anwendung der Methoden kann die Konsensfindung bei Umweltprojekten verbessert werden, was sich wiederum positiv auf die Effektivität und Effizienz der Projekte auswirken würde. Zudem können auch wichtige Schlussfolgerungen für die theoretische Weiterentwicklung der Methoden gewonnen werden.

# Contents

# 1. Introduction

## 1.1. Motivation and background

Managing natural resources is a challenging task and there are many different factors which impede this process. To ensure a sustainable use of natural resources, ecological, economic and social aspects have to be balanced. The problem is not only finding the right balance, but also that there are many different people and organizations involved who all have quite different priorities. Further, decisions taken in environmental management projects are often unique and associated with serious and irreversible consequences. This is why the process of decision making plays such a central role in environmental management projects.

This study analyzes how formal methodologies can support the decision making process in environmental management projects. Common decision support methods are Cost-Benefit Analysis (CBA) and Multiple Criteria Decision Analysis (MCDA). We focus on MCDA methodologies, since these methods have significant advantages in supporting environmental management projects: (i) MCDA methods aim to make the trade-offs between different objectives explicit, while CBA reduces the problem to a single monetary value, (ii) MCDA methods promote the learning process of involved stakeholders, (iii) MCDA methods avoid the necessity for monetary evaluation of environmental and social goods, and (iv) MCDA methods bypass many of the theoretical and practical shortcomings of CBA methods.

The modern history of decision analysis - one of the first MCDA methodologies - started with the mathematician John von Neumann and the economist Oskar Morgenstern (von Neumann & Morgenstern 1947). There are many different MCDA models and methods that have been developed and are applied in various areas. Decision analysis techniques are based on a normative model showing how decisions should be taken in a rational manner. Traditionally, they focus on the notion that only a single decision maker is involved. However, since multiple stakeholder interests play an important role in environmental management, there is a need to extend the single decision maker notion. Hence, the aim of this study is to analyze possible contributions of MCDA methods for decision making and conflict resolution in the multiple stakeholder setting.

The evaluation of MCDA methods for conflict resolution can not be studied very well in a laboratory setting; it requires real-world projects with real conflicts. This is one of the first studies that conducted extensive post-evaluations of stakeholders based on pre-defined hypotheses to evaluate method's contribution in real-world conflict situations. Since river rehabilitation projects have all the characteristics of complex environmental management projects, we chose river rehabilitation as our field of interest. It is important to emphasize that the main findings of this study is also transferable to other fields of environmental management.

This study is part of the interdisciplinary Rhone-Thur Project for the scientific support of river rehabilitation projects in Switzerland, initiated and funded by the Swiss Federal Office for Water and Geology (BWG), the Swiss Federal Institute of Aquatic Science and Technology (Eawag) and the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL). This study benefited from the scientific exchange and interaction with several subprojects within the Rhone-Thur Project.

## 1.2. Decision making in environmental management projects

### 1.2.1. Types of decisions

There is a wide range of different decisions people have to take. They can be divided into individual and collective decisions (Bots & Lootsma 2000). *Individual decisions* are made by a single person (or small group of people) and hence, are dominated by a single interest. They mainly affect one person or a small group of people. Many individual decisions are not very complex, such as the decision about the menu for dinner. However, there are also very complex decision situations, for example the choice of education. These decisions have far reaching impacts, and different criteria have to be considered (e.g. personal skills, potential income, job situation, work load). In contrast, there are many decisions which affect a large group of people or the public as a whole *(collective decisions).* Most of the decisions taken in administrations can be regarded as collective decisions.

One important area of collective decisions involves *environmental management problems*. For several reasons, environmental management problems are in many cases complex decision making situations (Figure 1.1):

- Many decisions involve *multiple, sometimes conflicting objectives* which have to be considered (Keeney & Raiffa 1976; von Winterfeldt & Edwards 1986; Clemen 1996). As stated above, decisions in environmental planning projects are often associated with ecological, economic and social objectives (Lahdelma *et al.* 2000). Hence, in such a case, one has to trade off benefits in one objective against costs in the other (Clemen 1996).
- Environmental management projects are often associated with *uncertain outcomes* (Keeney & Raiffa 1976; von Winterfeldt & Edwards 1986; Clemen 1996). For example, imagine that the authority responsible for river management proposes rehabilitation measures to improve the ecological condition of the river. However, prediction of the consequences of alternatives is associated with uncertainty. For instance, it is difficult to predict the impact of different measures on the fish population.
- There are a *large number of decision makers and stakeholders* involved in environmental planning projects. Decision makers are members of a project team which directly influences the decision. Stakeholders are any groups or individuals who can affect or are affected by the achievement of the organization's (or project's) objectives (Freeman 1984). Since the different decision makers and stakeholders represent various interest groups, they often have conflicting preferences. Therefore, a single, objectively best solution does not generally exist, and the planning process can be characterized as a search for acceptable compromise solutions (Lahdelma *et al.* 2000).
- There are *long planning and implementation phases* which may last months to several years or even decades. Further, decisions have to be taken at different phases of the planning and implementation process, and the knowledge gained at an earlier phase may need to be considered at a later phase (adaptive management).

Environmental management projects are projects which either have a significant impact on the environment or which concern about the management of natural resources. Examples for the first category are infrastructure planning projects such as construction of transportation systems (railway, highway), construction of power plants (e.g. hydro power plant) or modernization of waste water treatment plants. The second category involves resource management projects such as protection of biodiversity hotpots or ecosystem restoration. A major field of ecosystem restoration is the rehabilitation of river ecosystems *(river rehabilitation).* River rehabilitation is currently an issue at the top of the agenda for water authorities and river managers in many countries throughout the world (Nienhuis & Leuven 2001; Holl *et al.* 2003). Further, river rehabilitation projects have all the mentioned characteristics of highly complex management projects (see section 1.3). Hence, we chose this field as our case study.

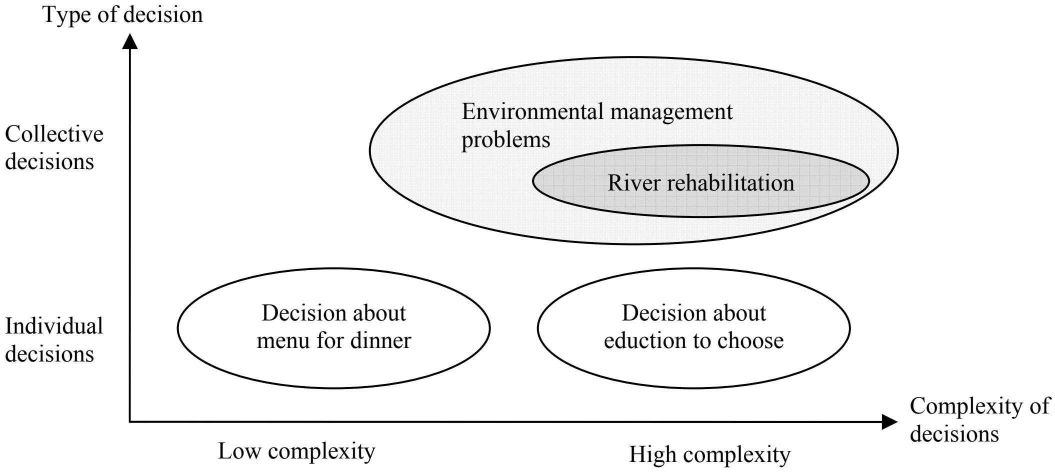


*Figure 1.1: Examples of individual and collective decisions and their complexity.*

### 1.2.2. Problems of unaided decision making

To solve complex decisions without methodological support can be difficult. Findings in behavioral research show consistently that, in experiments and real life situations, "humans are quite bad in making complex, unaided decisions" (Slovic *et al.* 1977). Without any help of methodology, people tend to focus on a small subset of objectives and do not consider the whole range of objectives which might be important (Bohnenblust & Slovic 1998). They respond to probabilistic information or questions involving uncertainty with predictable biases that often ignore or misprocess important information (Kahneman *et al.* 1982). Further, people seem to have little instinctive ability to create a wide variety of alternatives (Keeney 1992) or structure decision tasks (Simon 1990). In short, "there are many reasons to expect that, on their own, individuals (either lay people or expert) will often not make informed, thoughtful choices about complex issues involving uncertainties and value tradeoffs" (McDaniels *et al.* 1999, p.498).

### 1.2.3. Traditional approach of decision support

Formal methodologies such as multiple criteria decision analysis (MCDA) methods can support decision making. MCDA methods act as a framework for collecting, storing and processing all relevant information. Traditionally, major textbooks about decision analysis focus mainly on the two aspects of *multiple objectives* and *uncertainty* (Keeney & Raiffa 1976; von Winterfeldt & Edwards 1986; Clemen 1996). Von Winterfeldt & Edwards (1986) argued that "multiple objectives and uncertainty are the main topics of decision analysis, and addressing them adequately will more than exhaust our competence and your patience" (p. 7). Although Keeney & Raiffa (1976) and von Winterfeldt & Edwards (1986) also emphasized the notion of multiple stakeholders and group decision making, their textbooks mainly concentrate on the individual decision maker. For example, Keeney & Raiffa (1976) stressed that "there are many decision problems in the public sector where the decision maker can be viewed as a well-specified, identifiable, unitary entity" (p. 8).

Decision analysis is based on the *normative (or prescriptive) decision theory*. The normative model aims to show how decisions can be taken in a rational manner (Laux 2005). The rational decision rule prescribes that, among the options available, one should choose the one with the largest subjectively expected utility (SEU) (von Winterfeldt & Edwards 1986). In contrast, the *descriptive model* describes how people actually behave. Behavioral research has shown that people often do not behave according to the rational decision rule (Simon 1979; Kahneman *et al.* 1982). The contrast between the normative model of rational choice and the actual behavior of stakeholders will be an important aspect in the evaluation of MCDA methods within this study. For a more detailed discussion about the normative and descriptive decision theory, please refer to section 2.6.

Since decision analysis traditionally has emphasized the notion of a single decision maker (Losa *et al.* 2001; von Winterfeldt 2001), one might get the impression that there is only one decision maker who has to take the decision at a specific point of time. We will refer to this notion as *single decision maker and single point decision*. However, as we have discussed above, environmental management projects also include the complexity of *multiple stakeholders* and *multi-stage processes* (Table 1.1). Hence there is a need for an extension of the 'single decision maker and single point' notion. Otherwise, the complexity of environmental management projects cannot be properly handled by MCDA methodologies. The main focus of this study is to extend the traditional approach of decision analysis to the notion of *multiple stakeholders and multi-stage processes* and to analyze the major contribution of MCDA methods in the field of river rehabilitation.

*Table 1.1: Complexity of decision problems according to the categories 'objectives and uncertainty' and 'decision makers and stages'.*

| | Single objectives, low uncertainty | Multiple objectives, high uncertainty |
|---|---|---|
| Single decision maker, single point | Decision about which dress to wear. | Traditional approach of decision analysis |
| Multiple stakeholders, multi-stages processes | – | Environmental management projects (e.g. river rehabilitation) |

Table 1.1 also includes decision problems with single objectives and low uncertainty. These decision problems are not very common, since most decisions are characterized either by multiple objectives and/or high uncertainty. Hence, we will not go into further detail into these decision problems.

### 1.2.4. Multiple stakeholder and multi-stage extension

*Multiple stakeholder extension*

There are three main rationales for public involvement in environmental risk decisions: normative, substantive, and instrumental (Fiorino 1990; McDaniels *et al.* 1999). The *normative rationale* “derives from the principle that governments should obtain the consent of the governed, and consequently, citizens have the right to participate in public decision making”. Further, the normative rationale “accepts, as an ethical presupposition, that citizens are the best judge of their own interests”. The *substantive rationale* is that “relevant wisdom is not limited to scientific specialists”, since lay people see problems, issues, and solutions that experts miss. The *instrumental rationale* argues that “broader participation may contribute to better decision making, incorporate a broader range of values into decisions, and reduce the probability of error”. The instrumental rationale reflects the understanding that successful implementation is far more likely with broad public support (National Research Council 1996).

Besides these theoretical rationales, public involvement is required in several pieces of legislation, conventions and international policy documents (United Nations 2000). The EU Water Framework Directive explicitly stresses the importance of public involvement (European Parliament 2000). Another important convention in the field of environmental planning is the Aarhus Convention on access to information, public participation in decision making and access to justice in environmental matters (UNECE 1998). This convention was signed in 1998 by 35 countries and the European Union. The implementation of the three main elements - accessibility, public participation and justice - into European Union legislation is currently in progress. Further, the report of the World Commission on Water notes that in water policy and management, the old model of: ‘This is government’s business’ must be replaced by a model in which stakeholders participate *at all levels* (World Water Commission 2000). Despite the growing policy demands for effective public involvement in river basin management, there are only few guidelines and handbooks so far for public involvement in river basin management published in Europe (Welp 2001).

In the field of MCDA methods, the extension to multiple stakeholders was born out of necessity in the 1980s, when many practitioners of MCDA methods realized that there are usually many more stakeholders involved than just one single decision maker (von Winterfeldt 2001). However, this extension to multiple stakeholders was done primarily in theory, and MCDA methods have only rarely been used as a means for involving stakeholders and the public in public policy decisions (refer to section 1.2.5). Talking about the need of public involvement, one has to be aware that public involvement can also be associated with potential problems (e.g. increased demand of money, time and human resources). Potential goals and risks of public involvement are described in more detail in section 3.2.2.

*Multi-stage extension*

Beyond the extension to multiple stakeholders, researchers and practitioners realized that the MCDA methods cannot be used in isolation from the remaining decision process, but that they have to be integrated within a broader framework of problem structuring and organizational intervention (Belton & Stewart 2002). For most environmental management projects, there are different planning and implementation phases, and each phase has its specific decision making situation (DMS). In addition, the DMS are often connected to a specific spatial scale (national, regional, local). Hence, there is not only one decision which has to be taken at one stage of the process, but many different DMS which occur during the various project phases and are connected to different spatial scales. One has to be aware that the decisions at various stages are often connected to each other. Depending on the characteristics of the DMS, one can choose suitable MCDA methods which then have to be embedded in the decision making process (Guitouni & Martel 1998; Lahdelma *et al.* 2000; Haralambopoulos & Polatidis 2003; Greening & Bernow 2004). We will refer to this as a *multi-stage process*.

### 1.2.5. Need for further research

The extension to the 'multiple stakeholder, multi-stage process' shows that there is research needed at different levels. In general, the number of real-life applications of MCDA methods is increasing quite rapidly (Lahdelma *et al.* 2000). However, there is a lack of tested methods concerning two major aspects:

- *Incorporating stakeholder values*: despite growing consensus on the need for greater public participation in environmental policy, there is a lack of tested methods to explicitly incorporate stakeholder values in decision making (Ananda & Herath 2003a). Similarly, Marttunen & Hämäläinen (1995) conclude that MCDA methods have only rarely been used as a means for involving the public and other stakeholders in public policy decisions. However, there is a growing understanding that MCDA methods might offer procedures to guide public policy deliberations (Gregory *et al.* 2005)
- *Elicitation of stakeholders' feedback*: There are only a few studies in which experiences from real-life applications have been described from the participants' point of view (Marttunen 2005). Merkhofer *et al.* (1997) and Matsatsinis & Samaras (2001) point out that the applicability of MCDA methods needs to be extensively tested in real-world decision making situations so as to measure their importance and contributions in group decision making.

In one of the most comprehensive textbooks about MCDA methods, Belton & Stewart (2002) identified three major foci of research in the field of MCDA methodology:

- *Development of an integrative framework*: One major challenge of future MCDA research is the development of an integrative framework. By specifying key factors which characterize actual or potential MCDA interventions, we can begin to evaluate the extent to which different MCDA methods, individually or in combination, are useful in specific decision making situations defined by combinations of these factors.
- *Implementation research*: An important component of the development of MCDA must be the active pursuit of empirical research to explore the use and usefulness of methods. Such research should encompass, for example: the extent to which the stakeholders understand the process and to which genuine learning occurs as a consequence, and the extent to which shared understanding and agreement is achieved in groups.

- *Methodological research*: Future methodological developments should be fuelled by feedback and by the tensions between theory and practice, as well as by cross-fertilization of ideas between different schools of MCDA and by developments outside the field. Thereby, important categories of research are: 1) the analysis of special demands for particular application areas in which the general assumptions of any single model may not hold very well, and 2) the identification of general weaknesses in MCDA models and the extension of models to address these weaknesses (e.g. treatment of risk and uncertainty in MCDA models).

## 1.3. River rehabilitation as a typical environmental management project

### 1.3.1. Introduction

River rehabilitation projects have all the mentioned characteristics of complex environmental management projects. First, rehabilitation projects have to consider *multiple, sometimes conflicting objectives*. Further, there are *multiple stakeholders* involved, all with conflicting objectives. This is due to the fact that river floodplains and their surroundings are very densely utilized areas. Nowadays, former river floodplains are used for agriculture, infrastructure (such as highways, railways), urban and industrial purposes and water supply. The rehabilitation of the degraded river ecosystems often requires more space for the river. This can lead to significant conflicts with the current utilization of the area. As we will describe in more detail below, rehabilitation projects also consist of *long planning and implementation phases* (section 3.1). Last but not least, rehabilitation projects are often associated with *uncertain outcomes*.

The rehabilitation of aquatic ecosystem is an important task. The current state of aquatic biodiversity is far worse than for forest, grassland and coastal ecosystems (Johnson *et al.* 2001). Rivers were channelized for the purpose of navigation and regulated by weirs and sluices for water resource control and flood defense; habitats were fragmented, and floodplain land was reclaimed for urban and industrial purposes (Nienhuis & Leuven 2001). As a result, 77% of the total water discharge of the 139 largest river systems in North America north of Mexico, in Europe and in the republics of the former Soviet Union is strongly or moderately affected by fragmentation of the river channels by dams and by water regulation (Dynesius & Nilsson 1994). For western and southern Europe, only 0 – 20% of the river ecosystems remain in a natural state (Nienhuis *et al.* 1998). In Switzerland, only about 10% of the streams and rivers are in a natural or near natural condition (BUWAL 1997).

There are different types of measures to improve the ecological status of a river: improvement of the chemical and physical water quality, improvement of the eco-morphological status of the river and rehabilitation of the natural hydraulics (reduction of hydropeaking, increase of minimal flow). In Switzerland, the chemical water quality – measured by conventional parameters like DOC, nitrogen compounds and phosphorous – is usually good (Bundi *et al.* 2000). This is due to the enormous investments made for water treatment plants since the 1960s. Nowadays, in Switzerland, the main deterioration of river ecosystems is caused by degradation of the eco-morphological status and the hydraulics (due to hydropeaking and minimum flow). River rehabilitation has the goal to reinstate and improve the natural dynamics of river ecosystems.

### 1.3.2. Characteristics of rehabilitation projects in Switzerland

River rehabilitation measures started in Switzerland in the early 1990s. This was due to a philosophy change in the Swiss flood protection system from a traditional approach based on river correction and land reclamation to a sustainable approach including more space for running waters (Zaugg 2002, 2005). The fundamentally renewed hydraulic engineering legislation demands that each flood protection project also has to improve the ecological condition of the river (Federal Authority 1991a). The revised water protection law (Federal Authority 1991b) prescribes the conservation of natural aquatic ecosystems. As a result, the majority of rehabilitation projects in Switzerland are a combination of ecological rehabilitation and flood protection. However, one has to be aware that flood protection is the major driving factor for these projects, since it is politically easier to obtain subsidies for combined flood protection and ecological rehabilitation projects, compared to projects which aim to improve the ecological condition only.

Rehabilitation projects are mainly financed by federal and cantonal administrations. Since different administrations are responsible for the projects, it is very difficult to find a comprehensive list of all rehabilitation projects. As an indicator, we analyzed the projects financed by the Federal Office for Water and Geology (BWG). Between 1996 and 2002, the Federal Office for Water and Geology subsidized 138 projects, with a total length of 162km and total costs of 260 Mio. CHF (BWG 2003; Bratrich 2004). The federal administration subsidized two types of projects: 1) projects which mainly improve the ecological conditions of the river, and 2) projects which aim to improve the ecological condition as well as the flood protection level. According to the numbers, 38 projects (28%) belonged to the first category (mainly ecological rehabilitation), and 100 projects (72%) were combined projects (ecological rehabilitation and flood protection). The costs of the 38 rehabilitation projects totaled 25 Mio. CHF (10% of the total costs), while the costs of the combined projects totaled 235 Mio. CHF (90% of the total costs).

The rehabilitation projects in Switzerland have been on a relatively small scale. The average length of a ecological rehabilitation project is about 800 meters, while combined projects are on average 1300 meters in length (BWG 2003). Between 1996 and 2002, there were only five projects with a length greater than 5 km (BWG 2003; Bratrich 2004). These data show that the majority of projects are implemented on a local scale between 500 meters and 5km. The relative cost per meter is 780 CHF/meter for ecological rehabilitation projects, and 1800 CHF/meter for combined projects.

### 1.3.3. Goals of river rehabilitation

There are various aspects which should be included in river rehabilitation projects. Ehrenfeld (2000) refers to three major categories that are currently being used to develop goal statements: rehabilitation of species, rehabilitation of whole ecosystems or landscapes and rehabilitation of ecosystem services (such as water supply, water treatment, recreation and floodwater storage). Henry *et al.* (2002) and Jungwirth *et al.* (2002) point out that a balance between ecological considerations and economic and social considerations is necessary for the legitimacy of a rehabilitation project. However, this balance between different aspects does not have to be full of conflicts. For example, Nienhuis & Leuven (2001) conclude that ecological rehabilitation and flood protection can be regarded as synergistic principles. Not only has research but also practical experience emphasized the importance of the balance of different aspects. According to the federal administration, rehabilitation projects have to include all aspects of sustainability (BWG 2001). This includes environmental aspects (protection of nature), social aspects (flood protection, recreation, etc.) and economic aspects (economic proportionality). A right balance between these aspects helps to increase the acceptance of the project in the population. Bratrich (2004) showed that many rehabilitation projects have been highly accepted in the public after finalizing the rehabilitation measures.

Despite agreement on the important aspects at a general level, one has to be aware that goals for rehabilitation need to be developed appropriately for each project, relative to the scope and reasons for the rehabilitation effort (Ehrenfeld 2000). How to develop and define these goals will be discussed in section 2.2.

### 1.3.4. Types of rehabilitation projects

In Switzerland, most rivers were channelized over the past centuries and the area of floodplains has been drastically reduced. Figure 1.2 (left side) shows the Thur River, which is a typical degraded river system in eastern Switzerland. There are different types of rehabilitation measures applied in Switzerland (Table 1.2). One of the most popular measures is river widening which gives more space to the river. Thereby, the ecological conditions as well as flood protection level are improved. Further positive effects of river widening are the reduction of the erosion of the river bed, and a popular landscape for recreational use. A typical river widening is shown in Fig. 1.2 (right side). Over a length of 2 km, the river has been widened from the former width of 50 meters up to 150 meters. As a result, the river morphology has become more natural, with alternating gravel bars and a natural shoreline. Further, the flood protection capacity has increased from $1100 m^3/s$ to $1300 m^3/s$ (BWG 2004).

Besides river widening, there is a wide range of rehabilitation measures which influence the morphology of the river (Table 1.2). Most of them concern the lateral and longitudinal connectivity (e.g. removal of barriers, reconnection of side channels and oxbows, construction of fish ladder). Further, natural bed load and discharge regimes are also important tasks of rehabilitation measures.

*Table 1.2: Commonly applied river rehabilitation measures in Switzerland classified into the different areas they influence (Woolsey et al. 2005).*

| Area of influence of rehabilitation measure | Rehabilitation measure |
|---|---|
| Influencing morphology | River widening |
| | Removal of culverts |
| | Structuring of the river bed |
| | Improving the river bank |
| | Removal of barriers |
| | Creation or reconnection of side channels |
| | Reconnection of oxbows |
| | Construction of fish ladder |
| Influencing bed load | Removal of bed load collectors |
| | Addition of bed load |
| | Recreation of bed load permeability |
| Influencing the discharge regime | Recreation of near-natural, dynamic discharge and flow regime |
| | Increase of residual flow |
| | Reduction of hydropeaking regime |

*Figure 1.2: The Thur River, Switzerland, at Schaffäuli. Left: before rehabilitation in June 2001. Right: after rehabilitation in May 2004 (Photos by C. Herrmann, BHAteam, Frauenfeld).*

### 1.3.5. Selection of case studies

To analyze possible contributions of MCDA methods for decision making and conflict resolution, we chose two ongoing river rehabilitation projects to be our case studies: the Thur River in Switzerland (chapter 5) and the Alpine Rhine River, an international river stretch in central Europe (chapter 4). We chose these projects for the following reasons: (i) the case studies represented two main decision making situations of rehabilitation projects (comparison of alternatives at the Thur River, prioritization of locations at the Alpine Rhine River), (ii) the responsible authorities for river management indicated that they are open for collaboration with our research project, (iii) the characteristics of the case studies (geographic location, language of the involved countries) facilitated the interview process with stakeholders and decision makers, and (iv) the rehabilitation projects at the Thur and Alpine Rhine River belong to the most important rehabilitation projects in Switzerland. Due to the theoretical and practical relevance of the case studies, the expected results might also be relevant for other rehabilitation projects.

## 1.4. Research questions and goals of the study

The aim of this study is to incorporate MCDA methods in complex environmental management projects as well as to analyze possible contributions of MCDA methods for decision making and conflict resolution. The main research questions of this study are:

1. *Analysis of decision context*: what are the major project phases and decision making situations (DMS) of a river rehabilitation project? How should the MCDA methods be incorporated in the DMS? Thereby, an important question is how can we adapt MCDA methods to the complexities of multiple stakeholder and multi-stage processes?

2. *Implementation research*: what are the contributions of MCDA methods for decision making and conflict resolution in the identified decision situations? To answer these questions, we applied the MCDA methods to ongoing rehabilitation projects at the Thur and Alpine Rhine River and tested the following hypotheses:
   - Hypothesis 1: MCDA methods have a high validity to predict the final preferences of people in a) the multiple stakeholder setting, and b) the decision maker setting.
   - Hypothesis 2: The implementation of the MCDA method in the multiple stakeholder setting supports the negotiation and consensus finding process.
   - Hypothesis 3: the stakeholders and decision makers show a high acceptance of the method mainly due to fact that it helps to support learning and negotiation processes and not because it helps to predict their final preferences.

3. *Generalization and identification of further research*: what are the conclusions of the implementation research? Which findings are not only specific to river rehabilitation, but can be generalized to the whole field of environmental management projects? Which findings might be important for further research in the field of MCDA?

In summary, research question 1 requires a conceptual analysis of the DMS and how MCDA methods can be incorporated in the DMS. Research question 2 calls for verification of the contributions of MCDA methods to real-world applications. Finally, question 3 asks for generalization of the results and potential contribution to further research.

## 1.5. Contents of the book

To answer the research questions, this book is divided into three major sections (Fig. 1.3). The first part 'problem setting' introduces the theme of decision making in the field of environmental management projects and river rehabilitation (chapter 1). Chapter 2 gives a summary of different *decision support techniques*. Thereby, we mainly focus on multiple criteria decision analysis (MCDA) methods, although we also briefly refer to Cost-Benefit Analysis (CBA). This chapter is especially for readers who are not familiar with the formal methodologies of decision support.

To apply and evaluate MCDA methods in the field of environmental management projects, one needs a good understanding of the relevant decision context. Hence, chapter 3 gives an analysis of the *decision context of river rehabilitation*. Thereby, we describe the major project phases and decision making situations (DMS) of a rehabilitation project. We also analyze major objectives and appropriate mechanisms for public involvement for the specified DMS. Based on this characterization, we assess whether MCDA methods in general and which MCDA method in particular might be suitable for the various project phases. Chapter 3 then proposes a new integrative framework for the incorporation of MCDA methods in the field of river rehabilitation.

Based on the integrative framework, chapters 4 and 5 evaluate and test the major contribution of MCDA methods in river rehabilitation projects. Chapter 4 analyses method contributions for a *small group of decision makers* with similar interests. Thereby, we applied the Analytic Hierarchy Process (AHP) to compare and prioritize different locations within the Alpine Rhine River basin based on decision maker preferences. Chapter 5 evaluates the contributions of MCDA in a given *multiple stakeholder setting*. Based on interviews with a wide range of stakeholder groups, we compare different rehabilitation alternatives for a specific rehabilitation site at the Thur River. This was done using the multi-attribute value theory (MAVT) method. We compare the MAVT results to the real decision behavior of stakeholders and elicited stakeholder feedback to the results. Chapter 5 represents the heart of this study as we analyze in detail the strengths and weaknesses of MCDA methods in a multiple stakeholder setting.

The chapter *conclusions and outlook* (chapter 6) compares the main findings of this study with results of previous research. We discuss whether the findings elicited in the field of river rehabilitation can be generalized to the whole field of environmental management projects and give an outlook of important research in the future.

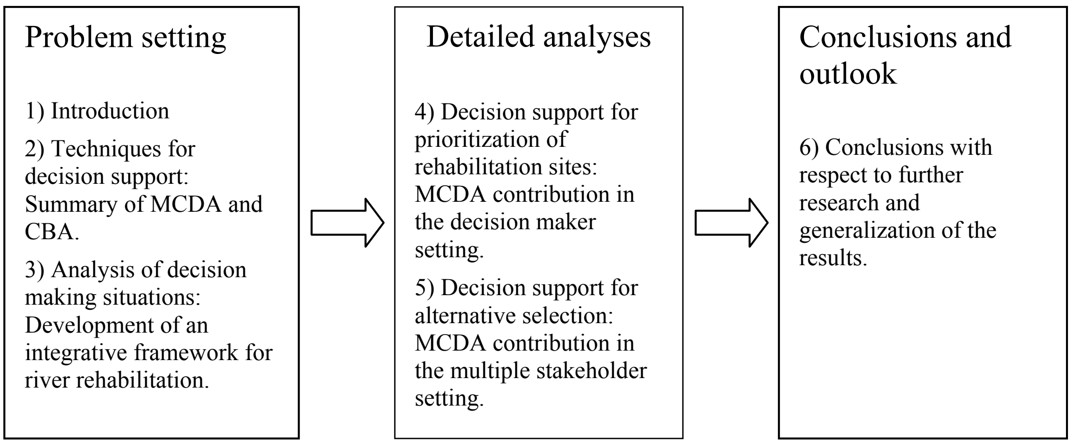


*Figure 1.3: Contents of the book.*

# 2. Techniques of decision support

## 2.1. Introduction

### 2.1.1. Decision support methods

This chapter gives a summary of different multiple criteria decision analysis (MCDA) methods. Based on the definition of Belton & Stewart (2002), *we use the expression MCDA as an umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter*. All MCDA methods aim at supporting complex planning and decision processes by providing a framework for collecting, storing and processing all relevant information (Lahdelma *et al.* 2000). However, the different MCDA methods vary how they process the relevant information. Vincke (1986) and Belton & Stewart (2002) classify MCDA models into three broad categories:

- *Value measurement models* in which numerical scores are constructed in order to represent the degree to which one decision option may be preferred over another. Common methods are multi-attribute value theory (MAVT) (Keeney & Raiffa 1976; von Winterfeldt & Edwards 1986), multi-attribute utility theory (MAUT) (Keeney & Raiffa 1976; von Winterfeldt & Edwards 1986; Clemen 1996; Eisenführ 2003), and the analytic hierarchy process (AHP) (Saaty 1980).
- *Outranking models* in which alternative courses of action are compared pairwise, initially in terms of each criterion, in order to identify the extent to which a preference for one over the other can be asserted. The two most prominent outranking approaches are the ELECTRE family of methods (Roy & Bouyssou 1993; Roy 1996) and the PROMETHEE approaches (Brans *et al.* 1986).
- *Goal, aspiration or reference level models* in which desirable or satisfactory levels of achievement are established for each of the criteria. The process then seeks to discover options which are in some sense closest to achieving these desirable goals or aspirations. A comprehensive review can be found in Lee & Olson (1999).

In addition to the mentioned MCDA methods, *Cost-Benefit Analysis (CBA)* is another well-known decision support methodology. CBA and MCDA are alternative responses to the problem of how to quantify or compare society's overall benefits when one party 'wins' and another 'loses' (Joubert *et al.* 1997). Since CBA is a very common and widespread decision support methodology, we will give a brief summary of CBA techniques and highlight the differences between CBA and MCDA.

### 2.1.2. What can we expect from decision support?

There are different myths which are sometimes associated with MCDA methods (Belton & Stewart 2002). Common myths are that "MCDA will give the right answer" and that "MCDA will provide an 'objective' analysis which will relieve decision makers of the responsibility of making difficult judgments". Being confronted with these myths, it is very important to emphasize that there is no such thing as the 'right answer'. MCDA is primarily an aid to decision making, which seeks to integrate objective measurement with value judgment. Clemen (1996) distinguishes between a 'good' decision and a 'lucky' decision. A good decision aims to carefully consider all information relevant to the decision (alternatives, outcomes of the alternatives and preference trade-offs). However, one has to be aware that you can make a good decision but still have an unlucky outcome. In this way, MCDA cannot improve your luck, but can help to better understand the problems being faced and thus make better decisions (Clemen 1996). Concerning the 'objective' analysis, one has to be aware that subjectivity is inherent in all decision making. MCDA does not dispel that subjectivity, it simply seeks to make the need for subjective judgments explicit and the processes by which they are taken into account transparent (Belton & Stewart 2002).

Hence, the principle benefit of MCDA is to facilitate decision makers' learning about and understanding of the problem faced, about their own, other parties' and organizational priorities, values and objectives, and through exploring these in the context of the problem to guide them in identifying a preferred course of action (Belton & Stewart 2002).

### 2.1.3. Selected MCDA methods

In the following, we will give a more detailed overview of different MCDA methods and the CBA methodology. Within the MCDA methods, we primarily focus on value-measurement models such as decision analysis approaches (MAVT, MAUT) (section 2.2) and analytic hierarchy process (AHP) (section 2.3). We will also give a short overview of outranking models such as ELECTRE and PROMETHEE (section 2.4). The value-measurement models and outranking models are the most commonly applied MCDA methods in environmental management projects (Reichert *et al.* 2005). Section 2.5 describes Cost-Benefit Analysis and highlights differences between CBA and MCDA. Section 2.6 summarizes the differences between the normative and descriptive approach of decision theory and discusses potential violations of the normative model. Finally, we conclude with an overview of the main characteristics of the selected decision support methods (section 2.7).

One has to be aware that this chapter does not aim to give a detailed description of the MCDA and CBA methods. For this, the interested reader should please refer to the corresponding textbooks. For an overview of different MCDA methods, please refer to Belton & Stewart (2002); for a more detailed description about decision analysis approaches, we suggest Keeney & Raiffa (1976), von Winterfeldt & Edwards (1986), Clemen (1996), and Eisenführ (2003). The analytic hierarchy process is described in detail in Saaty (1995) and Schmoldt *et al.* (2001); ELECTRE and PROMETHEE are described in Roy (1996) and Vincke (1999). An overview of CBA methods and environmental valuation can be found in Hanley & Spash (1993) and Hanley *et al.* (1997).

## 2.2. Decision analysis techniques (MAVT, MAUT)

### 2.2.1. Introduction

Decision analysis is based on the normative or prescriptive theory which is concerned how people ideally should reach their decisions. The origins of decision analysis can be traced to the eighteenth-century mathematician Daniel Bernoulli, who held that choice logically depends on the probabilities of the consequences of a decision and the utility (worth) of those consequences to the decider (Merkhofer 1987). The criterion to identify a 'best' alternative is largely the result of Neumann's and Morgenstern's effort (1947) "to find mathematically complete principles which define 'rational behavior'". Savage (1954) introduced the foundation for the *Subjective Expected Utility (SEU)* theory. The SEU model demands that, among the options available, one should choose the one with the largest subjective expected utility (von Winterfeldt & Edwards 1986). There are different axioms required to model decision maker preferences towards risk (for a more detailed discussion, please refer to Savage (1954), Keeney & Raiffa (1976) and von Winterfeldt & Edwards (1986)):

- *Comparability and completeness*: Given any two options *A* and *B*, the decision maker must be able to indicate whether she prefers *A* to *B*, *B* to *A* or is indifferent between the two options. The valuation must be complete in the sense that preferences are formulated for each option.
- *Transitivity*: if a decision maker prefers *A* to *B* and *B* to *C*, then she should prefer *A* to *C*. This property is meant to refer to a static situation. If the decision context changes, then the preferences might change as well.
- *Independence condition*: if the object *A* is preferred to object *B*, then a combination of *A* and any object *C* with stated probabilities is preferred to a combination of *B* and *C* with the same probabilities. This shows that the preferences between two options should be independent of their description.
- *Sure thing principle*: if one option is better than another in one state and at least as good in all other states, the dominant option should be chosen. According to von Winterfeldt & Edwards (1986), "the sure-thing principle is the cornerstone of SEU theory, and its violation would cast strong doubts on the applicability of the theory" (p.323).

The normative model implies that a decision maker has to choose the option with the highest subjective utility if she accepts the axioms of rational choice (Eisenführ 2003). The relation between the normative and the descriptive theory (which is concerned with understanding and predicting how people actually reach decisions) is discussed in section 2.6.

### 2.2.2. Methodological framework[1]

In the following, we describe a general procedure of how decision analysis techniques can be used to support river rehabilitation decisions. The procedure is divided into seven steps.

Step 1: Definition of the decision problem
Step 2: Identification of objectives and attributes
Step 3: Identification and pre-selection of alternatives
Step 4: Prediction of outcomes
Step 5: Quantification of preferences of stakeholders for outcomes
Step 6: Ranking of alternatives
Step 7: Assessment of results

These steps are mainly derived from the existing decision analysis literature. However, as described in more detail below, we will integrate a stakeholder involvement procedure with the primary goals of consultation and consensus-building. The stakeholder involvement aspects are mainly dealt with in steps 1-3, 5 and 7, whereas step 4 is based on scientific analysis and step 6 is a technical integration step, the results of which are interpreted in step 7. The seven steps are briefly described in the following sections in the context of decisions about river rehabilitation measures.

***Step 1: Definition of the Decision Problem***

Defining the decision problem is an important first step to set the framework for the subsequent steps of the decision support procedure. Two aspects of the decision problem are important to address: the scientific or technical part of the problem and the socio-economic part which, for public sector decisions, is intimately linked to the stakeholders involved in, or affected by, the decision.

In environmental management, the core of the scientific part of the problem is often a sustainability deficit of material flows or a disruption of habitats in ecosystems. The description of this part of the problem can be difficult because of lack of precise knowledge about the relevant mechanisms in the ecosystem. The definition of the desired state to be achieved links the natural scientific part of the problem to the socio-economic part, as it is up to society to decide in which environment we would like to live. A handle to the socio-economic part of the problem is obtained by performing a stakeholder analysis with the goal of eliciting their preferences and supporting consensus-building for a rehabilitation project (World Bank 1996; Grimble & Wellard 1997). Both assessments should be made at different spatial and institutional levels and confirmed or extended by the identified stakeholders.

***Step 2: Identification of Objectives and Attributes***

An objective is something a decision maker (or stakeholder) would like to achieve, and attributes are measurable system properties that can be used to quantify the degree of fulfillment of the objectives. Identification of objectives and attributes is the second step

[1] *This section consists of an excerpt of the article:*
Reichert P., Borsuk M., Hostmann M., Schweizer S., Spörri C., Tockner K. & Truffer B. (2005) Concepts of decision support for river rehabilitation. Environmental Modelling and Software, in press.

of the decision support procedure to ensure that the goals are laid out explicitly and that the correct and complete objectives are addressed by the alternatives, model and valuation processes. When combining decision analysis with stakeholder involvement, as suggested in this paper, objectives and attributes should be assessed from representatives of all considered stakeholder groups (traditionally they have been elicited from the single decision maker). This can best be done as a first part of the interview for the elicitation of stakeholder preferences in step 5. An objective hierarchy developed initially by scientists, such as that described below, can be useful to reduce the elicitation process and to serve as a check for completeness and adequate complexity.

*Objectives*

Objectives can be divided into fundamental objectives (directly related to what a decision maker would like to achieve) and means objectives (that lead to the accomplishment of fundamental objectives). Fundamental objectives are usually structured hierarchically according to their degree of concreteness (Clemen 1996; Eisenführ 2003). The objectives at each level of such a hierarchy should be mutually exclusive and collectively exhaustive (Keeney 1992). When applied to ecological goals, exhaustive means that all the most relevant aspects of ecosystem structure and function are represented. At lower levels of the objectives hierarchy, this needs a selection of sub-objectives that are indicative of the objective at the higher level; however, in this context, exhaustive cannot mean describing all aspects of the higher objective. For example, in the context of prediction of a future state of the system, biodiversity cannot be represented by the densities of all species. Instead, indicator organisms or functional groups must be used. Figure 2.1 provides a proposed hierarchy of fundamental objectives for a rehabilitated river reach. This hierarchy can serve as a guideline for other river rehabilitation projects. It was developed by scientists involved in the multidisciplinary Rhone-Thur project for support of river rehabilitation projects in Switzerland (Peter *et al.* 2005).

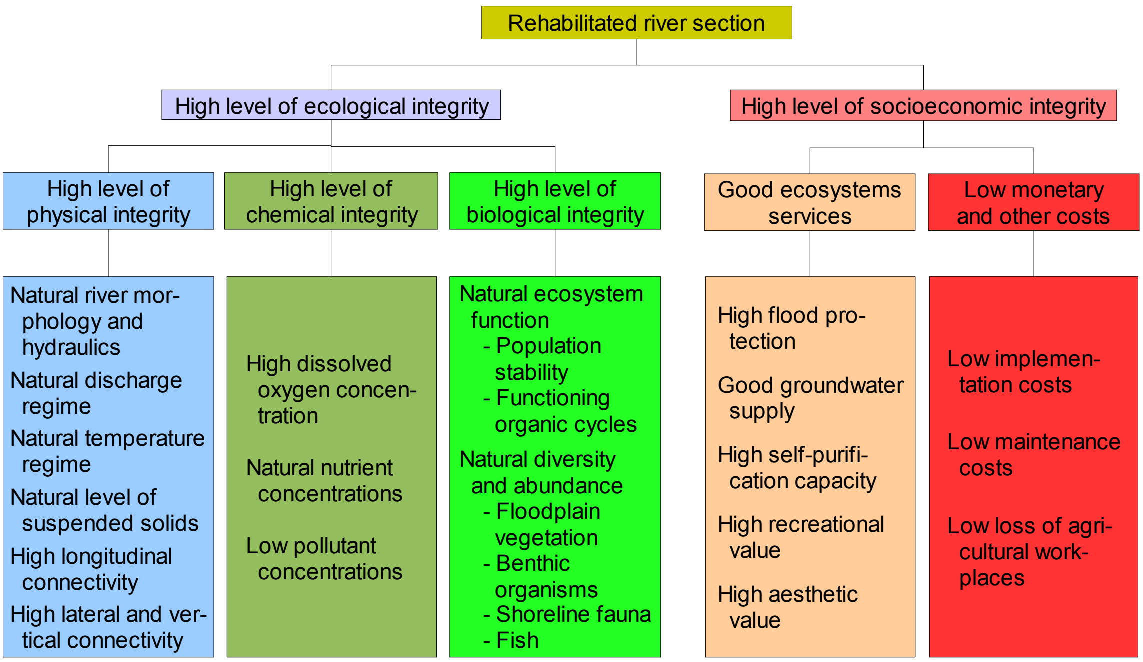


*Figure 2.1: Objectives hierarchy of a river rehabilitation project.*

*Attributes*

Careful selection of attributes is often overlooked in the rush to quantitative analysis. However, this is an important step as it provides the link between social objectives and scientific predictions. The lowest level objectives of the hierarchy shown in Figure 2.1 can be characterized by attributes. In some cases, these attributes can easily be used to quantify the degree of fulfillment of the corresponding objective. However, in other cases, the chosen attributes are a compromise between a good characterization of the objective and reasonable prediction accuracy. Care should be given to the problem that the attributes which are easier to predict not lead to too large an increase in the uncertainty of the value assessment step.

***Step 3: Identification and Pre-Selection of Alternatives***

To make the analysis concrete and limit the required effort of the analysis procedure, the next step of the decision support procedure is to identify and pre-select decision alternatives. Important options for rehabilitation of river sections include (Woolsey *et al.* 2005): local river widening, removal of culverts, structuring of the river bed, improving the river bank, removal of barriers, creation or reconnection of side channels, reconnection of oxbows, reconnection of floodplains, and construction of fish ladders. Decision alternatives typically consist of combinations of some of these measures with flood protection measures for cultivated or urban land. Some flood protection measures, such as retention basins, may increase the area of occasionally flooded terrestrial habitat. An assessment of the results of step 7 can help to derive new compromise alternatives. This leads then to an iterative use of the outlined procedure.

***Step 4: Prediction of Outcomes***

Once the alternatives to be included in the analysis process have been identified, their consequences must be predicted. This is done in step 4 of our decision support procedure. Predicting ecological consequences of rehabilitation measures is a difficult task. However, it is important to explicitly pursue this task as legislation in many countries states good ecological status to be a major goal to be achieved for all water bodies (an important example is the European Water Framework Directive (European Parliament 2000)).

Prediction of the consequences of rehabilitation measures requires a model of cause-effect relationships. Such a model must combine knowledge from all available sources, such as basic scientific knowledge, specialized literature, more detailed models, measured data, and expert knowledge. Probability network models provide a very useful model structure to combine different types of knowledge, divide a model into more easily tractable sub-models, and explicitly consider prediction uncertainty (Pearl 1988; Charniak 1991; Reckhow 1999; Borsuk *et al.* 2004). They consist of two components: (1) a graphical depiction of the most important cause-and-effect relationships among variables in the system, and (2) conditional probability distributions describing how each variable changes in response to changes in its causal parents. Because of the advantages described above, we decided to build the first integrative model of rehabilitation measures as a probability network. The graphical model in Figure 2.2 shows the causal relationships between the main variables describing the rehabilitation project and some of the decision attributes. This formed the starting point of model construction. More detail was then added by resolving the dominant relationships, adding important influence factors and identifying the boxes in Figure 2.2 as sub-models of an integrative model to predict the consequences of the rehabilitation measures. This resulted in the diagram shown in Figure 2.3.

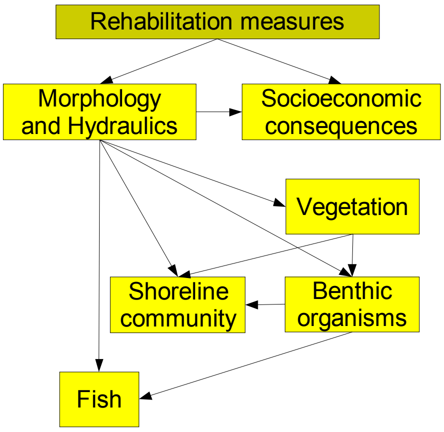


*Figure 2.2: Important relationships between consequences of river rehabilitation measures.*

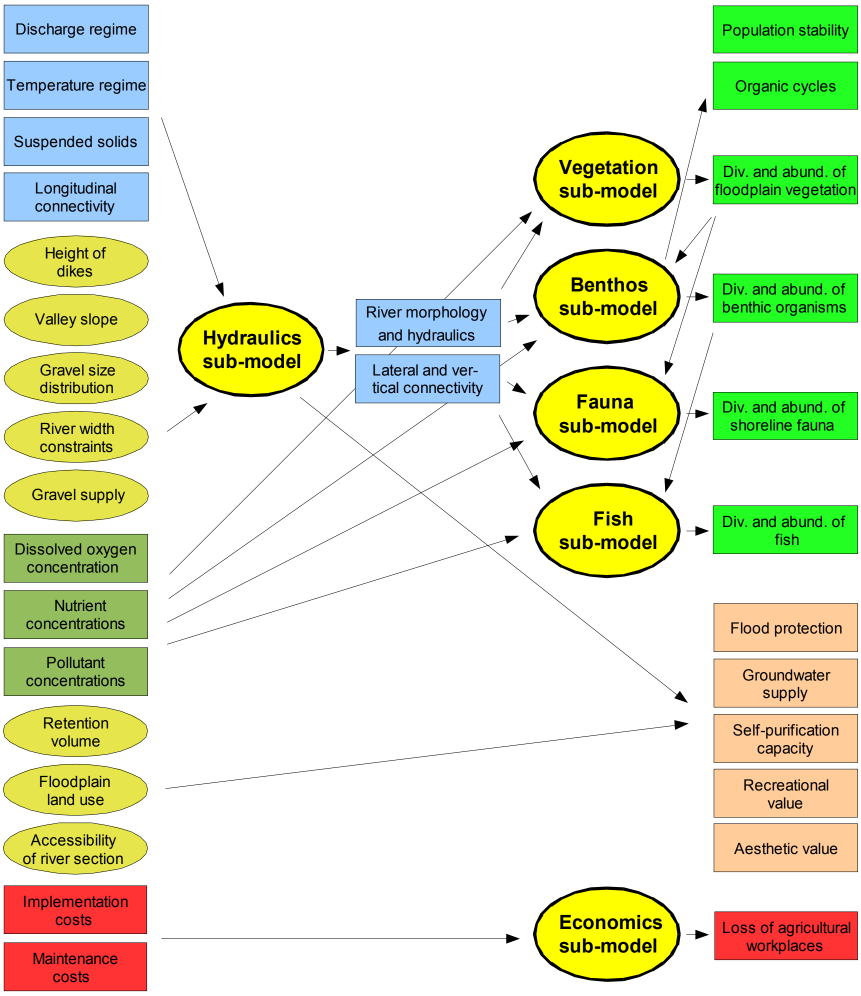


*Figure 2.3: Overview of the integrative model for the prediction of outcomes of decision alternatives for river rehabilitation. The rectangular nodes represent fields of assessment corresponding to objectives listed in Figure 2.1, the round nodes represent additional required inputs used to characterize the decision alternatives. Nodes in the left column represent model inputs (some of them influenced by the decision alternative), nodes in the central column intermediate nodes, and nodes in the right column model outputs.*

***Step 5: Quantification of Preferences of Stakeholders for Outcomes***

After having estimated the attribute ranges characterizing the outcomes of all decision alternatives, the preferences of decision makers or stakeholders for possible outcomes are elicited in step 5 of the decision support procedure. There exist several approaches for the quantitative representation of preferences of decision makers or stakeholders (Belton & Stewart 2002). In this section, we will refer to the value and utility function approaches of decision analysis (further approaches will be discussed in the next sections).

A value function is used to characterize an individual's preferences for outcomes by assigning a higher value to a more preferred outcome. Value functions are usually normalized to provide outputs between zero and unity for the least and most preferred combination of attributes, respectively. Such value functions have been proven to exist under very general assumptions of consistency and completeness of preferences (von Winterfeldt & Edwards 1986; Eisenführ 2003). As the value function is a mathematical construct that does not have its counterpart in the mind of the individual, elicitation should be done by asking the individual for preference orders or indifference between attribute combinations characterizing different possible outcomes and not by asking the person to specify values for outcomes directly. The value function is then constructed as a mathematical representation of these preferences. To facilitate the elicitation process, it is often assumed that the multi-attribute value function has the form of a weighted sum of single-attribute value functions. It should be realized, however, that the use of such additive value functions strongly limits the types of preference structures that can be represented.

The use of additive value functions may be a less severe restriction at higher levels of aggregation of the objectives hierarchy as they can represent trade-offs that have to be made between ecological and social goals. However, within the branch of ecosystem integrity there are certainly branches that cannot be represented by an additive function. Examples include abundances of species within different functional groups that can only be substituted by other species to a limited degree. In this case, achieving a reasonable ratio of species within different groups may be more important than maximizing the abundance of species within a particular functional group. Such preferences have to be represented by non-additive value functions or by using ecosystem diversity indices.

Value functions do not include information about risk attitudes of individuals or groups. Such risk attitudes can be considered by using utility functions instead of value functions (von Winterfeldt & Edwards 1986; Eisenführ 2003). Elicitation of utility functions, however, is much more difficult then elicitation of value functions because individuals have to be asked to express their preferences between probabilistic outcomes (typically lotteries of two different outcomes). Furthermore, utility functions alone do not allow the analyst to distinguish between non-constant marginal value and risk attitudes (Dyer & Sarin 1982; Eisenführ 2003). For this reason, it may be desirable to elicit value functions first and then consider risk attitudes by asking a second set of questions based on a small subset of attributes. This procedure would be much easier but is based on the assumption that risk attitudes are independent of the attribute for which they are elicited (Dyer & Sarin 1982).

When eliciting values or utilities of stakeholders for the attributes corresponding to the lowest level objectives in the objective hierarchy for river rehabilitation, two main problems may arise. First, the stakeholders may not be able to specify their preferences at such a detailed level of ecosystem description because they do not have sufficient knowledge of the importance of the different sub-objectives to overall ecosystem structure and function. Second, the elicitation process takes much time because of the large number of attributes. There are two options to overcome this problem. First, the objective hierarchy could be simplified by using objectives and corresponding attributes at a higher level of the objective hierarchy. The problem with this approach is that it is more difficult to find good attributes at higher hierarchical levels. One can use visualization of a semi-quantitative scale of ecological integrity to overcome this problem. An alternative would be to elicit value functions for detailed attributes related to ecosystem integrity from scientists and then let the stakeholders only assess the weights of these objectives relative to others based on a description of the range of possible outcomes. This procedure would facilitate the use of an additive value function at the higher aggregation level of the objectives hierarchy with weights provided by the stakeholders while still being able to switch to other forms of value functions within the ecosystem integrity branch.

***Step 6: Ranking of alternatives***

After having carefully predicted the outcomes of all alternatives and their associated uncertainties based on the scientific analysis in step 4 and having quantified the preferences of stakeholders and decision makers for the outcomes in step 5, these two aspects of the decision problem are merged to result in rankings of alternatives. Depending on the consideration of risk attitudes in the elicitation of preferences, we must distinguish two cases. When utility functions are elicited, a unique ranking can be derived for each decision maker or stakeholder group based on decreasing values of expected utilities calculated using the probability distributions of outcomes. As value functions do not contain information on risk attitudes, only probability distributions of rankings of the alternatives can be derived using probability distributions of outcomes and value functions. These probability distributions must be discussed with the stakeholders or decision makers to find the preferred alternative that also considers the risk attitude. Note that high prediction uncertainty of attributes does not necessarily lead to wide distributions of rankings of alternatives, as probability distributions of differences in predicted attributes may be much narrower than the distributions of the attributes themselves (Reichert & Borsuk 2005).

***Step 7: Assessment of Results***

The preference rankings in step 6 summarizing the results of steps 1 to 5 are useful results for the decision maker. However, even more useful are the insights gained by the application of the procedure and subsequent analysis of the results. This is the task of step 7 of our decision support procedure. Of special importance are the analysis of the conflict potential of the alternatives, the use of the results for the derivation of compromise alternatives with a lower conflict potential, and various types of sensitivity analyses that can be performed to assess the robustness of the results. The rankings derived in step 6 of the decision support procedure should be tested for their robustness by sensitivity analysis. It is useful to do sensitivity analysis with respect to the uncertainty in model predictions (input uncertainty, parameter uncertainty, model structure uncertainty) and with respect to the uncertainty in the quantification of preferences.

### 2.2.3. Applications of decision analysis techniques

Decision analysis methods (especially the MAVT method) belong to the most widely used MCDA methods in practice (Belton 1986). They have been applied in a broad range of thematic fields, such as energy, manufacturing and services, medical, military and public policy (Keefer et al. 2002; Kiker et al. 2005). In the following, we will give a brief overview of decision analysis applications in the field of environmental management projects.

In the field of energy policy, Keeney & McDaniels (1999) structured values of multiple stakeholders to help British Columbia Gas (BC Gas) develop an integrated resource plan. Hämäläinen et al. (2000) reported on the use of multi-attribute risk and utility analysis in nuclear emergency management. Keeney & McDaniels (2001) developed a framework based on value-focused thinking for the consideration of climate change policy choices. Jones et al. (1990) discussed the development and potential use of a model for considering energy policy options in the United Kingdom. Further applications have been made in transportation, hazardous waste management as well as forest planning. Bana e Costa (2001) used the MACBETH approach in evaluating public policy alternatives from allocating limited funds among inter-municipal road links in the Lisbon Metropolitan Region. Merkhofer et al. (1997) applied the multi-attribute utility theory (MAUT) method to select a site for a hazardous waste management facility. Ananda & Herath (2003a) used the value-function approach in modeling stakeholder values in regional forest planning. McDaniels & Trousdale (2005) describe how losses of non-market values experienced by aboriginal people could be valued based on decision analysis methods.

In the field of water management decisions, decision analysis techniques have been applied in various studies. Marttunen & Hämäläinen (1995), Hämäläinen et al. (2001) and Marttunen & Suomalainen (2004) applied decision analysis techniques to support multi-stakeholder decisions in water development projects in Finland. McDaniels et al. (1999) and Gregory et al. (2001) illustrated the decision aiding process by describing a stakeholder consultation involving water-use planning for a hydroelectric facility on the Alouette River in British Columbia, Canada. The framework of decision analysis has also been used for the generation of new alternatives. Gregory & Keeney (1994) described a process for identifying improved alternatives based on stakeholder values concerning the management of a coal mine in Malaysia. Soncini-Sessa et al. (2000) presented a procedure to solve conflicts in the operation of a transnational lake water system.

In sum, there has been a great increase in the application of decision analysis techniques recently. However, there are only few studies which incorporate stakeholder values in the field of water management projects. To our knowledge, there are hardly any studies which involve stakeholder values in the decision making process for river rehabilitation projects.

## 2.3. Analytic Hierarchy Process (AHP)

### 2.3.1. Methodological framework

The analytic hierarchy process (AHP), developed by Saaty (1980) is a mathematical method for analyzing complex decisions with multiple criteria. It belongs to the category of value measurement models (Stewart 1992; Lahdelma *et al.* 2000; Belton & Stewart 2002) and has in its implementation many similarities with the multi-attribute value function (MAVT) approach (Belton & Stewart 2002). In this sense, AHP can be viewed as an alternative means of eliciting a value function, although it rests on different assumptions about value measurement (Belton & Stewart 2002). The similarity of the AHP and MAVT approaches is evidenced by the convergence of supporting software; many software tools support both elicitation processes at the same time. However, in contrast to decision analysis methods, AHP is not grounded on any specific theoretical basis such as neo-Paretian welfare theory (Ananda & Herath 2003b). For a description of the axiomatic foundation of the AHP, please refer to Saaty (1986) and Saaty (1987).

The first three steps of using AHP are the same as for the decision analysis approaches: definition of the decision problem (step 1), identification of objectives and criteria (step 2), and identification and pre-selection of options (step 3). Within AHP, the objectives, criteria and options are called 'decision elements' and are structured in a hierarchy. The hierarchy descends from an overall goal, down to objectives which contribute to the overall goal, down further to criteria which are subdivisions of the objectives and finally to the options from which the choice is to be made (Saaty 1990b). For illustration of the concept, Figure 2.4 shows a hypothetical hierarchy for the overall objective 'sustainable river'.

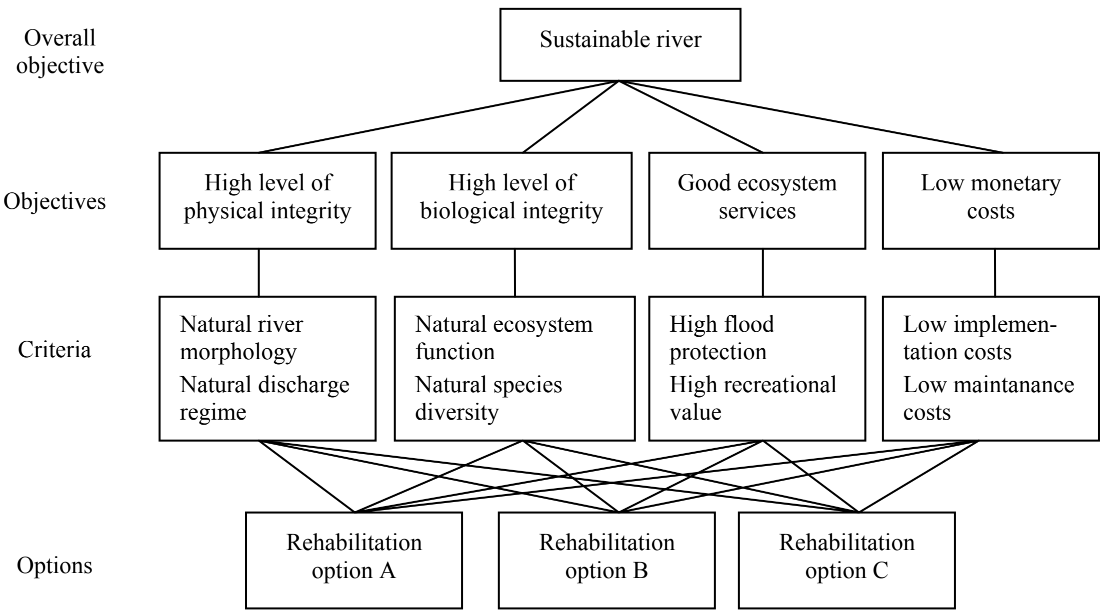


*Figure 2.4: Example how to structure a decision problem into a hierarchy based on AHP methodology.*

The main difference between AHP and the decision analysis approaches from a practical viewpoint are the prediction of outcomes (step 4) and the quantification of preferences (step 5). In the following, we will briefly describe how the AHP method faces these two steps:

*Prediction of outcomes (step 4)*
The main characteristics of AHP are the pairwise comparisons of all decision elements. For the prediction of outcomes, the different options are compared with respect to their outcomes on each of the criteria. This comparison of options is based on a nine-point fundamental scale (Table 2.1). Hence, rather than constructing a value function or an explicit qualitative scale against which the performance of options is assessed (as it is done within the decision analysis approaches), the user is required to respond to a series of pairwise comparison questions which leads to an implied numerical evaluation of the options according to each criterion (Belton & Stewart 2002). Due to the comparisons of options, the AHP method can also be applied in cases when reliable quantitative data about the outcomes of options are not available (Soma 2003). Interviews with decision makers, experts or stakeholders provide the information necessary for conducting a comprehensive decision-support survey.

In addition to the pairwise comparison, Saaty (1990b) suggests the so-called 'absolute measurement mode'. In this approach, a number of 'absolute' levels of performance on each criterion are defined, and it is these levels rather than the options which are compared pairwise, to generate numerical scores for each level of performance. Values for each option are then derived from those of the absolute performance levels for each criterion to which it most closely corresponds. The advantage of the absolute measurement mode is that the resulting scaling of the scores for each criterion is independent of the options. The absolute measurement mode approach is very close in spirit to the use of single attribute value function in MAVT (Belton & Stewart 2002).

*Table 2.1: The fundamental scale of AHP, adapted from Saaty (1980).*

| Intensity of relative importance | Definition |
|---|---|
| 1 | Equal importance |
| 3 | Moderate importance of one over the other |
| 5 | Essential or strong importance |
| 7 | Very strong importance |
| 9 | Extreme importance |
| 2,4,6 and 8 | Intermediate values between the two adjacent judgments |

*Quantification of preferences (step 5)*
Similar to the prediction of outcomes, the quantification of preferences is based on pairwise comparisons. First, the relative importance of the objectives is elicited from the user (decision maker or stakeholder). Thereby, the question is which of the two objectives is more important and how much more important. The intensity of preference can be expressed on the nine-point fundamental scale (Table 2.1). The criteria that belong to each of the objectives have to be compared in the same way (in case there is only one criterion for each objective, this step can be omitted).

The pairwise comparison data can then be analyzed using the eigenvalue technique proposed by Saaty (1980). Thereby, two main results can be calculated. First, the local priorities of the options describe the outcomes of the options with respect to the attributes. Second, the relative importance of each objective (and criteria) can be estimated. Computer programs such as Expert Choice or Logical Decisions® for Windows™ software can be used for these calculations. The aggregation modus of AHP is again very similar to the decision analysis procedure. Within AHP, the local priorities of each option are multiplied by the relative importance of the corresponding attribute, and added up to the global priorities of each option. This aggregation mode corresponds to the form of a weighted sum of single attribute value functions. The alternative with the highest score is then suggested to be the most prioritized management option.

*Criticism towards AHP*

There has been extensive debate about the AHP from a practical and theoretical point of view. It is beyond the scope of this study to cover this debate in detail. The interested reader should refer to Dyer (1990b, a), Harker & Vargas (1990), Saaty (1990a) and Stewart (1992). However, we will briefly discuss the most controversial aspect known as 'rank reversal'. Rank reversals refers to the fact that, in certain situations, the introduction of a new option that does not change the range of outcomes on any criterion may lead to a change in the ranking of the other options as determined by AHP. Dyer (1990b) concludes, based on the rank reversal problem, that the rankings produced by the AHP method are arbitrary. Harker & Vargas (1990) and Saaty (1995) argue that rank reversal is no problem itself, since rank reversals also occur in the way people make decisions naturally. One way to avoid rank reversals is to use the "absolute measurement mode" for the prediction of outcomes, which was suggested by Saaty (1990b), apparently largely in response to the rank reversal problem (Belton & Stewart 2002).

### 2.3.2. Applications of analytic hierarchy process

Together with the MAVT method, the AHP methodology belongs to the most widely used MCDA methods in practice (Belton 1986). It has been applied extensively in many areas with complex decisions and evaluation problems involving trade-offs of multiple objectives (Soma 2003). In the following, we will refer to a few applications which are relevant to environmental management projects and incorporate stakeholder values. Soma (2003) applied the AHP methodology in the shrimp fishery sector in Trinidad and Tobago. Thereby, the AHP method was found to be an "empowering, educating, focusing, facilitating and quantifying" tool. Herath (2004) evaluated the use of the AHP in wetland management based on interviews with 260 residents. He concludes that the AHP can explicitly incorporate stakeholder preferences and multiple objectives to evaluate management options. AHP has also been applied to support a conflict over stream diversion and land-water reallocation (Ridgley *et al.* 1997) and to evaluate different management options for the Rhine estuary (Ridgley & Rijsberman 1992).

Further applications of AHP without explicit involvement of stakeholder preferences are described in Kagazyo *et al.* (1997), Qureshi & Harrison (2001), Ramanathan (2001), Ananda & Herath (2003b) and Kablan (2004). For example, Qureshi & Harrison (2001) evaluated alternative riparian revegetation options in Scheu Creek catchment in North Queensland. Ananda & Herath (2003b) described the use of Analytic Hierarchy Process in regional forest planning using a hypothetical example, without eliciting stakeholder preferences directly. For a general overview of AHP applications, please refer to Saaty (1987), Vargas (1990), Saaty (1995) and Schmoldt *et al.* (2001).

## 2.4. Outranking approaches (PROMETHEE, ELECTRE)

### 2.4.1 Foundations of outranking methods

Outranking approaches differ from decision analysis techniques mainly in the quantification of preferences for outcomes (step 5). In contrast to decision analysis techniques, there is no underlying aggregative value function. The output of an analysis is not a value for each alternative, but an outranking relation on the set of alternatives. An alternative *a* is said to outrank another alternative *b* if, taking account all available information regarding the problem and the decision maker's preferences, there is a strong argument to support a conclusion that *a* is at least as good as *b* and not a strong argument to the contrary (Belton & Stewart 2002).

In contrast to decision analysis techniques, outranking methods accept incomparability and do not impose any transitivity properties. This also means that the preferences cannot be expressed by a unique numerical function and, consequently, that ranking the alternatives or choosing the best one is not a trivial problem (Vincke 1999). Vincke (1999) argues that the conclusion that two alternatives are incomparable is also decision-aiding. Incomparability between two options points out the conflicts or lack of information and invites the analyst and the decision maker to go more deeply into some aspects of the problem. The result of some of the outranking methods is a partial preorder, which can contain weak preference and indifference of alternatives. Figure 2.5 shows a graphical illustration of a possible result of the outranking methods. An arrow pointing from $a_t$ to $a_{t'}$ means that $a_t$ is preferred to $a_{t'}$ (for example $a_1$ dominates $a_2$ in figure 2.5). If two alternatives are indifferent, there is no arrowhead ($a_2$ and $a_4$). Two alternatives which are not connected are incomparable ($a_2$ and $a_6$).

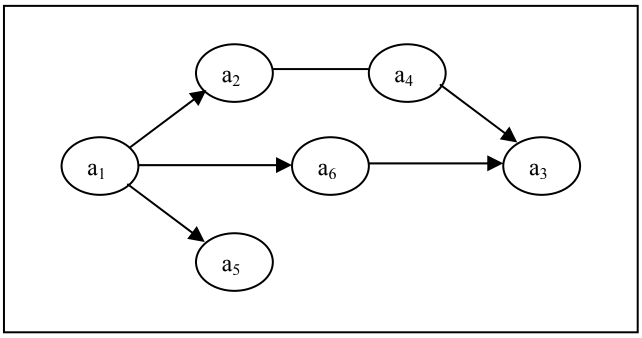


*Figure 2.5: One possible result of outranking methods is partial preorder.*

Brans *et al.* (1986) and Geldermann (1999) argue that partial preorder, especially with regard to incomparability, contains more realistic information than complete preorder. Especially the aggregation step for the definite ranking is one of the criticized steps in complete preorder (Geldermann 1999). Within outranking methods, such an aggregation step is not necessary, and therefore poor values in one criterion cannot be compensated by good values in another criterion. In a practical application, partial preorder gives the possibility of identifying the worst alternatives and eliminating them from further investigations (e.g. alternative $a_3$ is dominated by alternatives $a_4$, $a_6$, $a_2$ and $a_1$ in figure 2.5). In the case of incomparability of alternatives, further investigations about the most preferred alternatives are recommended.

In contrast to decision analysis, the effect of rank reversals can occur in outranking methods. Rank reversals means that the ranking of alternatives might change if some alternatives are excluded from the analysis or some new alternatives are included. The reason for this effect lies in the occurrence of weak preference. The effect of rank reversals makes clear that outranking methods can only be a guide to the decision process, and may not lead to a definite decision (Geldermann 1999). The most prominent outranking approaches are the PROMETHEE approaches, proposed by Brans *et al.* (1986), and the ELECTRE approaches, developed by Roy (1996). For a further description of these methods, the interested reader please refers to the appendix.

### 2.4.2. Characterizations of outranking methods

The main appeal of the outranking methods is to make use of a richer array of preference models in comparison to the value measurement models. The concepts of 'incomparability of alternatives' and the existence of grades of preferences ('weak' preference and 'strong' preference) might be good representations of how decision makers naturally form preferences. However, from a theoretical point of view, there is a lack of basic theory for outranking methods, which might be one of the reasons for the reservations expressed by some theoreticians who are used to justifying their methods and algorithms by mathematical theorems (Vincke 1986).

From a practical point of view, major drawbacks of outranking methods arise from the many rather non-intuitive inputs that are required, such as: concordance and discordance threshold levels; indifference, preference and veto thresholds; and the preference functions of PROMETHEE (Belton & Stewart 2002). Further, the algorithms tend to be complicated and difficult to understand for lay people and even decision makers. This problem has been shown in studies which compared different MCDA methods based on users feedback (Hobbs *et al.* 1992; Bell *et al.* 2001). Bell *et al.* (2001) found that users stated a quite poor understanding of the concept of ELECTRE. Hobbs *et al.* (1992) found that ELECTRE is rated more favorably for project screening than for other planning purposes.

In summary, Belton & Stewart (2002) conclude that the outranking methods may not be generally suitable for interactive use by decision analyst with decision makers and stakeholders. Outranking methods may thus be more appropriate for 'backroom' analyses by analysts and/or by support staff to the final decision makers (Belton & Stewart 2002).

### 2.4.3. Applications of outranking methods

Due to the practical drawbacks discussed above, ELECTRE and PROMETHEE are not as widely applied as the value measurement models (such as MAVT and AHP). However, there are still several fields within environmental management where outranking methods have been applied. A major application area is energy planning (Pohekar & Ramachandran 2004). For example, Haralambopoulos & Polatidis (2003) developed an integrated framework for achieving group consensus in renewable energy projects based on PROMETHEE II. Briggs *et al.* (1990) adapted the PROMETHEE method to the choice of a financing method and to several possible sites for nuclear waste management. The PROMETHEE method is also used in integrated evaluation of engineering (Geldermann 1999), irrigation planning (Raju & Pillai 1999a), and water management projects (Al-Kloub *et al.* 1997).

Applications of ELECTRE in energy planning include renewable plant selection (Georgopoulou *et al.* 1997), defining national priorities for greenhouse gas emissions reduction (Georgopoulou *et al.* 2003), and diffusion of renewable energy technology (Beccali *et al.* 2003). ELECTRE approaches have also been applied in the transportation sector, for example for the determination of which Paris metro station should be renovated (Roy *et al.* 1986). Both ELECTRE and PROMETHEE have also been evaluated for the use in strategic forestry planning (Kangas *et al.* 2001)

## 2.5. Cost-Benefit Analysis (CBA)

### 2.5.1. Introduction

Cost-Benefit Analysis (CBA) is rooted in utilitarian percepts aimed at the maximization of social welfare. CBA and MCDA are alternative responses to the problem of how to quantify or compare society's overall benefits when one party 'wins' and another 'loses' (Joubert *et al.* 1997). The operational differences between MCDA and CBA are essentially threefold (Joubert *et al.* 1997):

- CBA reduces problems to a *single dimension objective function* (real net present value). In contrast, MCDA explicitly introduces several criteria, each representing a particular dimension of the problem.
- In CBA all impacts and expressed preferences are converted into *common units* (money). In order to have common units of comparison, MCDA rates or ranks alternatives on a preference scale for each criterion and weights the criteria (thereby avoiding the need to convert to monetary units).
- Conventionally, CBA only attempts to make *trade-offs between the dimensions of the problem* explicit within sensitivity analyses, while under MCDA the trade-offs between different stakeholders and criteria are focus of attention.

Welfare economists conclude that there are two main arguments for putting a monetary valuation on environmental goods (Navrud 2001). First, there is a need to know the marginal value of environmental goods to find the socially optimal quantity or quality of different environmental goods. Second, if environmental goods are not valued explicitly they will anyhow be valued implicitly through policy decisions. However, economic valuation of ecosystems is complicated by the fact that ecosystems are characterized by multiple, interdependent services. Turner *et al.* (2000) define the Total Economic Value (TEV) as the sum of all use and non-use values provided by an ecosystem. *Use value* arises from humans' direct or indirect use of the ecosystem through ecosystem goods and ecosystem services. Typical use values associated with river ecosystems can include benefits arising from in-stream uses (fishing), withdrawal for drinking water or irrigation, enhanced aesthetics for recreational uses as well as consumptive activities (hunting) (Holmes *et al.* 2004). Nonuse value is associated with benefits derived simply from the knowledge that a resource, such as an individual species or an entire wetland, is maintained (Turner *et al.* 2000). Table 2.2 shows different use and non-use values of river ecosystems and corresponding valuation methods.

*Table 2.2: Use and non-use values of natural river ecosystems and corresponding valuation methods.*

| | Use values | | | Non-use values |
|---|---|---|---|---|
| | Direct use values | Indirect use values | Option values | Existence values |
| Values | Recreation<br>Fishery<br>Hunting<br>Shipping<br>Water supply | Floodwater storage and retention<br>Groundwater recharge<br>Water treatment | Potential use in the future | Knowledge that biodiversity and ecological functions are maintained |
| Valuation methods | Market analysis<br>Hedonic pricing<br>Travel cost method<br>Contingent valuation | Damage costs<br>Market analysis<br>Hedonic pricing<br>Contingent valuation | Contingent valuation | Contingent valuation |

The valuation methods can be divided into the direct and indirect approaches. *Direct methods* seek to infer individuals' preferences for environmental quality directly, by asking them to state their preferences for the environment. Contingent valuation surveys ask people for either their maximum willingness to pay (WTP) for an increase in environmental quality or their maximum willingness to accept compensation (WTA) to forgo such an increase. *Indirect methods* seek to recover estimates of individual' WTP for environmental quality by observing their behavior in related markets. One example is the hedonic pricing model, where the related market for urban air quality is the housing market. The travel cost approach tries to infer the value people place on an outdoor recreational site through their expenditure on travel to the site.

There are different problems associated with the contingent valuation method in specific and CBA in general (Hanley 1988; Gregory *et al.* 1993; Hausman 1993; Gregory & Slovic 1997). The accuracy of contingent valuation results has been called into question by experimental evidence demonstrating that the way in which such questions are asked – their context, wording and order – can have large effects on the magnitude of the respondents' answers (Kahneman & Knetsch 1992). These problems are usually referred to as problems of bias in the economic literature, because it is assumed that people hold true values that are distorted by poor measurement methods (Gregory & Slovic 1997). Major biases are known as *strategic bias* (under- or overestimation of WTP/WTA bids), *design bias* (choice of bid vehicle, starting point bias), *mental account bias* (elicitation of WTP from one environmental good in isolation from other goods), and *aggregation bias* (choice of appropriate population and time period as well as discount factor). A further question is whether people are generally able to put a monetary value on public goods such as the environment. Gregory *et al.* (1993) and Clark *et al.* (2000) deny this question, saying that individuals are not accustomed to interpreting environmental goods in monetary terms. For a more detailed discussion about CBA methods and problems associated with CBA, we refer the interested reader to the appendix.

### 2.5.2. Application of CBA studies

Considering the large amount of CBA studies, it is beyond the scope of this book to give a comprehensive overview of CBA applications in environmental management projects. However, we will refer to selected CBA studies which deal with river rehabilitation issues. Kosz (1996) and Schönbäck (1997) elicited the WTP for the 'Donau-Auen' national park and compared this measure with benefits of potential hydropower generation. They also included aspects such as shipping, groundwater protection, stabilization of the river bed, visitors' benefits, forestry, farming, fishing, hunting and the costs of establishing a national park. The results indicate that the protection of natural goods, like wetlands, in a natural state might be more efficient from an economic viewpoint than development projects (Kosz 1996; Schönbäck 1997). Holmes *et al.* (2004) compared the benefits and costs of riparian restoration project along the Little Tennessee River (North Carolina) based on a WTP study. The results showed that the benefit/costs ratio for riparian restoration ranged from 4 (for 2 miles of restoration) to 15.6 (for 6 miles of restoration). Hence, riparian restoration in this watershed is an economically feasible investment of public funds. Similarly, Loomis *et al.* (2000) measured the total economic value of restoring ecosystem services in an impaired river basin based on WTP bids. The ecosystem services included in the study were dilution of wastewater, natural purification of water, erosion control, habitat for fish and wildlife, and recreation. The costs for the restoration measures would be substantially less than even the most conservative estimate of WTP (Loomis *et al.* 2000).

Meyerhoff (1999) elicited the WTP of households for rehabilitation measures at the Elbe River, Germany. Thereby, the existence value (nonuse value) and the recreational value (use value) of a rehabilitated Elbe River were estimated. Similar to the studies listed before, the benefits from the restoration measures would exceed the costs even in the most conservative aggregation of the WTP bids. Based on the results of a meta-analysis of wetland contingent valuation studies (Brouwer *et al.* 1999), Brouwer & van Ek (2004) estimated an average WTP for both flood water retention and wildlife and landscape amenities. Thereby, the benefits and costs of rehabilitation measures were compared for the rehabilitation of a river delta in the Netherlands. The results revealed that the outcome of CBA is highly sensitive to the assumptions made on both the cost and benefit side and the valuation of the flow of costs and benefits in time through the applied discount rate.

The main characteristics of the mentioned CBA studies are summarized in Table 2.3. It is important to emphasize the difference in WTP bids elicited. For example, Holmes *et al.* (2004) elicited a WTP of $ 27 per household and year for a restoration project, while the WTP elicited by Loomis *et al.* (2000) is $ 252 per household and year. This might be partly due the fact that the WTP bids of the studies include different values (use and non-use values). On the other side, the significant differences in WTP might be a sign of the problems associated with contingent valuation studies.

*Table 2.3: Willingness to pay (WTP) bids of selected contingent valuation studies concerning river rehabilitation projects.*

| Study site | Author and year | Question of interest | Valued good of WTP bids | Number of respon-dents | Annual WTP elicited | Population of extrapolation in study site |
|---|---|---|---|---|---|---|
| Donau Auen (Austria) | Kosz (1996); Schönbäck (1997) | CBA for national park versus hydropower generation. | Non-use value: 'ecological value' of protected wetlands. | 962 (written interviews) | 329 ATS /person (ca. 24€ /person) | Country (Austria) |
| Little Tennessee River (USA) | Holmes *et al.* (2004) | CBA for a riparian restoration project. | Use and non-use values: abundance of game fish, water clarity, wildlife habitat, allowable water uses, and ecosystem naturalness. | 96 (oral interviews) | $27 /household | River catchment area |
| River Basin South Plate (USA) | Loomis *et al.* (2000) | CBA for a riparian restoration project. | Use and non-use values: dilution of wastewater, natural purification of water, erosion control, habitat for fish and wildlife | 96 (oral interviews) | $252 /household | River catchment area |
| Elbe River Basin (Germany) | Meyerhoff (1999) | CBA for rehabilita-tion of Elbe floodplains. | Non use-value: existence value | 1304 (oral interviews) | 7.5 € / household | River catchment area |
| Elbe River Basin (Germany) | Meyerhoff (1999) | CBA for rehabilita-tion of Elbe floodplains. | Use value: recreational value | 1304 (oral interviews) | 10.4 € / household | River catchment area |
| Rhine and Meuse delta (Netherlands) | Brouwer & van Ek (2004) | CBA for rehabilita-tion of river delta. | Use and non-use values: flood water retention and ecological habitat | Meta analysis based on 100 WTP-studies | 80 € / household | Province (South Holland) |

## 2.6. Normative and descriptive decision theory

### 2.6.1. Introduction

It is important to distinguish between the normative and descriptive approach of decision theory. The *normative decision theory* aims to show how decisions can be taken in a rational manner (Laux 2005). Decision analysis techniques (MAVT, MAUT) as well as the Cost-Benefit Analysis are based on the normative model of rational choice. The main paradigm of risky choices is that the decision maker should choose the option with the largest subjectively expected utility (SEU). In contrast, the *descriptive decision theory* is concerned with understanding and predicting how people actually reach decisions (Merkhofer 1987). Almost all of the familiar psychological models or theories are descriptive, not normative (von Winterfeldt & Edwards 1986). The set of descriptive decision-theoretic models is called behavioral decision theory (von Winterfeldt & Edwards 1986).

The normative model makes high demands on the quality of input information and the consistency of decision makers' preferences (Merkhofer 1987; Eisenführ 2003). The model of rational choice "calls for knowledge of all the alternatives that are open to choice. It calls for complete knowledge of, or ability to compute, the consequences that will follow on each of the alternatives. It calls for certainty in the decision makers' present and future evaluation of these consequences. It calls for the ability to compare consequences, no matter how diverse and heterogeneous, in terms of some consistent measure of utility" (Simon 1979). Hence, one has to be aware that the theory of decision making was conceived as a normative model of an *idealized* decision maker, not as a description of the behavior of real people (Tversky & Kahneman 1986).

### 2.6.2. Violations of axioms of rational choice

Behavioral research has shown that people often do not behave according to the rational decision rule (Simon 1979; Kahneman *et al.* 1982). In the following, we will refer to three main reasons for violations of the SEU model (for a summary of further sources of violations, please refer to Kahneman *et al.* (1982), von Winterfeldt & Edwards (1986) and Eisenführ 2003)):

- *Framing effect*: Framing effects describe the fact that preferences might depend on the formulation of the decision problem. It turns out that when alternatives are presented in different ways, people often make different choices, even though the alternatives themselves remain unchanged (Dawes 1998). A common pattern is that choices involving gains are usually risk averse, and choices involving losses are often risk seeking – except when the probability of winning or losing is small (Kahneman & Tversky 1979; Tversky & Kahneman 1986). Tversky & Kahneman (1986) state that variations in the framing of decision problems produce systematic violations of two main axioms of the SEU model: the independence condition and the sure thing principle.
- *Reference dependence*: A further assumption of the normative model is called 'reference-independence'. It assumes that the value that is assigned to a given state of wealth does not vary with the decision maker's initial state of wealth (Kahneman 2003). Based on a wide range of experiments, Kahneman & Tversky (1979) showed that the assumption of reference-independence is systematically violated in many

decision situations. Hence, Tversky & Kahneman (1981) argue that the reference dependence is a significant concern for the theory of rational choice.

- *Allais Paradox*: Allais (1953, 1979) introduced different examples which show that individuals tend to place too much weight on a certain outcome relative to uncertain outcomes. This inconsistency in decision making is also known as *certainty effect* (Tversky & Kahneman 1981). Based on this observation, Allais rejected the SEU model and its correlated decision techniques.

Tversky & Kahneman (1986) state that the deviations of actual behavior from the normative model are too widespread to be ignored, too systematic to be dismissed as random error, and too fundamental to be accommodated by relaxing the normative system. As a result, a wide range of new models based on descriptive decision theory have been introduced (Eisenführ 2003). A well-known model is the prospect theory introduced by Kahneman & Tversky (1979). However, up to now, none of these descriptive models have become as popular as the normative model of rational choice.

### 2.6.3. Concept of bounded rationality

Major criticism towards the theory of subjective expected utility (SEU) has repeatedly been posed by Herbert A. Simon (Simon 1959, 1978, 1979, 1984; Simon *et al.* 1987; Simon 1990; Simon 1993, 1995). He argues that the main limitation of SEU theory and the developments based on it are its relative neglect of the limits of human problem-solving capabilities in the face of real-world complexities (Simon *et al.* 1987). Simon found that humans do not behave rational especially in complex decision situations (Bendor 2003). Further, Simon (1986) emphasizes the following difference in the conceptualization of rationality: in economics, rationality is viewed in terms of the choices it produces *(substantive rationality)*; in the other social sciences, it is viewed in terms of the processes it employs *(procedural rationality)*. Simon especially rejected the substantive rationality, but he maintained that decision makers aim to proceed rational in terms of the decision making process itself (Schwartz 2002).

Simon (1979) states that most decisions are made according to the mechanisms of *bounded rationality.* Bounded rationality assumes that actors intend to be rational: they are goal-oriented and adaptive, but bounded rationality takes into account the cognitive limitations of decision makers in attempting to achieve those goals (Jones 1999). According to Simon, bounded rationality reflects a rationality "that is consistent with our knowledge of actual human behavior, assumed that the decision maker must search for alternatives, has egregiously incomplete and inaccurate knowledge about the consequences of actions, and chooses actions that are expected to...attain targets while satisfying constraints" (Simon 1997, p.17). The main notions of bounded rationality are the need to search for decision alternatives, the replacement of optimization by targets and satisfying goals, and mechanisms of learning and adaptation (Simon 1979).

### 2.6.4. Conclusions

As we have discussed above, there are various decision situations where the axioms of the normative model are violated. Even supporter of the normative model are aware of this. For example, von Winterfeldt & Edwards (1986) state that nobody believes that in practice all assumptions of the SEU model will be valid (p. 325). However, decision analyst argue that especially the difference between unaided decision making and the rational choice model reveals the need of a prescriptive norm as a guideline to find the optimal decision (Eisenführ 2003). Hence, the dispute between the descriptive and normative decision theorists can be summarized as follows: the descriptive decision theorists perceive the violations of the normative model to be significant enough to reject the SEU model. And the normative decision theorists emphasize that the SEU model is a valuable tool for decision support if one agrees with the axioms of the SEU model and is aware of their potential violations.

In our understanding, one can try to minimize the violations of the axioms in the case of a single decision maker. However, the multiple stakeholder setting in environmental management projects might have various discrepancies from the idealized normative model: (i) the failure of knowing all alternatives and inability to fully predict the outcomes of alternatives, (ii) the uncertainty in stakeholder present and future evaluations of the outcomes, (iii) the limitations of stakeholders to state preferences for diverse and heterogeneous objectives, and (iv) the fact that stakeholders might neither understand the axioms of the model nor are able to state their preferences according to these axioms. Therefore, one can question the usefulness of normative models in such decision situations. To answer this question, we applied the MAVT method to the multiple stakeholder setting and evaluated the contribution of the method in this setting (chapter 5).

## 2.7. Comparison of MCDA and CBA

### 2.7.1. Strengths of MCDA methods

Concerning the mentioned problems associated with the contingent valuation method in specific and Cost-Benefit Analysis in general (section 2.5), various studies have raised the need for different approaches to value environmental public goods. Sagoff (1998) concludes that the valuation of environmental goods should move toward a deliberative, discursive, jury-like methodology emphasizing informed discussion leading toward a consensus based on an argument about the public interest. Clark *et al.* (2000) emphasize that their WTP participants argued for a decision-making institution where local people could contribute to environmental policy decisions through dialogue with scientists and policy makers. Gregory & Slovic (1997) state that an improved measurement technique is needed despite the great effort to improve the contingent valuation technique and reduce its biases. Based on these arguments and on studies which compare MCDA methods with contingent valuation techniques (Gregory *et al.* 1993; Joubert *et al.* 1997; Gregory 2000), we see four major strengths of MCDA methods in environmental management projects.

- Environmental management projects are characterized by *multiple conflicting objectives*. MCDA methods aim to make the trade-offs between different objectives explicit. Especially in a multi-stakeholder context, the illustration of trade-offs of different interest groups provides important information to decision makers as an aid to stakeholder negotiation. In contrast, the reduction of the problem to a single monetary value in CBA is associated with the loss of important information.
- *The involvement of stakeholder values and promotion of learning* are important aspects of public involvement in environmental management projects (section 3.2). However, the elicitation of monetary valuation bids within contingent valuation studies does not really support these aspects. This is due to the facts that (i) many people do not agree with the valuation modes (monetary valuation of environmental goods), and (ii) the elicitation process of WTP/WTA bids is mainly one-way, reducing the stakeholder learning effect.
- Different studies have shown that *placing a monetary value* on certain environmental goods is questionable (Gregory *et al.* 1993; Vatn & Bromley 1995; Joubert *et al.* 1997; Sagoff 1998; Clark *et al.* 2000; Gregory 2000). MCDA avoids the necessity for monetary valuation, thus avoiding the ethical debate surrounding this issue (Joubert *et al.* 1997).
- CBA studies in environmental management projects are associated with a range of *theoretical and practical shortcomings* (Gregory *et al.* 1993; Hanley & Spash 1993; Hausman 1993). Especially mental account bias (elicitation of WTP from one environmental good in isolation from other goods) and aggregation bias (choice of appropriate population and time period as well as discount factor) are factors which can have a major influence on results. For example, Clark *et al.* (2000) concluded that respondents have an inability to work out a value for one environmental good in isolation from others in other parts of the country. Since MCDA avoids a classic utilitarian view of optimality in decision making, it bypasses many of the practical and theoretical criticisms (Joubert *et al.* 1997).

### 2.7.2. Weaknesses of MCDA methodologies

Despite the mentioned disadvantages of CBA, one has to be aware that MCDA methodologies also have potential weaknesses. One critical aspect is the elicitation of stakeholder preferences (e.g. attribute weights, value/utility functions for MAVT/MAUT, and threshold values for PROMETHEE/ELECTRE). The elicitation procedure of these preferences might be difficult for lay people, and they require additional time resources. Further, there has been a long discussion about biases in weight estimation and different weight elicitation techniques (von Winterfeldt & Edwards 1986; Hobbs *et al.* 1992; Clemen 1996; Pöyhönen & Hämäläinen 2001; Pöyhönen *et al.* 2001). One major question is how to structure the objectives into an objective hierarchy. Thereby, the splitting bias suggests that the weight of an attribute increases when it is divided into sub-attributes (Weber *et al.* 1988).

The elicitation process of stakeholder preferences is normally done by the MCDA analyst. The role of the MCDA analyst is very crucial for the outcome of the MCDA application. It is self-understanding that the MCDA analyst ideally has a neutral attitude towards the decision. Further, both the choice of the MCDA method and the way how to apply the method (choice of weighting method etc.) might influence the decision (Hobbs *et al.* 1992; Bell *et al.* 2001).

Unfortunately, there is no common terminology within the MCDA methods for important 'decision elements'. For example, decision analysis methods (MAVT, MAUT) call the elements to be achieved 'objectives', while outranking methods call the elements to be compared 'criteria'. The measurable properties for these elements are called 'attributes' within decision analysis methods, but 'criteria' within the AHP method. Even within one MCDA method, different authors use different terminologies for the same element. This does not ease the use of MCDA methods for non-specialists. Table 2.4 gives an overview how the different MCDA approaches label important decision elements. It is important to emphasize that this overview is not at all inclusive; it merely presents the most common terminology for each MCDA method.

*Table 2.4: Terminology: how different decision elements are named in MCDA methodologies.*

| General description of decision elements | Decision analysis techniques (MAVT, MAUT) | Analytic Hierarchy Process (AHP) | Outranking methods (PROMETHEE, ELECTRE) |
|---|---|---|---|
| Way to structure objectives/criteria | Objective hierarchy<br>Value tree | Hierarchy of decision elements | Hierarchy (structuring tree) |
| Overall element to achieve | Overall objective | Overall goal | - |
| Elements to achieve/compare | Objectives | Objectives (criteria) | Criteria |
| Measurable properties of elements | Attributes | Criteria | Criteria |
| Actions from which the choices are made | Alternatives | Options | Alternatives/Options |

### 2.7.3. Main characteristics of MCDA and CBA

Beside the mentioned characteristics of MCDA methods in general, each MCDA method has its individual strength and weakness (Table 2.5).

*Table 2.5: Comparison of different MCDA methods and CBA according to their main characteristics, strengths and weaknesses.*

| Method | Characteristics | Strengths | Weaknesses | Examples of software |
|---|---|---|---|---|
| Decision analysis techniques (MAVT, MAUT) | Ranking of alternatives based on a single, non-monetary value/utility measure.<br>Elicitation of value/utility functions and attribute weights. | Preferences are elicited for outcomes and not for alternatives.<br>Preference rankings of alternatives are independent of the considered alternatives. | Elicitation of preferences (value/utility function and attribute weights) of lay people might be difficult.<br>Detailed data required for prediction of outcomes of alternatives.<br>Role of analyst's (potential influence of the results). | Logical Decisions© for Windows™<br>Web-HIPRE<br>DEFINITE<br>MACBETH |
| Analytic Hierarchy Process (AHP) | Criteria weights and estimation of outcomes of options are based on pairwise comparisons of criteria and options. | Pairwise comparisons are easy to elicit from lay people.<br>There is no need for quantitative data about outcomes of options.<br>Widely applied in environmental management projects. | Introduction of new, irrelevant options might change the ranking of the other options (rank reversal).<br>Pairwise comparisons can be laborious for large amount of criteria or options.<br>Role of analyst's (potential influence of the results). | Logical Decisions© for Windows™<br>Expert Choice<br>Web-HIPRE |
| Outranking methods (PROME-THEE, ELECTRE) | Alternative *a* outranks alternative *b* if there is a strong argument to support a conclusion that *a* is at least as good as *b* and no strong argument to the contrary.<br>Outranking methods accept incomparability of alternatives. | Does not require the reduction of all criteria to a single unit.<br>Poor performance of an alternative in a single criterion can not easily be compensated by good performance on other criteria. | Algorithms used for outranking are complex and not well understood by decision makers and stakeholders.<br>Inputs for methods (e.g. indifference and preference thresholds) are rather non-intuitive for users.<br>Role of analyst's (potential influence of the results). | Decision Lab 2000<br>ELECTRE III, IV, IS & TRI |
| Cost-Benefit Analysis (CBA) | Conversion of impacts and preferences in monetary unit and construction of single dimension objective function. | Valuation of use and non-use goods with the same monetary unit.<br>Widely used decision support methodology, and hence, many applications which might be used for benefit transfer. | There are different ethical, theoretical and practical problems associated with CBA (e.g. inability to value environmental goods in monetary terms). | DEFINITE |

For the decision analysis techniques (MAVT, MAUT), potential weaknesses are the elicitation of value/utility functions and the requirement of detailed data for the prediction of outcomes. However, the pairwise comparisons of AHP can be laborious if there are many criteria or options to compare. Further, the rank reversal problematic of AHP has been discussed quite controversially. The outranking methods (PROMETHEE, ELECTRE) have the weakness that their algorithms are quite complex and not well understood by decision makers and stakeholders. Further, inputs required for the methods (e.g. indifference and preference thresholds) might be non-intuitive for users. For each of the decision support techniques, there is a wide range of software tools available (Table 2.5). For a more comprehensive list, please refer to Belton & Stewart (2002).

Concerning the theoretical basis of the methods, it is important to emphasize that the decision analysis techniques (MAVT, MAUT) and the CBA are based on the normative model of value/utility maximization. In contrast, AHP and outranking methods are not based on a specific theoretical basis. Having in mind the potential violations of the axioms of value/utility maximization (section 2.6); we consider this aspect to be a personal choice whether it is judged as an advantage or disadvantage. Hence, this aspect is not included in Table 2.5.

### 2.7.4. Conclusions

The discussion of MCDA and CBA methods has revealed that CBA has major deficits for the valuation of environmental goods. In line with other authors, we believe that the valuation of environmental goods should move to a deliberative approach in which stakeholders can contribute to environmental policy decisions (Gregory *et al.* 1993; Gregory & Slovic 1997; Sagoff 1998; Clark *et al.* 2000). Hence, we will focus in the following chapters on MCDA methodologies. As we have shown above, one has to be aware that MCDA methods also have their limitations and potential weaknesses. How these weaknesses might be reduced by wise implementation of the MCDA methods to the specific decision making situation will be discussed in chapter 3.

# 3. Multi-stage and multi-stakeholder process

Before one can apply and evaluate MCDA methods in river rehabilitation projects, one first needs a good understanding of the relevant decision making situations. The purpose of this chapter is to structure the different decision making situations (DMS) typically appearing in river rehabilitation and to identify potential MCDA applications. The chapter is organized as follows (Figure 3.1). We first analyze major planning and implementation phases and the corresponding DMS (section 3.1). Second, we describe the main objectives and mechanisms for public involvement (section 3.2). We then discuss which DMS can be supported by MCDA methods and which MCDA method is specifically suitable for the different DMS (section 3.3). Fourth, we refer to our own MCDA applications for different project phases (section 3.4). In total, this chapter introduces a new framework for analyzing decision problems in river rehabilitation. The importance of such integrative frameworks has been emphasized by (Belton & Stewart 2002). A comprehensive summary of the integrative framework is presented in section 3.5.

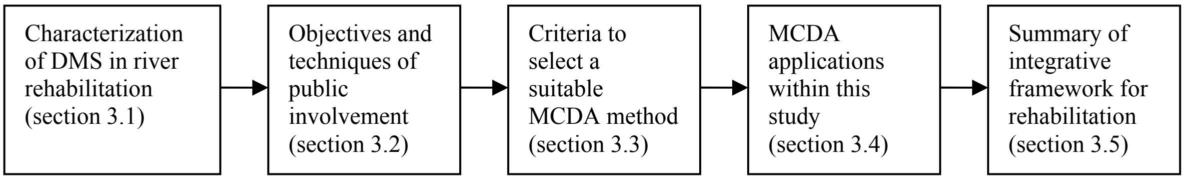


*Figure 3.1: Contents of multi-stage and multi-stakeholder process towards an integrative framework for river rehabilitation.*

## 3.1. Multi-stage process

To support the decision making process by MCDA methods, we need a framework describing the major decision making situations of rehabilitation projects. A decision making situation (DMS) describes the main characterization of the decision at hand. Roy (1996) suggests that the DMS can be categorized according to some decision problematics; like the description problematic, the choice problematic, the sorting problematic and the ranking problematic (section 3.3.2). There are three main institutional levels which are relevant for rehabilitation projects in Switzerland: national, regional and local level. On each level, there are different phases:

- Defining the problem and objectives
- Public involvement
- Assessment of options and decision making
- Implementation of selected option
- Evaluation of success

In the following, we will describe the three institutional levels and corresponding phases in more detail. The main DMS are illustrated in Figure 3.2 and summarized in Table 3.1.

### 3.1.1. National level

Nowadays, river rehabilitation measures are often conducted without any strategic planning process on national level. Rehabilitation projects rather react on local decisions such as flood defense work or road development (VAW 1993; Holmes 1998). Clarke *et al.* (2003) argue that river restoration will only be sustainable if it is undertaken within a process-driven and strategic framework with inputs from a wide range of specialists. Hence, there is a need of a management plan for rehabilitation projects at national level. The national management plan aims to characterize the various river basins according to their deficits and select important river basins for rehabilitation measures.

To achieve a management plan for rehabilitation projects, one first has to conduct *analysis of the deficits and main objectives*. Potential deficits are a deterioration of the ecological status, low flood protection level, artificial hydrology (hydropeaking or minimum flow) or poor recreational opportunities. National objectives might be, for example, achieving a good ecological status of the river (based on the European Water Framework Directive (EU-WFD) (European Parliament 2000)). The second step is the definition of the stakeholders to be involved *(public involvement)*. Important participants for public involvement are representatives from national organizations (e.g. national NGO's) and scientific experts. Local stakeholders (e.g. land owners) might not be involved at the national level.

The third step consists of the development and assessment of different options, as well as the decision about the options *(assessment of options and decision making)*. At the national level, the options are the various river basins in a country. The aim is to group the river basins according to their deficits (river basins with similar deficits belong to the same group). Based on the national objectives previously defined, one can select those river basins where rehabilitation measures should be conducted. At the national level, there is no construction in the field during the implementation phase (in contrast to the local level). The *implementation phase* corresponds rather to the fact that the national strategy is put into practice. Ideally, this means that for each river basin identified in the national strategy, the planning at the regional level has to be conducted. In this ideal case, the *success* of the national strategy can be evaluated after the planning and implementation phases at the regional and local levels are finished. However, one has to be aware that there is no clear chronology of the three institutional levels in today's practice.

### 3.1.2. River basin level

River basins are the major geographic unit where ecological, hydrological and hydrogeological processes are running. Hence, the European Water Framework Directive (EU-WFD) requires that rehabilitation measures should be planned on the river basin level (European Parliament 2000). There can be one or several countries involved within one river basin. There is a variety of DMS at the river basin level. One question is which type of measure is most appropriate to achieve the general objectives. However, since we focus on rehabilitation measures based on eco-morphological improvement (such as river widening), the comparison of different types of measures is not the main focus. In this study, we rather concentrate on the question of where to conduct the rehabilitation measures. In most cases, the measures have to be conducted at several locations within the river basin, and not just at one site. Hence, the prioritization of rehabilitation sites is a major task at this level.

For the prioritization of different locations, one first has to define the *problem and general objectives.* The responsible authority is mainly the regional administration (in consultation with the national administration). Important participants of *public involvement* are representatives of regional interest groups as well as the general public. The *assessment of options* consists of the identification and comparison of feasible locations within a river basin. A ranking of all feasible locations based on ecological and socio-economic criteria helps to choose the most appropriate locations. The result is a river management plan for implementing the selected rehabilitation measures *(implementation).* For *evaluation of the success*, one has to ask whether the pre-defined objectives of the river basin level are achieved (e.g. achieving a good ecological status). To test the achievement of these objectives, the rehabilitation measures at the local scale should first be implemented. Otherwise, the achievement of objectives at regional level can hardly be measured.

### 3.1.3. Local level

The decision making process at the local level focuses on a specific location (rehabilitation site). The main phases correspond to the national and river basin levels. However, there are still major differences in how the steps are conducted. The process starts with *defining the problem and the objectives*. For ecology, for example, specific species can be defined which should benefit from the rehabilitation measures. Concerning *public involvement*, mainly local stakeholders and the general public have to be involved in the decision process, since those people are affected by the rehabilitation measures. In the *assessment of options and decision making* phase, different rehabilitation alternatives are compared for the selected location. A ranking of the alternatives based on the selected objectives helps to choose the most preferred alternative. In contrast to the national and river basin levels, the *implementation phase* consists of construction of the measures in the field. After the construction is finished, the *success* of the rehabilitation measure can be evaluated. One has to be aware that it might take several years to see whether the aspired objectives are achieved.

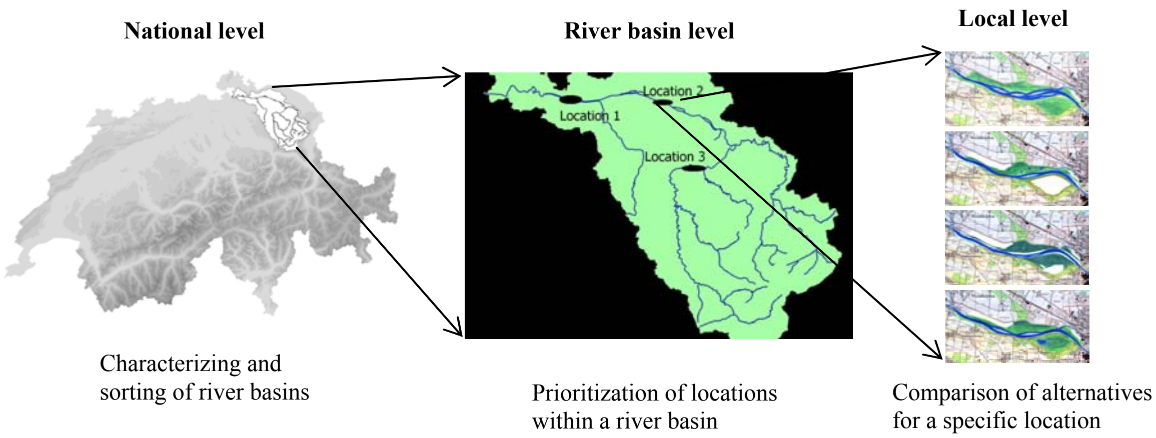


*Figure 3.2: Major institutional levels for river rehabilitation projects and corresponding decision making situations.*

*Table 3.1: Institutional levels and phases of river rehabilitation projects.*

| Institutional level | Phases | | | | |
|---|---|---|---|---|---|
| | Defining the problem and objectives | Public involvement | Assessment of options and decision making | Implementation | Evaluation of success |
| National | *Analysis of status quo:* what are the main deficits at the national level?<br>*Definition of objectives:* e.g. good ecological status (European Parliament 2000), flood protection level depending on protection objectives (BWG 2001). | *Responsible authority:* federal authority.<br>*Involved stakeholders:* experts, representatives of national organizations (e.g. NGO's). | *Options*: different river basins<br>*Decision making situation*: characterizing the river basins based on their deficits, selection of river basins to conduct rehabilitation measures. | Implementation of a national strategy. | Evaluation of success of national strategy. |
| River basin | *Analysis of status quo:* what are the deficits at the river basin level?<br>*Definition of objectives:* e.g. good ecological status, $HQ_{300}$ as flood protection level, etc. | *Responsible authority:* regional and federal authority.<br>*Involved stakeholders:* experts, representatives of regional organizations (e.g. NGO's) general public. | *Options*: different locations within a river basin.<br>*Decision making situation*: identification, ranking and selection of feasible locations within a river basin. | Developing a river basin strategy (management plan). | Evaluation of success of the management plan. |
| Local (specific site) | *Analysis of status quo:* what are the deficits at the specific site?<br>*Definition of objectives:* e.g. enhancement of certain habitats or species (e.g. fish species). | *Responsible authority:* regional and local authorities<br>*Involved stakeholders:* local stakeholders and general public. | *Options*: different rehabilitation measures (alternatives) for specific location.<br>*Decision making situation*: ranking of rehabilitation alternatives. | Implementation of chosen rehabilitation alternative (construction on field). | Evaluation of success of rehabilitation measures for specific site. |

## 3.2. Multi-stakeholder process: public involvement

Public involvement is an important topic of river rehabilitation projects. It is a core requirement of the European Water Framework Directive (Environmental Agency 2004) and one of the most important aspects for the success of rehabilitation projects (BWG 2001; Bratrich 2004). By definition, 'public involvement' is a process that involves the public in the decision making procedures of an organization or a project (Väntänen & Marttunen 2005).

However, on has to be aware that the 'public' is not a homogeneous group of people. Based on the work of Environmental Agency (2004), we group the different participants into the following categories:

- *Project team*: the project team consists of the project managers and the authorities responsible for river management. The project team can be supported by experts who provide the data and information from a scientific and engineering point of view.
- *Stakeholders*: stakeholders are any group or individual who can affect or is affected by the achievement of the organization's (or project's) objectives (Freeman 1984). The stakeholders are often organized into specific interest groups with similar interests (e.g. environmental organizations).
- *General public*: the general public can be defined as all people living in the project area who are not directly affected by the project and are not organized into specific interest groups.

### 3.2.1. Stakeholder identification and classification

The grouping of people into the mentioned categories is not an easy task. Especially the selection of relevant stakeholder groups can be difficult (Ananda & Herath 2003a). There exist different concepts to identify and classify stakeholder groups (Mitchell *et al.* 1997; Banville *et al.* 1998; Geiser *et al.* 2003; Mosler 2004). Mason & Mitroff (1983) suggest a systematic approach for identifying stakeholders by a set of complementary and sometimes overlapping procedures (imperative, positional, reputation, social participation, opinion leadership, demographic, organizational). The International Institute for Environment and Development propose a range of key questions to be asked for the identification of relevant stakeholder groups (IIED 2001):

- Who are potential beneficiaries?
- Who might be adversely affected?
- Who has existing rights?
- Who is likely to be voiceless?
- Who is likely to resent change and mobilize resistance against it?
- Who is responsible for intended plans?
- Who has money, skills or key information?
- Whose behavior has to change for success?

The process of stakeholder identification might result in a large list of potential stakeholders. Hence, stakeholders need to be classified according to different criteria (stakeholder classification). The stakeholder salience model (Mitchell *et al.* 1997) consists of three principles for stakeholder classification: power, legitimacy, and urgency. Mitchell *et al.* (1997) argue that stakeholder salience will be positively related to the cumulative number of stakeholder attributes – power, legitimacy, and urgency – perceived by managers to be present. A slightly different model for stakeholder classification is proposed by the International Institute for Environment and Development (IIED 2001). Thereby, stakeholders are classified according to their influence and importance. *Influence* is the power which a stakeholder has to control what decisions are made, facilitate implementation, or exert influence which affects the project negatively. *Importance* indicates the priority given by the project to satisfying a stockholder's needs and interests through the project. Based on the two criteria, one can (i) identify the primary stakeholders of the project (high influence and high importance), and (ii) identify stakeholders with similar characteristics (and eventually merge them into one stakeholder group).

### 3.2.2. Goals and risks of public involvement

***Goals of public involvement***

The success of public involvement in environmental planning projects is often evaluated by whether or not an agreement is reached and implemented (Connick & Innes 2003). There is wide agreement in the literature that consensus alone is only a partial measure of success (Daniels & Walker 1996; McDaniels *et al.* 1999; Gregory *et al.* 2001; Connick & Innes 2003). This is due to several reasons. First of all, conflicts might include factors which are beyond stakeholder control (Daniels & Walker 1996). However, agreements can also be achieved without gaining a good understanding of the problem and knowing remarkably little about the relevant objectives, range of alternatives, or the impacts and tradeoffs involved (McDaniels *et al.* 1999). Gregory *et al.* (2001) argue that focusing on dispute resolution and consensus can impede the creation of insights for decision makers and, in many cases, lead to the adoption of inferior policy choices. Connick & Innes (2003) conclude that if one focuses first and foremost on whether agreements were obtained, one misses the most important results of public involvement processes, such as the building of social and political capital, learning and change, the development of high-quality information, and new and innovative ideas.

The main objectives of public involvement can be summarized as follows (this list is based on the work of Beierle (1998), Mosler (2004) and Marttunen (2005), and modified for the purpose of this study):

*Inform the public*: One basic objective of public involvement is to inform people about the project. Without good information, other objectives such as understanding and social learning cannot be reached.

*Incorporate public knowledge and values*: According to Daniels & Walker (1996), a common phrase among natural resource managers is that "if the public only knew what we know, they would agree with us; how can they be taught that what we are doing is right?" Such a statement is based on the presumption that the worldview of the agency professional is both fully informed and somehow 'right', and the only participants needing to learn are the public (Daniels & Walker 1996). But since the management of environmental planning projects is a very complex and challenging task, the responsible managers can neither be neither fully informed nor fully correct. In fact, local knowledge and values can be very valuable information for environmental planning projects, and it is very important to incorporate this information into the decision making process. Another positive aspect of public involvement is that it challenges planners to consider much more carefully the assumptions and rationales behind their calculations and assessments (Marttunen 2005).

*Improve understanding*: One main objective of public involvement is the improved understanding of each stakeholder about the DMS, the alternatives and their outcomes, and potential objectives and criteria to evaluate the alternatives. According to Bogetoft & Pruzan (1991), one main reason for conflicts is stakeholder disagreement with regard to the outcomes of alternatives. Hence, a common understanding of the actual situation, potential alternatives and outcomes is very valuable for the negotiation process. The aspect of 'improve understanding' could also be named 'enhance individual learning'.

*Enhance social learning*: McDaniels & Gregory (2004) define social learning as building knowledge within groups, organizations, or societies. In the context of this study, major aspects are to learn about other stakeholders' objectives and preferences and about other stakeholders' knowledge. Hence, we focus here on learning aspects between stakeholder groups with different, sometimes conflicting objectives. This aspect is crucial since differences in preferences and trade-offs between objectives is one major reason for conflicts (Bogetoft & Pruzan 1991). To learn about other stakeholders objectives and trade-offs does not imply that there are no longer differences in preferences and trade-offs, but it is an important step towards a common vision of the problem.

*Building trust*: Many people have limited trust in public institutions and limited confidence in the decision making process (Marttunen 2005). Further, stakeholders with conflicting interests might also have limited trust in each other. It is clear that an atmosphere of mistrust is not beneficial for successful public involvement. Hence, to build up trust both between the project team and stakeholders as well as between stakeholders is an important objective.

*Reach consensus agreement*: We argued above that consensus agreement should not be the only measure of success for public involvement. However, one has to be aware that reaching consensus solutions might still be one important objective of public involvement in environmental planning projects. Thereby, all the mentioned objectives above can support the negotiation process among conflicting stakeholder groups.

***Risks of public involvement***

One has to be aware that public involvement is not only a flawless solution to environmental planning dilemmas, but that it might also be associated with potential problems (Duram & Brown 1998). One problem is that public involvement might demand increased allocation of money, time and human resources (Blahna & Yonts-Shepard 1989). Another aspect is the fear that the public has not enough expertise to participate in complex management projects (Garin *et al.* 2002). Further, the process of public involvement can also create conflicts (Moote *et al.* 1997; Kangas & Store 2003). And last but not least, there is always the question whether public participation should include the whole general public or focus on a small group of stakeholders (Renn *et al.* 1995).

The discussion about the goals and risks of public involvement reveals that it is very important to choose an appropriate public involvement mechanism for a specific context. An overview of different involvement mechanisms and their main purpose are described in the next sections.

### 3.2.3. Public involvement mechanisms

There are various mechanisms for public involvement in the decision making process, depending on the aim of the involvement (Fiorino 1990; Renn *et al.* 1993; Morgan 1998; Konisky & Beierle 2001; Beierle 2002; Environmental Agency 2004; Väntänen & Marttunen 2005). The mechanisms for public involvement can be divided into four categories (Väntänen & Marttunen 2005): 1) mechanisms primarily for informing and educating, 2) mechanisms primarily to seek public input, 3) mechanisms to promote information exchange and interaction, and 4) mechanisms that aim to find commonly agreed solutions (conflict resolution and negotiation). For each of these categories, there exist different methods (Table 3.2), which will be summarized below.

*Table 3.2: Mechanisms for public involvement.*

| Category | Mechanisms for public involvement |
|---|---|
| Information | Website, newsletter, information pavilions, exhibitions |
| Seeking public input | Surveys |
| Information exchange and interaction | Public meetings |
| | Expert workshops |
| | Stakeholder interviews |
| Finding agreed solutions | Stakeholder forum (advisory committee, steering committee) |

***Methods for information***

Good information for the public is a precondition for successful involvement in the process. There are different ways to inform people: websites, electronic or postal newsletters, information in different media (newspapers, radio and television), information pavilions, exhibitions etc.

***Surveys***

Surveys aim to gather the perceptions of the general public and their attitudes towards specific questions. Surveys can be conducted personally as well as in written form. The main advantage of surveys is that information can be gathered from a large number of people within a short timeframe (Väntänen & Marttunen 2005). In contrast to stakeholder interviews, the communication is mainly one way (from the public to the project team).

***Public meetings***

Public meeting is a suitable method to inform the public about the project as well as seek input from the public. In contrast to surveys, the public meeting is a forum for discussion, and the communication is two-sided. Public meetings aim mainly to identify the problematic aspects of the project. However, Morgan (1998) describes various problems with public meetings: first, the reluctance of many people to attend such meetings, and second, when they do attend, their reluctance to speak in public. Consequently, the meetings can be dominated by more vocal individuals or groups and can become confrontational and acrimonious, rather than encouraging and open with free exchange of information and views.

***Expert workshops***

In workshops, it is possible to systematically concentrate on the specific problems that require special attention (Morgan 1998). We will focus here on expert workshops with scientific information exchange (for stakeholder workshops, please refer to "stakeholder forum"). Expert workshops can be useful to discuss and solve the technical and scientific problems of a project.

***Stakeholder interviews***

Stakeholder interviews enable personal exchanges of information between the project team and a stakeholder group or individual. Stakeholder interviews are the most common way to discuss the relevant objectives and elicit stakeholder preferences based on MCDA methodologies. The personal interview is a good way to build up confidence between the stakeholder representatives and the project team. However, personal interviews are very time consuming, and only a limited number of stakeholder interviews can be conducted. Hence, the advantages and disadvantages of stakeholder interviews are opposite to the ones of a survey: the stakeholder interviews cover only a small number of people, but they are a suitable method to get a deeper insight into values and attitudes of stakeholders and building up confidence between stakeholders and the project team.

A potential disadvantage of stakeholder interviews is the subjectivity and sensitivity of the results towards the interviewer's own interpretation (Väntänen & Marttunen 2005).

***Stakeholder forum***

The stakeholder forum (or also called 'advisory committee' or 'steering committee') comprises representatives of all major stakeholder groups, brought together to support and encourage the active involvement of stakeholders in a project (Environmental Agency 2004). The aim of a stakeholder forum is not only information exchange, but also to find potential consensus solutions and eventually to agree on one solution. In today's river rehabilitation projects, the stakeholder forum has become a very popular institution for public involvement.

### 3.2.4. Characteristics of public involvement mechanisms

The description of the public involvement mechanisms revealed that each mechanism has its advantages and disadvantages, depending on the purpose of public involvement. Not all involvement mechanisms are equally suited to achieve the objectives of public involvement mentioned above. Table 3.3 gives an overview of which involvement mechanisms might be suitable to achieve which objectives.

Stakeholder interviews and stakeholder forums are most promising to achieve most objectives of public involvement (Table 3.3). This conclusion corresponds to the findings of Duram & Brown (1998) and Beierle (2002). Beierle (2002) examined 239 case studies of public involvement and concluded that the intensive involvement mechanisms (such as stakeholder interviews and forum) are often better funded and are more likely to produce higher-quality decisions. Duram & Brown (1998) conducted a mail survey of 64 watershed projects (asking mainly federal, state and local governments) and found that two-way communication mechanisms were judged to be most successful in getting the public involved. This finding is also in line with Bratrich (2004) who carried out personal interviews with 16 river managers from Europe and USA. Despite the fact that surveys have very limited potential in the collaborative planning process, they can be useful when opinions of a wider public are needed (Marttunen 2005).

*Table 3.3: Evaluation of public involvement mechanisms according to selected objectives, modified from Beierle (1998), Mosler (2004) and Marttunen (2005).*
*++ = very suitable, + = potentially suitable, – = not suitable*

| Public involvement method | Inform the public | Incorporate public knowledge and values | Improve understanding | Enhance social learning | Build trust | Reach consensus agreement |
|---|---|---|---|---|---|---|
| Website, newsletter | ++ | – | + | – | + | – |
| Surveys | + | ++ | – | – | – | – |
| Public meetings | ++ | + | + | + | + | – |
| Expert workshops | – | ++ | – | – | – | – |
| Stakeholder interviews | + | ++ | ++ | + | ++ | + |
| Stakeholder forum | + | ++ | ++ | ++ | ++ | ++ |

This indicates that the suitability of involvement mechanisms might also depend on the participants. For example, stakeholder interviews and stakeholder forums are generally more intensive than surveys or public meetings. Hence, they focus on the involvement of selected stakeholder groups, rather than the involvement of the whole public. Figure 3.3 shows which involvement mechanisms are appropriate for which audiences. However, it is important to state that the mechanisms ‘stakeholder interviews’ and ‘stakeholder forums’ could also be conducted with selected citizens from the public, rather than representatives of stakeholder groups (Renn *et al.* 1993).

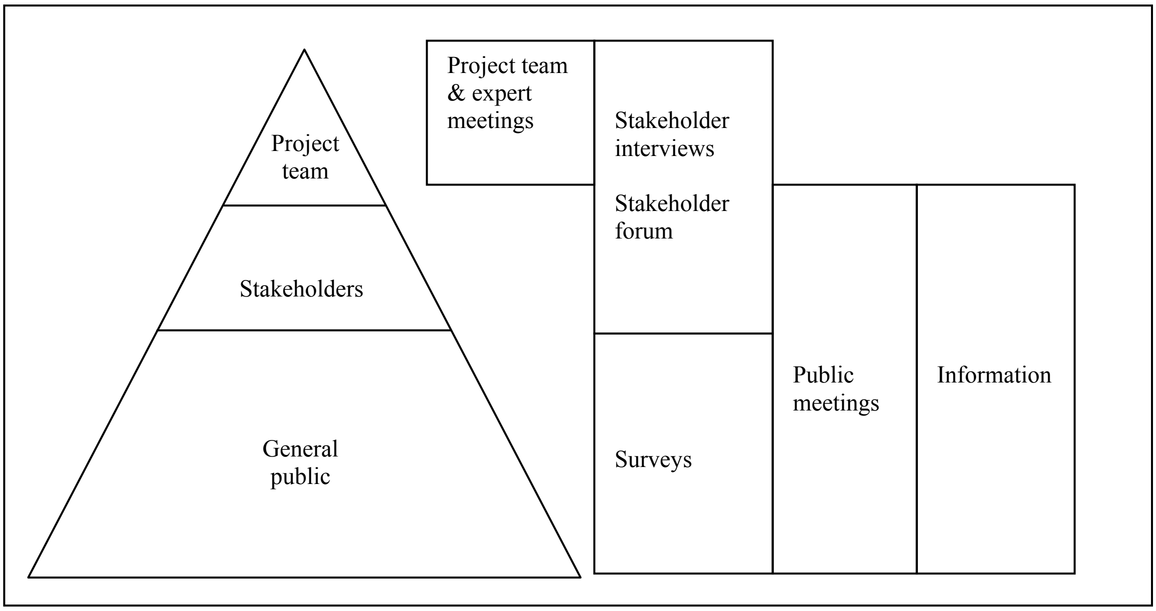


*Figure 3.3: Triangle of public participants and appropriate public involvement mechanisms, modified from Environmental Agency (2004).*

### 3.2.5. Public involvement in the project phases

Based on the characteristics of public involvement mechanisms, one can analyze which mechanisms might be suitable for which DMS. Information of the public and incorporating public knowledge and values are important objective at all DMS. Hence, the corresponding mechanisms (information methods, surveys) might be applied all three institutional levels. Similarly, the knowledge of experts is required at all institutional levels. At river basin level, a further objective is to improve understanding and social learning of regional stakeholder groups. Appropriate mechanisms are public meetings and stakeholder interviews with regional stakeholder representatives. The local level is probably the most conflict-potential environment of all three institutional levels. This is due to the fact that stakeholders are directly affected by the rehabilitation measures and that trade-offs between objectives are more concrete at this level. Hence, the mechanisms ‘stakeholder interviews’ and ‘stakeholder forum’ seem to be most suitable, since they support stakeholder understanding, social learning and consensus agreement.

This shows that for most DMS, a combination of different public involvement mechanisms might be most appropriate. Since stakeholder interviews and stakeholder forums seem to be most promising to achieve the major objectives of public involvement, we will focus in this study on the combination of MCDA methods and these two involvement mechanisms. Consequently, we concentrate on the upper two levels of the triangle in Figure 3.3, namely the project team and the stakeholders. The lower level of the triangle, the general public, is not the main focus of this research, and the corresponding mechanisms will be analyzed in another project within the Rhone-Thur project (Junker in preparation). How the MCDA methods might be applied in the various DMS is discussed in the next section.

## 3.3. MCDA methods for project phases

### 3.3.1. Introduction

MCDA methods might be more appropriate for some of the decision making situations (DMS) described in section 3.1 than for others. In case that a DMS can be supported by a MCDA method, it is defined as a MCDA problem. There are different aspects which constitute a MCDA problem. First, there must be some decision to be made. By definition, MCDA must also involve consideration and balance of 'multiple criteria' (Belton & Stewart 2002). The criteria are comprehensive and measurable representations of the decision maker's objectives (Belton & Pictet 1997). However, the presence of these two aspects does not require the application of MCDA methods in every case. There are many decisions we make each day which require the balancing of multiple criteria. For example, when you decide in which restaurant you would like to go for dinner, you probably take into account the style of food (e.g. Italian, Asian or French), the costs, the atmosphere of the restaurants, the location, etc. But to analyze this particular decision, only a few people would use a formal MCDA model. The reasons are that the decision is easy enough to take account of all factors in one's head, the consequences are not substantial, and mistakes are easily remedied (Belton & Stewart 2002). In other words, the decision does not matter that much.

However, there are many occasions, especially in environmental management contexts, where the decision might be more complex, and where the decision does matter. Decision situations might be complex due to several reasons: large amount of decision makers and stakeholders, uncertain outcomes, far reaching consequences, and large amount of data (section 1.2.1). When a DMS involves one or several of these aspects, MCDA methods can offer support. However, besides the mentioned points, one has to consider how the decision is coped with in today's practice. If detailed guidelines exist on how to come to a specific decision and the decision is already handled well in practice, there is no need for the application of a formal decision support method.

Considering the large amount of MCDA methods, an important question is which MCDA method might be most suitable for the specific DMS? MCDA approaches have been evaluated and compared in several studies (Belton 1986; Hobbs *et al.* 1992; Stewart 1992; Raju & Pillai 1999b; Mahmoud 2000; Bell *et al.* 2001; Stewart & Losa 2003; Greening & Bernow 2004). One main result is that none of the MCDA methods can be considered as the 'supermethod' appropriate to all DMS (Guitouni & Martel 1998). Each method has its own strengths and weaknesses (Mahmoud 2000). It is generally assumed that there are no better or worse techniques, but techniques better fitted than others to particular decision problems (Haralambopoulos & Polatidis 2003). Lahdelma *et al.* (2000) conclude that the choice of the appropriate method depends upon the nature of the problem and the kinds of information deemed relevant to the decision makers. Some approaches may be used at different stages of a deliberative process, in combination at a given stage, or as complements in the final decision making (Greening & Bernow 2004). Guitouni & Martel (1998) state that the MCDA method should be adapted to the specific DMS and not the opposite.

### 3.3.2. Criteria for selection of MCDA methods

Unfortunately, in practice, the choice of the method is in many cases motivated by a sort of familiarity and affinity with a specific method, rather than the suitability of the method for the given decision making situation (Guitouni & Martel 1998). This might be due to limited guidelines on how to choose an appropriate MCDA method for a specific DMS. Hence, we propose the following criteria for the selection of appropriate MCDA methods (modified from Guitouni & Martel (1998) and Belton & Stewart (2002)):

- *Decision problematic:* What kind of information does the decision maker want to gain from the analysis? According to Roy (1996), we will use the term "problematic" and remain close to the original French word "problématique", even if it seems like jargon. Roy (1996) identifies four different problematic, for which MCDA might be useful:
  - The choice problematic: To choose a "best" alternative from a set of alternatives.
  - The sorting problematic: To sort actions into categories, such as "definitely acceptable", "possibly acceptable but needing more information", and "definitely unacceptable".
  - The ranking problematic: To place actions in some form of preference ordering which might not necessary be complete.
  - The description problematic: To describe actions and their consequences in a formalized and systematic manner, so that decision makers can evaluate these actions. Belton & Stewart (2002) describe this problematic as a learning problematic, in which the decision maker seeks simply to gain a greater understanding of what may or may not be achievable.
- *Stage of process:* Is the aim of the method a preliminary screening, an initial evaluation with special interest groups or the direct involvement of stakeholders in the final decision?
- *Client group/number of stakeholders:* Who is the client group? Is this only one decision maker, a group of decision makers with more or less common interests or a larger group of stakeholders with conflicting interests? What is the methodological background of the client group (are the people experienced with the methodological background of MCDA methods, or are they lay people)?
- *Input information:* What is the quality and quantity of input information available? On which scale is information available (ordinal/cardinal scale)?
- *Set of alternatives:* How many alternatives are under consideration? Is the set of alternatives limited to a specific number, or does the decision maker aim to develop new and consensus-oriented alternatives?

One has to be aware that there are other criteria which might also influence the choice of an appropriate MCDA method. However, we believe that the mentioned points are the major criteria for the topic "river rehabilitation". The main decision making situations are characterized based on these criteria in Table 3.4. Based on this characterization, we conclude that all DMS constitute a MCDA problem, since they involve several aspects of a complex decision situation (e.g. multiple objectives, multiple decision makers and/or stakeholders, far reaching consequences).

*Table 3.4: Characterization of decision making situations based on criteria for MCDA selection.*

| | **Decision making situation** | | | |
|---|---|---|---|---|
| | Assessment of options national level | Assessment of options river basin level | Assessment of options local level | Evaluation of success national, river basin and local levels |
| Decision problematic | Sorting of river basins with similar characteristics (sorting problematic). | Ranking of feasible locations. Selection of most feasible locations (ranking problematic). | Choice of the most suitable alternative (e.g. with lowest conflict potential). (choice problematic) | Choice problematic (strategy/project successful or not). |
| Stage of process | Very early stage of process. Preliminary screening. | Early stage of process. Initial evaluation of locations. | Final decision about alternatives, direct involvement of decision makers/ stakeholders. | Evaluation of national strategy/river basin strategy or local project. |
| Client group | River managers (mainly federal administration). No active involvement of stakeholders and the public. | River managers (federal and cantonal administration). Involvement of regional stakeholder groups. | Active involvement of local stakeholders and the public in the decision making process. | River managers (mainly federal and regional administration) |
| Input information | Information available only on spatial-wide scale (regional or national scale). | Information available mainly on regional scale (qualitative and semi-quantitative estimations). | Detailed information available (e.g. cost estimates for alternatives). | Information gathered from specific studies after finalizing the rehabilitation project. |
| Set of alternatives | Number of river basins defined and limited. | Number of locations defined and limited. | Number of alternatives not limited, elaboration of new alternatives with lower conflict potential. | Number of alternatives defined (status before and afterwards). |

### 3.3.3. Suitable MCDA methods for rehabilitation project process

In the following, we analyze which MCDA methods might be suitable for the specific DMS. For a more detailed description of the MCDA methods, please refer to chapter 2.

***National level: assessment of river basins***

The aim of the national strategy is to sort the river basins into groups with similar characteristics (e.g. bad flood protection level, deterioration of eco-morphology, artificial hydrology). Since the strategy stands at the early stage of the process, information is only available at a spatial-wide scale (regional or national scale). ELECTRE I and II consider these aspects, since they aim to conduct a sorting of alternatives, and they are suitable to handle qualitative information. One disadvantage of the ELECTRE methods is the limited number of options (e.g. river basins) which can be compared. Further, ELECTRE methods should ideally be applied by a professional analyst, since the underlying algorithms might even be too complex for sophisticated river managers.

Besides the ELECTRE methodologies, the decision analysis approaches (MAVT, MAUT) and the AHP method should be considered for this project phase. The main advantage of the multi-attribute value theory (MAVT) method is that it can be easily implemented in the geographic information system (GIS) software (e.g. Arc View GIS 3.3) (Pereira & Duckstein 1993; Store & Kangas 2001; Rohde *et al.* 2005). The MAVT and AHP method conduct a ranking of river basins, rather than a sorting of river basins (as the ELECTRE method does). In section 3.4.1, we introduce an integrative search strategy which is based on the combination of MAVT method and GIS to explore the suitability of river basins for rehabilitation measures.

Another suitable methodology at national level might be Cost-Benefit Analysis (CBA). The CBA method requires different input information. First, one needs a rough estimation of the costs of rehabilitation measures for each river basin. For example, the measures for flood protection and rehabilitation at the Rhone River basin in the canton Wallis (Switzerland) are estimated to be about 850 Mio SFr (Kanton Wallis 2000). Similar cost estimates exist for other river basins in Switzerland (e.g. Alpine Rhine River, Linth, Thur). Second, the potential benefits of the rehabilitation measures should be estimated. Major benefits of rehabilitation measures are reduced damage potential, increased ecological status and improved recreational possibilities. While the damage potential can be quite easily expressed in monetary units, the ecological and recreational benefits are not easily put in monetary valuations (section 2.5). However, the CBA method seems to be suitable to give a rough estimation of potential costs and benefits for rehabilitation measures for different river basins. Based on this information, various river basins could be compared and the river basins with the most promising benefit-cost ratio could be selected for rehabilitation measures.

***River basin level: prioritization of locations***

At river basin level, the main question is where to conduct the rehabilitation measures with what priority. Hence, the decision problematic is to identify and rank feasible locations for river rehabilitation. The project phase stands at a quite early stage of the process, and information is available mainly on a river basin scale. The client group is the responsible river managers, but regional stakeholder groups might also be involved in the decision making process. Therefore, the method should be understandable for lay people as well. Considering all these aspects, the AHP method and value function approaches (MAVT) are the most suitable methodologies for regional planning. The main advantage of the AHP method is that it is suitable to handle qualitative input information (Soma 2003). This is important since no detailed information might be available at this early stage of the process. However, the AHP method is based on pairwise comparisons of alternatives (e.g. locations), and hence, the number of locations to be compared with each other is limited. In contrast, the decision analysis approaches (MAVT, MAUT) do not have a limitation in the number of alternatives to be compared. However, the main disadvantage is the elicitation of preferences (value/utility functions and attributes weights) for an unknown impact range of the alternatives.

***Local level: assessment of alternatives for one location***

The aim of the local level is to decide which rehabilitation alternative should be implemented. In contrast to the national and river basin level, the key characteristic is that new alternatives can be elaborated. Considering this point, the multiple attribute value theory (MAVT) has major advantages. The elicitation of preferences based on MAVT does not directly depend on the alternatives (only the ranges of attributes must be specified). Hence, the preferences of stakeholders do not have to be re-elicited during the negotiation process when new alternatives are developed. In contrast to the regional level, detailed information about the outcomes of alternatives is available at this stage of the process. This eases the elicitation of value functions and weights for the attributes.

Other MCDM methods might also be suitable for this decision making situation, but have significant disadvantages in comparison to the MAVT method. The MAUT method is based on utility functions, and the elicitation of utility functions is much more difficult than the elicitation of value functions (see section 2.2). For the AHP, ELECTRE and PROMETHEE approaches, the elicitation of preferences depends on the alternatives (pairwise comparison of alternatives). Hence, preferences of river managers/stakeholders might have to be re-elicited when new alternatives are elaborated.

***Evaluation of success***

The success of a *local rehabilitation project* is evaluated by the comparison of the status before and after the rehabilitation measures. In today's practice, there is a lack of guidelines how to measure the success of river rehabilitation, and as a result, most rehabilitation projects do not undertake a formal success control (Bratrich 2004). Suitable MCDA methods are multi-attribute value theory (MAVT), Analytic Hierarchy Process (AHP) and PROMETHEE. These three methods differ in how the comparison of the two statuses (before and after) is accomplished. The MAVT method requires the elaboration of value functions for all attributes (based on reference conditions). The elaboration of value functions can be very demanding; however, the resulting functions might be generalized. The AHP method is based on the pairwise comparison of the two statuses for all attributes (weak/strong preference of one status over the other). This procedure does not require as much information as the elicitation of value functions. However, the pairwise comparisons have to be done for each application and cannot be generalized. For the PROMETHEE method, indifference and preference thresholds have to be defined by river managers and/or scientific experts (for an application of the PROMETHEE method, please refer to section 3.4.2).

The success of the *river basin strategy* is ideally evaluated after the measures at local levels are finished. Otherwise, the achievement of the objectives at the river basin level can not be measured (e.g. whether the "good ecological status" is reached or not). In general, the DMS is very similar to the local level, since it includes a comparison of the status before and after the rehabilitation measures on a river basin level. Hence, we propose the same MCDA methods for the river basin level as for the local level (MAVT, AHP or PROMETHEE). The same argumentation is valid for the national strategy.

***Conclusion***

The suitability of MCDA and CBA methods for the major project phases of river rehabilitation is summarized in Table 3.5. One has to be aware that this study focuses on MCDA and CBA methods. Other methods such as statistical methods might also be suitable for some DMS, but can not be discussed within this study.

*Table 3.5: Suitable MCDA and CBA methods for specific decision making situations. ++ very suitable, + suitable, - not specifically suitable*

| Decision making situation | Multi-attribute value theory (MAVT) | Multi-attribute utility theory (MAUT) | Analytic Hierarchy Process (AHP) | PROME-THEE | ELECTRE | Cost-Benefit Analysis |
|---|---|---|---|---|---|---|
| National level: assessment of river basins | ++ | + | + | + | ++ | + |
| River basin level: assessment of locations | + | – | ++ | + | + | – |
| Local level: assessment of alternatives | ++ | – | – | – | – | – |
| Evaluation of success (all levels) | ++ | + | ++ | ++ | + | + |

## 3.4. Applications of MCDA methods for river rehabilitations

This section refers to the MCDA applications which have been conducted within this study. We implemented MCDA methods for each DMS described above. The main focus of this study is the MCDA application at the river basin level and local level. Hence, these two applications are described in detail in chapter 4 and 5. We also applied MCDA methods at national level to develop a national strategy, and for the evaluation of success of a local rehabilitation project. This was done in combination with other research groups from the Rhone-Thur project. In the following, we will briefly discuss potential application of MCDA methods for these two DMS.

### 3.4.1. MCDA application for 'national strategy'

This section introduces a search strategy on national level to conduct a ranking of river basins based on their suitability for rehabilitation measures. The search strategy identifies river basins where present environmental (e.g. natural flow, sufficient bed load material) and socio-economic (e.g. public attitude) template conditions favor eco-morphological restoration of the floodplain. We will give now a short summary of the search strategy; for a detailed description and preliminary results, please refer to Rohde *et al.* (2005).

The integrative search strategy is designed to perform a pre-screening process at the national level and is based particularly on spatial information. A hierarchical filter process combines the facilities of GIS with multi-criteria decision analysis (MCDA) to generate restoration suitability maps. The filter process is based on a list of criteria and indicators that capture the ecological key factors that drive floodplain restoration (hydrology, bed load, connectivity, biodiversity, water quality) as well as socio-economic aspects (e.g. flood protection, public attitude) that need to be taken into account when planning for floodplain restoration. The search strategy focuses on local eco-morphological floodplain restoration by means of river widening, man-made secondary channels or flood levee reallocation.

Restoration suitability is determined by constraints and factors which might restrict or favor restoration efforts. The task of assessing restoration suitability is completed in a hierarchical filter process (Filter 1-3) where the corresponding filters consist of several criteria (Figure 3.4). Filter 1 determines river basins which are not suitable for eco-morphological river restoration based on limiting constraints. All river basins not excluded by this filter are generally suitable for eco-morphological river restoration. Filter 2 evaluates the restoration suitability according to specific ecological criteria (e.g.

hydrology and biodiversity). The restoration suitability of a river basin from an ecological point of view is assessed using the Ecological Restoration Suitability Index (ERSI). The combination of the different ecological indicators into the ERSI was done based on the multi-attribute value theory (MAVT) approach. The third filter (Filter 3) takes into account socio-economic factors that can play an important role in selecting a suitable river basin.

The result of the search strategy is the identification of river basins and stream systems suitable for morphological restoration according to both ecological and socio-economic criteria. Once a promising river basin or stream system is identified, more detailed investigations are necessary to choose suitable locations for restoration (river basin level, chapter 4).

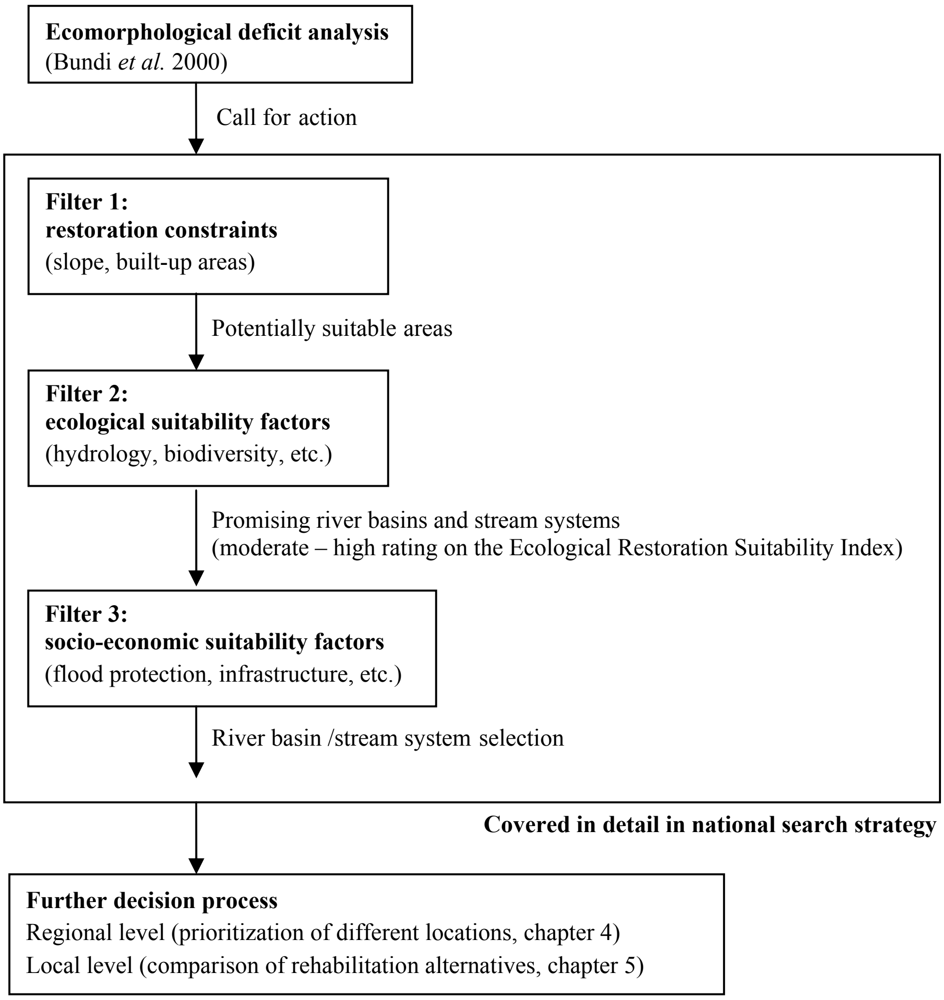


*Figure 3.4: Filter-based search strategy to identify river basins highly suitable for floodplain restoration according to ecological and socio-economic indicators.*

A main strength of the proposed search strategy is the combination of the facilities of GIS (spatial explicit data) with a multi-criteria decision analysis (MCDA) methodology. The spatially explicit data implemented in GIS enables the identification of deficits of the status quo of different river basins. However, one has to be aware that the search strategy focuses on one type of measure, namely the eco-morphological restoration of floodplains. Other restoration measures like removing dams and reducing water abstraction are not specifically addressed. Further, measures for reducing socio-economic deficits (e.g. retention basins for flood protection) are not addressed either. Therefore, further research is required to develop a national strategy which: 1) conducts a sorting of river basins into groups with similar characteristics, 2) compares the groups of river basins with similar characteristics and 3) evaluates which type of measures might be most efficient to reduce the actual deficits (ecological as well as socio-economic deficits).

### 3.4.2. MCDA application for project phase 'evaluation of success'

Evaluating the success of a local rehabilitation project can be done based on various MCDA methods: PROMETHEE, multi-attribute value theory (MAVT) approach, and Analytic Hierarchy Process (section 3.3.3). We will now give a short description of how to apply the PROMETHEE method to this project phase. For application of the MAVT method, please refer to (Woolsey *et al.* 2005).

To evaluate the success of a project, the status after conducting the rehabilitation measures has to be compared with the status beforehand. This comparison is done based on ecological and socio-economic criteria. For each criterion, one has to ask whether there is a change from beforehand to afterwards and whether this change can be judged as a success or not. This judgment can be done in PROMETHEE by a preference function for each criterion which represents the intensity of preference of the status afterwards with regard to the status beforehand. For the definition of the preference functions, one has to identify the indifference and preference thresholds (Brans *et al.* 1986). The *indifference threshold* can be interpreted as the greatest value below which there is no success of the project for this criterion. The *preference threshold* is the lowest value above which there is a strong success of the project.

For a better understanding, we give a hypothetical example based on the ecological criterion 'number of fish species'. We assume that only 4 fish species were present in the river before conducting the rehabilitation measures. At the same time, we know based on historical data that 14 fish species were counted under natural conditions. After conducting the rehabilitation measures, the number of fish species increased up to 8 species. This is a doubling in comparison to beforehand, but only a 40%-increase of the potential increase considering the natural condition (increase of 4 fish species in comparison to a potential increase of 10 fish species). The question is whether this increase in 4 fish species is already a large or only a small success. To answer this question, we need the identification of the indifference and preference thresholds. These thresholds have to be defined by the responsible river managers *before* conducting the rehabilitation measures. The indifference threshold defines the value below which there is no success. For our hypothetical example, we assume that the river managers defined the indifference threshold to be equal to 2 fish species (Table 3.6). Further, we assume that high success is defined if the fish population reaches the maximum number of 14 fish species (increase by 10 species). This means that the preference threshold is equal to 10.

*Table 3.6: Number of fish species beforehand and afterwards and thresholds*

| Criterion | Status before | Status after | Difference in fish species | Natural reference | Indifference threshold q | Preference threshold p |
|---|---|---|---|---|---|---|
| Number of fish species | 4 | 8 | 4 | 14 | 2 | 10 |

Based on the indifference and preference thresholds, the preference function is defined (Figure 3.5). An increase in the fish population up to 2 fish species is considered as no success, an increase between 2 and 10 fish species is considered as weak success and an increase of 10 fish species and more is a strong success. As we have mentioned above, we assume an increase of 4 fish species in our example, which equals a weak success in this criterion (and a relative preference value of 0.25). This relative preference value is then multiplied by the weight of the criterion. Having the preference function and the weights for all criteria, the multi-criteria preference index $\Pi$ can be calculated (for further description of the PROMETHEE method, refer to the appendix).

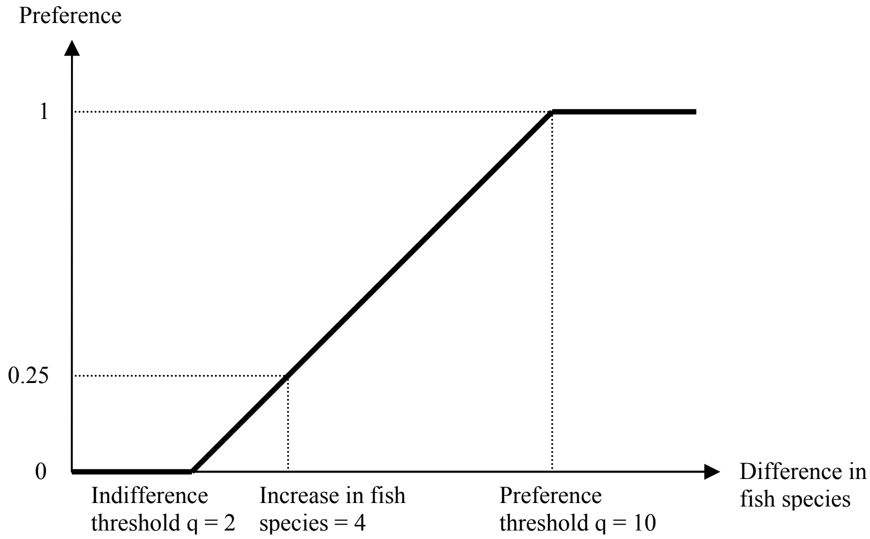


*Figure 3.5: Example of a preference function for criterion "number of fish species".*

This example shows that the PROMETHEE method might be used to describe which improvement in a specific criterion can be judged as a big, a small or no success. To do that, the river managers have to specify the indifference and preference thresholds for each criterion and the criteria weights. By defining these values, the river managers explicitly state which improvement in each criteria can be judged as a success. It is important to emphasize that the river managers have to define these values *before* the implementation of the rehabilitation measures. The pure listing of the indicator values in a consequence table has the disadvantage that the river managers have not defined in advance which improvement they want to achieve.

One has to be aware that the preference functions of PROMETHEE cannot be generalized, since the indifference and preference thresholds might be different in each case. As a result, different projects cannot be compared with each other; only the status before and after the rehabilitation measures can be compared for each project.

## 3.5. Conclusions

Based on the detailed investigations of the former sections, this section now summarizes the whole integrative framework for the field of river rehabilitation. The general concept of the integrative framework consists of different steps (Table 3.7). First, one has to identify the decision making situations (DMS) and the institutional level at which they occur. In the field of river rehabilitation, we identified four major DMS: assessment of options at the national, regional and local levels, and evaluation of success. After the DMS are generally identified, one has to define the main characteristics of the DMS. Important aspects are: stage of the process, client group, input information, time and resource availability, decision problematic and the set of alternatives. The core point at the national level is that data are available only on a spatial-wide scale. For the regional level, there are hardly any detailed quantifications of outcomes available. The local level is the most conflict DMS, since a broad range of stakeholder interests are affected by the decision. The evaluation of success is based on real measurements, and only two alternatives have to be compared (status before and after rehabilitation).

Since public involvement is a major aspect in environmental management projects, one should also define the objectives which should be achieved by public involvement. At the national level, the main objective is to inform the public, since no major stakeholder involvement takes place. The objectives at the river basin level include the incorporation of public values and knowledge and the improvement of stakeholder understanding. The focus at local level is to support stakeholder understanding and social learning, to build trust and to reach consensus agreements. The main objective of the success evaluation is to improve further projects based on the learning process of river managers and to inform the public about the success of the project.

Based on the main characteristics of the DMS and the objectives of public involvement, one can select the MCDA method which best suits the specific DMS. The proposed MCDA methods are listed in Table 3.7 (for a detailed discussion, please refer to section 3.3). Last but not least, the MCDA method has to be incorporated in the specific decision process. It is important to emphasize that the manner of incorporating the MCDA method in the decision process is one of the most important questions for a successful MCDA application. In the following, we will focus on MCDA applications for which we conducted extensive post-evaluation studies: prioritization of locations at the river basin level (chapter 4) and comparison of alternatives at the local level (chapter 5).

*Table 3.7: Contents of integrative framework for river rehabilitation.*

| Decision making context and institutional level | Major characteristic of DMS | Main objectives of public involvement | Suitable MCDA methods | MCDA application within this study (chapter & scientific article) |
|---|---|---|---|---|
| *National level:*<br>Grouping of river basins according to their deficits. | Data are available only on spatial-wide scale.<br>No major stakeholder involvement. | Inform the public | ELECTRE I, II<br>MAVT | Chapter 3.4.1.<br>Rohde *et al.* (2005) |
| *River basin level:*<br>Prioritization of locations within a river basin. | Hardly any detailed quantification of outcomes for locations. | Inform the public<br>Incorporate public values and knowledge<br>Improve stakeholders' understanding | AHP | Chapter 4:<br>Alpine Rhine River Project |
| *Local level:*<br>Comparison of alternatives for a location. | Most conflict DMS, since broad range of stakeholder interests are involved. | Incorporate public values and knowledge<br>Improve stakeholders' understanding and social learning<br>Building trust<br>Reach consensus agreement | MAVT | Chapter 5:<br>Thur River Project<br>Hostmann *et al.* (2005a)<br>Hostmann *et al.* (2005b) |
| *Local level:*<br>Evaluation of success. | Comparison of two alternatives (status before and afterwards).<br>Real measures for outcomes (not only prediction of outcomes). | Inform the public<br>Incorporate public knowledge and values<br>Improve river managers' learning | PROMETHEE<br>MAVT<br>AHP | Chapter 3.4.2.<br>Woolsey *et al.* (2005) |

# 4. Decision support for prioritization of rehabilitation sites

This chapter evaluates the contribution of MCDA for prioritization of locations within a river basin. It is structured as follows: we first give an introduction to the major decision making situation and the case study Alpine Rhine River (section 4.1). Second, we describe the main objectives for prioritization, the subjects, and the locations to be compared (section 4.2). We then present the results of the study (section 4.3) and conclude with a discussion of the main contribution of MCDA in this setting (section 4.4).

## 4.1. Introduction

A major decision support situation (DMS) at the river basin level is to identify and compare feasible locations for rehabilitation. At present, rehabilitation sites are often selected opportunistically and on an ad hoc basis rather than according to a strategic planning process (Hobbs & Norton 1996; Clarke *et al.* 2003). However, modern legislation, such as the European Water Framework Directive (EU-WFD), emphasizes the importance of strategic planning at the river basin level. A central aspect of the EU-WFD is the requirement that all rivers in Europe have to achieve good ecological status by the year 2015 (European Parliament 2000). Since the aim of a good ecological status can hardly be achieved by reactive, site-to-site activity, the Directive points out that the best model of water management at the river basin level (European Parliament 2000). The Directive prescribes river management plans which have to be elaborated for each river basin and which coordinate the programs of measures to achieve the environmental objectives of the EU-WFD.

There is a growing number of decision support systems (DSS) in the field of river basin management (Llewellyn *et al.* 1996; Verbeek *et al.* 2000; Lamy *et al.* 2002; Lauri & Virtanen 2002; Pieterse *et al.* 2002; Mysiak *et al.* 2005). Many of these DSS are based on geographic information systems (GIS) and support the establishment of strategies on a broad, basin-wide scale. However, Tippett (2005) emphasizes that one of the key difficulties in river basin planning is to connect the strategic, basin-wide planning with the local scale, which is generally the scale at which the public is engaged and project decisions are made. Despite the awareness of this difficulty, there is a lack of tested methods to link the river basin scale with the local scale. This chapter describes how the two scales can be linked by implementing the basin-wide strategy at specific sites within the river basin. In many cases, rehabilitation measures can not be implemented along the whole range of the river. Therefore, a comparison and prioritization of locations is necessary to guarantee that rehabilitation measures are most effective according to the basin-wide strategy.

The aim of this chapter is to evaluate the contribution of MCDA methods for the prioritization of locations based on preferences of a small group of decision makers. We applied the Analytic Hierarchy Process (AHP) method to an ongoing rehabilitation project at the Alpine Rhine River in central Europe. We conducted structured interviews with representatives of the project team and elicited their preferences with regard to important objectives. Furthermore, we analyzed the advantages and disadvantages of the locations with regard to the objectives. Based on this information, we conducted a ranking of the locations according to their urgency to be implemented. The decision makers were confronted with methods' results, and their feedback gave us important insight in the main contribution of MCDA methods in this setting.

### 4.1.1. Case study Alpine Rhine River

The Alpine Rhine River (in German: Alpenrhein) is an international river stretch in central Europe. The catchment area of the Alpine Rhine River covers 6119 km$^2$ and includes part of the cantons Grisons and St. Gallen in Switzerland, part of Vorarlberg (Austria), the whole principality of Liechtenstein and a very small part of Italy (Figure 4.1). The Alpine Rhine River with a length of 90km refers to the stretch from Reichenau (confluence of Vorderrhein and Hinterrhein) to the Lake of Constance (Bodensee).

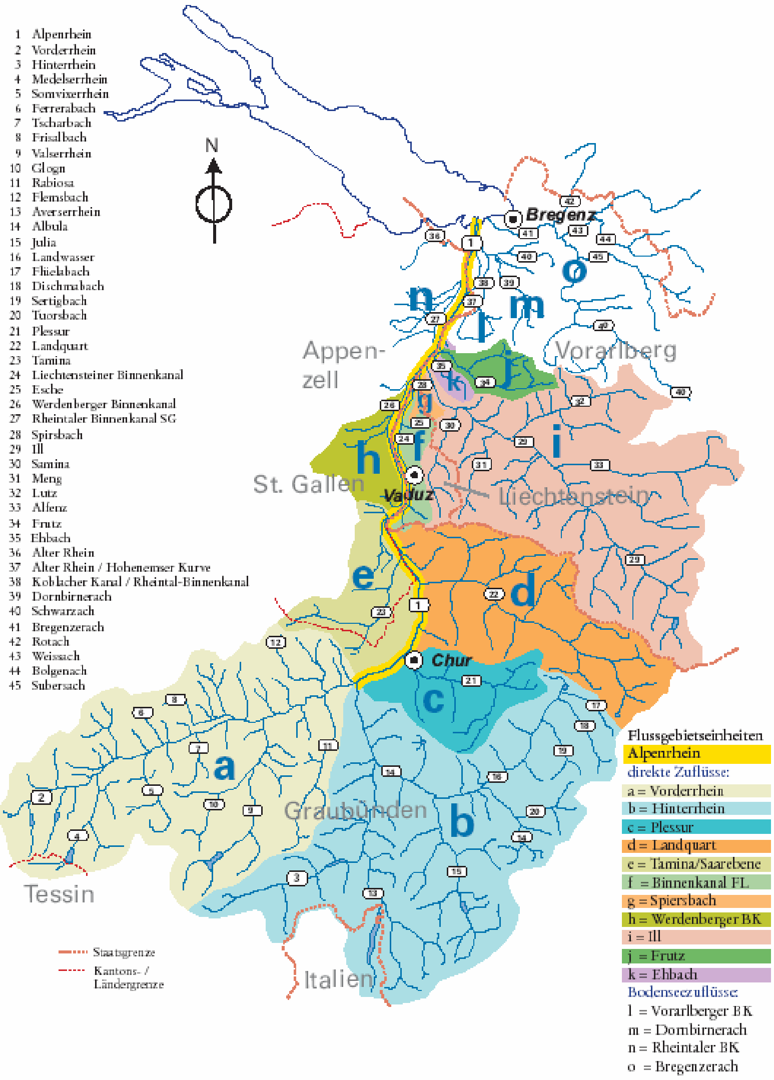


*Figure 4.1: Catchment area of the Alpine Rhine River (IRKA 2004b).*

The Alpine Rhine River consists in its natural state of three major morphological types. The *braided river type* extends in the natural Alpine Rhine River from Felsberg to Trübbach/Balzers. This river type is characterized by high dynamics and is divided into several side branches. The *meandering-braided river type* corresponds to the transition between the braided river type and the meandering river type (IRKA 2003c). In the natural Alpine Rhine River, the meandering-braided river type extends between Trübbach/Balzers and St. Margarethen/Höchst and corresponds to the largest stretch of the Alpine Rhine River. The meandering-braided river type is characterized by a high diversity of morphological structures and ideal habitat conditions for more or less all fish species (IRKA 2003c). The *meandering river type* corresponds to the lowest stretch between St. Margarethen/Höchst and the estuary in Lake of Constance. In the natural status, the river flow claimed big parts of the Rhine valley. Figure 4.2 (left side) shows a picture of the Rhine River drawn in the year 1826.

*Figure 4.2: Alpine Rhine River between Bad Ragaz and Sargans in the year 1826 (left side) and in the year 2004 (right side). (left side: Amt für Umweltschutz, Fürstentum Liechtenstein, right side: Markus Hostmann).*

However, the Alpine Rhine River is not in a natural status anymore due to several impacts. Between 1850 and 1930, the Rhine River was channelized and the area of floodplains was drastically reduced (Figure 4.2, right side). Further, a large amount of gravel has been taken out from the river since 1954. As a result, the river bed between Landquart and the river mouth Ill has been lowered by up to 5 meters (IRKA 2003c). Besides the morphological degradation, the Alpine Rhine River also shows an artificial hydrology. In total, there are about 40 hydropower reservoirs within the catchment area of the Alpine Rhine River (IRKA 2003c). The hydropower generation results in an artificial increase and decrease of the water level in the Alpine Rhine River (hydropeaking effect). The water level in the Alpine Rhine River changes by more than one meter within a few hours (IRKA 2003b).

The sum of the canalization of the river, the erosion of the river bed and the hydropeaking has had severe impacts on the river and the surrounding area. The ecological condition of the Alpine Rhine River was analyzed based on the classification of the EU Water Framework Directive (European Parliament 2000), (Table 4.1). Nowadays, 65% (59km) of the Alpine Rhine River has a bad ecological status (level 5), and 31% (28km) has a poor ecological status (level 4) (IRKA 2003b). Only one section with a length of 3.3km (4%) (Mastrilser Rheinauen) shows a moderate ecological condition. This section has not been channelized and hence is still in a near-natural morphological condition. However, due to the hydropeaking effect, the ecological condition is not higher than the status ‘moderate’.

*Table 4.1: Ecological status classification according to the EU Water Framework Directive (European Parliament 2000).*

| Level | Ecological status classification |
|---|---|
| 1 | High |
| 2 | Good |
| 3 | Moderate |
| 4 | Poor |
| 5 | Bad |

In addition to the ecological conditions, the Alpine Rhine River also has deficits in flood protection. Along the whole stretch of the Alpine Rhine River, the capacity of discharge is guaranteed for a 100-year flood event. However, in the case of a severe flood event (300-year flood event or more), the damage potential is predicted to be significant. The predicted damage potential for a 300-year flood event is 5’677 Million CHF (only for the lower section), and 11’100 million CHF in the case of an extreme flood event (for the whole Alpine Rhine River) (IRKA 2003d) (Table 4.2). It is noteworthy that the damage potential at the lower section is much higher than at the upper and middle sections. The underlying reasons are that: 1) the flow capacity of the upper and middle sections is higher than of the lower section, and 2) the river valley at the lower section is densely populated.

*Table 4.2: Estimated damage potentials at the Alpine Rhine River valley for different flood events (IRKA 2003d).*

| River section | Damage potential for a 300-year event ($FQ_{300}$) (Mio. CHF) | Damage potential for an extreme flood event (>$FQ_{300}$) (Mio. CHF) |
|---|---|---|
| Upper section (Reichenau – Landquart) | 8 | 353 |
| Middle section (Landquart – Illmündung) | No data existing yet | 2’651 |
| Lower section (Illmündung – Lake Constance) | 5’677 | 8’096 |
| Total | 5’685 | 11’100 |

After the canalization, the surrounding area of the river has been used for different purposes. Currently, about 450’000 people live in the Alpine Rhine valley, and the majority of people live and work in former floodplain areas (IRKA 2003d). Furthermore, the surrounding area of the river is used for farming and forestry. Major transportation systems (highway, railway) have been constructed near the channelized river bed. Another important aspect is groundwater recharge. The Alpine Rhine River has an important influence on the groundwater table and groundwater quality. Because of erosion and clogging of the river bed, the infiltration of the Rhine water is nowadays reduced. This has resulted in a lower groundwater table and reduced groundwater quality (IRKA 2003c).

**River management plan**

The river management plan (in German: Entwicklungskonzept) aims to reduce the deficits of the Alpine Rhine River. It is the foundation for all future measures at the Alpine Rhine River. Within the river management plan, all important aspects (e.g. flood protection, groundwater, ecology and energy) will be coordinated and future measures will be proposed. All affected countries (Cantons Grisons and St. Gallen, Switzerland; Vorarlberg, Austria; Principality Liechtenstein) are represented in the core team of the project. In addition to the political representatives of all countries, the core team is led by an independent project manager. The planning of the proposed measures will be done by a group of international engineering agencies.

The river management plan is based on various objectives which describe the target state of the Alpine Rhine River (IRKA 2004a). This target state is the foundation for the planning of future measures. The river management plan focuses mainly on improvement in flood protection, river bed stability as well as ecological condition. Based on the EU Water Framework Directive (European Parliament 2000), the ecological status of the river ecosystem has to reach a good condition (Table 4.1). Further, the following objectives also play an important role: good recreational opportunities, protection of groundwater and drinking water, maintenance of the energy potential, maintenance of agricultural activity and success control of the measures (IRKA 2004a).

### 4.1.2. Decision making situation

To improve the mentioned deficits at the Alpine Rhine River, different types of measures have to be conducted at various locations along the river. Along the 90km length of the Alpine Rhine River, the river management plan suggests measures at 35 different locations. The main types of measures are as follows:

*1) Improvement of connectivity to side streams*

Due to the erosion of the river bed in the last decades (erosion up to 5 meters), many side streams are no longer properly connected to the main river. Currently, only 5 of 17 side streams (29%) are passable for all fish species (IRKA 2003c). To achieve a good ecological condition, this situation has to be improved.

*2) River widening*

Widening of the river bed provides more room for the river. This measure improves the ecological condition as well as the flood protection level. Further, the widening helps to stabilize the river bed and improves the exchange of river water with groundwater. Hence, river widening is the main type of measure proposed in the river management plan. River widening measures are planned at 18 locations along the 90km river stretch.

*3) Reduction of hydropeaking*

Reduction of the hydropeaking effect helps to improve the ecological condition of the river. Without the reduction of hydropeaking, it is not possible to reach the aim of a good ecological status of the river ecosystem. Hydropeaking can be reduced by retention basins or by changing the operation of the hydropower plant (no reallocation of water flow for peak period) (IRKA 2004c).

For each of the 35 proposed locations, one or more types of measures are planned. However, the measures cannot be conducted at all locations simultaneously. Therefore, the main question to be answered is which locations have a higher priority over others. This question is important for several reasons:

- The river management plan aims to conduct measures at all 35 locations. However, it is not clear whether the countries will be able to finance measures at all locations. Therefore, it is very important that the measures at the most appropriate locations can be implemented with high priority.
- Even if the involved countries agree to finance measures at all locations, the planning and construction of all measures will last about 20-30 years. However, some locations might have a higher urgency than other locations with regard to the deficits (e.g. flood protection, ecological conditions, erosion of river bed).
- The rehabilitation measures are cost-intensive and need space to be undertaken. Hence, it is important that the stakeholders and the public can be convinced about the importance of the measures; otherwise, conflicts are likely to arise. This means that the first measures should be successful and not create too many conflicts; otherwise, it will be even more difficult for the following locations.

Based on the relevance of this question, the political authorities of the Alpine Rhine River decided that the project team has to elaborate a prioritization of the locations. In the following, we suggest how this prioritization can be conducted based on MCDA methods.

## 4.2. Description of objectives, subjects and locations

### 4.2.1. Important objectives

The river management plan defines various objectives which describe the target state of the Alpine Rhine River (IRKA 2004a). The following aspects are mentioned as main objectives:

- High flood protection level
- Good ecological status
- Stabilization of river bed
- Good recreational opportunities
- Maintaining the energy potential
- Availability of land

Besides these aspects, further objectives might be important for the comparison and ranking of different locations. Based on interviews with representatives of the project team, the following objectives were added:

- Low costs
- Potential for a combination with other projects (e.g. gravel excavation)
- Low conflict potential

Each objective is described by a measurable criterion. The objectives and criteria are shown in Table 4.3.

### 4.2.2. Subjects

To manage the different measures within the Alpine Rhine River basin, the cantons of Grisons and St. Gallen (Switzerland), the region Vorarlberg (Austria) and the principality of Liechtenstein established the International Commission for the Alpine Rhine River (IRKA). The project team of the IRKA is responsible for defining the strategy and elaborating the river management plan. Thereby, the project team is supported by a group of scientific experts in the field of hydrology, river construction, flood protection and ecology.

In order to evaluate the contribution of MCDA methods for the prioritization of locations, we conducted interviews with four representatives of the project team of the IRKA. Thereby, two interview partners represented the responsible administrations (federal administration and regional administration). One interview partner was the planning expert, and one was the project manager of the river management plan. It is important to emphasize that our collaboration with the IRKA was on a scientific basis and that our work was conducted independently from the remaining planning efforts of the IRKA.

*Table 4.3: Objectives, criteria details, and anticipated ranges of criteria for the Alpine Rhine River.*

| Objectives | Criteria | Description of criteria | Units | Range |
|---|---|---|---|---|
| High flood protection level | Damage limit | The damage limit describes the discharge that can occur without causing damage to features requiring protection. The damage limit refers to a specific event (e.g. 100-year event $FQ_{100}$). | FQ | $FQ_{100}$ - $FQ_{300}$ |
| Good ecological status | Ecological status | Ecological status is analyzed based on the classification of the EU Water Framework Directive (European Parliament 2000). | Scale:<br>1 = high ecological status<br>5 = bad ecological status | 1-5 |
| Stabilization of river bed | Erosion of the river bed | Changes (erosion, sedimentation) of the river bed predicted for the next 25 years (IRKA 2003b). | Meters | ± 1.5 |
| Good recreational opportunities | Area of recreation | Attractive and accessible area for recreation. | ha ($10^4$ $m^2$) | 0-50 |
| Maintaining energy potential | Energy potential | Energetic potential of the river with regard to a specific river stretch (IRKA 2003a). | GWh | 40-160 |
| Availability of land | Area of agriculture | Area for agricultural activities. | ha ($10^4$ $m^2$) | 5-30 |
| Low costs | Costs of measures | Costs of construction of measures. | $10^6$ Euro | 6-20 |
| Potential for combinations | Potential for combinations | Potential for combinations with other projects (e.g. gravel excavation). | Scale:<br>1 = very good potential for combination<br>5 = very bad potential for combination | 1-5 |
| Low conflict potential | Conflict potential | Potential for conflicts concerning the implementation of measures. | Scale:<br>1 = very low conflict potential<br>5 = very high conflict potential | 1-5 |

### 4.2.3. Description of locations

River widening is the main type of measure at the Alpine Rhine River proposed by the river management plan. Hence, for our case study, we focused mainly on this type of measure to compare different locations. Out of the planned 18 locations for river widening, we selected the following 5 locations for our case study: Zizers, Bad Ragaz, Saarmündung, Eschener Au and Illspitz. The planning committee of the Alpine Rhine River classified the measures at these locations to be urgent, in contrast to the remaining locations which show a low or medium urgency. These locations are urgent due to bad river bed stability, poor ecological status or large potential for combination with other projects. The main characteristics of the locations are described below in detail.

*Zizers*

The location *Zizers* is the most upstream location and lies fully in the canton Grison in Switzerland. Nowadays, the river bed is limited to a width of 100 meters. The river management plan wants to widen the river bed up to 300 meters in width and 2km in length. Currently, this area is used mainly for forestry. Directly adjacent to the project area, a major gravel industry is located.

*Bad Ragaz*

The location *Bad Ragaz* (Figure 4.3) stretches over a length of 4km and boarders the cantons of Grison and St. Gallen. The actual river morphology is similar to the location Zizers. In addition, the erosion of the river bed is a major problem at this location. The river bed has already eroded by 3 meters within the last 50 years, and for the next 25 years, an additional erosion of 1.5 meters is predicted (IRKA 2003b). A widening of the river bed up to 200 meters in width and 4km in length aims to improve the ecological status and stabilize the river bed. The location directly follows the last natural river stretch of the Alpine Rhine River; the floodplains of Mastrils are located 2km upstream of Bad Ragaz.

*Saarmündung*

The location *Saarmündung* (Figure 4.3) lies in the international river stretch and boarders Switzerland and the Principality of Liechtenstein. The planned measures include a widening of the river bed (length: 3.5km, width: 100 to 200 meters) as well as the reconnection of a major side river. The area necessary for the river widening is used for farming and forestry. Furthermore, the dikes on both sides would have to be moved.

*Eschner floodplain*

The location *Eschner floodplain* boarders Switzerland and the Principality Liechtenstein and stretches over a length of 3km. The rehabilitation measures include a widening of the river bed up to a width of 200 meters. For this, the dike on the right side of the river has to be moved. The area necessary for the river widening is used for farming and forestry.

*Illspitz*

The location Illspitz lies in the international stretch between Switzerland and Austria and stretches over a length of 4km. The main characteristic of this location is the confluence of the river Ill from Austria and the Rhine, where major rehabilitation and reconstruction measures have already been conducted (rehabilitation finished in the year 2002). The river management plan now proposes a widening of the Rhine River up to 300 meters in width and a relocation of the dike on the right side. The area gained for rehabilitation would be about 100ha.

*Figure 4.3: The locations Bad Ragaz (left side) and Saarmündung (right side) at the Alpine Rhine River (Photos by Markus Hostmann).*

## 4.3. Results

### 4.3.1. Impacts of locations

To conduct a ranking of the locations, we first estimated the potential impact of the locations on the identified criteria. The estimation of the potential impacts was based on the detailed analysis of the status quo of the Alpine Rhine River and its deficits (IRKA 2003b, c, 2004b, c). Further, we conducted individual discussions with representatives of the project team. This was done based on the methodological framework of the Analytic Hierarchy Process (section 2.3). We compared the advantages and disadvantages of the locations concerning each criterion. Thereby, we conducted pairwise comparisons of the locations based on the nine-point fundamental scale by Saaty (1990b) (Table 2.1).

We will illustrate this procedure based on the criterion 'erosion of the river bed' at the locations 'Zizers' and 'Bad Ragaz'. The main question is: at which location is the erosion of the river bed more severe? Once we established this, we want to quantify how much worse the erosion of the river bed is at one location compared to the other location? The answer is that the erosion of the river bed is worse at Bad Ragaz compared to Zizers. But regarding the fact that Zizers also has problems with river bed erosion, the difference between Bad Ragaz and Zizers concerning this criterion is only moderate.

This pairwise comparison was done for all locations and criteria. Afterwards, the data were analyzed using the 'eigenvalue technique' proposed by Saaty (1980). The calculation of the eigenvalues was done using Logical Decisions® for Windows™ software. The resulting number represents the strength of a location concerning a specific criterion. This number is called 'local priority'. Concerning the criterion 'erosion of the river bed', Bad Ragaz has the highest local priority (0.460) (Table 4.4). Hence, Bad Ragaz has the highest importance to stabilize the river bed. In contrast, Eschner Au has the lowest priority for river bed stabilization.

*Table 4.4: Local priorities of the locations at the Alpine Rhine River.*

| Locations | Criteria | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Damage limit | Ecologi-cal status | Erosion of river bed | Area of recreation | Energy potential | Area of agriculture | Costs | Potential for combina-tion | Low conflict potential |
| Zizers | 0.20 | 0.047 | 0.145 | 0.067 | 0.147 | 0.358 | 0.231 | 0.289 | 0.268 |
| Bad Ragaz | 0.20 | 0.246 | 0.460 | 0.102 | 0.059 | 0.344 | 0.077 | 0.289 | 0.234 |
| Saarmündung | 0.20 | 0.467 | 0.247 | 0.062 | 0.059 | 0.148 | 0.231 | 0.053 | 0.268 |
| Eschner Au | 0.20 | 0.074 | 0.072 | 0.492 | 0.305 | 0.070 | 0.231 | 0.289 | 0.061 |
| Illspitz | 0.20 | 0.166 | 0.076 | 0.277 | 0.431 | 0.079 | 0.231 | 0.080 | 0.169 |

Based on the local priorities, one can identify the advantages and disadvantages of the locations concerning each criterion. Zizers has the best impact on the aspects 'maintaining area of agriculture' and 'potential for combination', while Bad Ragaz has best impacts on the aspects 'stabilization of river bed' as well as 'maintaining area of agriculture'. The main advantages of Saarmündung are for the aspects 'good ecological status' and 'stabilization of river bed', while Eschner Au and Illspitz are beneficial for the aspects 'area of recreation' and 'maintaining energy potential'. Concerning the aspects 'damage limit', all locations have the same local priority. This is due to the fact that all locations are situated in the upper and medium section of the Alpine Rhine River, where the flood protection level is the same (approved for a 300-year flood event).

It is important to emphasize that the main purpose of this procedure is to analyze the main advantages and disadvantages of the locations in comparison to each other. One has to be aware that the local priorities of locations can be associated with uncertainty. This indicates that it is important to analyze whether the results are robust towards uncertainty in the judgment of pairwise comparisons (section 4.3.4).

### 4.3.2. Decision maker priorities for criteria

The project team members were also asked to weight the criteria concerning the question which criterion has a higher or lower priority. Within this study, we decided that the pairwise comparison method of AHP would be too time consuming due to the large amount of criteria. Hence, weights for the criteria were elicited using a version of the ration estimation technique (von Winterfeldt & Edwards 1986). Each criterion and its range were illustrated on a card. The respondents were asked to arrange the criteria cards on a measuring instrument with a scale from 0 to 100. The most important criterion was assigned a relative importance of 100. Next, the respondents judged how much less important the next attribute was, and so on. They were instructed to consider the criteria range when assigning the importance to the criteria.

The results show that the criterion 'damage limit' is the most important criterion for the majority of project representatives, followed by the criterion 'ecological status' (Figure 4.4). This result is not surprising, since these two criteria are at the same time the main goals of the whole project. In other words, locations with a significant deficit in flood protection level and ecological status have a high priority. However, further criteria are considered to be important as well, even though they are not the main goals of the project. These criteria are 'conflict potential', 'potential for combinations', 'costs' and 'area of agriculture'. For the representative of the regional administration, these four criteria are even more important than the remaining criteria. In other words, these 'soft' factors can have a significant influence on the prioritization of locations.

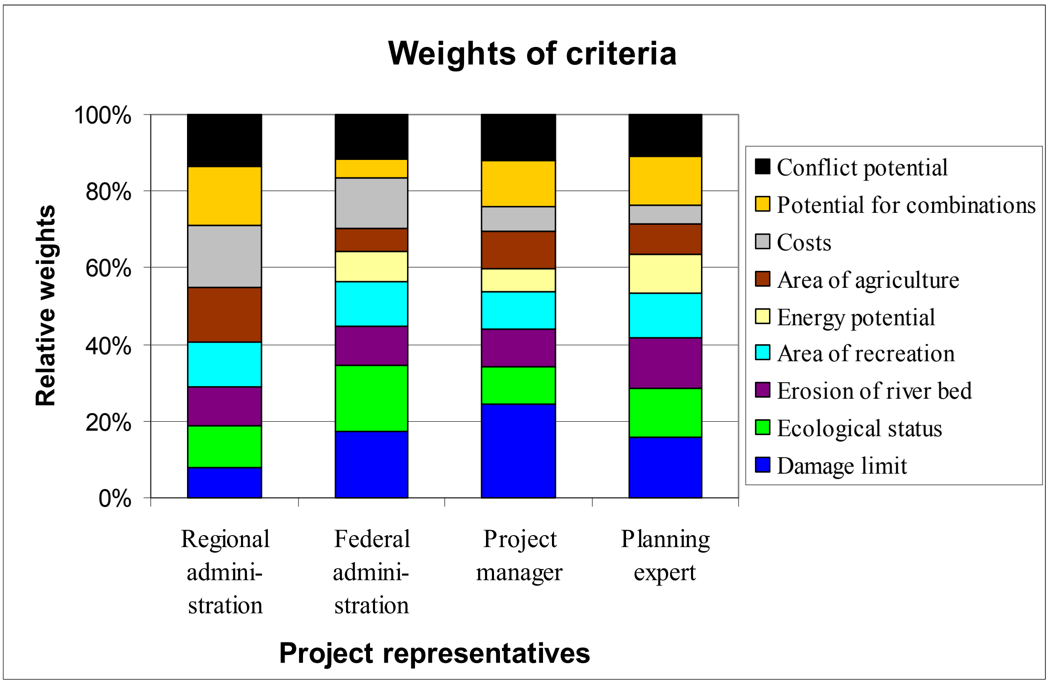


*Figure 4.4: Weights for the objectives by project representatives of the Alpine Rhine River.*

### 4.3.3. Ranking of locations

Based on the local priorities (Table 4.4) and the criteria weighting (Figure 4.4), we calculated the global priorities for each location (Table 4.5). Thereby, the local priorities for each location are multiplied by the corresponding criteria weight, and added up to the global priorities of each location. This calculation was done based on Analytic Hierarchy Process (AHP) using Logical Decisions® for Windows™ software. Hence, it is important to point out that the project representatives did not rank the locations directly. The global priorities of the locations express the priority of each location concerning the question of where to start with the measures (one has to be aware that the global priorities add up to the value 1 for each respondent).

Figure 4.5 shows the ranking of the locations based on the global priorities in Table 4.5. For example, for the representative of the regional administration, the location 'Bad Ragaz' has the highest global priority, and hence is ranked at first place.

*Table 4.5: Global priorities for different locations at Alpine Rhine River.*

| Locations | Project representatives | | | | |
|---|---|---|---|---|---|
| | Regional administration | Federal administration | Project leader | Planning expert | Average |
| Zizers | 0.215 | 0.175 | 0.195 | 0.186 | 0.193 |
| Bad Ragaz | 0.244 | 0.213 | 0.223 | 0.233 | 0.231 |
| Saarmündung | 0.201 | 0.225 | 0.199 | 0.195 | 0.206 |
| Eschner Au | 0.185 | 0.192 | 0.199 | 0.201 | 0.191 |
| Illspitz | 0.155 | 0.196 | 0.183 | 0.184 | 0.178 |

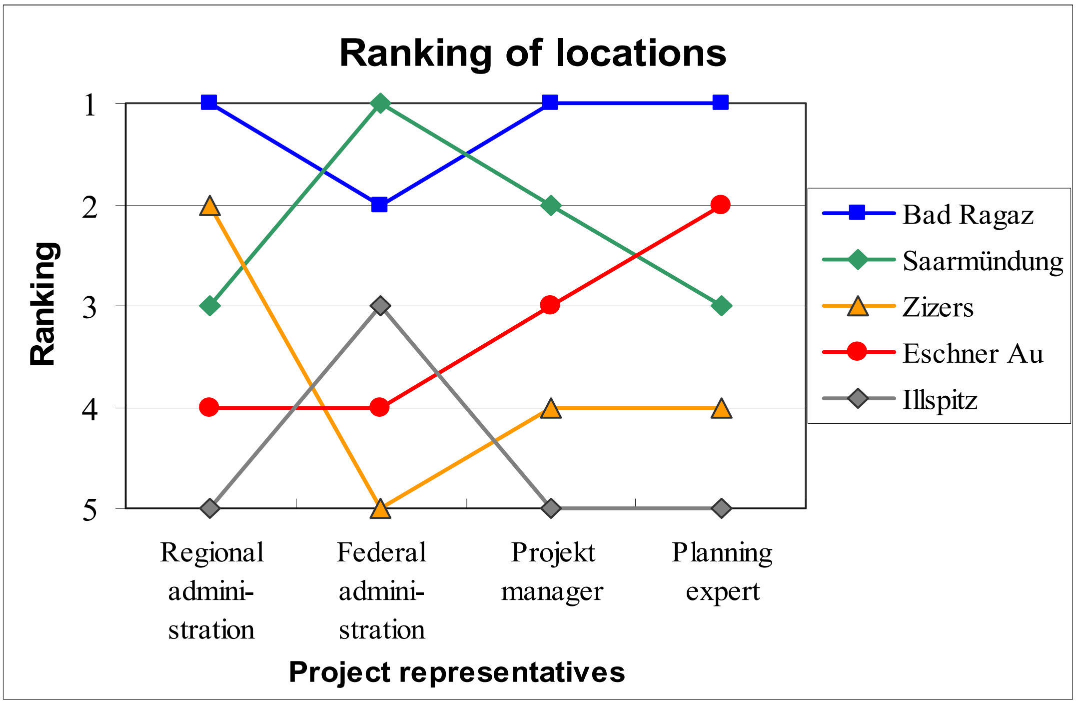


*Figure 4.5: Ranking of locations at the Alpine Rhine River for the project representatives.*

For three out of four interview partners, the location *Bad Ragaz* is ranked in first place. Only for the federal administration is it ranked in second place. The reason for the high ranking of Bad Ragaz is the fact that it has good outcomes for the following objectives which were considered to be quite important by the project representatives: stabilization of the river bed, ecological status, availability of land and potential for combinations. The interview partners confirmed the high priority of Bad Ragaz. The project representatives especially stressed the urgency to stabilize the river bed at this location.

The location *Saarmündung* seems to have the second highest priority. This location is ranked between 1 and 3 for the project representatives. The main advantages of this location are the improvement of ecological condition (river widening including reconnection of a side river) as well as the stabilization of river bed. *Eschner Au* is ranked higher than *Zizers* for three representatives, and might therefore have a slightly higher priority than Zizers. Eschner Au has its advantages in the objectives 'good recreation' and 'potential for combinations'. The main advantages of Zizers are the availability of land, the potential for combinations and a low conflict potential. The location *Illspitz* is ranked in last place for the majority of project representatives. That is because the main advantage of Illspitz - the objective 'energy potential' - was not considered to be very important by the project representatives.

### 4.3.4. Sensitivity analysis

For a more detailed analysis of the results, it is important to analyze whether the results are robust towards uncertainty in the input information. There are two input information to conduct the rankings: the criteria weights (Figure 4.4) and the local priorities of locations (Table 4.4). Concerning the criteria weights, we assume that the different weightings by project representatives give a good image of the uncertainty range. Hence, the ranking of the locations for the different project representatives indicates the robustness of the results towards different weighting schemes (Figure 4.5). As we have discussed above, the location Bad Ragaz is in first or second place for all project representatives, and the location Illspitz is in last place for three out of four representatives. Hence, these rankings are quite robust towards different weighting schemes. In contrast, there is a higher variation for the locations Saarmündung, Zizers and Eschner Au.

Further, we also tested the robustness of the results concerning the uncertainty in the local priorities. As discussed above, the local priorities were assessed based on pairwise comparisons using the nine-point fundamental scale of AHP. However, there can be significant uncertainty to estimate the appropriate intensity of one location over the other concerning a specific criteria. For example, it might be difficult to say whether location A has a strong advantage in contrast to location B (value 5 on nine-point scale) or only a medium to strong advantage (value 4 on nine-point scale). To test the robustness of the results towards this uncertainty, we reassessed the local priorities of the locations and estimated the upper and lower boundaries of these local priorities. For the upper boundary, we conducted more extreme pairwise comparisons (that means that the advantage of one location over the other is estimated to be more extreme than in the original analysis). For the lower boundary, the differences between the locations were assessed to be more balanced. The ranges of 'how more extreme' and 'how more balanced' were extracted from the interviews with the project representatives.

The results from the sensitivity analysis concerning the pairwise comparisons of locations are shown in Figure 4.6. Similar to the sensitivity in criteria weights, there is very little change for the first and the last place. Bad Ragaz is still ranked in first place for three project representatives, and Illspitz is still ranked in last place for all interview partners except the federal administration. However, there is a change in ranking regarding the locations on second, third and fourth positions. For example, the location Eschner Au is ranked significantly higher in the lower boundary ranking than in the upper boundary ranking. This change in rankings reveals that the differences between the three locations Saamündung, Zizers and Eschner Au are not as large as between Bad Ragaz and the three mentioned locations.

In summary, the results from the sensitivity analysis confirm the main characteristics of the original ranking. There is a clear priority concerning where to start with the rehabilitation measures (Bad Ragaz) and which location is ranked in last place (Illspitz). In contrast, the differences between rank orders two through four are not very large.

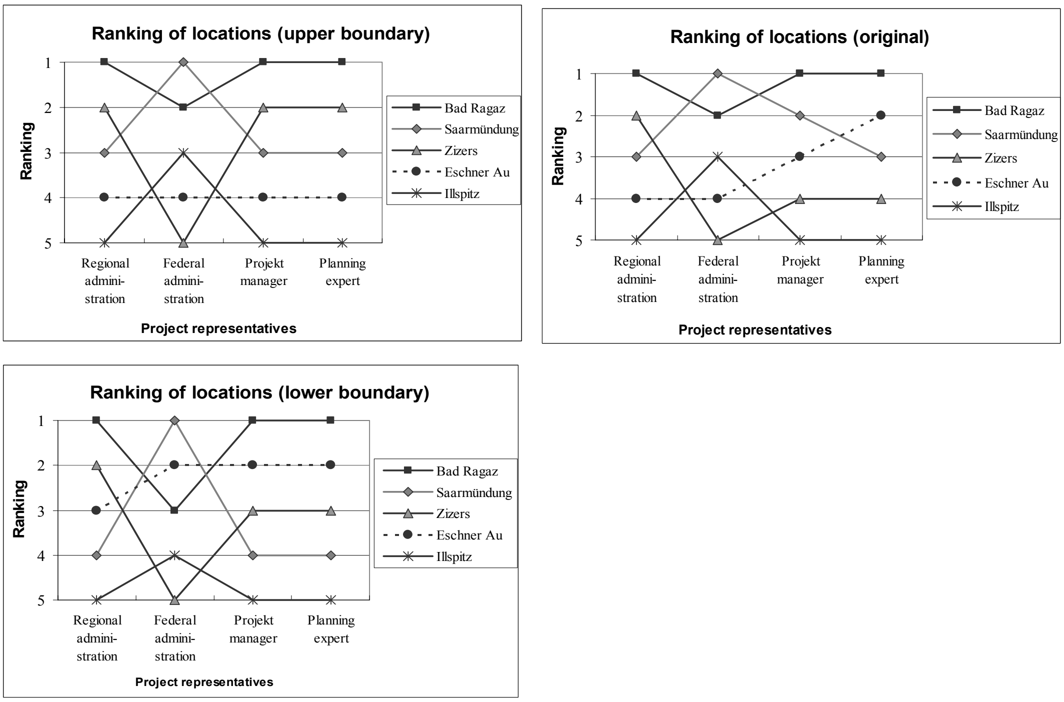


*Figure 4.6: Sensitivity analysis concerning the uncertainty in the estimation of outcomes. Upper boundary corresponds to more extreme comparisons and lower boundary corresponds to more balanced comparisons.*

### 4.3.5. Feedback from project representatives

The ranking of locations was calculated during the interviews with the project representatives. Hence, we presented the rankings of locations to the interview partners and elicited their feedback to the results. Thereby, the following questions were discussed:

- How does the ranking based on AHP really represent the final preferences of the project representatives?
- How suitable is the AHP method as a framework for comparing different locations within a river basin?
- How relevant is the decision making situation (comparison of locations) for the river basin management of the Alpine Rhine River?

First, the project representatives compared how they would have ranked the locations without the AHP with the result based on AHP. The project representatives stated clearly which location they considered to have the highest priority, and the ranking based on AHP corresponded well with this. However, there are slight differences in ranking between the AHP ranking and the direct ranking for positions 2 to 5. Since the global priorities of AHP are sometimes very similar within these positions, this finding is not very surprising.

The second question was whether the project representatives considered the AHP method as a suitable framework to prioritize different locations. Their feedback towards this question was positive. They attested the framework to be comprehensible and transparent, and that the strengths and weaknesses of each location can be compared in a quantifiable way. The project representatives stressed that it is very important to distinguish between the subjective preferences towards the objectives, and the strengths and weaknesses of the locations regarding the objectives. However, they also pointed out that several circumstances should hold in order to compare different locations based on such a formal framework. One aspect is that the surrounding conditions have to be comparable. That means that the locations should not differ too much in their morphology. Furthermore, the measures planned at the different locations should be comparable. Otherwise, it would be very difficult to conduct the pairwise comparison of the locations.

There was a discrepancy between the project representatives concerning the relevance of comparing different locations. Two out of four interview partners felt that it was highly relevant. The main reasons given were: 1) there are 35 potential rehabilitation sites and due to restriction of resources, a prioritization of locations needs to be done, 2) the whole project will last for 20 to 30 years, and some locations have a higher urgency to minimize the deficits than others, and 3) it is important to start at those locations where the potential for a good outcome is highest so as to convince the public about the necessity of rehabilitation. The two other project representatives argued that there are other questions within the river management plan which are more important, such as defining the main deficits of the river and strategies to minimize these deficits. However, all project representatives agreed that the prioritization of location is increasingly important especially in view of very limited financial resources.

In summary, the project representatives considered the prioritization of locations within a river basin area to be potentially important and found the AHP-method to be a suitable framework for this DMS. All project managers stressed that the MCDA framework could also be a suitable methodology for comparing different alternatives for one location. The application of the MCDA framework for this specific decision making situation is described in more detail in chapter 5.

## 4.4. Conclusions

The purpose of this chapter was to evaluate the contributions of MCDA methods for the prioritization of rehabilitation sites. This was done based on preferences of a small group of project representatives. The results of this study revealed that the AHP is a suitable framework to compare and prioritize different locations within a river basin. The project representatives asserted that the framework allowed different options to be evaluated in a comprehensive and transparent manner. Hence, the main strength of the MCDA method in this setting was to provide structure and guidance for systematic thinking of the responsible decision makers. However, the contributions of the employed MCDA method were limited due to the following reasons:

- *Rationality of decision making*: For the interviews, we used client group who were representatives of the project team, and hence, experts in river rehabilitation projects. The project team would have evaluated the different locations in quite a rational manner even without the use of formal MCDA methods. They would also have considered the impact of locations on major criteria (e.g. flood protection level, stabilization of river bed, ecological condition). Therefore, the learning effect for the project representatives was limited. The main contribution of the MCDA approach was that project managers became more aware of separating the subjective preferences of objectives from the impacts of locations towards the objectives.

- *Foundation of prediction of outcomes*: Within the MCDA application, the impact assessment of the locations was based on expert knowledge and studies from the project team. Hence, the underlying information for the impact assessment was the same for the MCDA application and for the ranking of locations without formal MCDA methods.

To increase the contribution of formal MCDA methods for this DMS, we propose further development as follows:

- *Step 1: Increasing the number of locations*: Within our study, we compared and evaluated five locations at the Alpine Rhine River. Increasing this number up to 18 locations (the total number of locations for river widening) would lead to a significant increase in complexity. The decision making without a formal MCDA methodology would then be very complex, since one can hardly compare 18 locations based on half a dozen criteria in one's head.
- *Step 2: Increasing the client group*: Up to now, we only conducted interviews with representatives from the project team. However, regional stakeholder groups might also be involved in the decision making process at a regional level. Hence, for further applications, we propose that the preferences of regional stakeholder groups are elicited as well. The similarities and differences of preferences among various stakeholder groups and between stakeholder groups and the project team can then be discussed in a stakeholder forum.

At the beginning of this chapter, we referred to Tippett (2005), who argued that one of the key difficulties in river basin planning is to connect the strategic, basin-wide planning with the local scale. The proposed inclusion of regional stakeholders in the decision making process could significantly help to overcome this difficulty. Preferences and values of stakeholders would already be incorporated at a regional level, and stakeholder groups would improve their understanding and social learning at an earlier stage of the process. This could improve the basis for decision making at a local level, which is often characterized by conflicts between various stakeholder interests. This connection of the regional and local scale based on stakeholder preferences could be an interesting topic for further research.

# 5. Decision support for alternative selection

## 5.1. Introduction

This chapter analyzes the contribution of multi-attribute value theory (MAVT) methodology for decision making in the *multiple stakeholder* setting. We applied the MAVT method to an ongoing river rehabilitation project at the Thur River (Switzerland) where different alternatives are under consideration. Since a broad range of stakeholder interests are affected by the decision, conflicts between different interest groups are expected to be significant. To evaluate the method's contribution to the decision process, we conducted three major interview phases with the stakeholder groups:

- *Elicitation of preferences*: In interview phase I, we adapted the MAVT method in the traditional approach to the multiple stakeholder setting. We elicited the preferences (value functions and weights) of eight major stakeholder groups. Thereby, we interviewed pairs of representatives from each stakeholder group at the same time. In total, 26 respondents were asked to state their preferences. Based on the stakeholder preferences and MAVT methodology, we determined the ranking of five management alternatives.
- *Evaluation of method's contribution*: The purpose of the second interview phase was to evaluate the strengths of the MAVT method in the multiple stakeholders setting. An important research question was whether the MAVT method is able to predict stakeholders' final preferences, or whether there are other potential contributions. We also examined stakeholder understanding and acceptance of the results. This was done in the form of three workshops involving specific stakeholder groups with potentially similar positions.
- *Comprehensive stakeholder forum*: The purpose of interview phase III was to discuss the results from phase II with all stakeholder groups. Hence, we combined all stakeholders in one stakeholder forum and examined stakeholders' general impressions of the method for conflict resolution.

The main characteristics of the three interview phases are summarized in Table 5.1 and illustrated in Figure 5.1. These phases constitute at the same time the major contents of this chapter. The general outline of this chapter is as follows: (5.2) elicitation of stakeholder preferences, (5.3) sensitivity analysis of the results, (5.4) evaluation of method's contribution, (5.5) comprehensive stakeholder forum, and (5.6) conclusions.

*Table 5.1: Characteristics of the three interview phases with stakeholders.*

| | Elicitation of stakeholder preferences | Evaluation of method's contribution | Comprehensive stakeholder forum |
|---|---|---|---|
| Goal | Elicitation of stakeholder preferences (value functions and weights) based on MAVT. | Present results of phase I to the stakeholders, analyze method's predictive validity and investigate the change in stakeholder preferences. | Discussion of results from phase II with all stakeholder groups. Examination of main contribution of MAVT for conflict resolution. |
| Elicitation methodology | Personal interviews<br>(15 interviews) | Workshops<br>(3 workshops) | Stakeholder forum |
| Stakeholder setting | Pairs of stakeholders from the same stakeholder group. | Combining stakeholder groups with potentially similar interests to 3 workshops. | Combining all stakeholders together. |
| Chronology | May to September 2003 | March 2004 | January 2005 |
| Chapter | 5.2 | 5.4 | 5.5 |

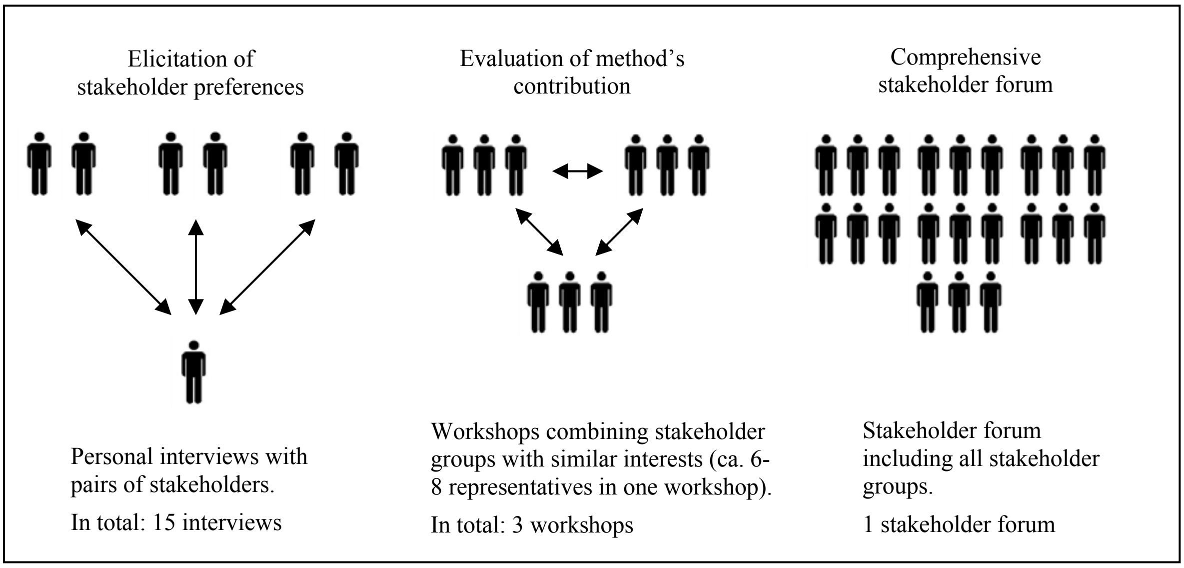


*Figure 5.1: Stakeholder setting in three interview phases.*

## 5.2. Elicitation of stakeholder preferences[2]

### 5.2.1. Introduction

The decision making process of a local river rehabilitation is complicated by several factors. First, rehabilitation measures affect many interests and therefore many stakeholders. A survey conducted in the Netherlands concluded that conflicting stakeholder interests are one of the main problems facing stream restoration projects (Verdonschot & Nijboer 2002). Similar problems have been experienced in Switzerland (BWG 2001). Further, the different project phases of a rehabilitation project (planning, construction, and evaluation) usually require several years, occasionally decades. Finally, rehabilitation measures are confronted with a high uncertainty in the outcome.

Multiple criteria decision analysis (MCDA) approaches can offer helpful techniques when faced with the problem of high complexity, uncertainty and multiple conflicting objectives (Clemen 1996). Recently, there has been a great increase in the literature available on these techniques as applied to environmental issues (Agrell *et al.* 1998; Hämäläinen *et al.* 2001). However, in the field of river management, there are only a few approaches described which include different stakeholder views. Prato (2003) utilized a linear additive utility function, based on hypothetical stakeholder preferences, to compare five management alternatives for the Missouri River system. Qureshi & Harrison (2001) used the analytic hierarchy process (AHP) as a means of structuring the decision problem and estimating importance weights for the objectives of various stakeholders. AHP has been adapted to incorporate stakeholder values as well in the field of fisheries management (Soma 2003). Based on the method of improving directions, Hämäläinen *et al.* (2001) developed a framework for multicriteria modelling and support of multi-stakeholder decision processes in water resources management. Other authors have adapted decision support systems (DSS) for river rehabilitation, but did not explicitly incorporate stakeholder values (Llewellyn *et al.* 1996; Lamy *et al.* 2002; Lauri & Virtanen 2002; Pieterse *et al.* 2002; Verdonschot & Nijboer 2002). Despite growing consensus on the need for greater public participation in environmental policy, there is a lack of tested methods to incorporate stakeholder values explicitly in decision making (Ananda & Herath 2003a). Particularly in the field of river rehabilitation, where there tend to be many different stakeholder interests, a multiple stakeholder approach might increase the likelihood of success for the rehabilitation project.

The aim of this section is to use the decision analysis framework (Keeney & Raiffa 1976; von Winterfeldt & Edwards 1986; Clemen 1996) to clarify, structure, and quantify stakeholder opinions. This approach is based on multi-attribute value theory (MAVT) to analyze stakeholder values. The proposed multiple stakeholder approach then intends to estimate the conflict potential for different rehabilitation alternatives and to show a possible direction towards a consensus solution for the involved stakeholders. It has been empirically validated at the Thur River in Switzerland. The reported research project is part of the Rhone-Thur project, a broad multidisciplinary project in Switzerland about scientific support for river rehabilitation (Peter *et al.* 2005).

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[2] *This section is an excerpt of the article:*
Hostmann M., Borsuk M., Reichert P. & Truffer B. (2005) Stakeholder values in decision support for river rehabilitation. Archiv für Hydrobiologie Supplement 115/1-4, p.491-505

### 5.2.2. Methods

**Research area**

The Thur River lies in the east of Switzerland and is one of the main tributaries of the Rhine River (Figure 5.2). The active river bed of the Thur River is approximately 50 meters wide. According to the EEC classification, it is classified as a large river (Haslam & Wolseley 1987). Over the past centuries, the Thur River has been channelized and the area of floodplains has been drastically reduced (Frauenlob 2003). After a series of large floods between 1960 and 1980, the authorities realized that the present flood protection level was no longer adequate (Amt für Umwelt 1999). Since 1991, several rehabilitation measures have been conducted at the Thur River to improve the flood protection level as well as the ecological status (Hostmann & Knutti 2002; Zaugg 2002).

The present study focuses on an intended rehabilitation project at the Thur River between the towns of Weinfelden and Bürglen (Figure 5.2). The project area stretches over a length of 4 km and a width of 300 to 700 meters. Dikes are located at the border of the project area, protecting the surrounding towns and villages from a 100-year flood. Within the project area, the active river bed is limited to a width of 50 meters and the rest of the area is used for farming and forestry. The cantonal administration, the authority responsible for river management, has drawn up a preliminary plan for rehabilitation which includes widening the river bed and constructing a retention basin for flood protection. Important stakeholder groups and the public have been informed, and different views exist among stakeholders on the appropriate river management in the project area.

It is important to emphasize the differences between the experimental setting of the research project and the real decision process of the rehabilitation project. Our research project had the possibility to apply the MAVT method to an ongoing rehabilitation project with potential conflicts. This was possible due to the collaboration of the involved stakeholders and the authority responsible for river management. However, the involved stakeholders were aware that the results of the research project had mainly informative character for the real decision making process. But since both the river management authority and stakeholders were really interested in the research project, the practical relevance of the research project was assured.

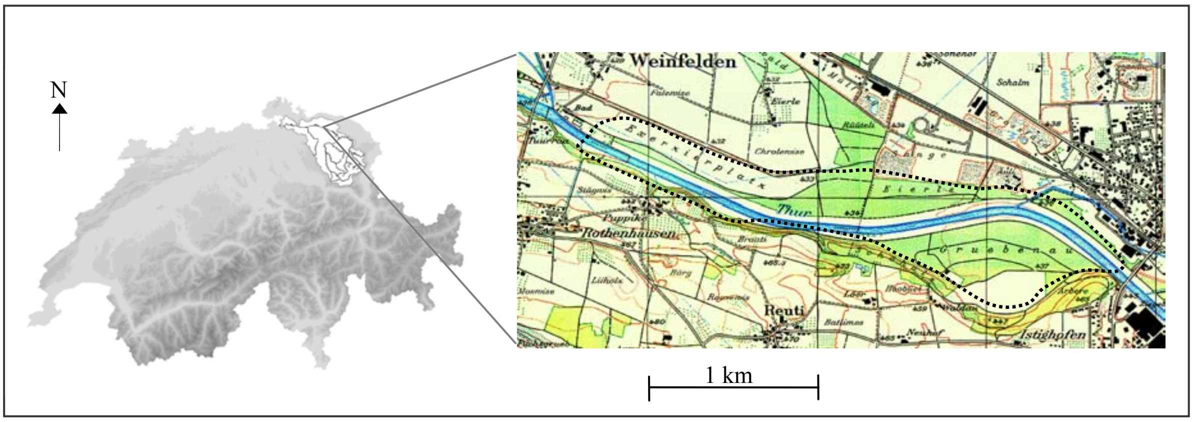


*Figure 5.2: Switzerland with the Thur River basin (left) and the project area (status quo) between Weinfelden and Bürglen (right, area within dashed line) (BFS 2003; Swisstopo & Federal Office of Topography 2003).*

**Attributes for valuation of outcomes**

River rehabilitation projects are associated with a wide range of ecological, economic and social benefits and costs. Within this study, seven major objectives were identified: "high flood protection level", "low costs", "short realization time", "good ecological status", "good recreational opportunities", "maintain agricultural activity", and "create employment opportunities". The determination of these objectives was based on a formal interview process with several experts and stakeholders. All these objectives contribute to the overall goal of a sustainable Thur River (Figure 5.2). Besides the selected objectives, others might also contribute to sustainable river management (e.g. social values such as cultural-historical values). However, such values were not identified as major objectives by the stakeholders within this case study. The achievement of each major objective will be assessed using measurable attributes (Table 5.2). The potential outcomes of the alternatives (Figure 5.4) define the ranges of the attributes.

The selection of suitable attributes was based primarily on the historical development of the problem and data availability. For example, "costs of damages" was chosen to evaluate the objective "high flood protection level", since flood damage is a major political issue at the Thur River and specific studies have been conducted to assess the damages costs caused by severe flood events. The objective "good ecological status" was described using a constructed scale between 1 (very poor ecological status) and 5 (very good ecological status). Ecological status was assessed based on the morphological condition of the river (BUWAL 1998) and occurrence of indicator species (Reichert *et al.* 2005). The objective "good recreational opportunities" was characterized by the attribute "area of recreation" that is attractive and accessible for the public. The most common forms of recreation in the Thur River area are fishing, hiking, cycling, picnicking, riding, and hunting.

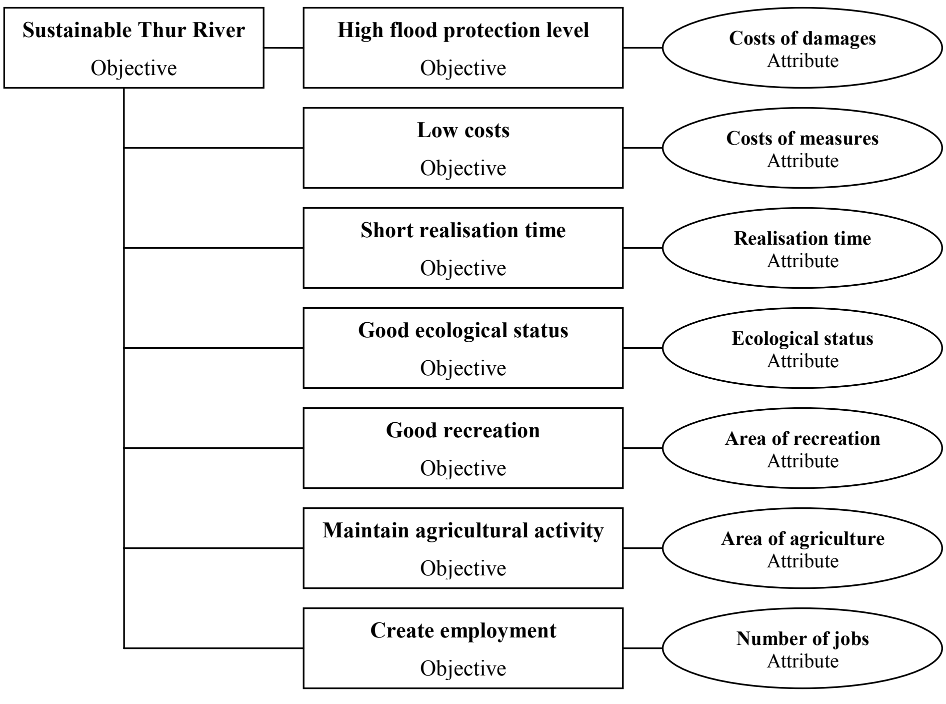


*Figure 5.3: Objectives hierarchy for sustainable river rehabilitation at Thur River.*

*Table 5.2: Attribute details and anticipated ranges of outcomes.*

| Attributes | Description | Units | Range |
|---|---|---|---|
| Costs of damages | Expected damage in the region for a 1000-year flood. | $10^6$ CHF | 0-370 |
| Costs of measures | Costs of construction and maintenance for the next 50 years. | $10^6$ CHF | 0-40 |
| Realization time | Time until planning and construction phase is finished. | Years | 10-30 |
| Ecological status | Integrative measure of the ecological status of the river. The assessment of the ecological status is based on the morphological condition of the river and the occurrence of indicator species. | Constructed scale: 1 = very poor ecological status, 5 = very good ecological status | 1-5 |
| Area of recreation | Attractive and accessible area for recreation. | ha ($10^4$ $m^2$) | 0-120 |
| Area of agriculture | Area for agricultural activities. | ha ($10^4$ $m^2$) | 0-50 |
| Number of jobs | Number of jobs created by measures during the construction phase. | Number of jobs | 0-30 |

**Stakeholder identification and classification**

Stakeholders are any group of people, organized or unorganized, who share a common interest or stake in a particular issue or system (Grimble & Wellard 1997). In river rehabilitation projects, a broad range of interests are involved. There exist different concepts to identify and classify stakeholder groups (section 3.2.1). For our study, stakeholder identification and selection was based on our knowledge of the situation and help of experts from the cantonal administration. Moreover, we asked stakeholders during each interview phase to identify additional stakeholders ('snow ball sampling'). We ended up with a list of 30 stakeholder groups and categorized them according to their 'importance' and 'influence' (IIED 2001). Importance is defined as the priority given by the project to satisfying a stakeholder needs and interests through the project. Influence refers to the power stakeholders have in affecting the success of the project (Grimble & Wellard 1997). The relative influence of a stakeholder group was estimated by three criteria: Legal norms (for example position in government, appeals, protection of ownership), social networks (such as organizations) and specific knowledge (either expert or local).

Based on this categorization, the selected stakeholder groups were aggregated into eight categories (Table 5.3). In total, 26 respondents were asked to state their preferences for the objectives. We interviewed pairs of representatives from each stakeholder group at the same time. These interviews were conducted between May and September 2003. Each interview took about 1 to 1.5 hours.

This study focused mainly on organized stakeholder groups (e.g. environmental organizations, recreational organizations) and unorganized groups of people who are directly affected by the project (e.g. agricultural representatives, forest rangers). The interests of the local residents are examined by another study within the Rhone-Thur project (Junker 2003).

*Table 5.3: Stakeholder categories and corresponding stakeholder groups for Weinfelden-Bürglen.*

| Category | Stakeholder groups (number of representatives) |
|---|---|
| Agricultural representatives | Cantonal office for agriculture (1); farmers (2); |
| Forest rangers | Forest rangers (2) |
| Environmental organizations | BirdLife (1); Rheinaubund (1); World Wildlife Found (1) |
| Industry | Gravel industry (2); power generation and -supply (2) |
| Recreational organizations | Cavalry (1); fishery (1); hunting (1); scouts (1) |
| Communities | Bürglen (2); Bussnang (1) Weinfelden (1) |
| Cantonal administration | Environmental administration (1); administration of spatial planning (1); forestry administration (1) |
| Federal administration | Federal Office for Water and Geology (1); Swiss Agency for the Environment, Forest and Landscape (2) |

**Multi-attribute value theory**

Multi-attribute value theory (MAVT) is a useful framework for decision analysis with multiple objectives (section 2.2). Within this study, we adopted the form of the additive value function (weighted sum of single-attribute value functions):

$$V(A) = \sum w_i v_i(a_i) \qquad (5.1)$$

where $a_i$ represents the outcome for attribute $i$ resulting from alternative $A$, $v_i(a_i)$ represents the single-attribute value functions, $w_i$ the weights, and $V(A)$ describes the total value of this alternative. Note that the formulation of (5.1) is only strictly valid under stringent assumptions (von Winterfeldt & Edwards 1986; Belton 1999). To calculate the values of alternatives according to (5.1), we need single attribute value functions, the weights and a prediction of the outcomes resulting from the alternatives. It is important to emphasize that the single attribute value functions and weights were elicited from the stakeholder representatives, while the outcomes resulting from the alternatives were predicted by ourselves based on existing studies (Hostmann *et al.* 2003).

For the assessment of single attribute value functions, the direct-rating method is the most widely used numerical estimation method (von Winterfeldt & Edwards 1986). In this method, the respondent is asked to estimate the strengths of preferences for different levels of an attribute on a numerical scale. First, the most and least preferred levels are identified and valued with 100 and 0, respectively. The remaining levels are then rated between the two endpoints. The relative spacing between the levels of the attribute reflects the strength of preference of one level compared with another. Within this study, we elicited stakeholders' preferences for three to five levels for each attribute (two endpoints and one to three levels in between to elicit the form of the single attribute value function). Each level was illustrated on a card, and the respondents were asked to arrange the level-cards on a measuring instrument with a scale from 0 to 100. Once the two endpoints and the level(s) in between were defined, we fitted a functional curve through the elicited points (single attribute value function).

Weights for the different attributes were elicited using a version of the ratio estimation technique (von Winterfeldt & Edwards 1986). In the present study, each attribute and its range were illustrated on a card (similar to the elicitation process of the single attribute value functions). The respondents were asked to arrange the attribute cards on a measuring instrument with a scale from 0 to 100. The most important attribute was assigned a relative importance of 100. Next, the respondents judged how much less important the next attribute was, and so on. They were instructed to consider the attribute ranges when assigning the importance to the attributes.

In the current study, best professional judgment was used to predict the outcomes of different alternatives and their uncertainty range as measured by the attributes. More detailed economic and natural scientific models are in development to form the basis for predictions in future analyses (Schweizer *et al.* 2004; Reichert *et al.* 2005).

For each of the 26 stakeholders, single attribute value functions and weights were estimated for the seven attributes. In total, 182 value functions and 182 weights were elicited in stakeholder interviews. Single attribute value functions were aggregated using attribute weights and additive assumptions to obtain the total value of a specific alternative for each respondent. This calculation was done using Logical Decisions® for Windows™ software. Within one stakeholder group, the total values of the different representatives were averaged.

### 5.2.3. Results and discussion

**Rehabilitation alternatives**

For the Thur River, we developed three different rehabilitation alternatives and compared them with the status quo. The *status quo* option refers to the actual situation at the Thur River, which is characterized by a poor ecological status (strongly affected morphological condition caused by channelized river bed, and low occurrence of indicator species) and limited recreational possibilities (Figure 5.2). The *administration option* adopts the idea of the cantonal administration to build a retention basin and widen the river bed. The retention basin would capture the peak of a flood and therefore reduce the damage potential downstream. Furthermore, some widening of the river bed would allow river braiding or meandering and hence improve morphological condition and occurrence of indicator species. However, this alternative would result in a significant loss of agricultural area (Figure 5.4a). The *nature reserve option* involves further widening the river bed and developing floodplain forests and pools. There would be no land available for agriculture and no retention basin for flood protection (Figure 5.4b). The *minimum option* proposes simply doubling the width of the river bed so that the rest of the project area would still be available for agriculture and forestry. Again, no retention basin would be built (Figure 5.4c).

Within this study, we assessed the outcomes of the alternatives based on best professional judgment and existing studies (Hostmann *et al.* 2003). The expected *costs of damages* in the region for a 1000-year flood event were predicted based on a comprehensive study of the administration responsible for river management (Amt für Umwelt 1997). The *costs of the measures* were evaluated based on experience of prior rehabilitation projects in the region (Hostmann 2003). Further, we used the framework of the input-output analysis to predict the *number of jobs* created by measures during the construction phase (Spörri *et al.* 2005). The *ecological status* was evaluated based on the eco-morphological status of the river (BUWAL 1998) including the relative shoreline length (van der Nat *et al.* 2002) and occurrence of indicator species. The impact of the alternatives on the remaining attributes (realization time, area for recreation, area for agriculture) was already defined by the alternatives themselves. For example, the area of agriculture is defined by the fact which area is used for the measures. The predicted attribute levels of status quo and the current three management alternatives are listed in Table 5.4.

*Table 5.4: Attribute levels of rehabilitation alternatives for the Thur River (including standard deviation indicating the range of uncertainty in brackets).*

| | Costs of damages ($10^6$ CHF) | Costs of measures ($10^6$ CHF) | Realization time (years) | Ecological status (constructed scale 1-5] | Area of recreation (ha) | Area of agriculture (ha) | Number of jobs (#) |
|---|---|---|---|---|---|---|---|
| Status quo option | 370 (±40) | 4.5 (±0.5) | 0 | 1.5 (±0.2) | 15 (±2) | 50 (±1) | 5 (±0.5) |
| Administration option | 12.3 (±2) | 18.1 (±2) | 20 (±5) | 3.4 (±0.3) | 55 (±5) | 15.5 (±2) | 23 (±2) |
| Nature reserve option | 370 (±40) | 26.5 (±2.5) | 30 (±5) | 4.7 (±0.3) | 31.4 (±3) | 0 | 30 (±3) |
| Minimum option | 370 (±40) | 9.8 (±1) | 10 (±5) | 2.5 (±0.2) | 28.6 (±3) | 33.1 (±3) | 12 (±1) |
| Negotiation option | 113.5 (±10) | 12.2 (±1) | 15 (±5) | 2.9 (±0.3) | 26.8 (±3) | 45.4 (±4) | 15 (±1.5) |

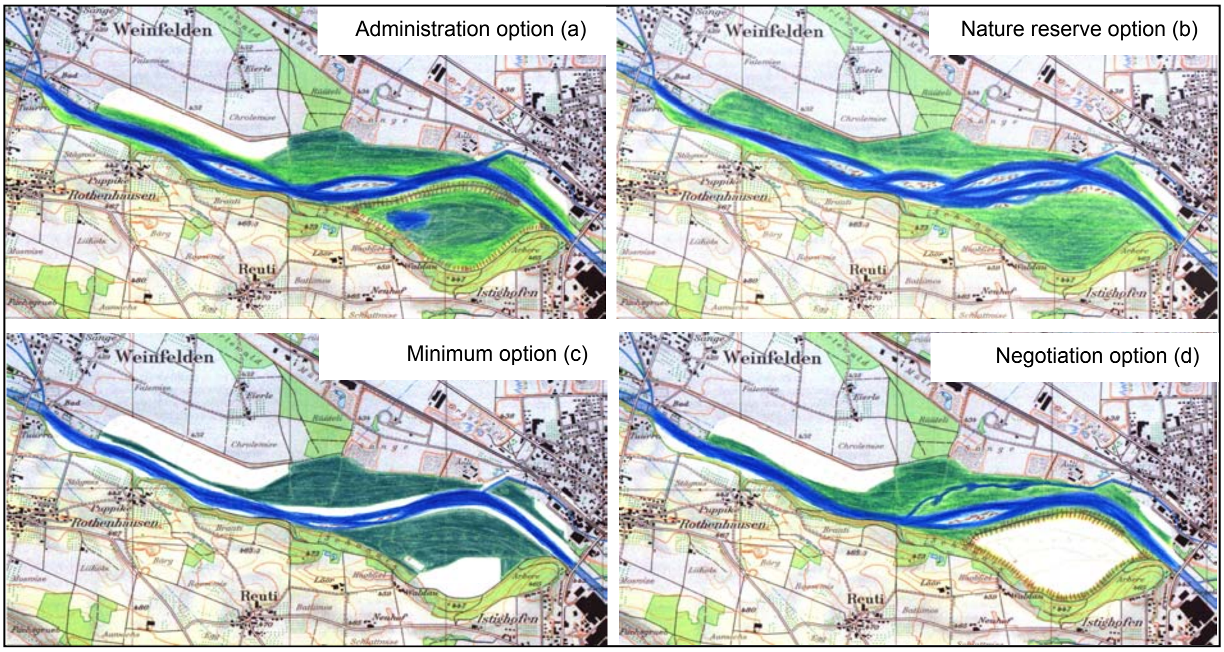


*Figure 5.4, a-d: Rehabilitation options for the Thur River: administration option (a) includes a retention basin and widening of the river bed, nature reserve option (b) focuses on ecological improvement, minimum option (c) involves doubling the width of existing river bed, and negotiation option (d) combines flood protection with agricultural activity and ecological improvement. Agricultural area is represented by white color and forest area by green color.*

**Stakeholder preferences**
Stakeholder groups showed significant variation in weighting the attributes (Figure 5.5).

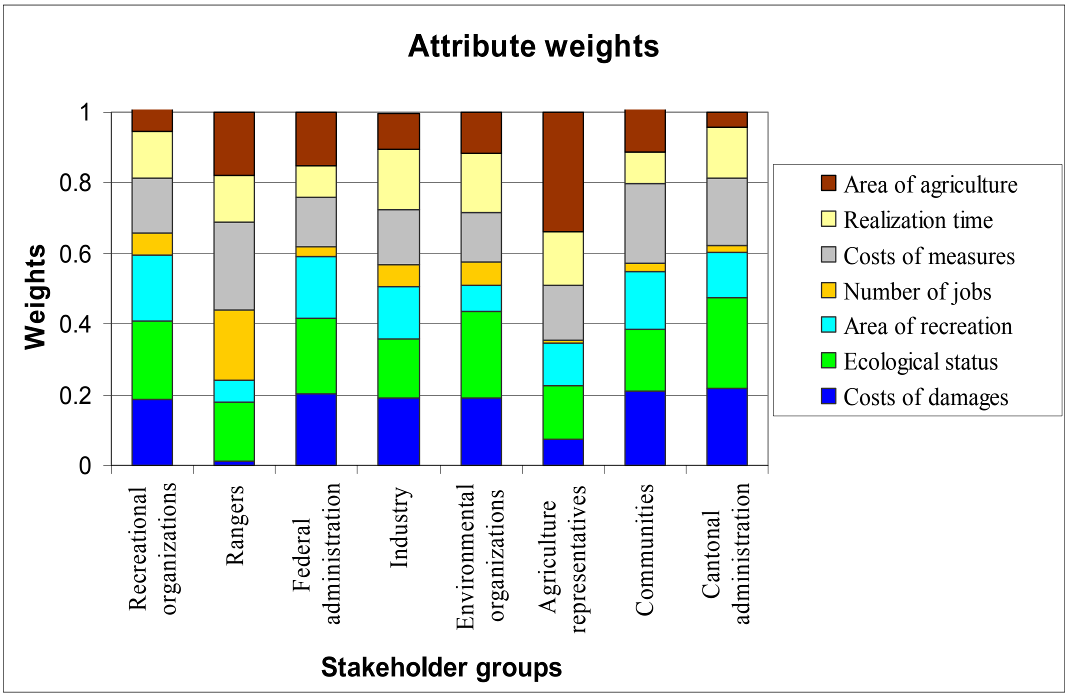


*Figure 5.5: Attribute weights by the stakeholder groups. The relative weight of each attribute is expressed by the length of its section.*

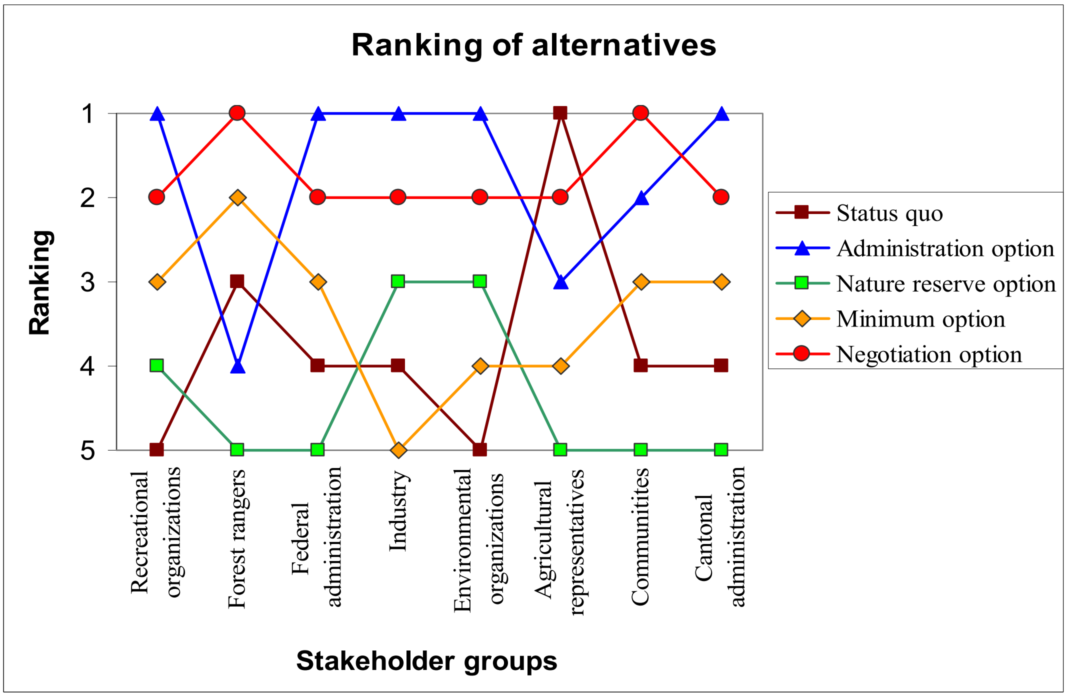


*Figure 5.6: The ranking of the alternatives for the stakeholder groups. The stakeholder groups are listed according to their relative influence potential on the horizontal axis (from low influence on the left side to high influence on the right side).*

Four out of eight stakeholder groups ranked “ecological status” as the most important attribute. “Costs of damages” and “costs of measures” were also ranked high by the majority of stakeholders. Major differences in ranking occurred for the attribute “area of agriculture”, which was weighted very high by agricultural representatives but relatively low by recreational organizations and the cantonal administration. The single-attribute value functions elicited from stakeholder representatives are listed in the appendix.

Based on the total value of the alternatives for the stakeholder groups (Eq. 5.1), we determined the ranking of the different alternatives (Figure 5.6). It is important to point out that the stakeholders did not rank the alternatives directly but rather the levels and weights of the attributes. It is beyond the scope of this section to formally account for the uncertainty in predicted attribute levels and stakeholder preferences, however, sensitivity analyses showed that these uncertainties have a limited influence on the ranking of alternatives (section 5.3). This corresponds to the finding of Reichert & Borsuk (2005) who suggest that a ranking of alternatives can be more robust than the numerical values themselves.

**Conflict potential of rehabilitation alternatives**

The conflict potential of a rehabilitation alternative depends on a combination of: 1) how the alternative is ranked for the stakeholder groups and 2) the influence potential of the stakeholder groups. Conflict potential arises when an alternative is ranked lower than the status quo for a specific stakeholder group and this stakeholder group also has a high influence potential. Furthermore, if there is a large variation in ranking among all the stakeholder groups for a specific alternative, then this can also result in a large conflict potential.

The *status quo option* is ranked poorly for the majority of stakeholder groups (Figure 5.6). In contrast, it is the most preferred option for the agricultural representatives, since the conservation of agricultural area is very important for them and status quo is the best option for conservation of agricultural area. The *administration option* is the most preferred option for five stakeholder groups. However, it is ranked worse than the status quo option for the forest rangers and the agricultural representatives. As the agricultural representatives have a high influence potential, the conflict potential for this option is significant. The *nature reserve option* shows the poorest ranking for five stakeholder groups. Surprisingly, it is only ranked third for environmental organizations. The reason is that the nature reserve option focuses mainly on good ecological status and does not lead to very good outcomes on the attributes ‘area of recreation’, ‘costs of damages’ and ‘costs of measures’. Since environmental organizations stated these attributes to be important in addition to good ecological status, the nature reserve option is not ranked highest for them. Based on the poor ranking for the majority of stakeholder groups, the realization of the nature reserve option is not thought to be desirable. The *minimum option* does not seem a suitable alternative either, for two reasons: it is ranked worse than the status quo for two stakeholder groups and there is a high variation in ranking among all stakeholder groups. Furthermore, it is ranked lower than the administration option for all stakeholder groups except the rangers which are one of the least powerful stakeholder groups.

A possible way towards a consensus solution involves a combination of improvement in flood protection and ecological status as well as preservation of agricultural activity. Preservation of agricultural activity aims to improve the ranking for the agricultural representatives and forest rangers. Improvement in flood protection and ecological status are important attributes for the remaining stakeholder groups. Based on this analysis of the attributes, we developed a fourth rehabilitation alternative, namely the *negotiation option* (Figure 5.4d). It includes a retention basin which can be used for agricultural activities so long as a flood does not occur. Widening the river bed as well as creating a new side river would lead to a significant ecological improvement (Table 5.3). From Figure 5.6 we can conclude that the negotiation option would be the most preferred option for forest rangers and communities. Further, it is ranked second best for the remaining stakeholder groups. It is judged better than the status quo by all stakeholders except by agricultural representatives. The reason for this high ranking is that the negotiation option achieves a significant improvement in flood protection, ecological condition, as well as recreation opportunities compared to the status quo option. Further, the negotiation option results in higher preservation of agricultural area, lower costs and shorter realization time compared to the administration option. From this we can expect that the conflict potential might be lowest for the negotiation option. Demonstrating these results in discussions with stakeholders can be expected to facilitate the process of finding a consensus solution.

### 5.2.4. Conclusions

The aim of this study was to support the decision making process for river rehabilitation, to analyze multi-stakeholder conflicts, and to develop a consensus solution based on stakeholder preferences. The results of this study revealed that the multi-attribute value theory (MAVT) approach is a useful technique for eliciting stakeholder values and evaluating river rehabilitation options. The technique helps to clarify the values and opinions of stakeholders and pinpoint the sources of disagreement. This improves the transparency and credibility of decision making in river rehabilitation measures. The classification of stakeholders based on their influence potential seems to be a suitable approach to show the conflict potential for different management alternatives.

For our application to the Thur River, the negotiation option achieved the lowest conflict potential. It would lead to significant improvement in ecological status, flood protection and recreational opportunities in comparison to the status quo. From the viewpoint of rehabilitation, the administration option would have even better outcomes on these three objectives. However, the administration option was also associated with higher loss in agricultural activity, higher costs and longer realization time. Since those factors were important objectives for powerful stakeholder groups, the administration option resulted in a higher conflict potential than the negotiation option. Hence, the negotiation option could show a possible direction towards a consensus solution for the involved stakeholders. Besides the five stated alternatives, one could conceive many additional rehabilitation options. The presented framework is a straightforward approach to create further alternatives and test their conflict potential for the involved stakeholder groups.

Even considering the soundness of this approach, there is still a dispute in the literature about the usefulness of multiple criteria decision analysis (MCDA) methods for conflict resolution. Studies which have applied different MCDA methods have indicated that users are generally skeptical about the value of MCDA methods and prefer the freedom of unaided decision-making (Hobbs *et al.* 1992; Bell *et al.* 2001). Some potential obstacles of MCDA methods are 1) the danger of being seen as a "black-box" approach, 2) the complexity of decomposing the problem into several objectives, and 3) the possibility of missing attributes or lack of confidence in the attributes that were chosen.

These points indicate that further research is needed to investigate whether stakeholders accept the results from such a study, and whether they believe this approach will facilitate the negotiation process. In addition, the approach needs to be tested extensively in other real-world situations to investigate its contribution to conflict resolution.

## 5.3. Sensitivity analysis of results

### 5.3.1. Introduction

The main question of sensitivity analysis is "what makes a difference in the results?" (Clemen 1996). In other words, the sensitivity analysis aims to test the robustness of the results towards uncertainty in the input information. As we described in the last chapter, the main result is the ranking of the alternatives. Thereby, we used different input information to conduct the rankings based on the MAVT methodology: (1) attribute levels of rehabilitation alternatives (Table 5.3), and (2) valuation of the attributes (value functions and weights) elicited from the stakeholders. Both of these inputs might be associated with significant uncertainty. In the following, we will first give a short methodological background on how these uncertainties might influence the results, followed by the results of the sensitivity analysis.

### 5.3.2. Methodological background

***Uncertainty in attribute levels of alternatives***

The question is how the uncertainty in attribute levels might influence the rankings of alternatives for the different stakeholder groups. To answer this question, we take a hypothetical example of the attribute 'number of jobs'. We assume that an alternative is predicted to create 10 jobs during the construction phase. Based on the single-attribute value function shown in Figure 5.7, the corresponding dimensionless value is 0.8. Further, we assume that the uncertainty range of the estimation of jobs is ±5, which means that the alternative could also result in 5 or 15 jobs. The reduction of number of jobs from ten to five results in a reduction of the relative value from 0.8 to 0.6. However, the increase of number of jobs from ten to fifteen results only in an increase of the relative value from 0.8 to 0.85.

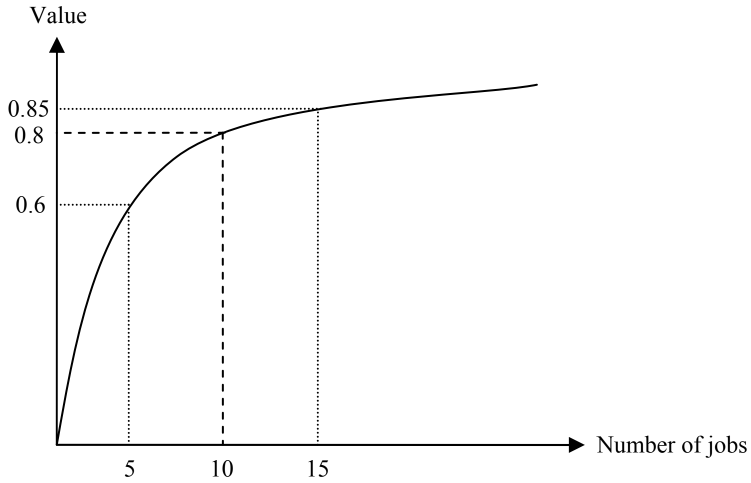


*Figure 5.7: Sensitivity in the attribute 'number of jobs' and the corresponding values.*

Hence, the effect on the relative value is different, even if the uncertainty range is equal for both directions. This is due to the non-linearity of the value function. This shows that the uncertainty of the outcomes can influence the results differently, depending on the shape of the corresponding value function.

***Uncertainty in valuations***

Further, there is an uncertainty in the valuation of the attributes (value functions and weights) elicited from the stakeholders. For our hypothetical example, we assume as a starting point a linear value function (Figure 5.8). Thereby, the attribute level '10 jobs' corresponds to a relative value of 0.4. However, if the value function is concave or convex instead of linear, the relative values for the same attribute level are different. For the concave value function (opening downward), the corresponding value is 0.7, and for the convex value function (opening upward), the value is 0.1. Hence, this example illustrates that the shape of the value function can have a significant effect on the corresponding value.

To estimate the total value of an alternative, the single-attribute value functions are multiplied by the corresponding weight of the attributes (Eq. 5.1). Hence, the relative weight of the attribute might also have a significant influence on the ranking of alternatives.

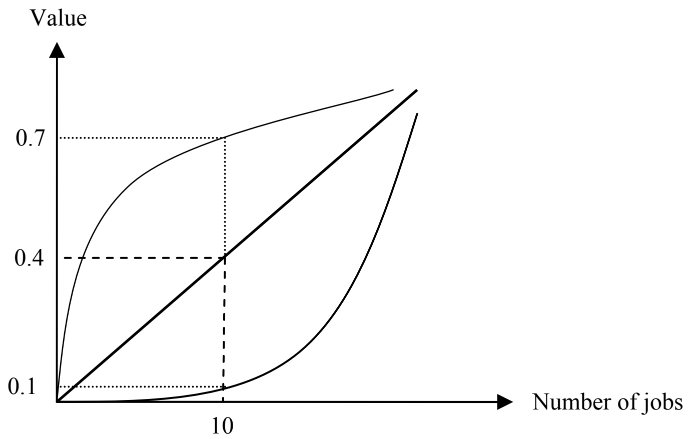


*Figure 5.8: Effect of different value functions on the dimensionless value number.*

### 5.3.3. Sensitivity based on attribute levels

The endpoint for the sensitivity analysis is the average value of each alternative for the different stakeholder groups. Within this study, best professional judgment was used to predict the attribute levels and their uncertainty range (Table 5.3). We defined the uncertainty range as a normal distribution with a given standard deviation and implemented the uncertainties directly in Logical Decisions® for Windows™ software.

The goal was to test the robustness of the results towards the uncertainty in the attribute levels. For the majority of the stakeholder groups, the uncertainty in outcomes can result in a change of adjacent rankings (e.g. change in ranking between positions 1 and 2, or between positions 4 and 5) (Figure 5.9). However, there is not a complete inversion of the results (for example that the most preferred alternative becomes the least preferred alternative and vice versa). It is noteworthy that the ranking of the alternatives is more robust for some stakeholder groups compared to others. For example, for the agricultural representatives, the uncertainty in the attribute levels might result only in a change between the administration option and minimum option (change between positions 3 and 4 in ranking). The preferred alternative (status quo option), the second option (negotiation option) and the least preferred option (nature reserve option) are very robust in their ranking. However, the ranking of alternatives for the forest rangers are less robust, since the relative values of the alternatives are closer and the final uncertainty ranges are higher. For the forest rangers, three alternatives could be in position one considering the uncertainty range: the negotiation option, the minimum option and the administration option. The difference in the uncertainty range between the stakeholder groups is due to the fact that the value functions elicited from these stakeholder groups are different, and hence, the uncertainty in the attribute levels has different effects.

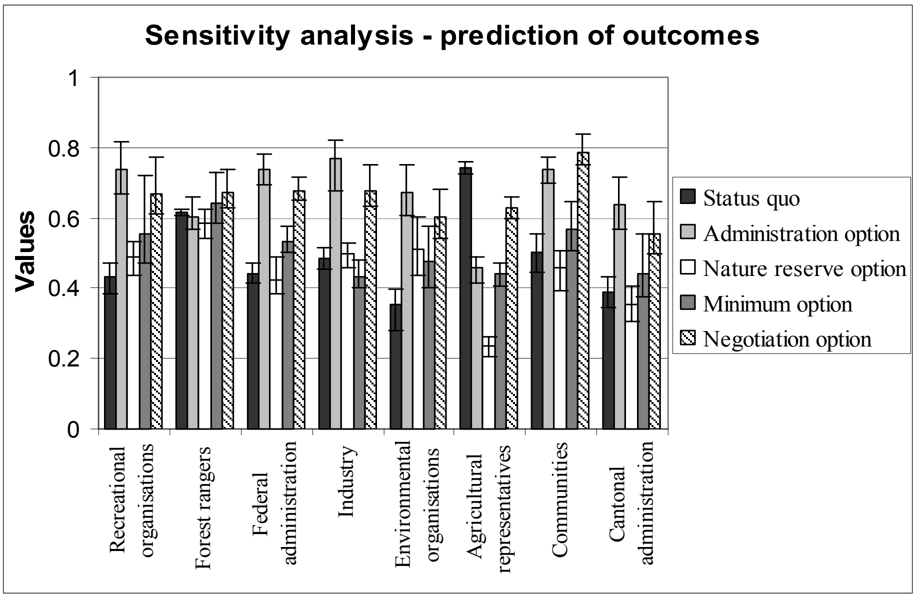


*Figure 5.9: Sensitivity analysis based on the uncertainty in attribute levels of rehabilitation alternatives.*

### 5.3.4. Sensitivity based on valuations

Besides the uncertainty in the attribute levels, there is also an uncertainty in the valuation elicited from stakeholder groups. We elicited the following preferences from the stakeholder groups: single-attribute value functions and attribute-weights. The endpoint is again the average value of each alternative for the different stakeholder groups. To estimate the uncertainty in the preferences, we compared the differences in preferences for the representatives within one stakeholder group. The more similar the valuation within one stakeholder group, the more homogeneous is the stakeholder group, and vice versa.

Figure 5.10 shows the average values of the alternatives for each stakeholder group. Further, the range of values across the different stakeholder representatives is indicated by the uncertainty range (error bars). One might realize that the different stakeholder groups do not have the same uncertainty range, and hence are not equally homogeneous. For example, the federal administration seems to be a homogeneous group, since the differences in values are relatively small. This is due to the fact that their representatives stated quite similar value functions and weights for the attributes. Stakeholder groups with bigger differences in value numbers are the recreational organizations and industry. This is due to the fact that the members of these groups represent quite different positions, and hence stated different value functions and weights. But even thought these stakeholder groups are not very homogeneous, the resulting change in rankings is limited (which means that there is not a complete change from the least to the most preferred option).

It is noteworthy that the resulting values for the agricultural representatives are very similar for most of the alternatives, except for the nature reserve option. This is due to the fact that some representatives stated a high preference for a long realization time, while one representative stated a high preference for a short realization time. And since the nature reserve option is estimated to have a long realization time, the resulting value numbers are quite different.

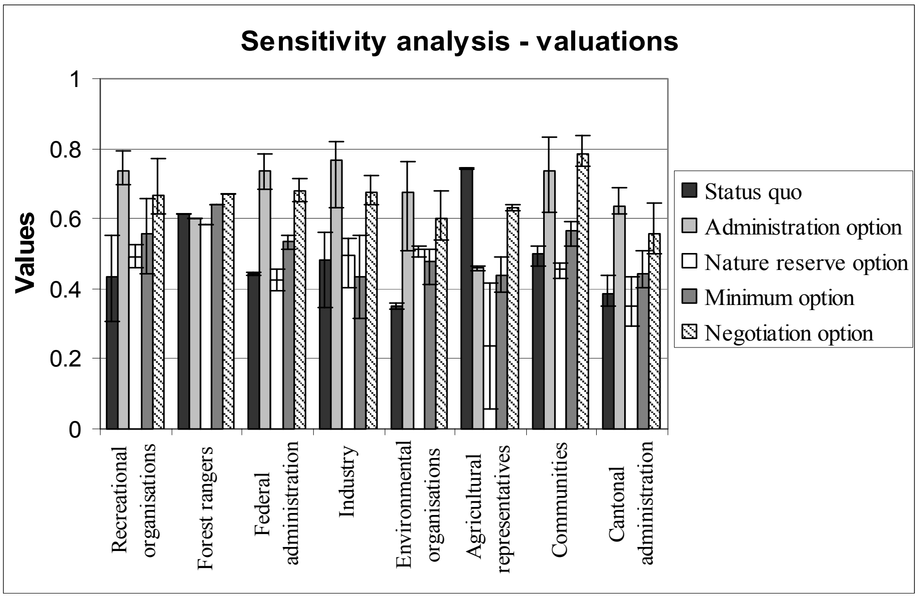


*Figure 5.10: Sensitivity analysis based on the uncertainty in valuation (value functions and weights) elicited from the stakeholders.*

### 5.3.5. Conclusions of sensitivity analysis

The results of the sensitivity analyses revealed that the uncertainty in attribute levels and valuations can have a significant effect on the results. However, within this study, this effect was limited, since there was not a complete change of the rankings of alternatives. Comparing the sensitivity to attribute levels with the sensitivity to valuations, the uncertainty range is similar for the two aspects. However, one has to be aware that the sensitivity to valuations can be very different for various stakeholder groups, depending on how homogeneous the stakeholder groups are. Should the stakeholder representatives state quite different preferences, this might result in a severe change of the rankings. Furthermore, a high uncertainty in attribute levels might also significantly influence the rankings. However, note that a high prediction uncertainty of attributes does not necessarily lead to wide distributions of rankings of alternatives, as probability distributions of differences in predicted attributes may be much narrower than the distributions of the attributes themselves (Reichert & Borsuk 2005). Within the Rhone-Thur Project, more detailed economic and natural scientific models are in development to form the basis for predictions in future analyses (Schweizer *et al.* 2004; Reichert *et al.* 2005). Once these models are finished, further analysis of sensitivity to uncertainty in attribute levels and valuations can be conducted.

## 5.4. Evaluation of method's contribution [3]

### 5.4.1. Introduction

**Problem description**

This section analyzes the contribution of the multi-attribute value theory (MAVT) method for conflict resolution and decision making in river rehabilitation projects. As we have discussed above, conflicting stakeholder interests may be an important impediment to the realization and success of projects. Such conflicts may arise for many reasons, including: 1) stakeholders have different objectives, operate with different trade-offs between objectives, and prefer different attributes for the characterization of objectives; 2) stakeholders disagree with regard to the outcomes of alternatives; and 3) they encounter difficulties in communicating with each other (Bogetoft & Pruzan 1991). The traditional way of decision making and stakeholder involvement has limitations when it comes to resolving such conflicts. Stakeholders typically concentrate first on potential management alternatives and only afterwards address the objectives and criteria that are required to evaluate the alternatives. Keeney (1992) refers to this approach as *alternative-focused thinking*. The potential drawback of this approach is that stakeholders anchor prematurely on a specific alternative and focus on just a few objectives. As a result, the discussion between the stakeholders tends to be emotionally charged.

Conflict resolution could, in principle, be facilitated by clarifying stakeholders' positions (quantifying their valuations), improving transparency with respect to outcomes of alternatives, and increasing the set of possible objectives. *Value-focused thinking* addresses these issues and might thus perform better in conflict resolution. It focuses first on values and later on alternatives that might achieve these values (Keeney 1996). This process helps to identify values and opinions of stakeholders and pinpoints sources of disagreement (von Winterfeldt & Edwards 1986; Belton & Pictet 1997). Moving the discussion away from alternatives towards fundamental objectives and value trade-offs facilitates negotiation because it encourages people to think about their common interest and avoids discussion in which each stakeholder anchors on a preferred alternative (Raiffa 1982). Further, people are able to make better informed, more thoughtful, and hence, higher quality decisions (Arvai *et al.* 2001). Typically, multiple criteria decision analysis (MCDA) methods are used as a formal framework for the value-focused thinking approach. Despite of the mentioned advantages of MCDA methods for conflict resolution, there are only a few studies that describe successful MCDA-based stakeholder involvement in real-world situations (Brown 1984; Ridgley & Rijsberman 1992; Marttunen & Hämäläinen 1995; Hobbs & Horn 1997; McDaniels 1999; Bana e Costa 2001; Hämäläinen *et al.* 2001; Marttunen & Suomalainen 2004). Moreover, studies that have applied MCDA methods indicate that users are generally skeptical about the value of such methods and often prefer the freedom of unaided decision making (Hobbs *et al.* 1992; Bell *et al.* 2001). Therefore, we believe that further research is required to elicit why users are skeptical, and in what ways the application of MCDA methods might facilitate conflict resolution and negotiation.

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[3] *This section is an excerpt of the article:*
Hostmann M., Bernauer T., Mosler H.-J., Reichert P. & Truffer B. (2005) Multi-Attribute Value Theory as a Framework for Conflict Resolution in River Rehabilitation. Journal of Multi-Criteria Decision Analysis, accepted.

The aim of this section is to analyze the contribution of MAVT, a particular kind of MCDA method, for decision making and conflict resolution in environmental planning projects. One potential contribution of the MAVT method is to predict the preferences of stakeholders (predictive validity). Thereby, the MAVT method could be used as a framework for pinpointing sources of disagreement and interpersonal conflict between different stakeholder groups *before* principled positions get locked in. Moreover, the MAVT method could facilitate negotiations among stakeholders in an interactive way. That is, it could produce changes in stakeholders' preferences towards more consensus-oriented decisions. An important precondition, which we will also analyze, is that stakeholders understand and accept the method and its result. To test these propositions, we apply the MAVT method to the river rehabilitation project at the Thur River described in section 5.2.

**Hypotheses**

In analyzing the contribution of the MAVT method to conflict resolution, we sought answers to three questions: 1) Can the MAVT method predict the final preferences of stakeholders and therefore anticipate conflicts at an early stage? 2) Do stakeholders reconsider and change their preferences after using the MAVT method? 3) If they do, does this result in more consensus-oriented decisions?

***1) Predictive validity***

*Hypothesis 1:* The correlation between the MAVT ranking and stakeholders' final preferences (final holistic ranking) is higher than the correlation between the initial and final holistic ranking.

This hypothesis looks at the method's ability to predict the final holistic ranking of alternatives after applying the MAVT method and reviewing the results (predictive validity). We assume that the final holistic ranking represents the stakeholders' most informed and final preferences. A high correlation between the MAVT ranking and the final holistic ranking would indicate that the MAVT ranking is a good predictor of stakeholders' final preferences. Confirmation of this hypothesis would imply that the method is helpful in predicting conflict among stakeholders at an early stage of the project.

***2) Changes in stakeholders' preferences***

*Hypothesis 2:* There are significant differences between the rankings of the alternatives between the initial and final holistic rankings.

This hypothesis addresses whether stakeholders reconsider and change their initial opinion when confronted with the results of the value-focused thinking approach. Stakeholders engaged in three different ranking exercises: initial holistic ranking, ranking based on the MAVT method, and final holistic ranking. Based on questionnaires and structured discussions with stakeholders, we also investigated potential reasons for changes in preferences.

***3) Contribution to consensus solution***

*Hypothesis 3:* Changes in preferences induced by the MAVT method lead to more consensus-oriented decisions.

This hypothesis investigates whether a potential change in preferences results in more balanced and hence more consensus-based decisions, or whether it results in more opposed preferences.

## 5.4.2. Experimental design and methods

**Decision making context**

We tested the three hypotheses discussed above in a real-world conflict situation in the field of river rehabilitation at the Thur River (section 5.2.2). However, it is important to emphasize that this study was done in a research setting to analyze the contribution of MCDA. Therefore, stakeholders were aware that the results do not have to interfere with the real decision process. On the other side, stakeholders (including the cantonal administration) took the interviews and workshops very seriously.

This rehabilitation project is at an early stage; that is, various rehabilitation alternatives are under consideration. The aim of the cantonal administration, the authority responsible for river management, is to improve the deficit in flood protection and ecological condition. It has drawn up a preliminary plan for rehabilitation, which includes widening the river bed and constructing a retention basin for flood protection. At the time of writing, the area necessary for these measures was used for farming and forestry and major conflicts among stakeholders were emerging.

**Subjects**

The subjects for the second interview phase are the same as in the first phase. For a detailed description of stakeholder identification and classification, please refer to section 5.2.2.

**Objectives and alternatives considered**

Seven objectives were chosen to compare different rehabilitation alternatives by interviewing several scientific experts and stakeholders. These objectives are “high flood protection level”, “low costs”, “short realization time”, “good ecological status”, “good recreational opportunities”, “maintain agricultural activity” and “create employment opportunities”. Each objective was operationalized by measurable attributes (Table 5.5).

For the Thur River, we developed four rehabilitation alternatives and compared them to the status quo: the administration option, the nature-reserve option, the minimum option and the negotiation option. For a detailed description of the alternatives, please refer to section 5.2.3. The effects of these alternatives on the attributes are summarized in Table 5.5.

*Table 5.5: Performance of the alternatives on the attributes.*

| Objectives | High flood protection level | Low costs | Short realization time | Good ecological status | Good recreational opportunities | Maintain agricultural activity | Create employment opportunities |
|---|---|---|---|---|---|---|---|
| Attributes | Costs of damages ($10^6$ CHF) | Costs of measures ($10^6$ CHF) | Realization time (years) | Ecological status (scale 1-5) | Area of recreation (ha) | Area of agriculture (ha) | Number of jobs (#) |
| Status quo | 370 | 4.5 | 0 | 1.5 | 15 | 50 | 5 |
| Administration option | 12.3 | 18.1 | 20 | 3.4 | 55 | 15.5 | 23 |
| Nature-reserve option | 370 | 26.5 | 30 | 4.7 | 31.4 | 0 | 30 |
| Minimum option | 370 | 9.8 | 10 | 2.5 | 28.6 | 33.1 | 12 |
| Negotiation option | 113.5 | 12.2 | 15 | 2.9 | 26.8 | 45.4 | 15 |

**Interview design**

The data used for this section was gathered in two interview phases. The main purpose of interview phase I was to elicit stakeholders' preferences based on the value-focused thinking approach (section 5.2). For each of the eight major stakeholder groups, three to four representatives were interviewed – 26 people in total. We elicited single attribute value functions and weights for the seven attributes from each of the 26 representatives. The respondents were asked to express their preferences as representatives of their stakeholder group, and not as individuals. For this reason, we interviewed in pairs of two within the same stakeholder group. Interview phase I took place from May 20, 2003 to September 9, 2003. After interview phase I, we worked out the five rehabilitation alternatives and calculated their effects on the attributes (Table 5.5). In addition, the stakeholders' preferences were analyzed to calculate the total value of a specific alternative for each respondent. This was done based on multi-attribute value theory (MAVT) using the Logical Decisions® for Windows™ software. The results of interview phase I are described in detail in section 5.2.

The purpose of interview phase II was to present the results to the stakeholders, analyze the methods' predictive validity, and investigate changes in stakeholders' preferences. We also examined stakeholders' understanding of the method and acceptance of the results. We planned that the same stakeholder representatives would participate in both interview phases so that we could study their learning effect. From the initial 26 respondents in interview phase I, 20 respondents (77%) participated in interview phase II. We conducted the second interview phase in the form of three workshops involving specific interest groups with potentially similar positions – this was done to stimulate discussions. The workshop group *society* consisted of the representatives from recreational and environmental organizations; the workshop group *administration* included communities, cantonal administration, and federal administration; the workshop group *economic interests* included agricultural representatives, forest rangers, and the power and gravel industry. The three workshops were held separately, each lasting two hours. They took place from March, 17 to March 24, 2004.

In the first part of each workshop, we introduced the rehabilitation alternatives to the stakeholders (Figure 5.11). Based on the alternative-focused approach (not the MAVT method), stakeholders then carried out the initial holistic assessment of these rehabilitation alternatives (ranks 1-5 and ratings of 0-100). In step 2, the MAVT method was explained to provide the participants with the conceptual understanding of this approach. They were then informed of the results from the MAVT rankings, which were based on their preferences towards the attributes elicited in interview phase I. Thereafter, they were questioned about their understanding and acceptance of the method and its results (based on questionnaires and structured discussions). At the end of the workshop, stakeholders were asked to conduct once again a holistic ranking of the alternatives (final holistic ranking). The comparison of the initial holistic ranking with final holistic ranking allows us to analyze whether stakeholders' preferences changed, and in what direction.

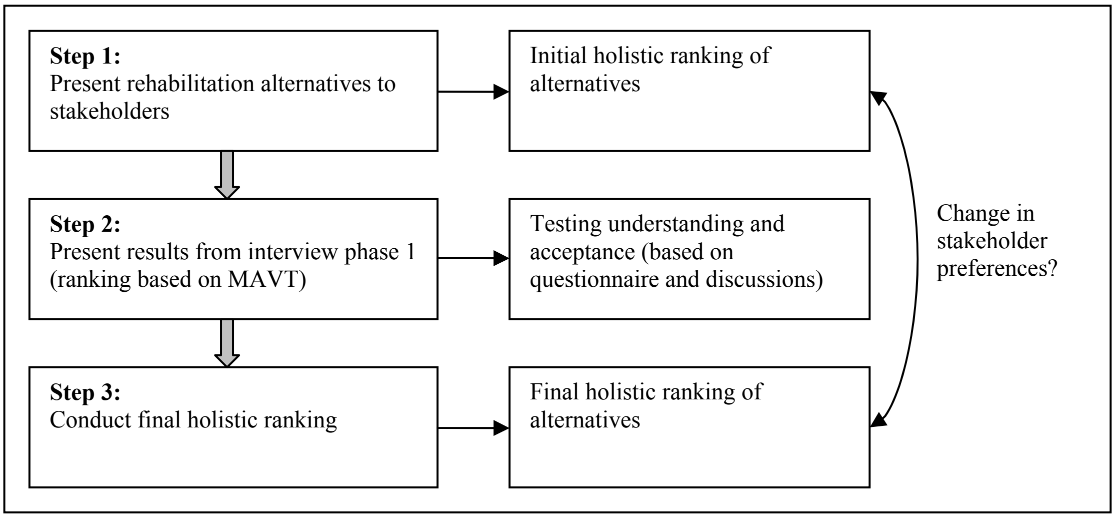


*Figure 5.11: Steps of interview phase II (left side) and information gathered from stakeholder (right side).*

## Methods

*Data analysis*

The data obtained from the questionnaire was analyzed by calculating the Spearman's correlation coefficient ρ for various pairs of indicators (e.g. understanding and acceptance of MAVT method). The MAVT method's performance in predicting the final holistic ranking (predictive validity, hypothesis 1) was analyzed using the Spearman's correlation ρ between the assessments' ranking (1-5). Based on Bell *et al.* (2001), we define this 'intermethod correlation' as the correlation between two assessments' results for a specific user, averaged across all users:

$$\frac{1}{W}\sum_{a=1}^{W}\mathrm{cov}\left(r_{sa}, r_{ta}\right) / \sigma_{r_{sa}}\sigma_{s_{ta}} \tag{5.2}$$

where $r_{sa}$ and $r_{ta}$ are participant $a$'s rankings for assessment $s$ and $t$, *cov()* is the covariance, $\sigma_{rsa}$ and $\sigma_{rta}$ represent deviation of participants rankings for assessment $s$ and $t$, and $W$ the number of users.

Hypothesis 3 addresses whether changes in preferences lead to more consensus-oriented decisions. To test this hypothesis, interperson correlations were compared for all three assessments' rankings. 'Interperson correlation' is defined as the correlation between policy rankings for a given method for a pair of users, averaged across all pairs of users (Bell *et al.* 2001):

$$\frac{1}{\binom{W}{2}}\sum_{a=1}^{W}\sum_{b>a}^{W}\frac{\mathrm{cov}(r_{sa},r_{sb})}{\sigma_{r_{sa}}\sigma_{r_{sb}}} \tag{5.3}$$

where $r_{sa}$ and $r_{sb}$ are the vectors of policy ranks from method $s$ for participants $a$ and $b$. All statistical analyses were conducted using the SPSS 11.0 for Windows software.

### 5.4.3. Results and discussion

The application of MAVT method has to meet at least two conditions so as to contribute to conflict resolution: stakeholders should understand the method and accept its results, and they should regard the method as potentially useful. Accordingly, we first present some general findings on stakeholder involvement, followed by findings on stakeholders' understanding, acceptance and perceived usefulness of the method and its results. We then discuss our results for the three hypotheses 'predictive validity', 'changes in preferences', and 'contribution to conflict resolution'.

**Stakeholder involvement**

The respondents were first asked whether stakeholders should, in general, be involved in the decision-making process in river rehabilitation. We thus wanted to know whether stakeholders had fundamental objections against open and transparent decision making and how they felt about the process up to the date of the interview. Stakeholders from all workshop groups stated that stakeholder involvement is very important (Figure 5.12). Responses to the question about stakeholder satisfaction exhibited more variation. The economic interest group was not satisfied at all with its previous involvement in decision making, while the society group and administration group were satisfied with the decision-making process. Representatives of the economic interests group also held more negative views about the rehabilitation project as such. Note that our research was directed at an ongoing planning project. Consultations between the government and individual stakeholders had been initiated about two years before our interviews.

**Understanding, acceptance and perceived usefulness**

We then examined stakeholders' understanding of the method, their acceptance of the results, and whether they considered the MAVT method a useful tool for conflict resolution. Stakeholders were first requested to rate their ease of understanding of the method and its result from 1 (not understandable) to 5 (very understandable). All of the involved stakeholder groups ranked their understanding of the MAVT method as 'fairly high' (Figure 5.12). In addition, stakeholders were asked whether they considered their own personal rankings, as they resulted from the application of the MAVT methodology, to be adequate. On a scale of 1 (no acceptance) to 5 (high acceptance), the average was 'fairly high acceptance' (average score = 4.0). 'Understanding' and 'acceptance of results' are moderately correlated ($\rho=0.399$, $p<0.05$). Moreover, stakeholders stated on average that in applying the MAVT method, they experienced a moderate awareness of new aspects and a moderate to fairly high gain in information about the river restoration project. 'Increased information' correlates moderately with 'acceptance of the results' ($\rho=0.489$, $p<0.02$).

We also tested whether stakeholders might reject the method because of its potential shortcomings. In doing so, we tested the influence of three potential obstacles: disagreement with performance of attributes; complexity of decomposing the problem into several objectives; and black box problem. On average, the stakeholder groups expressed ‘fairly high’ to ‘very high’ agreement with the performance of attributes (average score = 4.3) (Figure 5.12). Slightly less positive was their answer to the question whether they agree with the decomposition of the objectives (average score = 3.9) and whether they consider the MAVT method as a non-transparent black box (average score 4.1). Overall, these results show that the stakeholders did not experience the mentioned problems as severe. Finally, the respondents were asked whether they considered the MAVT method a useful tool for conflict resolution. Most respondents regarded the method as highly useful for representing different stakeholder positions (average score = 4.3) and helping negotiations (average score = 4.3). Focusing now on the correlations between the factors ‘understanding’, ‘acceptance’, ‘awareness of new aspects’ and ‘perceived usefulness’, it is outstanding that each factor is correlated with the following one (Figure 5.13). In contrast, the factor ‘perceived usefulness for negotiation’ shows no correlation with the factors ‘understanding of the method’ and ‘acceptance of the results’. This finding indicates that it is not enough if stakeholders understand the method or accept its results. They also have to experience a learning effect (increased information, awareness of new aspects) in order to appreciate the method as useful for conflict resolution.

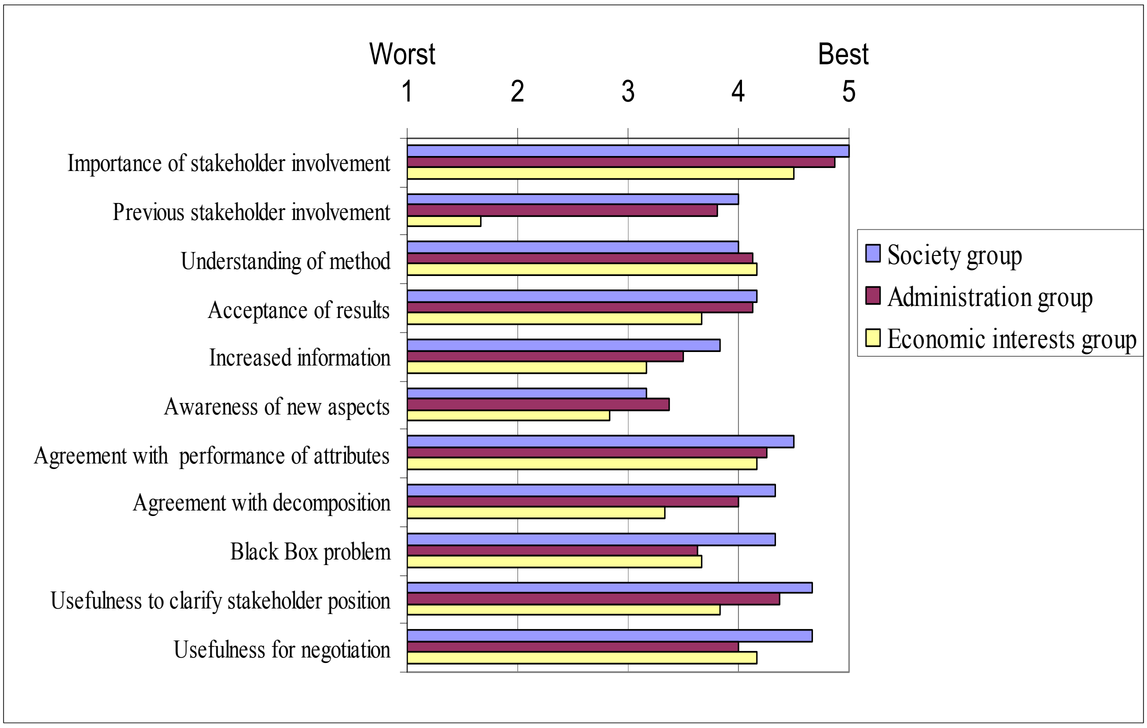


*Figure 5.12: Average evaluation of MAVT method based on stakeholders’ feedback.*

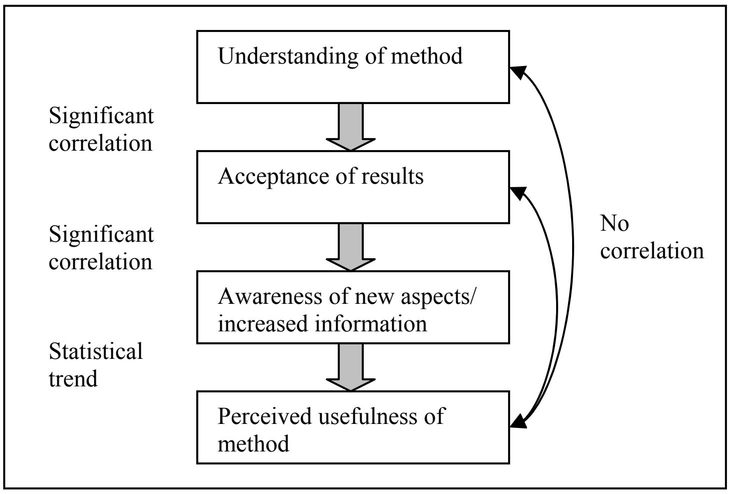


*Figure 5.13: Tested correlation between understanding, acceptance, awareness of new aspects, and perceived usefulness.*

In summary, the surveyed stakeholders showed a high understanding and acceptance of the value-focused thinking approach and attributed a high usefulness to the method for conflict resolution and negotiation. It is remarkable that all stakeholder groups came to virtually the same conclusion, even those groups which were very critical of the rehabilitation project as such. These findings from the questionnaire were confirmed by stakeholders' feedback in the structured discussion (Table 5.6). In general, stakeholders judged the value-focused thinking approach more objective and comprehensive than alternative-focused thinking. However, participants also noted some critical points in regard to value-focused thinking and the MAVT methodology.

*Table 5.6: Strengths and potential obstacles of value-focused thinking approach mentioned by stakeholders in the discussion.*

| Strength of value-focused thinking approach for conflict resolution | Potential obstacles of value-focused thinking approach for conflict resolution |
|---|---|
| Value-focused thinking is more objective and comprehensive than alternative-focused thinking.<br>Decisions based on value-focused thinking are more balanced since one has to acknowledge different objectives.<br>Discussions based on value-focused thinking are more honest, since the results from the discussion are not obvious straight away.<br>Stakeholders become aware that nobody can consider only his or her own interests but also has to acknowledge other stakeholder groups with various interests.<br>Value-focused thinking helps to better identify the similarities and differences between the stakeholder groups.<br>Based on value-focused thinking, stakeholders can reconsider and change their opinion during negotiation, in contrast to alternative-focused thinking where people tend to anchor on a specific alternative. | The value-focused thinking approach might pretend an objectivity which does not exist (e.g. the overall value of alternatives (Eq. 5.1) pretends to be very detailed).<br>I fear that the responsible authority could lose control over the decision process.<br>When judging the objectives, I had difficulty separating between the stakeholder group-view and the individual view.<br>If the stakeholders have the feeling that the facilitator tries to influence the decision, the negotiation process will be fundamentally harmed. |

**Predictive validity**

The findings just discussed indicate a high degree of perceived usefulness of the method and a high degree of understanding and acceptance by the respondents. We now turn to the question whether the method may in fact facilitate conflict resolution. First we test the method's ability to predict the preferences of stakeholders.

*Hypothesis 1:* The correlation between the MAVT ranking and stakeholders' final preferences (final holistic ranking) is higher than the correlation between the initial and final holistic ranking.

To evaluate this hypothesis, Spearman's correlations between the initial holistic ranking, MAVT ranking, and final holistic ranking were estimated (Eq. 5.2). Initial and final holistic assessments are strongly correlated (average correlation of 0.89 between each person's rankings) (Figure 5.14). The correlation between the MAVT ranking and final holistic ranking was somewhat lower (average correlation of 0.67 between each person's rankings). That is, our hypothesis has to be rejected. The final holistic ranking is closer to the initial holistic ranking than to the MAVT ranking. The fact that MAVT ranking is not highly correlated with final holistic ranking is consistent with previous research (von Winterfeldt & Edwards 1986; Hobbs & Horn 1997; Bell *et al.* 2001). The reasons might be as follows: First, it is possible that the ranking based on the MAVT method does not include all factors that are relevant for stakeholders' preferences (e.g., missing objectives or "irrational aspects" of stakeholder decisions). Second, stakeholders may not wish to present their real preferences for tactical reasons, since they are part of an ongoing political process. Third, stakeholders need more time to reflect, and change their preferences if need be, than the short time frame of one workshop allows.

Note, even though our hypothesis has to be rejected, the average correlation of 0.67 indicates that the MAVT ranking and final holistic ranking is still fairly correlated. In addition, the MAVT method predicted for the majority of stakeholders (55%) the same top-ranked alternative which was chosen afterwards in the final ranking. From this we conclude that the MAVT method has some potential to predict conflicts between stakeholders at an early stage of the project, with all the limitations stated above. In general, it is important to emphasize that even a low predictive validity does not indicate that the method per se is ineffective in providing insights into the decision making problem. To test the contribution of the MAVT method in terms of facilitating reconsideration of stakeholders' opinion we now move on to hypotheses 2 and 3.

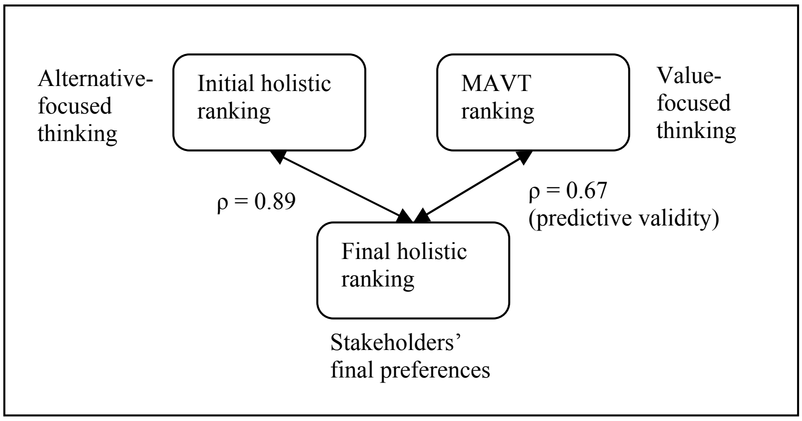


*Figure 5.14: Intermethod correlation ρ between different alternative rankings.*

**Change in stakeholder preferences and conflict resolution**

*Hypothesis 2:* There are significant differences between the rankings of the alternatives between the initial and final holistic rankings.

For each respondent, initial and final holistic rankings of the alternatives were compared. The results show that the majority of participants (55%) changed their initial opinion after they had been confronted with the results of the value-focused thinking approach. Stakeholders stated various reasons for why they might have changed their opinion (Table 5.5). First, they had considered more objectives for the final decisions after having applied the value-focused thinking approach. Second, stakeholders had become more aware of and acknowledged the interests of other stakeholder groups. Finally, the MAVT framework had given them the possibility to reconsider and change their initial opinion without loosing their credibility in the other stakeholders' eyes.

This leads to the question whether changes of preferences have led to more balanced and consensus-based decisions, or whether they have resulted in more heterogeneous and conflicting opinions.

*Hypothesis 3:* Changes in preferences induced by the MAVT method lead to more consensus-based decisions.

This hypothesis was evaluated by quantitative as well as qualitative analysis. The quantitative analysis examined whether the final holistic ranking is more homogeneous than the initial holistic ranking. To that end we computed interperson correlations for all three assessment rankings (Eq. 5.3). We use 'interperson correlation' as an indicator for conflict-intensity; the higher the interperson correlation, the lower the intensity of conflict between stakeholders. The resulting coefficients show that the final holistic ranking was somewhat more homogenous (higher interperson correlations, $\rho=0.26$) than the initial holistic ranking ($\rho=0.12$) (Figure 5.15). This finding suggests that preferences changed in a direction that might led to more balanced decisions. However, rankings turned out to be most homogenous for the MAVT ranking ($\rho=0.47$). This result is consistent with the findings of other studies, which have concluded that formal MCDM methods tend to produce a stronger convergence of preferences than holistic valuations (von Winterfeldt & Edwards 1986; Hobbs & Horn 1997).

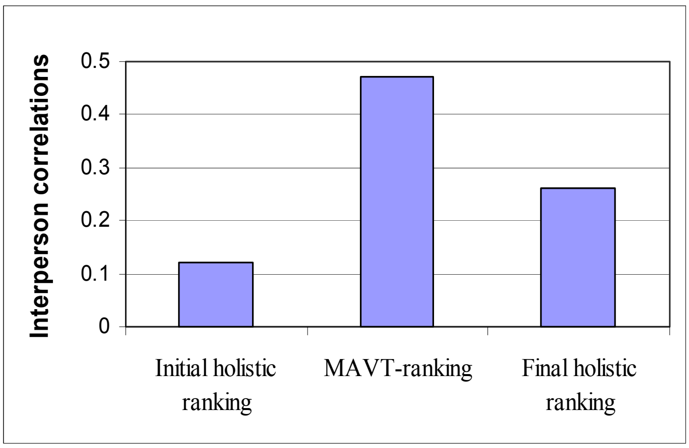


*Figure 5.15: Interperson correlations for three alternative rankings.*

As a follow up we examined where changes in rankings took place (Figure 5.16). In comparing the initial and final holistic assessment, it is striking that the negotiation option exhibits the strongest convergence in rankings; three stakeholder groups (federal administration, cantonal administration, forest rangers) rated the negotiation option higher in the final assessment than in the initial holistic assessment. The negotiation option was developed during our research to include the most conflicting objectives (improvement of flood protection and ecological condition on the one hand and maintaining agricultural activity on the other hand). In contrast, the nature-reserve option was ranked lower by three stakeholder groups in the final assessment than in the initial holistic assessment. The nature-reserve option is the most extreme option within the selected alternatives and focuses mainly on one objective: ecological improvement. Rankings of the remaining alternatives changed much less; the administration option improved for one stakeholder group, the minimum option improved for one group and decreased for another group, and the status quo option did not change at all.

In brief, the most balanced and consensus-oriented alternative (negotiation option) experienced the highest increase in rankings, and the most extreme alternative (nature-reserve option) experienced the highest decrease in rankings. This result supports our finding that the value-focused thinking approach leads stakeholders to more balanced and more consensus-based decisions than the alternatives-focused approach.

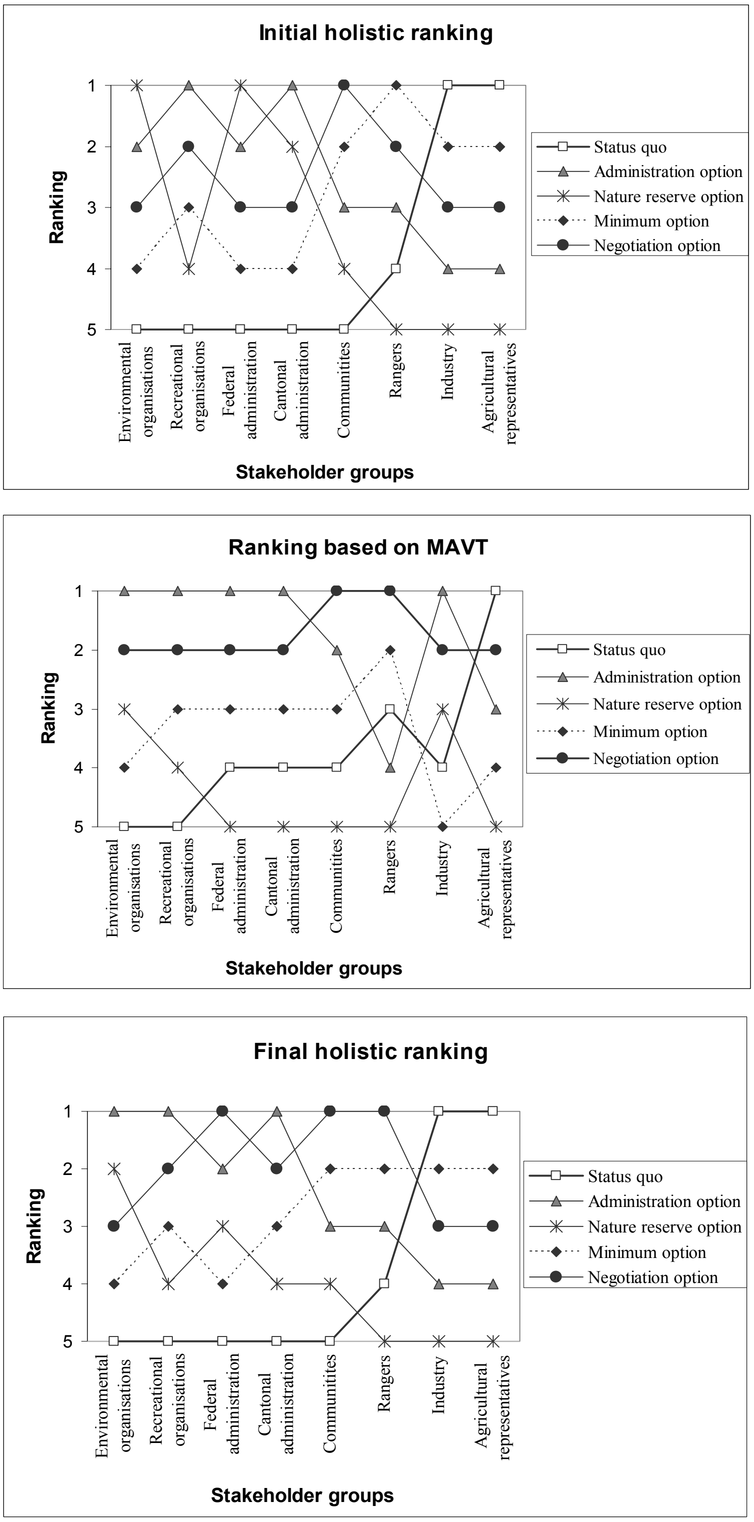


*Figure 5.16: Rankings of rehabilitation alternatives for society group (environmental organizations, recreational organization), administration group (federal administration, cantonal administration, communities) and economic interest group (rangers, industry, agricultural representatives).*

### 5.4.4. Conclusions

The aim of this study was to analyze the contribution of the multi-attribute value theory (MAVT) method to decision making and conflict resolution in environmental planning projects. We first asked whether the MAVT method meets basic requirements for a successful application in conflict resolution efforts. Our findings show that the involved stakeholders displayed a high understanding and acceptance of the method and its results. In contrast to some previous studies (Hobbs *et al.* 1992; Bell *et al.* 2001), the stakeholders in our case also expressed a high perceived usefulness of the technique for supporting negotiation processes.

As a first hypothesis, we tested the methods' ability to predict the final preferences of stakeholders. It turned out that the predictive validity of the MAVT method was limited, since the MAVT-ranking and the final holistic ranking was not highly correlated. This finding might be due to the fact that the rational framework of the MAVT methodology does not include all determinants of stakeholders' preferences (e.g., emotional aspects of stakeholder decisions). Although the method does not fully predict stakeholders' final preferences, this does not mean that it is not useful for conflict resolution. The MAVT methodology may still serve as a framework that enables participants to gain more insights and reach better-informed decisions (McDaniels *et al.* 1999; Arvai *et al.* 2001). This leads us to the second and third hypothesis. The majority of stakeholders reconsidered and changed their preferences after they had been confronted with the results of the value-focused thinking approach. Even more important, stakeholders changed their preferences towards more balanced and more consensus-oriented decisions. This result is in line with Keeney *et al.* (1990) who argue that the process of eliciting and reconciling value information can lead to changes in the participants' evaluations. From this we conclude that the main strength of the MAVT method in multi-stakeholder settings lies not in the prediction of stakeholders' final preferences, but rather in the methods' ability to facilitate more consensus-oriented decisions.

In practical terms, these findings suggest that MCDA methods should be applied as straightforward and transparent as possible and should be explained carefully to the involved stakeholder groups. Otherwise, a low understanding and acceptance of the method by stakeholders will reduce the methods' usefulness for negotiation. Furthermore, stakeholders should be aware that MCDA methods are decision *support* methods, and not a substitute for actual decisions. Awareness of this point reduces stakeholders' fear of losing control over the decision process. Finally, stakeholders need time to be able to reflect on their preferences based on the value-focused thinking approach. This time is worthwhile spending if the subsequent project phases (implementation and construction) will require significantly less time as stakeholders have agreed on a consensus solution.

It is important to emphasize the limits of this research setting and its results. Due to the fact that this research was implemented in a real-world conflict situation, it was not possible to use a control group. Therefore, one can question whether the change in final preferences was due to the use of the MAVT method, and not due to some other factors. To analyze this question in more detailed, we conducted the third interview phase which is described in the next section.

## 5.5. Comprehensive stakeholder forum

The third interview phase aims to evaluate whether the change in preferences was due to the MAVT method and not due to some other factors. Therefore, we analyze why some stakeholders changed their preferences towards more consensus-based decisions, and why other stakeholders did not change their preferences. Further, we asked the stakeholders about the major contributions of the value-focused thinking approach for the negotiation process, and which results from this study are important for the further planning process. To answer these questions, we elicited stakeholder feedback based on a questionnaire and a structured discussion including all stakeholder groups.

### 5.5.1. Results from questionnaire

The main questions of the questionnaire were 1) why stakeholders changed their rankings or not, 2) what is the anticipated conflict potential of the rehabilitation alternatives, and 3) what is the most important information resulting from the study for the further decision making process. The questionnaire was sent out in January 2005 to all stakeholders who participated in the second interview phase. Of the initial 20 people, 15 persons (75%) filled in and returned the questionnaire.

***Change in rankings***

As we have discussed in section 5.4, about half of the stakeholders changed their rankings of alternatives during the stakeholder workshop. The stakeholders mentioned different reasons for changing the rankings. First, they received more detailed information about the outcomes of the alternatives. This led to a better understanding about the advantages and disadvantages of the different alternatives. Second, the stakeholders became aware of new aspects which might influence their decision. In other words, the stakeholders considered only a few objectives when they first conducted the initial holistic ranking, but after applying the value-focused thinking approach, they included more aspects in their decision making. Third, the stakeholders learned more about the values of other stakeholder groups, which influenced their final holistic ranking as well. All three aspects indicate that the application of the MAVT method improved stakeholder understanding and social learning.

As we mentioned above, about half of the people did not change their rankings. The most frequently stated reason was that the stakeholders were clear about their opinion already from the beginning. This answer reveals that it is very difficult to overcome the anchoring of alternatives for some of the stakeholders, even after applying the value-focused thinking approach. Furthermore, a few stakeholders stated that they did not gain new information based on the MAVT method, and that the method's results did not seem reasonable to them.

***Anticipated conflict potential***

We also asked the stakeholders as well about the anticipated conflict potential of the different alternatives. The stakeholders were asked whether they consider the alternatives to have a low, medium or high conflict potential. Figure 5.17 shows that the majority of stakeholders (86%) judged the *status quo option* to have a low conflict potential. The *minimum option* is anticipated to have a low to medium conflict potential, while the *negotiation option* is classified in average to have a medium conflict potential. Furthermore, the stakeholders expect a significant conflict potential for the *administration option* (50% classified the administration option to have a big conflict potential), and a very high conflict potential for the *nature reserve option* (93% of the stakeholders expect the negotiation option to have a high conflict potential).

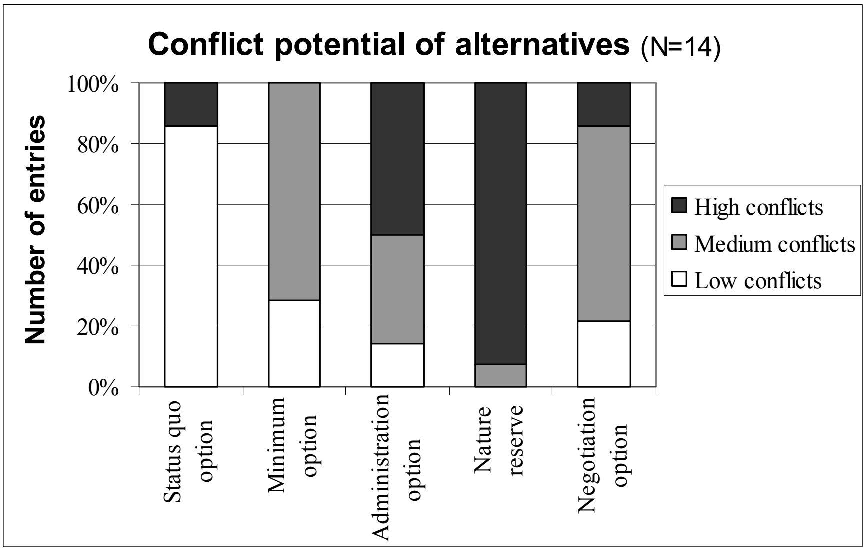


*Figure 5.17: Anticipated conflict potential of rehabilitation alternatives by the stakeholders.*

***Important information for further process***

Finally, we asked the stakeholders which results from this study might be important for the further decision making process. First, all respondents stated that the elaboration of potential consensus solutions is an important result of the study (Figure 5.18). The identification of alternatives with high conflict potential was also an important result for about 50% of the stakeholders. Further, it is striking that the stakeholders judged the weighting of objectives to be much more important than the ranking of the alternatives. This might be due to the fact that the MAVT ranking does not fully represent stakeholders' final preferences, as shown in section 5.4. Furthermore, the information about the weights of objectives is more constructive for the elaboration of consensus solutions compared to the ranking of a limited number of alternatives.

In general, the stakeholders judged the information resulting from interview phase II (elaboration of consensus solutions) to be more important than the results from interview phase I (weights of objectives, ranking of alternatives). This reveals the finding that the main strength of the method is to support the learning process rather than the elicitation of the 'true' preferences of stakeholders.

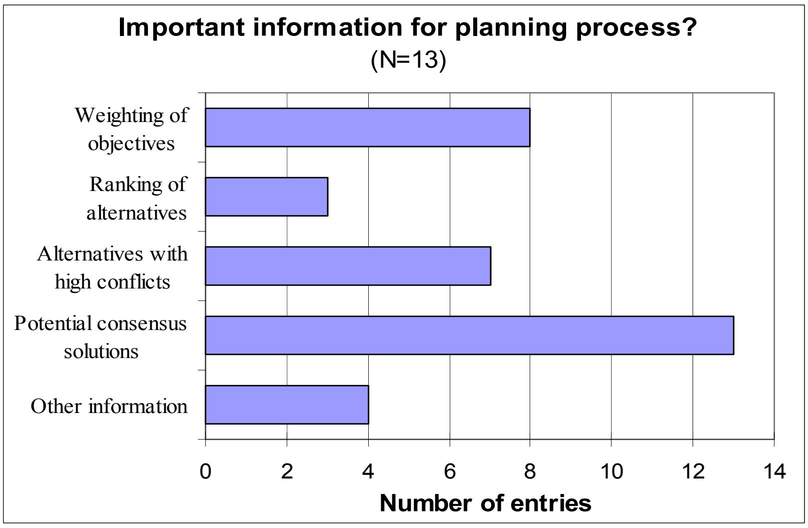


*Figure 5.18: Important information for the further planning process*

### 5.5.2. Results from structured discussion (stakeholder forum)

***Interview design***

The stakeholder forum of interview phase III was the first time that all stakeholder groups came together. It took place on January 19, 2005 in Weinfelden, Switzerland. From each of the eight stakeholder groups, one to two representatives joined the meeting (in total 14 stakeholder representatives). By bringing all stakeholder groups together, the stakeholders had the possibility to exchange their arguments, even those stakeholder groups with conflicting interests.

The stakeholder forum consisted of two parts. First, we presented the results from interview phases I and II to the stakeholders. Major results from interview phase I included how the different stakeholder groups weighted the objectives and how the alternatives were ranked based on the MAVT method (section 5.2). Major results from interview phase II were how the stakeholders ranked the alternatives in the first and final holistic rankings, and stakeholder feedback to the results from the MAVT method (section 5.4). After presenting the former results, we conducted a structured discussion and asked the stakeholders about their feedback to the results. Thereby, one major question was how the stakeholders evaluate the contribution of the MAVT method for negotiation and elaboration of potential consensus solutions.

***Stakeholder feedback***

Stakeholder feedback to the MAVT method was in general very positive. Stakeholders emphasized that there are different advantages of the value-focused thinking approach in comparison to alternative-focused thinking. On one hand, stakeholders gained insight on a personal level (individual learning). The MAVT method thereby increased stakeholder understanding of the whole rehabilitation project. Especially lay people, who are not experts in the river rehabilitation thematic, gained a much better understanding and broader view of the whole rehabilitation project. This means that the stakeholders experienced a learning effect on an individual level. Furthermore, the value-focused thinking approach also forced the stakeholders to think hard about their fundamental objectives, and eventually rethink their attitude towards different aspects of the rehabilitation project.

On the other hand, stakeholders benefited on a group level (social learning), as well. The identification of similarities and differences between stakeholder groups was one benefit of the method. Even more importantly, stakeholders stated that they improved their understanding of other stakeholders' interests. Hence, they also improved their understanding and appreciation of the position of other stakeholder groups. This improvement of mutual understanding is one major step towards consensus solutions.

***Further implementation of the method***

The cantonal administration, the authority responsible for the rehabilitation project, gave very positive feedback to the MAVT methodology. They stated that after this successful application of the MAVT method in the research project, they would like to implement the method in the real decision making process. The representative from the federal administration stated that the MAVT method has major advantages compared to the alternative focused thinking process, and therefore, that it should be applied in all major rehabilitation projects in Switzerland.

### 5.5.3. Causality of results

There are two main reasons which indicate that the change in preferences is mainly due to the use of the MAVT method, and not due to some other factors:

- *Procedure of preference elicitation*: Stakeholders were asked to give their initial and final ranking of alternatives within one workshop (section 5.4.2). Stakeholders carried out the initial holistic ranking at the beginning of the workshop, and the final holistic ranking at the end of the workshop. In between, stakeholders were informed of the results from the MAVT rankings. Since there was no further information which could have influenced the final holistic ranking, we can conclude that the change in stakeholder preferences was due to the MAVT method.

- *Stakeholder feedback*: Stakeholders confirmed in the final discussion that the MAVT method contributed to resolve conflict. Stakeholders emphasized that the MAVT method supported their individual and social learning. They also revealed that this learning process was the main reason why they changed their preferences to a more consensus based decision.

Both these aspects give a strong indication that the change in preferences is mainly due to the application of the MAVT method, and not due to any other factors. The causality of this finding could be supported by further studies in a similar research setting.

## 5.6. Conclusions

The aim of this chapter was to evaluate the main contributions of MCDA methods in the multiple stakeholder setting. Thereby, one question was whether the normative model of rational choice holds in this setting. However, the results from this study revealed that stakeholders did not behave according to the rational decision rule, since their final holistic ranking was not highly correlated with the ranking of the normative model. This result is in line with many findings in behavioral research (Simon 1979; Kahneman *et al.* 1982). In our understanding, this finding is due to several reasons. First, the normative model makes high demands on the quality of input information and consistency of stakeholder preferences, such as knowledge of all alternatives and their consequences, certainty in stakeholder present and future preferences, and ability to compare diverse and heterogeneous objectives. Within our study, stakeholders seemed to have difficulties to express and quantify their preferences in such a consistent way as is required by the MAVT method.

Second, we think that the aspects of reference dependence and Allais Paradox might play an important role in environmental management projects (section 2.6.2). *Reference dependence* implies that many preferences appeared to be determined by attitudes to gains and losses, defined relative to a reference point (Kahneman & Tversky 1979; Tversky & Kahneman 1981). This effect seems to be an important aspect due to the fact that many conflicts are based on the question who gains and who looses in reference to the status quo. The *Allais Paradox* says that individuals tend to place too much weight on a certain outcome relative to uncertain outcomes (Allais 1979). Again, this effect might play an important role, since stakeholders have to compare a well-known and certain outcome (status quo) with an uncertain status after conducting the rehabilitation measures. This certainty effect might be one reason for the fact that the acceptance rate of rehabilitation projects is generally much higher after finalizing the measures compared to beforehand (Bratrich 2004).

Third, the rational framework of the MAVT methodology does not include further determinants of stakeholder preferences, such as emotional aspects of stakeholder decisions. Thereby, the attitude of the stakeholders towards the responsible administration plays an important role. Stakeholders might have negative emotions towards the responsible administration due to potential conflicts in previous management projects. Hence, the previous history of the rehabilitation project is an important aspect for the decision making process of a rehabilitation project (Zaugg 2005).

Even though stakeholder did not behave according to the normative model, the MAVT method was still a useful framework for decision support in the multiple stakeholder setting. The main contribution of the MAVT method within this study was to support major aspects of the negotiation process and public involvement. First of all, stakeholders reported that they improved their understanding on an individual level. Further, stakeholders also stressed the contribution of the MAVT method for social learning. When asked how the MAVT might facilitate negotiation, the participants stated the following advantages: (i) identification of similarities and differences in values between stakeholder groups, (ii) increased understanding about the values and preferences of other stakeholder groups, and (iii) improved acceptance of other stakeholder positions. Stakeholders also emphasized that the discussion based on the MAVT framework can be carried out on a more objective and comprehensive level. This improves trust between the project team and stakeholders as well as between conflicting stakeholder groups. All these aspects contributed to the fact that stakeholders changed their preferences towards more balanced and consensus-oriented decisions. We believe that this contribution is even more important than a high predictive validity. A high predictive validity might be able to identify potential conflicts at an early stage of the project, but once the conflicts are identified, they should also be solved.

One has to be aware that these contributions could not be achieved based on stakeholder interview alone. Table 5.7 shows which objectives of public involvement could be met by which interview phase. Most of the objectives could only be met by interview phases II and III (discussion of methods' results within stakeholder workshops and stakeholder forum). The main advantage of interview phase I was to incorporate stakeholder values and knowledge into the decision process and elicit the information for the further discussion. However, the elicitation of stakeholder preferences alone did neither support the social learning of stakeholders nor the elaboration of consensus agreements. Hence, we conclude that the MAVT method has the highest contribution in the multiple stakeholder setting when it is applied in an interactive and inclusive manner, including the discussion of the results with the stakeholders.

*Table 5.7: Evaluation of the three interview phases at the Thur River based on selected objectives for public involvement. The objectives for public involvement are modified from Beierle (1998), Mosler (2004) and Marttunen (2005).*
*++ = high achievement, + = medium achievement, – = no achievement*

| Interview phase | Inform the public | Incorporate public knowledge and values | Improve stakeholder understanding | Enhance social learning | Build trust | Move towards consensus agreement |
|---|---|---|---|---|---|---|
| I) Elicitation of stakeholder preferences | + | ++ | + | – | + | – |
| II) Discussion of the results in stakeholder workshops | + | + | ++ | ++ | + | ++ |
| III) Discussion of the results in stakeholder forum | + | + | + | ++ | ++ | ++ |

# 6. Conclusions and outlook

This chapter is structured as follows: First, we summarize the main findings of this study (section 6.1) and compare the findings to other results in the literature (section 6.2). We then refer to general insights which are not empirically validated, but which still might be valuable for river rehabilitation projects and MCDA applications in the future (section 6.3). Next, we discuss which findings in the field of river rehabilitation can be generalized to other fields of environmental management projects (section 6.4), and conclude with aspects for further research (section 6.5).

## 6.1. Main findings of this study

### 6.1.1. Hypotheses

The aim of this study was to evaluate possible contributions of MCDA methods in the multiple stakeholder setting of environmental management projects. Thereby, we tested the following hypotheses:

- Hypothesis 1: MCDA methods have a high validity to predict the final preferences of people in a) the multiple stakeholder setting, and b) the decision maker setting.
- Hypothesis 2: The implementation of the MCDA method in the multiple stakeholder setting supports the negotiation and consensus finding process.
- Hypothesis 3: the stakeholders and decision makers show a high acceptance of the method mainly due to fact that it helps to support learning and negotiation processes and not because it helps to predict their final preferences.

To test the hypotheses, we applied MCDA methods to two rehabilitation projects. First, we applied the multi-attribute value theory (MAVT) method in a multiple stakeholder setting at the Thur River to evaluate stakeholder preferences for different rehabilitation alternatives. We identified and classified important stakeholders and conducted three interview phases: i) elicitation of stakeholder preferences (for the MAVT ranking), ii) evaluation of the MAVT results and direct ranking of alternatives, and iii) discussion of the results including all stakeholders. In the second case study, we implemented the analytical hierarchy process (AHP) focusing on a small group of decision makers to compare and prioritize different rehabilitation sites within the Alpine Rhine River basin. We conducted structured interviews including post-evaluation with selected representatives of the authority responsible for river management.

### 6.1.2. Results

*Hypothesis 1a (predictive validity - multiple stakeholder setting)*

The results showed that the MAVT method only has a limited validity to predict the final preferences of stakeholders for different rehabilitation alternatives. This is shown by the limited correlation of the MAVT ranking of alternatives (based on stated values for attributes characterizing the main objectives and predicted outcomes of these attributes for all alternatives) and stakeholder final preferences stated for alternatives directly. Hence, one can conclude that the normative model does not hold for the individual stakeholder. There are several reasons for this finding. First, stakeholders might have difficulties to express and quantify their preferences in such a consistent way as is required by the MAVT method. Second, potential violations of the normative model (reference dependence, certainty effect) seem to play an important role in river rehabilitation projects. Third, the rational framework of the MAVT methodology does not include further determinants of stakeholder preferences, such as emotional aspects of stakeholder decisions.

*Hypothesis 1b (predictive validity - decision maker setting)*
In contrast to the multiple stakeholder setting, method's validity to predict final preferences in the decision maker setting was slightly better. The ranking based on AHP corresponded to decision maker final preferences in fundamental positions (e.g. location with highest or lowest priority). There are different reasons for this finding. Decision makers might be trained to evaluate the various locations in quite a rational manner, even without the formal support of MCDA. Further, emotional aspects seemed to play a minor role, since the preferences of decision makers were quite similar. However, since the AHP ranking did not fully correspond to the final preferences, the hypothesis has to be rejected.

*Hypothesis 2 (support of negotiation process)*
This hypothesis evaluates whether the MAVT method can facilitate the negotiation process among conflicting stakeholder groups. Within this study, stakeholders reconsidered and changed their preferences towards more balanced and consensus-oriented decisions after they had been confronted with the MAVT results. This was mainly due to the fact that the MAVT method supported stakeholders' individual and social learning. Based on the structured discussion of all objectives, stakeholders became aware of a larger amount of objectives which influence the decision. Further, stakeholders learned more about other stakeholder objectives and preferences and improved their acceptance of other stakeholder positions (social learning). Hence, this hypothesis can be accepted.

*Hypothesis 3a (reasons for high acceptance - multiple stakeholder setting)*
This hypothesis investigates the main reason why stakeholders and decision makers might state a high acceptance of the method. The results show that the high acceptance is mainly due to contribution of the method to support the learning and negotiation processes, rather than the prediction of stakeholder final preferences. We arrive at this conclusion through the final discussion with all stakeholders. Thereby, all stakeholders emphasized that the support of learning and elaboration of consensus-oriented solutions is an important result of the method. In contrast, only 23% of the respondents considered the ranking of the alternatives based on the MAVT method to be important for the decision process. This finding might be due to the fact that stakeholders generally prefer the freedom of unaided decision making for their individual decision, but approve the contribution of the method in the multiple stakeholder setting.

*Hypothesis 3b (reasons for high acceptance – decision maker setting)*
Decision makers stated a high acceptance of the AHP method and considered the method as a suitable framework to prioritize different locations. They found the framework to be comprehensive and transparent, and agreed that the strengths and weaknesses of each option can be compared in a quantitative way. Decision makers generally preferred the method to structure the decision process, rather than to predict their final preferences. But in contrast to the multiple stakeholder setting, the MCDA method could not contribute significantly to the learning effect of the decision makers, since they would have evaluated the options in a rational manner even without the formal MCDA framework.

## 6.2. Relation to previous research

### 6.2.1. Relation to MCDA and behavioral research

As discussed in hypothesis 1, stakeholders did not fully behave according to the normative model of rational choice. This is in line with findings in behavioral research which have demonstrated that humans often do not conform to the structure of the rational model (Simon 1979; Kahneman *et al.* 1982; Tversky & Kahneman 1986; Jones 1999). It is also consistent with previous research in decision theory which have shown that a method's ranking often does not correlate well with the final holistic ranking (von Winterfeldt & Edwards 1986; Hobbs *et al.* 1992; Bell *et al.* 2001). Hence, there is a growing understanding within the decision analysis literature that the main contribution of MCDA methods is to provide insight into the decision (McDaniels *et al.* 1999; Gregory *et al.* 2001; Hämäläinen *et al.* 2001; Marttunen 2005). McDaniels & Gregory (2004) even propose that learning is important enough to be treated as one of several explicit fundamental objectives for the policy decision at hand, although it is effectively a means to better long-term performance on other objectives. The aspects of providing insight and learning is consistent with our second hypothesis, which says that the MAVT method supports individual and social learning of stakeholders, and hence contributes to the negotiation process.

Within our study, we experienced that the creation of new, consensus-oriented alternatives is a major strength of the interactive application of MAVT. Again, this finding corresponds to McDaniels & Gregory (2004), who conclude that the most important benefit of including learning as an objective is that it can enhance the creation of new, more attractive policy alternatives. The importance of incorporating MCDA methods in the decision process was also stressed by Arvai (2003), whose results indicate that the main strength of public participation methods is to support the decision-making *process* rather then the *outcome* of the decision itself.

Hypothesis 3 showed that the involved stakeholders and decision makers responded well to the proposed MCDA method and its results. This aspect has been discussed ambivalent in the MCDA literature. Some studies have shown that users are generally skeptical about the value of such methods and often prefer the freedom of unaided decision making (Hobbs *et al.* 1992; Bell *et al.* 2001). Other studies reported a successful application of MCDA methods in the multiple stakeholder setting (Ridgley & Rijsberman 1992; Keeney & McDaniels 1999; McDaniels *et al.* 1999; Gregory & Wellman 2001; Marttunen 2005). These controversial results could be due to differences in the implementation of the MCDA method in the decision making process. In line with other authors (Hämäläinen 2003; Kangas & Kangas 2005; Marttunen 2005), we believe that MCDA methods should be applied in an interactive manner and as straightforward and transparent as possible. To support further MCDA applications, we propose in section 6.4 an integrative concept for MCDA implementation in environmental management projects.

Our findings in the multiple stakeholder setting have many similarities to the theory of bounded rationality (Simon 1979, 1997; Jones 1999). First of all, stakeholders did not behave according to the rational model of the MAVT method; even though they considered themselves to be goal-oriented and expressed a high understanding and acceptance of the method and its results. Second, the aspects of learning and elaboration of potential consensus solutions were the main contributions of the MAVT method, and are at the same time important notions of bounded rationality (Simon 1979). Third, a major aspect of the MAVT application was to support the decision making *process*, rather than to achieve a specific *outcome*. This is also in line with Simon, who especially rejected the *substantive rationality* of economic models, which is viewed in terms of the choices it produces. On the other hand, Simon maintained that decision makers aim to proceed rational in terms of the decision making process *(procedural rationality)* (Schwartz 2002).

### 6.2.2. Contribution of this study

Many studies have emphasized the importance of post-evaluation based on stakeholder feedback (Merkhofer *et al.* 1997; Matsatsinis & Samaras 2001; Belton & Stewart 2002; Marttunen 2005). Up to now, MCDA methods in multiple stakeholder settings have mainly been evaluated based on analysts' impression instead of participants' feedback (Marttunen 2005). This is one of the first studies that conducted an extensive post-evaluation of stakeholders to evaluate the contribution of the method in real conflict situations. This evaluation was based on pre-defined hypotheses.

Decision analysis methods were originally developed to support an individual decision maker. Despite the fact that the underlying normative model does not hold for an individual stakeholder, this study found that the methods are very useful in the setting of multiple stakeholders. The principle advantage of the MAVT method is to enhance conflict resolution among stakeholder groups as a result of individual and social learning of stakeholders. The results of this study are valuable both on a practical as well as on a theoretical level. On the practical level, this study shows how MCDA methods can support decision making in environmental management projects. At the same time, this study can also offer valuable help to further theoretical MCDA research. One important aspect is the development of appropriate techniques to elicit single-attribute value functions and weights from lay people. Based on the experiences of this study, further research can take place to analyze how stakeholder preferences can be elicited in a pragmatic and theoretical value manner (section 6.5.2). Another important aspect is the implementation of MCDA methods in different application areas. This study proposes a chain how to characterize major decision making situations (DMS) and how to identify potential MCDA applications for the field of river rehabilitation.

Obviously, it is important to take into consideration that we tested the MCDA methods on multiple stakeholders only in one real-world project. One of the limitations of real-world studies is that no comparative tests can be done as it would be the case in laboratory settings. Therefore, it is important to state that there is a need for further applications and post-evaluations of MCDA methods in real-world management projects. Ideally, this should be done in various fields of environmental management, and the results (either positive or negative) should be reported as detailed as possible.

## 6.3. General insights from the study

In addition to the empirical results (section 6.1), this study also elaborated an integrative framework for river rehabilitation. Further, we will also refer to the main experiences with the applied MCDA methods.

### 6.3.1. Framework for river rehabilitation

For a successful implementation of MCDA methods in the decision making process, one first needs a good understanding of the relevant decision making situations (DMS) and their key aspects. The analysis of river rehabilitation projects revealed that there is not only a single point, but rather various DMS within the planning and implementation phases. We identified major DMS at three institutional levels: national, river basin and local levels. For each DMS, we analyzed which MCDA method might be most suitable, and proposed a procedure for implementing the MCDA method in the decision making process. The main DMS can be summarized as follows.

At *national level*, we propose to implement a national management plan which aims to sort the various river basins according to their deficits. Thereby, one can evaluate those river basins where rehabilitation measures should be conducted and analyze which measures would be most effective to reduce the deficits (e.g. improvement of morphological condition, reduction of hydropeaking, increase residual flow, etc.). Another important institutional level is the *river basin level*. This is due to the fact that river basins are the major geographic unit where ecological, hydrological and hydro-geological processes are running. Hence, modern legislation such as the European Water Framework Directive (EU-WFD) requires that rehabilitation measures should be planned on the river basin level (European Parliament 2000). Within a river basin, an important DMS is to prioritize feasible locations for rehabilitation. Due to limited financial resources, rehabilitation measures might not be implemented at all feasible locations within a river basin. Hence, the measures should be conducted at those locations which have a high priority according to ecological, social or economic criteria. The *local level* is generally the scale where different rehabilitation alternatives are compared and evaluated. This is probably the most conflict-potential DMS, since a broad range of stakeholder interests are involved.

### 6.3.2. Experiences from MCDA applications

We will now briefly refer to our experiences of the strengths and weaknesses of applied MCDA methodologies in the multiple stakeholder and decision maker setting. In line with Marttunen (2005), we believe that reporting about experiences of MCDA applications helps to improve further applications and future methodological developments of MCDA.

The main strength of the *MAVT method* in the multiple stakeholders setting was the potential to generate new alternatives (e.g. consensus-oriented alternatives) without the preferences of stakeholders having to be re-elicited. We found that stakeholders experienced more difficulties stating their single-attribute value functions than stating weights for the attributes. However, one has to be aware that there are also potential mistakes and biases regarding weight estimation (Belton 1986; von Winterfeldt & Edwards 1986; Hobbs *et al.* 1992; Clemen 1996; Pöyhönen & Hämäläinen 2001). Hence, for further applications with lay people, we propose that the elicitation process should be done as simply as possible. From our experience, illustrating the different attribute levels and attributes on cards, and asking the respondents to arrange the cards on a measuring instrument with a scale from 0 to 100 was a very useful approach. But one has to be aware that there is a need for further research on how to elicit single-attribute value functions and weights from lay people.

The main advantage of the *AHP method* at the river basin level was the fact that the outcomes of the locations could be compared based on semi-quantitative data. This was due to the procedure of pairwise comparison of the locations with respect to their outcome on each of the criteria. The involved decision makers responded well to the methodology of pairwise comparisons. However, a disadvantage of the AHP method is that the algorithms of the eigenvalue technique are difficult to explain to users. Further, in contrast to the MAVT method, we experienced difficulties conducting sensitivity analyses regarding uncertainties in the estimation of outcomes.

*Table 6.1: Advantages and disadvantages of MAVT and AHP methodology experienced within this study.*

| MCDA method | Context of application | Advantages | Disadvantages |
|---|---|---|---|
| Multi-attribute value theory (MAVT) | Comparison of alternatives.<br>Interviews with wide range of stakeholder groups (lay people). | Stakeholders stated a good understanding of the theoretical concept of the additive value function.<br>Elaboration of new, consensus-oriented alternatives based on stakeholder preferences. | Stakeholders experienced difficulties stating preferences for the elicitation of value functions. |
| Analytic Hierarchy Process (AHP) | Prioritization of locations.<br>Interviews with project representatives (decision maker). | Decision makers responded well to the methodology of pairwise comparisons.<br>Estimation of outcomes based on pairwise comparisons with semi-quantitative data. | Underlying algorithms of AHP method (eigenvalue technique) are difficult to explain to interview partners.<br>Difficulty to conduct sensitivity analysis for the estimation of outcomes (since it is based on pairwise comparisons). |

For further applications, we identified three questions we found to be important for choosing an appropriate MCDA method in the context of river rehabilitation projects:

- Who are the people that make up the client group? Is there mainly a small group of decision makers or various stakeholders (who are mainly lay people)? In the latter case, we suggest applying MCDA methods which are easy to understand for stakeholders (without complex algorithms).
- What is the quality and quantity of input information available? If no detailed assessment exists about the outcomes of the alternatives, we suggest MCDA methods which can be used with qualitative input data (e.g. based on pairwise comparisons of alternatives).
- How many alternatives are under consideration? If the aim is to develop new, consensus-oriented alternatives, we suggest using decision analysis techniques (MAVT, MAUT), since they are not based on pairwise comparisons of alternatives.

One has to be aware that the way the MCDA method is applied is at least as important as the choice of which method is used. Therefore, this study did not mainly focus on comparing different MCDA methods, but on the contribution of MCDA methods in real-world decision making situations.

## 6.4. Generalization of results

The results of this study are mainly based on MCDA applications at the Thur River in Switzerland and the international stretch of the Alpine Rhine River. A first question is whether these results are relevant for rehabilitation projects outside Switzerland. In our understanding, the results are relevant for other rehabilitation projects, since the main elements of the decision process are quite similar in Switzerland and other developed countries. For example, both the Swiss guidelines (BWG 2001) and the European Water Framework Directive (EU-WFD) (European Parliament 2000) emphasize the importance of stakeholder involvement in water management projects. It is also important to ask which findings elicited in the field of river rehabilitation can be generalized to other fields of environmental management projects. This question will be discussed in more detail below.

### 6.4.1. General procedure of MCDA application

Due to different DMS, the elaborated framework for river rehabilitation cannot completely be adapted to other fields of environmental management. However, the main characteristics of the decision (multiple objectives, multiple stakeholders, uncertain outcomes and multi-stage processes) might be similar in many infrastructure and resource management projects. Hence, we focus on the generalization of the methodological framework and propose a procedure for how MCDA methods can be embedded in the decision process in environmental management. The general procedure consists of the following steps (Figure 6.1).

First, one has to identify the decision context and the relevant DMS. The decision to be taken can be located at various institutional and geographical levels. Relevant institutional levels might be the international, national, regional and local levels. Second, it is important to identify which objectives of public involvement should be achieved and which audience of the public should be involved in the decision making process. Third, one has to decide whether the decision to be taken constitutes a MCDA problem, and which MCDA method might be most appropriate. Major criteria for the selection of a MCDA method are: (i) the client group for the analysis, (ii) quality and quantity of input information, and (iii) number of alternatives under consideration. Last but not least, one has to implement the MCDA method in the decision process, which will be discussed in more detail below.

It is important to emphasize that the formal framework of MCDA might not be helpful for all environmental management projects. Especially in the context of international management projects, the success of a project hinges primarily on political processes in which institutional arrangements are designed and implemented (Bernauer 2002). Hence, social science theories might be more appropriate to gain further insights into international environmental policy projects.

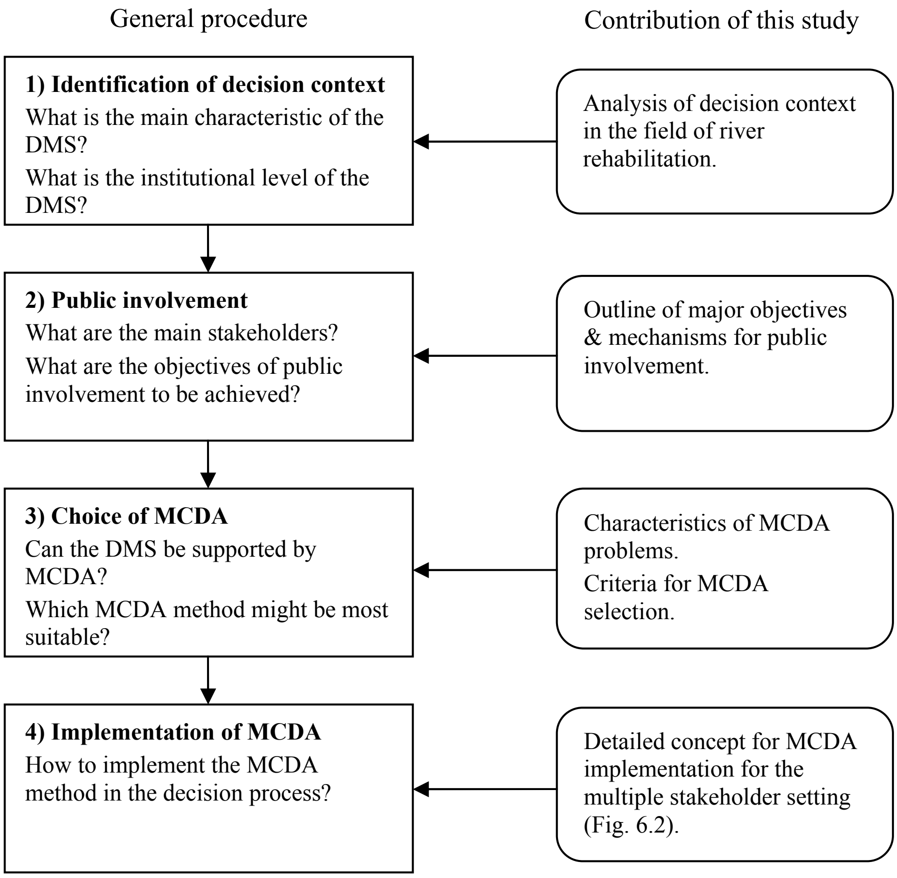


*Figure 6.1: Major steps for MCDA application in environmental management projects and specific contributions of this study.*

### 6.4.2. MCDA implementation in the multiple stakeholder setting

This section proposes a procedure for implementation of MAVT method in the multiple stakeholder setting. One main insight given by this study is that the MAVT application should not be limited to the pure elicitation of stakeholder preferences, but rather to utilize MAVT as a framework to improve understanding and social learning. This implies that the method is applied in an interactive manner. Another important aspect is that stakeholders and project team members should be treated equally in the MCDA application. The proposed procedure is not a framework to convince stakeholders to agree with project team's attitude, but rather a framework to enhance learning processes of both project team and stakeholders. Hence, it is important that the objective hierarchy involves values and objectives from both the project team and stakeholders. Second, not only stakeholders, but also project team members belong to the target group of MCDA application. Therefore, we suggest that interviews should be conducted by a neutral MCDA analyst who is not primarily involved in the project.

The general procedure for the implementation of MAVT in the decision making process is shown in Figure 6.2.

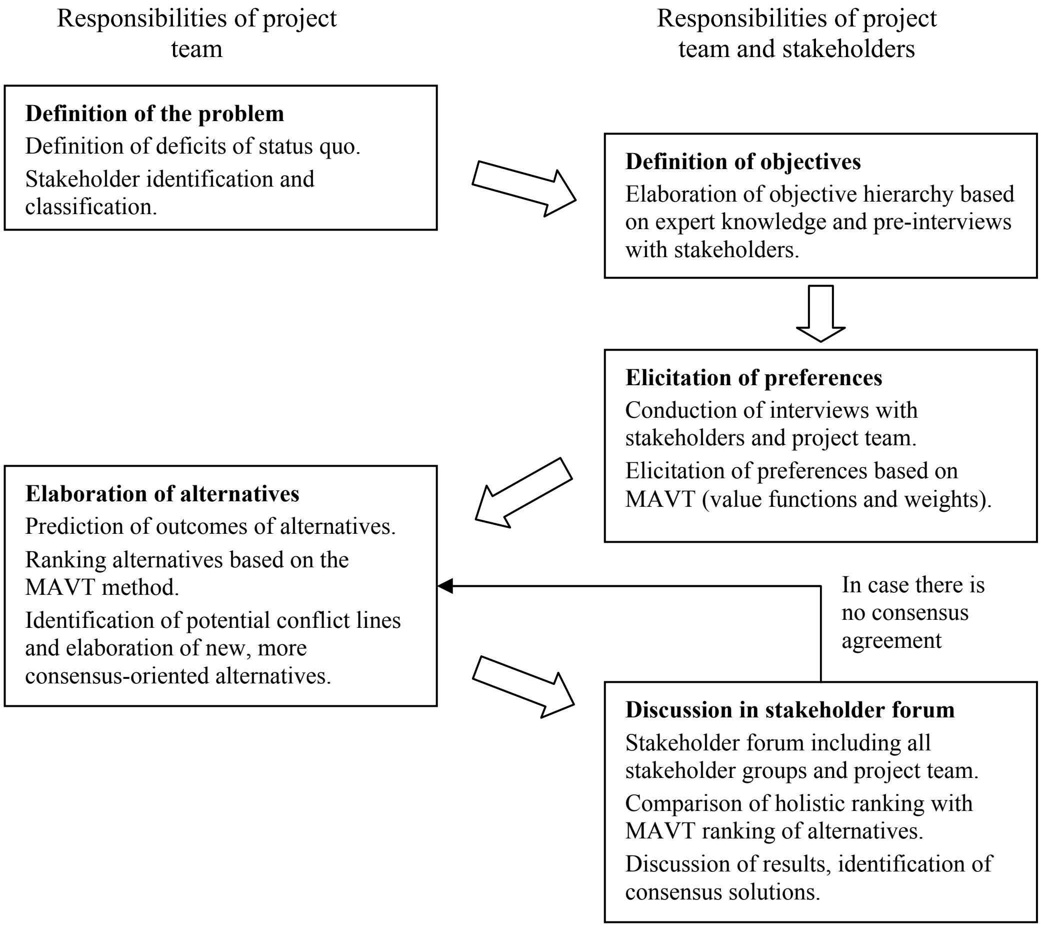


*Figure 6.2: Procedure how the MAVT method can be implemented in a multiple-stakeholder setting with conflicting interests.*

First, the project team has to analyze the main deficits of the status quo and has to identify and classify the stakeholders to be involved in the process. Second, the project team defines the main objectives of the project in cooperation with the stakeholders. This step might be facilitated by a neutral MCDA analyst, since the structuring of the decision problem is an important task. Once the objectives are defined, the MCDA analyst (or another person) can elicit the preferences of project team and stakeholders with regard to the objectives. Based on our experience, we propose to conduct the interviews in small groups of people (1-4 persons). This insures that the preferences from each representative can be incorporated in the decision process. Fourth, the project team has to elaborate different alternatives to achieve the objectives. For each alternative, the outcomes of the alternatives on the objectives have to be predicted. This will be done by the project team in collaboration with experts. Based on the prediction of outcomes and elicited preferences, the alternatives can be ranked according to the MAVT method.

The fifth step involves discussion of the results with all stakeholders and project managers. In addition to the ranking based on the MAVT method, we suggest that stakeholders and project managers also rank the alternatives without formal methodology (holistic ranking). The comparison of the MAVT ranking and the holistic ranking might enhance the learning effect of both stakeholders and project managers. Further, the differences between all participants can be discussed in an objective manner, since one focuses first on objectives and only later on alternatives. It is important to emphasize that this discussion might not be finished after one meeting, but might continue over several stakeholder meetings. This is due to the fact that stakeholders and project managers need time to learn about their own and others objectives. Further, stakeholder representatives need time to discuss their positions with other people within their stakeholder group. Ideally, the project team and stakeholders agree at the end of this process on a common solution. If not, new alternatives have to be elaborated or new information gathered which might resolve the conflict. Hence, the whole process should be conducted in an iterative way, so that new information can always be incorporated in the process. One has to be aware that this approach does not guarantee consensus solutions among conflicting stakeholder groups. In this case, top-down political decisions may still be required.

It is important to emphasize that the procedure is not limited to a specific group of participants. Hence, the procedure can also be conducted with selected citizens from the public, rather than representatives of stakeholder groups.

## 6.5. Future perspectives

In the previous chapters, we mentioned different aspects where there is need for further research. In this final section, we discuss some of these aspects in more detail.

### 6.5.1. Implementation research

*Local level*

The importance of conducting implementation research and exploring the use and usefulness of MCDA methods based on stakeholder feedback has been stated in many places (von Winterfeldt & Edwards 1986; Merkhofer *et al.* 1997; Matsatsinis & Samaras 2001; Belton & Stewart 2002; Marttunen 2005). The problem is that the contribution of the methods for conflict resolution cannot be studied very well in laboratory settings; it requires real conflicts (von Winterfeldt & Edwards 1986). It also requires the collaboration of the responsible management authorities and stakeholder representatives to implement the MCDA methodology in the decision making process. And last but not least, the realization of stakeholder interviews, stakeholder workshops and forums is quite time-consuming for both the MCDA analyst and the interview partners. These might be the main reason why this is one of the first studies that conducted an extensive post-evaluation of stakeholders to evaluate the contribution of the method in real-world conflicts. However, after going through the whole process of the implementation research, we are more convinced than ever that this is the only way to analyze the major contributions of MCDA methods in real-life applications. As we have emphasized before, there is a need for further applications and post-evaluations of MCDA methods in real-world management projects.

*River basin level*

Modern legislation, such as the European Water Framework Directive (EU-WFD), emphasizes the importance of strategic planning at a river basin level (European Parliament 2000). Since public involvement is a core requirement of the EU-WFD, initial pilot studies have been conducted to analyze different public involvement techniques in river basin planning (Environmental Agency 2004). Based on the results of this study, we believe that MCDA methods have a potential to contribute to public involvement not only at the local, but also at the river basin level. However, there is a need for further research analyzing this contribution of MCDA methods. Thereby, an important question is which participants for public involvement are most suitable in order to connect the river basin-wide planning with the local scale, which is generally the scale at which the public is engaged and project decisions are made.

*National level*

The strength of the proposed search strategy at national level is the combination of spatially explicit data implemented in GIS with MCDA methodologies (section 3.4.1). However, this search strategy focuses mainly on one type of measure, namely the eco-morphological restoration of floodplains. In addition to morphological degradation, many rivers are affected by further influences, such as hydropeaking, reduction of minimum flow, and poor water quality. Hence, further research is required to develop a national strategy which compares different river basins according to their deficits (ecological or socio-economic deficits) and evaluates which type of measures might be most efficient to reduce the actual deficits.

*Concepts of integrative framework*
This study proposes an integrative framework for river rehabilitation projects. We are aware that this framework can only be a first outline. Further studies are necessary to analyze the DMS and suitability of MCDA methods for the specific DMS. Based on further MCDA applications at the local, regional and national levels, the concept of an integrative framework can be extended and enhanced. Ideally, this should be done in the field of river rehabilitation as well as in other environmental management topics.

### 6.5.2. Methodological research

*Elicitation of stakeholder preferences*
There is a wide range of techniques describing potential elicitation procedures for single-attribute value functions and weights. However, in our understanding, most of these techniques are either too complex to be used with lay people, or theoretically questionable. Within our study, we found that stakeholders experienced more difficulties stating their single-attribute value functions than stating weights for the attributes. This might be due to the fact that the value function is a mathematical construct which does not have its counterpart in the mind of the individual (Reichert *et al.* 2005). However, other studies emphasize that the weight elicitation process is also a critical stage of MCDA application (Kangas & Kangas 2005; Marttunen 2005). Hence, there is a need for further research to analyze how stakeholder preferences (value functions and weights) can be elicited in a pragmatic and theoretical valid manner.

*Complexity of objective hierarchy*
Many environmental problems might be characterized by a relatively complex objective hierarchy with a large number of objectives and attributes (e.g. objective hierarchy for a river rehabilitation project, Figure 2.1). However, single attribute value functions and attribute weights can only be elicited for a limited number of attributes. This is due to the fact that the elicitation process would take too much time and would be too complex for the involved stakeholders. Further, stakeholders might not have sufficient knowledge to state preferences at a very detailed level of the objective hierarchy. Within this study, we used visualization of a semi-quantitative scale to describe complex objectives (such as ecological integrity) to overcome this problem. Reichert *et al.* (2005) suggest as an alternative to elicit value functions for detailed attributes about ecosystem integrity from scientists and then let the stakeholders only assess the weights of these objectives relative to each other based on a description of the range of possible outcomes. Thereby, the application of non-additive value functions could thus also be evaluated. These comments reveal that there is need for further research how valuation from scientists for detailed attributes can be combined with valuation from stakeholders for higher level objectives.

*Incorporating uncertainty in MCDA*
Environmental management projects are often characterized by uncertain outcomes of alternatives. For our case study at the Thur River, we conducted a preliminary sensitivity analysis to evaluate the robustness of alternative rankings concerning uncertainty in prediction of outcomes and valuations (section 5.3). After completing the more detailed models within the Rhone-Thur Project (Reichert *et al.* 2005), one can refine and enhance the sensitivity analysis.

Within this study, the elicitation of stakeholder preferences was based on the framework of multi-attribute value theory (MAVT). One has to be aware that value functions do not include information about risk attitudes of stakeholders. Such risk attitudes can be considered by using utility functions instead of value functions. However, eliciting utility functions is much more difficult than elicitation of value functions because stakeholders have to be asked to express their preferences between probabilistic outcomes (Reichert *et al.* 2005). Hence, a potential solution is to elicit value functions first and then consider risk attitudes by asking a second set of questions based on a small subset of attributes (Reichert *et al.* 2005). This procedure is based on the assumption that risk attitudes are independent of the attribute for which they are elicited (Dyer & Sarin 1982). However, there is a need for further research regarding the question whether this assumption holds for real-world management projects and how the procedure could be implemented in stakeholder interviews.

*Complementary use of MCDA and CBA*

We argued in this study that the MCDA methods have significant advantages compared to CBA for decision support in the multiple stakeholder setting. At the same time, we indicated as well that CBA methods might be useful for strategic management at the national or the river basin levels. Due to the fact that both MCDA and CBA have its strength and weaknesses, it would be interesting to examine how these two methodologies can be applied in a complementary manner (Hostmann 2000).

*Normative and descriptive decision theory*

Due to the deviations of actual behavior of people from the normative model, a wide range of new models based on descriptive decision theory have been introduced. However, the development of these models and their empirical validation is still in process (Eisenführ 2003). Since descriptive decision models are concerned with understanding and predicting how people actually reach decisions, they might also potentially be useful for environmental management projects. For example, descriptive decision models could help to identify potential conflicts at early stage of the process or increase the understanding of other stakeholder positions. This shows that there is a need for further research concerning the use of descriptive models for environmental decision making.

### 6.5.3. Final remark

The focus of this study has been on the evaluation of MCDA methods to support decision making in river rehabilitation projects. In this final chapter we have discussed how these findings can be generalized and could potentially be used in other environmental management projects. We are aware of the fact that MCDA methods are no panacea for all problems and complexities concerning environmental management. Especially in the context of international resource management, the success of projects mainly depends on political processes in which institutional arrangements are designed and implemented (Bernauer 2002). Hence, the formal framework of MCDA might not be suitable to support the decision process in such a context. However, this study has shown that MCDA methods might be a useful framework for decision support and conflict resolution in the multiple stakeholder setting at local and regional level. Therefore, we believe that increased application of MCDA methods in this setting would lead to more effective and efficient environmental projects.

# Appendix A: Other approaches for decision support

# A.1. Outranking approaches (PROMETHEE, ELECTRE)

## A.1.1. PROMETHEE

The PROMETHEE methods (Preference Ranking Organization METHod for Enrichment Evaluations) belong to the family of the outranking methods and were introduced by Brans *et al.* (1986).

The PROMETHEE method is based on the following information for each criterion $g_j$:

- A "weight" $w_j$ expressing the relative importance of the criterion $g_j$
- A valued strict preference function *P (a,b)* for each criterion $g_j$, which represents the intensity of preference of action *a* with regard to action *b* regarding the specific criterion $g_j$.

The preference function can be ordered into the following four groups (Brans *et al.* 1986):

- P (a, b) = 0 means indifference between *a* and *b* or no preference of *a* over *b*;
- P (a, b) ≈ 0 means weak preference of *a* over *b*;
- P (a, b) ≈ 1 means strong preference of *a* over *b*;
- P (a, b) = 1 means strict preference of *a* over *b*.

Brans *et al.* (1986) propose six different shapes of such a preference function (Figure A.1). The preference function takes on values between 0 and 1. The user can select the desired shape of function, and specifies any parameters that are needed. Important input parameters are indifference and preference thresholds. The *indifference threshold q* is the greatest value of the difference *d* below which the user considers the corresponding alternatives as indifferent. The *preference threshold p* is the lowest value of *d* above which there is strict preference of one alternative over the other. The six proposed preference functions in Figure A.1 should be sufficient for most of the practical cases (Brans *et al.* 1986). If this is not the case, every decision maker can formulate its own preference function for the required criteria. For a detailed description of the preference functions, please refer to Brans *et al.* (1986).

***Procedure of PROMETHEE***

The procedure of PROMETHEE can be summarized as followed:

1) Determination of a ***preference function P(d)*** for each criterion $g_j$

2) Determination of the ***weight*** $w_j$ expressing the relative importance of the criterion $g_j$

3) Determination of the multicriteria preference index Π (defined as the weighted average of the preference functions (d)):

$$\Pi (a, b) = \sum_{j=1}^{k} w_j * P_j (a,b) / \sum_{j=1}^{k} w_j \qquad (A.1)$$

Π (a, b) represents the intensity of preference of the decision maker of alternative *a* over alternative *b*, when considering all criteria. The multicriteria preference index Π is a number between 0 (weak preference of a over b) and 1 (strong preference of a over b).

4) The ***leaving flow*** of alternative *a* is defined as:

$$\phi^+(a) = \sum_{b \in K} \Pi\ (a, b) \qquad (A.2)$$

The leaving flow is the sum of the preference index between alternative *a* and all other alternatives *k* and provides a measure of the outranking character of alternative *a*. In other words, the leaving flow is a measure of strength of alternative *a*.

5) The ***entering flow*** of alternative *a* is defined as:

$$\phi^-(a) = \sum_{b \in K} \Pi\ (b, a) \qquad (A.3)$$

The entering flow measures the outranked character of alternative *a* (a measure of the weakness of alternative a).

6) The ***net flow*** of alternative *a* is defined as:

$$\phi(a) = \phi^+(a) - \phi^-(a) \qquad (A.4)$$

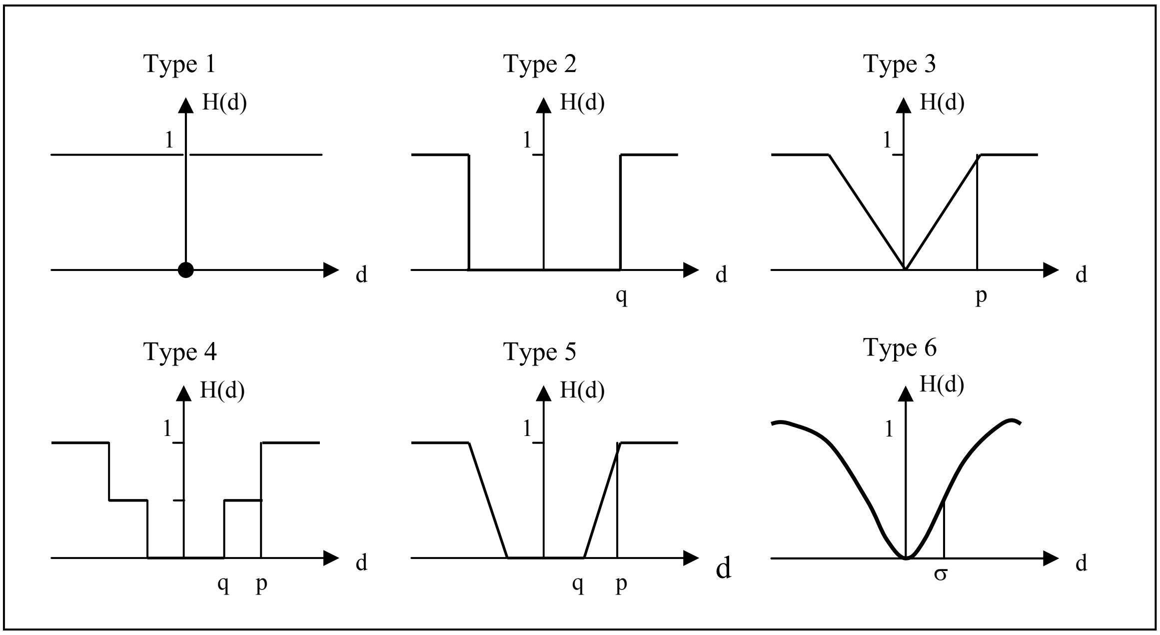


*Figure A.1: Preference functions in PROMETHEE, adapted from Brans et al. (1986).*

***PROMETHEE I***

The method PROMETHEE I calculates a partial preordering based on the leaving flow and on the entering flows. The higher the leaving flow and the lower the entering flow, the better the alternative. The partial preorder can obtain the following results:

| | |
|---|---|
| Alternative *a* outranks *b*: | if $\phi^+(a) > \phi^+(b)$ and $\phi^-(a) < \phi^-(b)$<br>or $\phi^+(a) > \phi^+(b)$ and $\phi^-(a) = \phi^-(b)$<br>or $\phi^+(a) = \phi^+(b)$ and $\phi^-(a) < \phi^-(b)$ |
| Alternative *a* is indifferent to *b*: | if $\phi^+(a) = \phi^+(b)$ and $\phi^-(a) = \phi^-(b)$ |
| Alternative *a* and *b* are incomparable: | otherwise |

In summary, the method PROMETHEE I can result in preference of alternative *a* over *b*, in indifference of alternative *a* and *b*, or in incomparability of alternative *a* and *b*.

***PROMETHEE II***

The result of the method PROMETHEE II is a complete preordering of all of the alternatives. The complete preorder is based on the net flow of each alternative (the net flow is the difference between the leaving flow and the entering flow of one alternative). Although it is easier for the decision maker to resolve the decision problem by using the complete preorder, the partial preorder contains more realistic information (Brans 1986). Especially the fact that poor values in one criterion can be compensated by good values in another criterion is a negative effect of complete preorder.

## A.1.2. ELECTRE

The ELECTRE methods differ according to the degree of complexity of the information required or according to the nature of the underlying problem. In the following, we will give a detailed description of ELECTRE I, which is the earliest and simplest of the ELECTRE methods.

The ELECTRE methods are based on the evaluation of two indices, the *concordance* index and the *discordance* index, defined for each pair of options *a* and *b*. The concordance index, *C(a,b)* varies from 0 to 1 and can be considered as a measure of the arguments in favor of the assertion "*a* outranks *b*".

The concordance index used in ELECTRE I is defined as:

$$C(a,b) = \frac{\sum_{i \in Q(a,b)} w_j}{\sum_{i=1}^{m} w_j} \tag{A.5}$$

where *Q(a,b)* is the set of criteria for which *a* is equal or preferred to *b*. The concordance index is the proportion of criteria weights allocated to those criteria for which a is equal or preferred to b (Belton & Stewart 2002). The higher the value, the stronger the evidence in support of the claim that *a* is preferred to *b*. A value of 1 indicates that *a* performs at least as well as *b* on all criteria (so that *a* dominates or is equivalent to *b*).

The discordance index can be defined as:

$$D(a,b) = \frac{\max_{i \in R(a,b)} \left[ w_i \left( z_i(b) - z_i(a) \right) \right]}{\max_{i=1}^{m} \max_{c,d \in A} \left[ w_i \left| z_i(c) - z_i(d) \right| \right]} \tag{A.6}$$

The discordance index for *a* compared to *b* is the maximum weighted value by which *b* is better than *a*, expressed as a proportion of the maximum weighted difference between any two alternatives on any criterion. A high value indicates that on at least one criterion *b* performs substantially better than *a*. This form of discordance index is only appropriate if all evaluations are made on a cardinal scale and the weights render scales comparable across criteria, which are quite restrictive assumptions (Belton & Stewart 2002).

An alternative definition of the discordance index is:

$$D(a,b) = \begin{cases} 1 & \text{if } z_i(b) - z_i(a) > t_i \text{ for any } i \\ 0 & \text{otherwise} \end{cases} \tag{A.7}$$

Thereby, $t_i$ is defined as the veto threshold for each criterion *i*, such that *a* can not outrank *b* if the score for *b* on any criterion exceeds the score for *a* on that criterion by an amount equal or greater than its veto threshold.

The concordance and discordance indices for each pair of options can then be used to build an outranking relation. For that, we need to specify concordance and discordance *thresholds* $C^*$ and $D^*$. Alternative *a* is defined as outranking alternative *b* if the concordance coefficient *C(a,b)* is greater than or equal to the threshold $C^*$ and the discordance coefficient *D(a,b)* is less than or equal to $D^*$. The values of $C^*$ and $D^*$ are specified for a particular outranking relation and they may be varied to give more or less severe outranking relations – the higher the value $C^*$ and the lower the value $D^*$, the more difficult it is for an alternative to outrank another (Belton & Stewart 2002).

The last step in the decision process in ELECTRE is to make use of the relation for decision support. This procedure will depend on the nature of the problematic. Thereby, the question is whether one aims to determine the “best” option, to rank the options, or to segregate them into different categories (for a more detailed description of these decision problematic, please refer to chapter 3.3). ELECTRE I aims to assist in the identification of the preferred alternative, while ELECTRE II produces a ranking of alternatives rather than simply indicate the most preferred. ELECTRE III permits more sophisticated modelling of preferences on individual criteria than does ELECTRE II, but does call for more work in modelling preferences with respect to each individual criterion. Further, there are variations on each of the methods (ELECTRE IV, ELECTRE TRI), which are described in detail by Vincke (1999).

## A.2. Cost-Benefit-Analysis (CBA)

The general procedure for CBA is slightly different than the seven-step procedure of MCDA techniques. The main steps of CBA are the following (based on Hanley & Spash (1993) and Joubert *et al.* (1997)):

Step 1: Definition of the decision problem
Step 2: Definition of the set of alternatives
Step 3: Assess the impacts of each alternative
Step 4: Monetary valuation of impacts
Step 5: Discounting of costs and benefits flow
Step 6: Applying the net present value test
Step 7: Sensitivity analysis

As we have seen above, the main difference between MCDA and CBA is the conversion of preferences into common units (steps 4-6). Hence, we will now discuss different methods for monetary valuation.

### A.2.1. Valuing Environmental Goods – the methods

***Travel Cost Method***

The Travel Cost Method (TCM) can claim to be the oldest of the non-market valuation techniques, first proposed in a letter from Harold Hotelling to the US Forest Service in the 1930s (Hanley & Spash 1993). This method involves using travel costs as a proxy for the price of visiting outdoor recreational sites. These consumption costs include travel cost, entry fees, on-site expenditures and outlay on capital equipment necessary for consumption. A statistical relationship between observed visits and the cost of visiting is derived and used as a surrogate demand curve from which consumer's surplus per visit-day can be measured (Hanley *et al.* 1997). The travel costs for an individual for a given site depend on several variables: 1) distance of travel and costs per mile of traveling, 2) time costs, which depend on how long it takes to get to the site and the value of an individual's time, and 3) fee which might be charged for entrance to site.

The strength of the Travel Cost Method is that it is linked to the actual behavior of people. However, there are also various problems associated with the Travel Cost Method. One aspect is the question about multi-purpose trips. For some visitors, the site in question is only part of the purpose for their journey. The question is how much of their travel cost should be apportioned to the site of interest? Another aspect of debate is the value of time. Time cost is an important variable for the total travel cost of an individual. As a scarce commodity, time clearly has an implicit price (Hanley & Spash 1993). If individuals are giving working time in order to visit a site, the wage rate is the correct opportunity cost. But most recreation time is spent at the expense of alternative recreational activity. The estimation of the value of time in this case is a controversial subject in the literature (Freeman 1993).

In general, the travel cost model is well established as a technique for valuing the non-market benefits of outdoor recreation resources (Hanley & Spash 1993). But one has to be aware that the Travel Cost Method can only measure use values such as recreational benefit, and is not able to estimate non-use values.

***Hedonic Pricing Method***

Hedonic Pricing (HP) seeks to find a relationship between the levels of environmental services (e.g. noise level, air quality) and the prices of the marketed goods (e.g. houses). This means that the house price should reflect the value of environmental quality to the house owner.

First, the analyst has to decide which environmental quality variable is of interest. It is important that sufficient spatial data are available for both the environmental variable and the house prices and housing characteristics. The method continues with an estimation of a hedonic price function. In this step, the relationship between the environmental variable of interest ($Q_k$) (eg. air quality) and a related marketed good is estimated. It is understood that there are many other variables, which are relevant for determining the price of a house. Some of those variables might be site characteristics ($S_i$) as the number of rooms, neighborhood characteristics ($N_j$) such as the number of schools in the area. Therefore, the hedonic price equation ($P_h$) has the following form:

$$P_h = P\ (S_j, N_j, Q_k) \tag{A.8}$$

The second step of the HP process involves estimating a demand curve for environmental quality using the information gained from stage one. The demand curve for the environmental variable is dependent on the price and socio-economic variables such as income and age.

Problem areas of the Hedonic Pricing method are the limited mobility of buyers (people might be restricted to an area), regulated market (which biases the willingness to pay for a house), and information level (the hedonic pricing model can only give an accurate estimate of the value of good air quality if all buyers in the housing market are perfectly informed of air quality levels at every housing location and the effect of bad air quality). In sum, the Hedonic Pricing Method is incapable of estimating non-user values. It is mainly used for eliciting values of environmental quality which are reflected by house prices.

***Avoided Cost Approach***

If the quality of an environmental good is decreasing, people can make expenditures to mitigate the effects and protect the household from welfare reductions. An example is an increase in aircraft noise due to a new airport. The value of the environmental quality "no noise" can be inferred directly from expenditures to avoid the noise (e.g. double glazing, better technology in aircraft transport etc). Another example is the restoration of a river. The value of a natural river habitat is estimated as least as much as the expenditures of the restoration measures.

Problem areas of the Avoided Cost Approach are threefold. First, in most applications, the environmental quality to be valued and the expenditures to avoid a reduction are imperfect substitutes. For example, one cannot noise-proof the garden against aircraft-noise. Therefore, expenditures for a reduction in noise levels (e.g. double glazing) would underestimate the benefit of such a reduction, since some aspects of noise pollution cannot be reduced. Second, the expenditures to avoid a reduction of one environmental good may also generate other benefits. Double glazing not only cuts noise levels but also reduces heat losses and thus saves on energy bills. Restoration measures not only increase the natural habitat, but also might improve the groundwater quality. Third, the

Avoided Cost Approach is based on the assumption of rational behavior. But especially for governmental expenditures, this assumption of rational behavior is not always valid. This can lead to an under- or overestimation of the damage.

Overall, the costs to mitigate a negative effect will almost certainly underestimate the benefits for all but the marginal user (Hanley & Spash 1993). In practice, the Avoided Cost Approach is treated as an accepted minimum level of environmental damages (Endres 1998). Equal to the Travel Cost and the Hedonic Pricing Method, the Avoided Cost Approach is limited to use values and incapable of estimating non-user values.

***The Contingent Valuation Method***

The approach of the contingent valuation method (CVM) is easy and straightforward. Some consumers are asked for their willingness to pay (WTP) or willingness to accept (WTA) for a change in environmental quality, in a carefully structured hypothetical market (Hanley & Spash 1993). In difference to the direct methods discussed above, the contingent valuation can give an estimation of nonuse-values for environmental goods. WTP measures give an estimate of compensating value for welfare-improving moves and assume equivalent value for welfare decreasing moves. WTA measures give information about compensating variation for welfare-decreasing moves and assume equivalent value for welfare-increasing moves.

The contingent valuation method can be split into the following five stages (Hanley & Spash 1993):

*Hypothetical market*: The first step is to set up a hypothetical market for the environmental quality to be valued. Respondents of the survey must be told the actual conditions of the environmental good, the planned measures (e.g. restoration of the river) and the effects of the measures (e.g. improvement in fish population). The respondents must be clear about the reason for payment, when no direct payment through the market actually exists. The survey should also explain whether all consumers will pay a fee if the change goes ahead, and how this fee will be set.

*Eliciting WTP/WTA*: The survey can be done either by face-to-face interviewing, telephone interviewing or mail shot. Individuals are asked to state their WTP in order to have the environmental improvement go ahead (or to prevent a decrease in environmental quality) or to state their minimum WTA to go without the improvement (or to accept the deterioration of the environmental good). Once the bids (WTP or WTA) have been gathered in, an average bid is calculated: typically both mean and median are reported.

*Investigating determinants of WTP/WTA*: Investigating the determinants of WTP/WTA bids is useful in aggregating results and for assessing the validity of the CVM exercise. A bid curve can be estimated, using the WTP/WTA amounts as the dependent variable and a range of independent variables.

*Aggregating data*: Thereby, the mean WTP/WTA bids are converted to a population total value figure. Discussions over aggregation revolve around two main issues. First, the choice of the relevant population. Thereby, the aim is to identify all those whose utility will be significantly affected by the action. The group might be the local, regional or national population. Second is the choice of the time period over which benefits should be aggregated. If the present value of environmental benefit flows over time of interest and wanted, then benefits are normally discounted. Where an irreversible environmental loss is involved, then the present value is calculated by taking perpetuity.

*Evaluating the CVM exercise*: This entails an appraisal of how successful the application of CVM has been. For example, did the survey result in a high proportion of protest bids? Is there evidence that respondents understood the hypothetical market? How well did the hypothetical market capture all aspects of the environmental good?

### A.2.2. Problems associated with CVM

One major advantage of the Contingent Valuation Method is the potential to estimate non-use values of environmental goods (in contrast to Travel Cost, Hedonic Pricing and Avoided Costs Methods, which can only estimate use values). But the use of CV methods has attracted many critics, from within and outside the evaluation community (Hausman 1993). Major problems associated with Contingent Valuation Method are the following:

*Strategic bias*: Respondents might underestimate or overestimate their WTP/WTA bids. For example, if respondents believe that their bids are purely hypothetical, they may overestimate WTP for an environmental benefit, as this increases the probability of the improvement to go ahead. Further, if respondents believe that bids will be collected, they may understate their WTP.

*Design bias*: The survey design can affect the responses in various ways. First, the choice of bid vehicle (tax, entry fee etc.) as well as the nature of information provided can influence the average bid. Second, the starting point given to respondents can affect the final bid, since the starting point suggests what size of bid is appropriate.

*Choice of welfare measure*: There is a big debate going on whether the WTP or WTA measure should be used. Empirical work showed that stated WTP was significantly lower than stated WTA (Rowe *et al.* 1980; Hanley 1988). This might be (amongst other) due to "loss aversion", which means that individuals value a given reduction in entitlements more highly than an equivalent increase in entitlements (Knetsch 1989).

*Mental account bias*: Contingent valuation studies elicit WTP/WTA bids from respondents mainly for a specific environmental good such as "preservation of blue whales". The problem is now that a person's entire "species preservation budget" could be expended on blue whales, even though they care about preserving other species too (Hanley & Spash 1993). Eliciting respondents' feedback after a contingent valuation study, Clark *et al.* (2000) concluded that respondents have an inability to work out a value for one environmental good in isolation from others in other parts of the country.

*Valuing environmental goods*: The contingent valuation method is based on a hypothetical market. However, the question is whether people are able to put a monetary value on public goods such as environment. In reviewing much of the literature, Gregory *et al.* (1993) argue that individuals are not accustomed to interpreting environmental goods in monetary terms. Clark *et al.* (2000) came to the same conclusion, since WTP-respondents stated their feelings that values for nature were not commensurable with monetary valuation.

*Aggregation bias*: As described above, the mean WTP/WTA bids are converted to a population total figure. Thereby, there are two problems; the choice of the relevant population (local, regional or national), and the choice of time period and the discounting factor. Especially the derivation of the appropriate discount factor is a major item of controversy (Hanley & Spash 1993).

### A.2.3. Benefit transfer

Implementing a new CBA study can be very time and cost demanding. Hence, there is a growing interest in models for valuing environmental services which do not rely upon expensive and time-consuming survey work, but rather extrapolate results from previous studies (Brouwer *et al.* 1999). Environmental benefit transfer is commonly defined as the transposition of monetary environmental values estimated at one site (study site) through market-based or non-market based economic valuation techniques to another site (policy site) (Brouwer *et al.* 1999). Important criteria for selecting studies for benefit transfer are that: (1) the study is based on adequate data and correct empirical technique, (2) the environmental good is comparable to the good at the policy site, (3) the study contains regression results that describe willingness to pay as a function of socioeconomic characteristics, (4) the study and policy site are similar, and (5) the markets for the study and policy site are similar (Brookshire & Neill 1992; Desvousges *et al.* 1992; Muthke 2002).

There exist various databases to support the benefit transfer. For example, the Environmental Valuation Reference Inventory (EVRI) contains more than 2000 CBA studies in the field of environmental goods and human health (http://www.evri.ca/). Thereby, one can search for empirical studies based on the following criteria: geographic characteristics, environmental assets, environmental goods and services, valuation techniques. Another database with empirical studies concerning environmental goods is ENVALUE (environmental valuation database, http://www2.epa.nsw.gov.au/envalue/).

# Appendix B: Value functions of stakeholder representatives

# Recreational organizations

<table>
<tr><th></th><th>Flood retention</th><th>Costs</th><th>Realization Time</th><th>Ecological status</th><th>Recreational opportunities</th><th>Agricultural jobs</th><th>Employment</th></tr>
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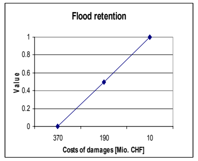
<td>
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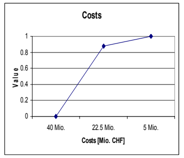
<td>
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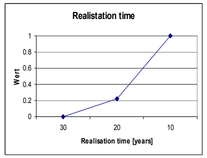
<td>
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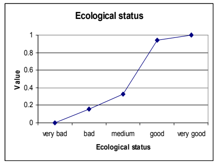
<td>
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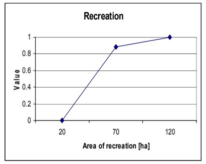
<td>
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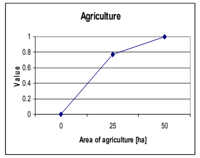
<td>
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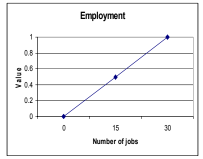
<td>
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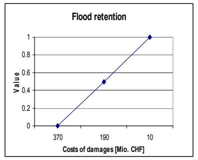
<td>
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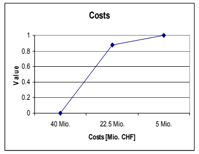
<td>
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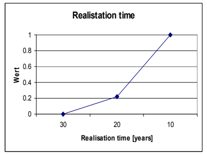
<td>
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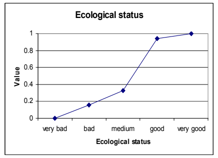
<td>
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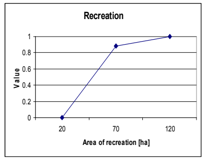
<td>
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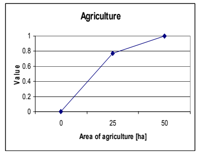
<td>
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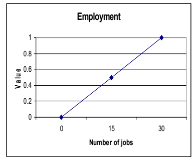
<td>
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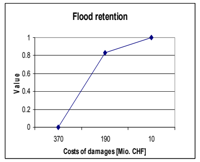
<td>
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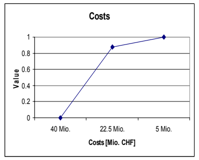
<td>
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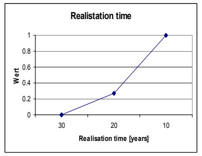
<td>
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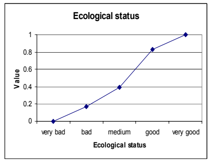
<td>
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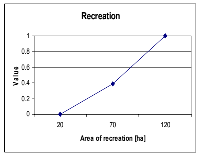
<td>
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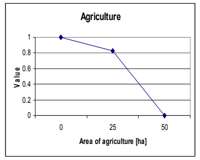
<td>
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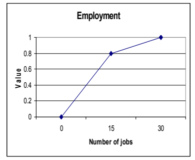
<td>
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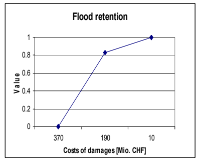
<td>
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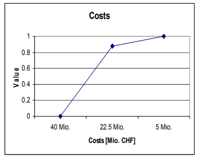
<td>
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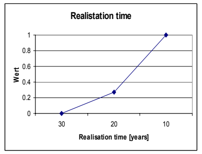
<td>
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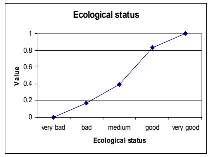
<td>
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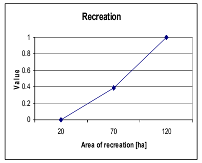
<td>
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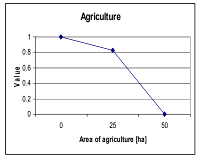
<td>
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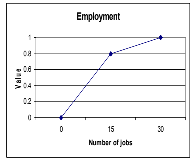
<td>
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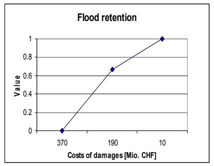
<td>
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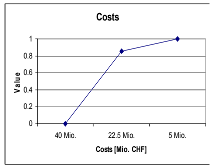
<td>
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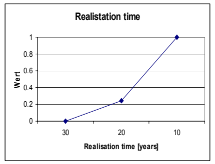
<td>
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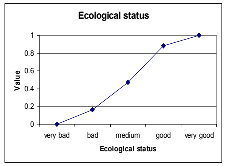
<td>
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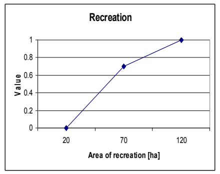
<td>
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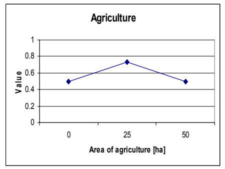
<td>
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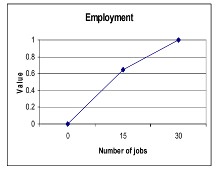
<td>
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# Rangers

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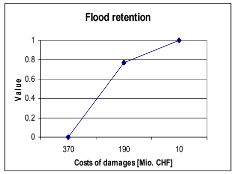
<td>
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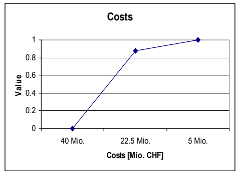
<td>
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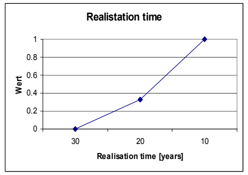
<td>
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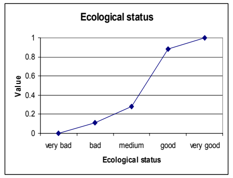
<td>
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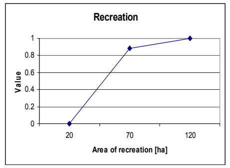
<td>
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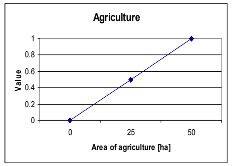
<td>
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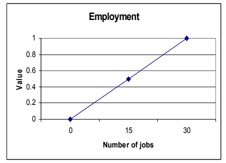
<td>
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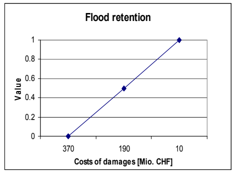
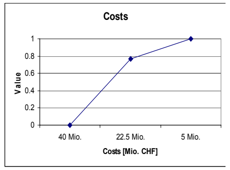
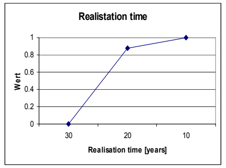
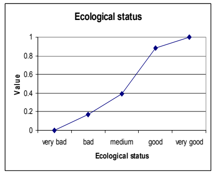
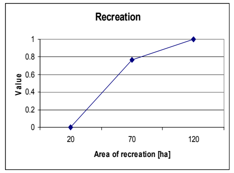
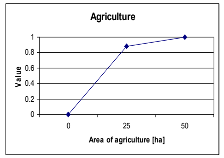
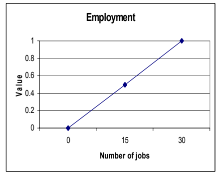
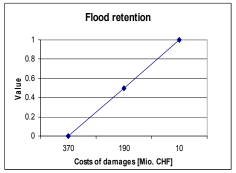
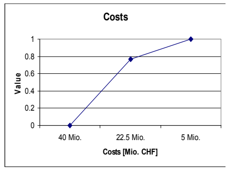
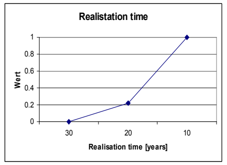
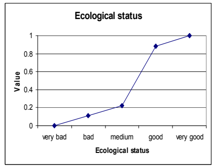
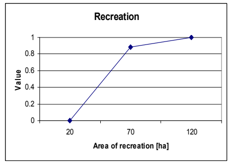
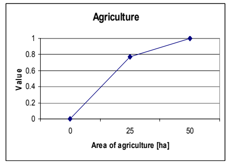
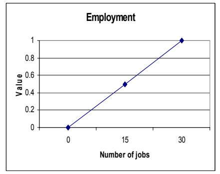
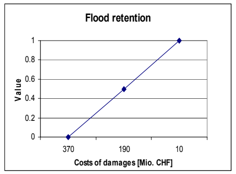
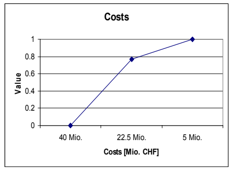
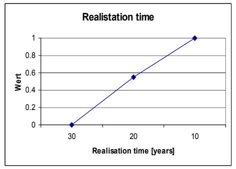
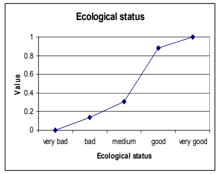
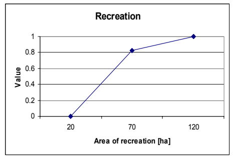
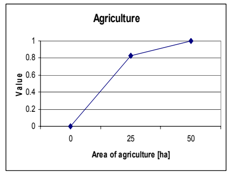
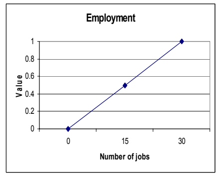
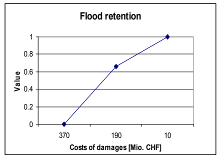
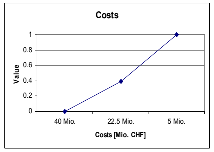
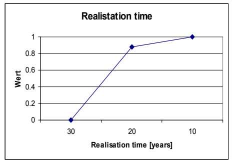
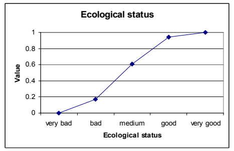
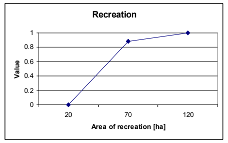
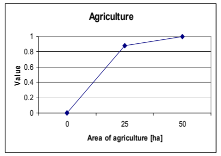
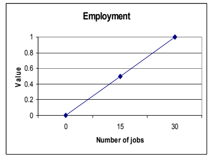
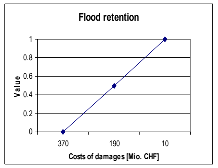
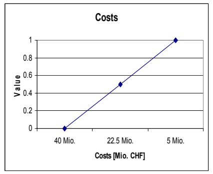
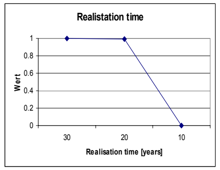
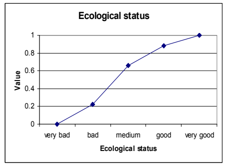
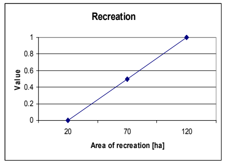
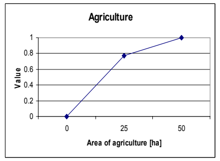
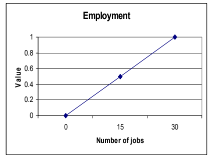
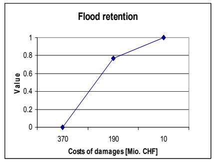
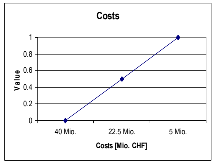
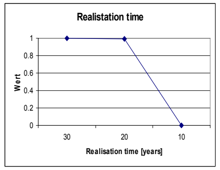
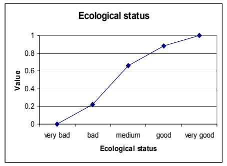
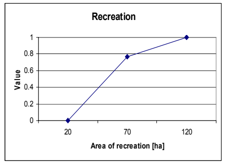
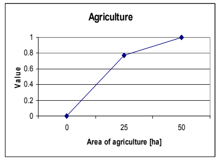
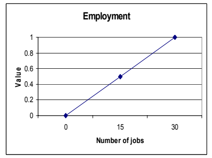
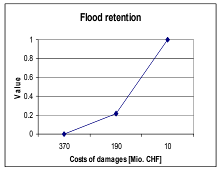
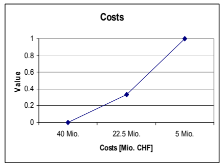
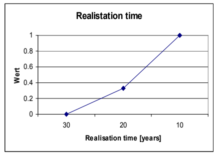
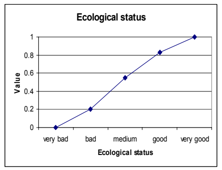
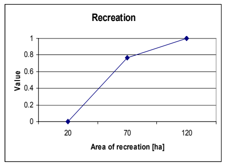
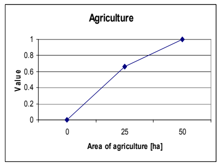
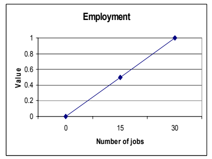
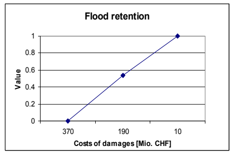
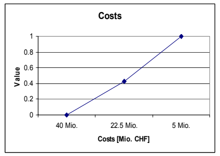
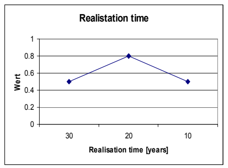
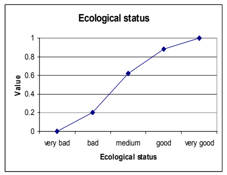
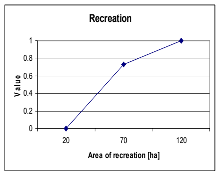
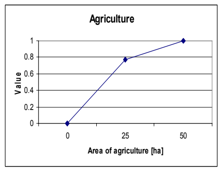
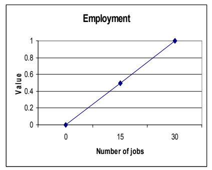
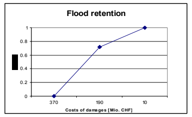
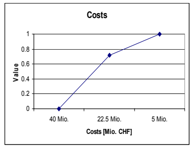
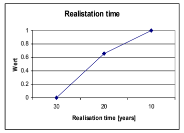
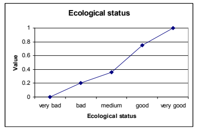
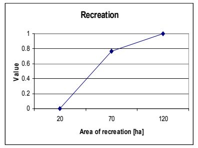
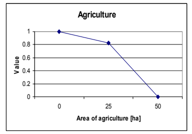
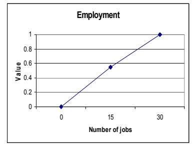
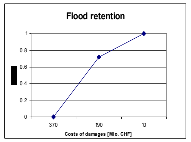
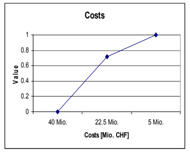
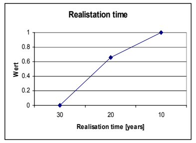
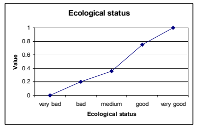
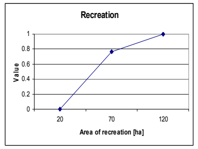
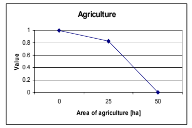
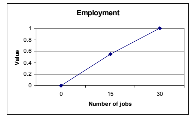
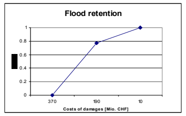
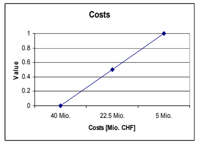
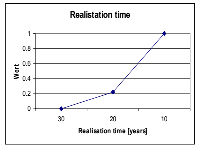
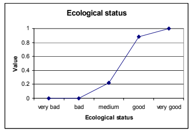
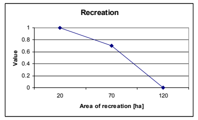
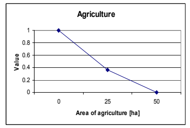
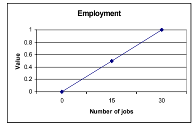
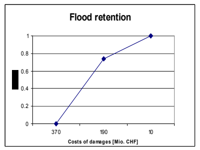
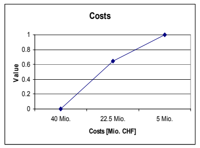
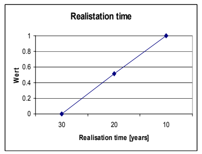
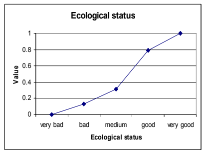
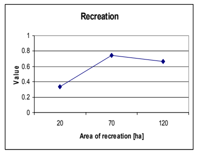
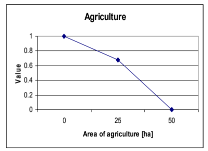
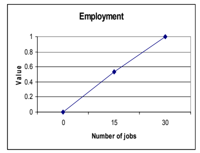
## Federal administration

| | Flood retention | Costs | Realization Time | Ecological status | Recreational opportunities | Agricultural jobs | Employment |
|---|---|---|---|---|---|---|---|
| Represen-tative 1 |  |  |  |  |  |  |  |
| Represen-tative 2 |  |  |  |  |  |  |  |
| Federal administra-tion averaged |  |  |  |  |  |  |  |

## Industry

| | Flood retention | Costs | Realization Time | Ecological status | Recreational opportunities | Agricultural jobs | Employment |
|---|---|---|---|---|---|---|---|
| Represen-tative 1 |  |  |  |  |  |  |  |
| Represen-tative 2 |  |  |  |  |  |  |  |
| Represen-tative 3 |  |  |  |  |  |  |  |
| Represen-tative 4 |  |  |  |  |  |  |  |
| Industry averaged |  |  |  |  |  |  |  |

# Environmental organizations

| | Flood retention | Costs | Realization Time | Ecological status | Recreational opportunities | Agricultural jobs | Employment |
|---|---|---|---|---|---|---|---|
| Representative 1 |  |  |  |  |  |  |  |
| Representative 2 |  |  |  |  |  |  |  |
| Representative 3 |  |  |  |  |  |  |  |
| Environmental organizations averaged |  |  |  |  |  |  |  |

# Agriculture representatives

| | Flood retention | Costs | Realization Time | Ecological status | Recreational opportunities | Agricultural jobs | Employment |
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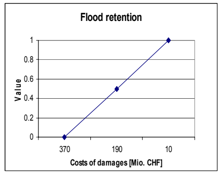
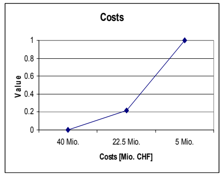
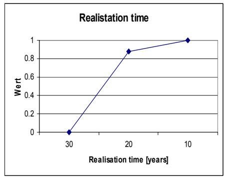
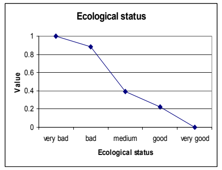
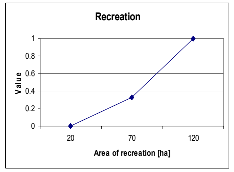
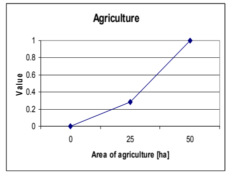
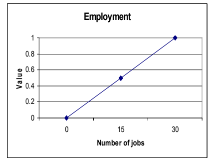
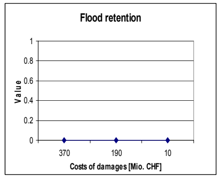
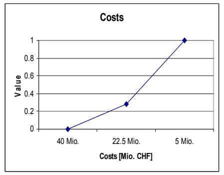
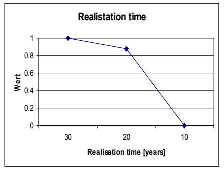
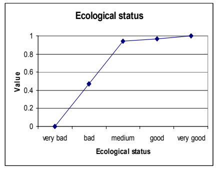
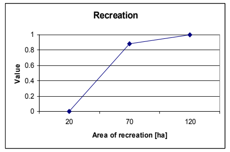
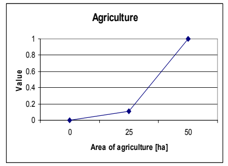
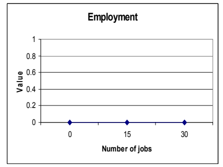
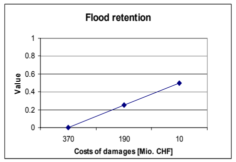
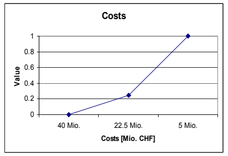
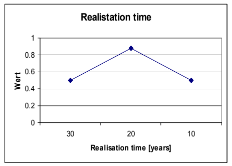
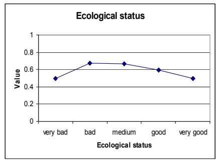
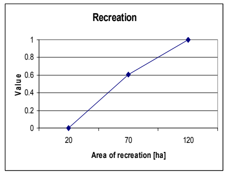
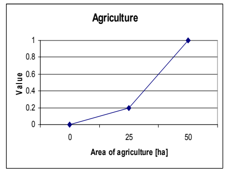
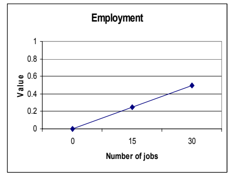
| Represen-tative 1 & 2 |  |  |  |  |  |  |  |
| Represen-tative 3 |  |  |  |  |  |  |  |
| Agriculture averaged |  |  |  |  |  |  |  |

## Communities

| | Flood retention | Costs | Realization Time | Ecological status | Recreational opportunities | Agricultural jobs | Employment |
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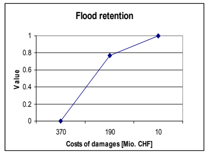
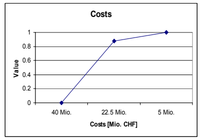
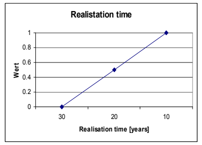
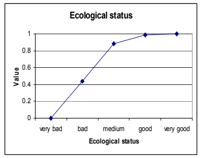
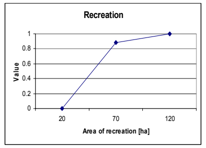
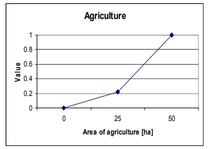
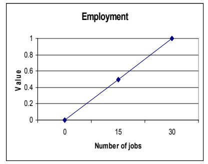
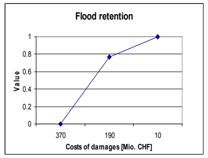
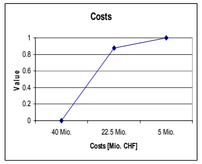
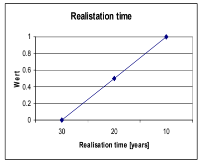
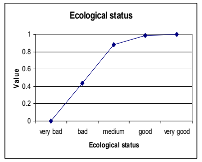
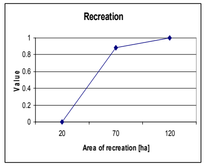
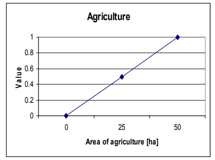
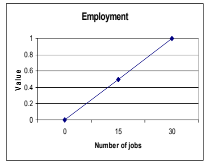
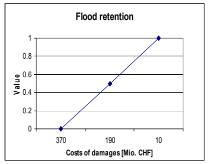
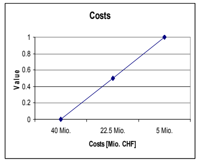
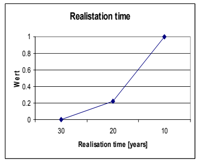
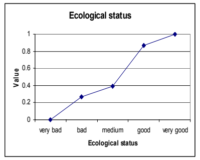
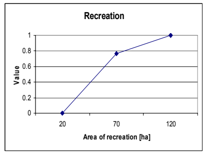
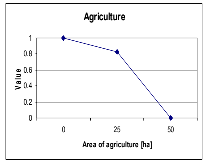
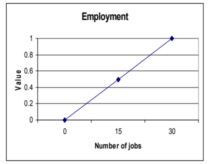
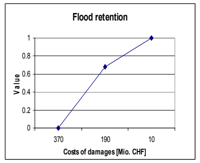
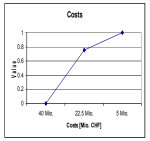
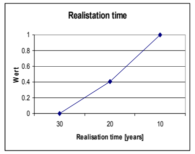
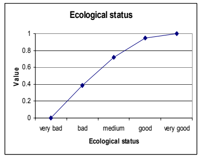
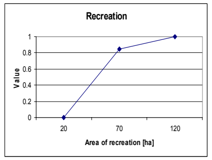
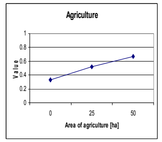
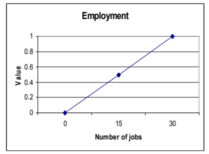
| Represen-tative 1 |  |  |  |  |  |  |  |
| Represen-tative 2 |  |  |  |  |  |  |  |
| Represen-tative 3 |  |  |  |  |  |  |  |
| Communities averaged |  |  |  |  |  |  |  |

# Cantonal administration

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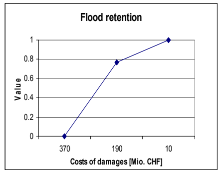
<td>
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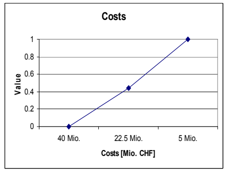
<td>
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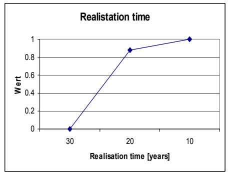
<td>
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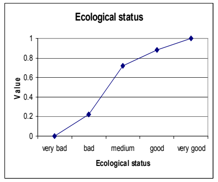
<td>
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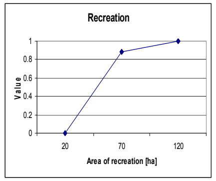
<td>
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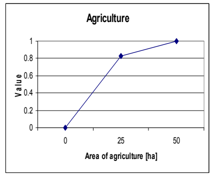
<td>
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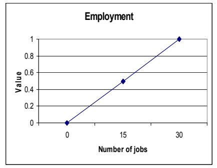
<td>
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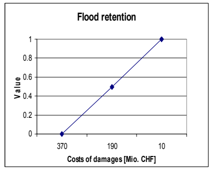
<td>
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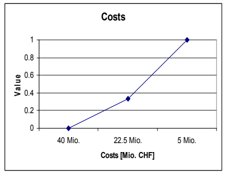
<td>
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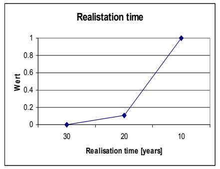
<td>
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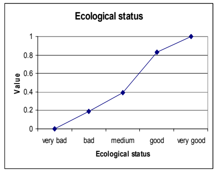
<td>
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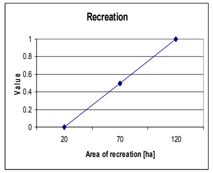
<td>
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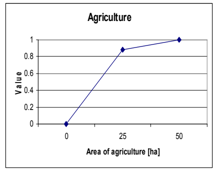
<td>
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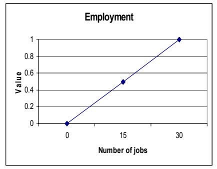
<td>
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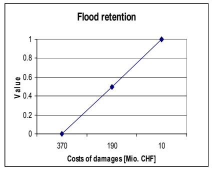
<td>
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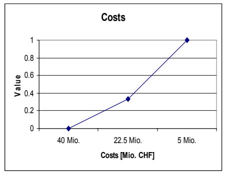
<td>
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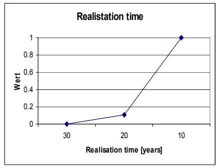
<td>
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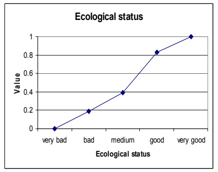
<td>
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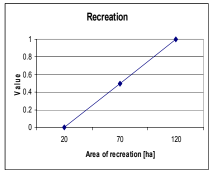
<td>
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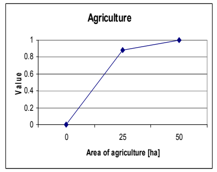
<td>
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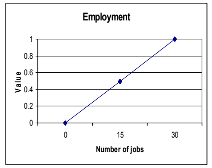
<td>
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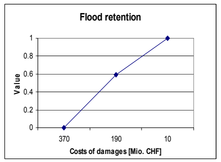
<td>
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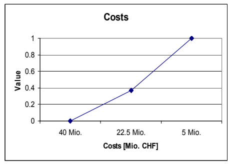
<td>
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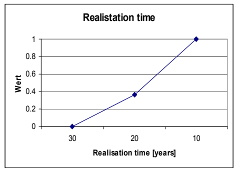
<td>
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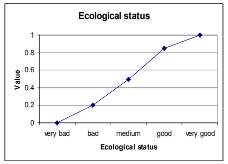
<td>
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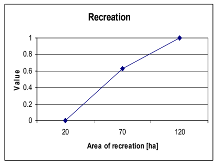
<td>
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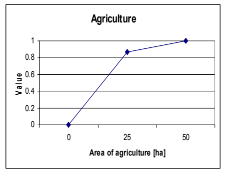
<td>
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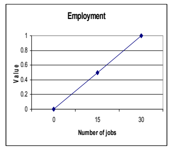
<td>
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| 10/1995 – 10/2000 | Master Degree in Environmental Sciences at ETH Zurich |
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