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Using Multicriteria Methods in Environmental Planning and Management

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ABSTRACT / In environmental planning and decision processes several alternatives are analyzed in terms of multiple noncommensurate criteria, and many different stakeholders with conflicting preferences are involved. Based on our experience in real-life applications, we discuss how multicriteria decision aid (MCDA) methods can be used successfully in such processes. MCDA methods support these processes by providing a framework for collecting, storing, and processing all relevant information, thus making the decision process traceable and transparent. It is therefore possible to understand and explain why, under several conflicting preferences, a particular decision was made. The MCDA framework also makes the requirements for new information explicit, thus supporting the allocation of resources for the process.

In this paper we describe the use of multiple criteria decision aid (MCDA) methods in public environmental planning and decision processes. Many of the opinions and views presented are based on the authors' experiences in a number of real-life applications. Some of these applications are listed in Table 1, which shows for each application the year(s) when the process took place, the applied MCDA methods, and references to publications.

Environmental planning and decision-making are essentially conflict analyses characterized by sociopolitical, environmental, and economic value judgements. Several alternatives have to be considered and evaluated in terms of many different criteria, resulting into a vast body of data that are often inaccurate or uncertain. To complicate the process further, there are typically a large number of decision-makers (DMs) with conflicting preferences. The different points of view of various interest groups also should be considered in the process. Therefore, a single, objectively best solution does not generally exist, and the planning process can be characterized as a search for acceptable compromise solutions.

Problem-solving without any methodology may distort the final results. Without the help of tools, the DMs tend to focus on a small subset of criteria, fix their opinions based on insufficient information, miscalculate uncertainties of events, and make motivational distortions (Tversky and Kahneman 1986, Payne and Bettman 1992). Simon (1955) explains these phenomena through the so-called bounded rationality behavioral model.

Different MCDA methods aim at supporting such complex planning and decision processes by providing a framework for collecting, storing, and processing all relevant information. The core of the selected MCDA method is the decision model, which is a formal specification of how different kinds of information are combined together to reach a solution. MCDA methods are used in environmental planning and decision-making processes in order to clarify the planning process, to avoid various distortions, and to manage all the information, criteria, uncertainties, and importance of the criteria. MCDA methods can alleviate the problems caused by limited human computational power. Intuitive or adaptive choices are replaced by a justified and jointly accepted model.

The problem setting in multiple criteria decision-making problems is typically one of the following:

1. Choose one or more best alternatives. This problem setting is most frequent in MCDA literature. However, in real environmental problems, the DMs often dislike the idea that some MCDA method would make the decision for them.

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Table 1. Some environmental MCDA applications in Finland

Application	Year	Method(s)	Reported in
Uusimaa municipal solid waste management system[a]	1991–92	Electre II	Hokkanen and others (1995)
Jämsä municipal solid waste management system[a,b]	1993	Electre III	Hokkanen and Salminen 1994)
Oulu municipal solid waste management system[a,b]	1993	Electre III	Hokkanen and Salminen (1997a)
Locating a waste treatment plant in Savonlinna area[a,b]	1994–95	Promethee I & II	Hokkanen and Salminen (1997b)
Helsinki Harbor environmental impact assessment (EIA) procedure[a]	1994–95	SMAA	Lahdelma and others (1998) Hokkanen and others (1999a)
Kirkkonummi general plan EIA	1996	SMAA-3	Hokkanen and others (1998a)
Toukolanranta technology competition of cleaning polluted soil	1997	SMAA-2 & AHP	Hokkanen and others (1998b)
South-Karelian waste treatment EIA	1998–99	SMAA-O	Hokkanen and others (1999b)
Pietarsaari multifuel power plant EIA	1998–99	SMAA-O	Manuscript
Huuna landfill reparation	1999	SMAA-O	Manuscript

[a]These applications are also summarized in the report by Salminen and others (1996).

[b]These applications are also summarized in the report by Salminen and others (1998).

2. Complete or partial ranking of the alternatives. In real environmental problems, the DMs often require a ranking of the alternatives even in cases where the final decision is to choose the best alternative. This approach gives the DMs more freedom to choose the second, third, etc., best alternative if they for some reason want to.
3. Acceptability analysis of the alternatives. The result is a description of what kind of preferences would give the best rank, or any specific rank, for each alternative. This approach allows maximum freedom for the DMs.

Because the planning and decision process in public environmental problems involves many people and organizations and may last from months to several years, it is necessary to split the process into distinct phases. One possible phase model is illustrated in Figure 1. First, based on a general problem statement, the various stakeholders are identified. The stakeholders typically include the DMs, various interest groups affected by the decision, experts in the appropriate fields, and planners and analysts responsible for the preparations and managing the process. Then the problem is defined formally in terms of alternative solutions and the various criteria to be considered. The criteria consist typically of measures for technical feasibility, cost effectiveness, probable impacts on different population groups, various environmental impacts, etc. It is important that all stakeholders or their representatives have the opportunity to participate in this phase so that all different points of view are taken into account. Measurement of the various impacts and their uncertainties is typically performed by experts in appropriate fields. The decision analyst should select a decision aid method and model suitable for the problem. However, it is important that also the DMs understand the model and accept the necessary assumptions for its use. Only after the decision model has been selected, it is meaningful to collect preference information from the DMs, interest groups, or both. Depending on the problem setting, the decision model can then be applied to provide one or more draft solutions or some other descriptive information. In the end the DMs make the final decision based on the draft solution and all information produced so far. Because the DMs are responsible for the consequences of the decision, they must still have the freedom to deviate from the draft solution.

The phases are not necessarily executed in strict sequence. Some phases may be executed in different order or in parallel, and learning during the process may make it necessary to repeat some of the phases.

In the environmental context we emphasize two central ideas in the above process. Firstly, the different stakeholders should be identified early, and they should also be allowed to participate in the different phases of the process. This provides a maximal amount of information into the process and ensures that all different points of view are taken into account. Certain situation-specific information that otherwise would be ignored can be incorporated through early participation, since only local stakeholders can provide it. Different stakeholders are also more likely to accept the final decision when they have had the opportunity to participate. Normally, several stakeholder meetings are required at each phase. It may be possible to replace some meetings by using e-mail or teleconferencing. Secondly, application of MCDA methods ensures that

Stakeholders	Define alternatives & criteria	Make measure-ments	Choose decision aid	Provide preference information	Form draft solution(s)	Make final decision
DMs	X		(X)	X		X
Interest groups	X			(X)		
Experts	X	X				
Planners	X	(X)	X		X	

Figure 1. Phases and stakeholder participation in environmental multicriteria decision processes.

all relevant data, uncertainties, and preferences can be considered explicitly. This makes the process traceable and transparent. It is thus possible to understand and explain why, under several conflicting preferences, a particular decision was made.

Stakeholders

The stakeholders consist of all the different people associated with the planning and decision process. In the beginning of the process one should identify all stakeholders and explicitly determine who should participate in the planning process, in which phases, and to what extent. There must be explicit and convincing arguments for adding or dropping a stakeholder. Interestingly, any argument to include or exclude different stakeholders provides useful information to the planner about the problem. After this process, the supervisory group, based on voluntary and institutional participation, eventually is formed (Alterman and others 1984).

The stakeholders can be classified into standard stakeholders and interest groups. Standard stakeholders are those who have the legitimate responsibility to participate in the process. Standard stakeholders include the DMs, experts, and planners and analysts responsible for the preparations and managing the process. In many countries the DMs in public decision-making are elected through a democratic process. In Finland, the number of DMs in municipal administrations is usually quite large, varying from the 5–20 members in the municipal boards up to some 100 members in municipal councils. The majority of these DMs have other full-time jobs and thus have very limited time to dedicate for the preparation of decision-making. The DMs' know-how of environmental questions and their ability to understand the causality between different impacts varies greatly.

Interest groups are typically political parties, civic organizations, or residents of the impact area. Each interest group has their own point of view for evaluating potential alternatives and often has different relational systems of preference (Roy and Vincke 1984, Bana e Costa 1988). Depending on their interests, the groups will stand up for different alternatives and objectives, thus creating competition and conflicts based on misunderstanding, opposing interests, and different values (Dietz and others 1989, Keeney 1992, Banville and others 1998). Interest groups add a sociopolitical dimension to the process in the sense that those views and alternatives that they find so important must effectively be taken into account when the actual decision is made (Douglas 1986). However, the points of view may be implicit or, unless specifically questioned, people may simply refrain from expressing them. Often people intuitively choose their best (or worst) alternative and then express such environmental preferences that justify their choice.

For successful planning and decision making, it is important to identify the true points of view of stakeholders. Consider, for example, people who do not want a new waste management system be built in their residential area, because that would decrease the value of their houses and lower the prestige of their neighborhood. In a preference poll with a predefined palette of commonly approved environmental criteria, the stakeholders might express that they consider certain emissions caused by this plant the most severe environmental problem that should be alleviated at any cost. The unsatisfying result from using this false preference information might then be to build an even larger waste management system with more efficient cleaning apparatus at the same location, instead of relocating the plant somewhere else.

Only after all points of view of different stakeholders are recognized, it is possible to identify the criteria necessary for decision-making. Thus, the criteria come from the stakeholders involved in the process, i.e., the criteria are context dependent. Value conflicts should also be recognized, because disagreements between stakeholders are often due to the fact that different stakeholders emphasize criteria differently. For example, no one can dispute the harmful impacts caused by environmental damage and decreasing jobs, but opinions differ as to whether environmental damage poses a greater threat than decreasing jobs.

Keeping all stakeholders informed from the beginning of the project will increase the probability of a successful decision process. The reason for this is that early participation makes stakeholders more engaged to the problem, prevents conflicts arising from ignorance, and thereby allows the participants to concentrate to relevant aspects of the current problem. Identification of the necessary participants can be done together with the standard stakeholders who are the easiest to identify. Different techniques, such as the systematic approach presented by Mason and Mitroff (1981), can be used for identifying other interest groups. Identifying the potential reasons for people to mobilize around any aspect of the problem also may help to identify stakeholders. Problem-oriented maps (Blair and others 1990) can also be used along with other techniques such as brainstorming, Delphi, and the nominal group technique (see, e.g., Hwang and Lin 1987).

The interest groups have something to win or lose in the decision-making. This highlights the interest conflicts that can be, for example, economic, esthetical, cultural, social, or political. The interest groups can be classified by developing the factions proposed by Susskind (1985) and Martin (1985) as follows:

1. Boosters are those who see the issue as essential to their survival.
2. Friends are those to whom the issue is important, but not essential for survival.
3. Guardians are those who in principle are neutral and can thus easily switch between factions.
4. Nonparticipants or silent ones are totally uninterested in the problem. They may feel that they have no power to influence decision-making or they may put all their trust on the DMs.
5. Hostiles are those with erroneous perceptions, inconsistent behavior, or fragile loyalty, who often unknowingly act against their own interests.
6. Preservationists are those who will do anything to oppose the alternatives considered. They favor the so-called zero alternative of rejecting the project.

Defining Alternatives and Criteria

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

Defining Alternatives

In real-life environmental problems, alternatives can be divided into standard and innovative ones. Standard alternatives are obvious from the decision context alone: the actual project, the so-called zero alternative (rejection of the project), and other alternatives presented by the stakeholders. Innovative alternatives are those emerging through different kinds of negotiations during the process.

The number of alternatives is highly situation dependent. There can be dozens of viable alternatives for choosing a solid-waste management system or in planning specific land usage. The number of alternatives is usually smaller in zoning projects, perhaps three to five. In many situations the number of potential alternatives is in principle infinite, but the decision-making process requires that a finite number of distinct alternatives be formed. However, the set of alternatives should be allowed to grow or shrink during the process; the initial set of possible alternatives usually leads to a second and third one as the result of hearing different interest groups, making measurements and calculations, etc. It is often also possible to form new alternatives by combining the best parts from existing alternatives. For example, in the Kirkkonummi General Plan EIA case, two of the regions were redefined (Hokkanen and others 1998a). In the Helsinki Harbour EIA, a total of 25 alternatives were generated from different combinations of alternative navigation channels and railway and road routes (Hokkanen and others 1999a).

The feasibility of the alternatives is defined by the stakeholders. It should be noted that new alternatives may affect new groups of people, who then augment the set of stakeholders. These new stakeholders again may bring up new criteria and alternatives. There is no formal way of constructing a list of possible alternatives and no concrete way of knowing when the set of stakeholders is complete enough, other than relying on experience, intuition, and on the vague concept of diminishing marginal return of satisfaction (Banville and others 1998).

Banville and others (1998) also present the idea of classifying alternatives into categories based on which stakeholders support them, resist them, or are indifferent. This classification of alternatives can serve not only to elicit new ones, but also as a starting point for identifying stakeholders' points of view. Once these standard alternatives have been identified, it is useful to create innovative alternatives and to improve existing ones (Gregory and Keeney 1994). New alternatives may arise in other phases of planning also. These should be seen to reflect the increased understanding of the

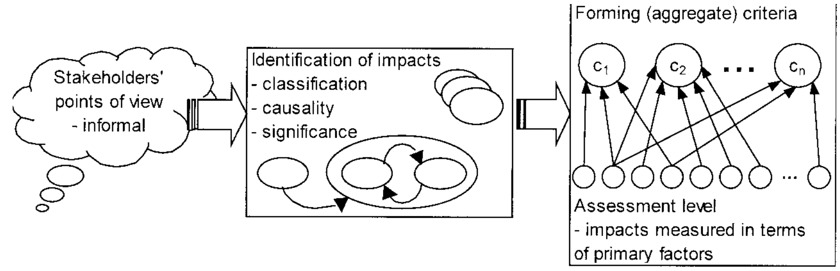

Figure 2. From stakeholders' points of view to identification of impacts and forming aggregate criteria.

problem. Accordingly, creation of new alternatives may often be more valuable than focusing on the existing ones (Ozernoy 1984).

Development of new alternatives is not always beneficial. Some interest groups may try to invent arbitrary new alternatives far away from their area just to prevent, for example, a landfill being located in their neighborhood. This, of course, only slows down the decision process and does not help in the search of good creative compromises.

Identification of Impacts and Constructing the Set of Criteria

In the multiple criteria approach, the criteria provide numerical measures for all relevant impacts of different alternatives. Various classifications are useful for identifying different impacts and evaluating their relevance. The most common environmental impacts in environmental planning projects include impacts on the soil, groundwater, surface water, regional air quality, atmosphere, local flora and fauna, biodiversity, and landscape, as well as disturbing noise. Besides these environmental impacts, there are impacts that relate to the economy, employment, attainability and valuation of different areas, use of energy, services, safety, and health. Direct impacts on the physiobiological environment indirectly generate significant social impacts, which can be classified into demographic changes, institutional conditions, community/area infrastructure, impacts on life-style, impacts on attitudes, and conflicts between different social groups.

The impacts can also be classified according to their temporal, spatial, and regulatory properties. Temporally, impacts can be classified as unique, recurrent, or continuous. Continuous and recurrent impacts can be either short or long term. Spatially, impacts can classified as local, regional, national, international, or global. Impacts may be formally regulated or not regulated at all. For nonregulated impacts, it should be decided how the temporal and spatial differences are taken into consideration (Grassin 1986, Bouyssou 1990). For example, the impacts of large construction projects (roads, industrial plants, harbors, etc.) are clearly different during the construction phase from the impacts generated during operation. The impacts of new road projects are dispersed geographically on very large areas of different type. Finally, impacts may be classified as marginal or significant.

The relevance of different impacts depends on stakeholders' points of view. Various techniques have been proposed for determining these points of view. Roy (1985) considers that these points of view will emerge after a thorough analysis of various consequences, taking into account the cultural background of the stakeholders involved. Keeney and Raiffa (1976), Keeney (1992), and Saaty (1980) advocate a hierarchical way of constructing the criteria through the decomposition of an overall objective into subobjectives that are further decomposed, until the relevant impacts are reached. The bottom-up and hierarchical top-down approaches are, of course, not mutually exclusive. Both approaches have been used in planning processes. We have mostly used a bottom-up approach in our real-life applications, as illustrated in Figure 2.

In the early phases of defining criteria, the experts and the supervisory group can specify impacts caused by the alternatives. The starting point may, for example, consist of the demands set by legislation and acquired problem-related expertise. As for environmental impacts, four main approaches have been suggested to assist in their identification: map overlays, impact checklists, impact matrices, and cause–effect networks (Julien and others 1992). The impact matrices and cause–effect networks identify the environmental impacts by establishing the important causal links between the sources and the targets of the impacts.

At this phase, special meetings for the different stakeholders or open public meetings should be organized. With these meetings the planner is seeking the points of view and alternatives that different stakeholders feel important enough to be taken into consideration when the decision is made. It is important that stakeholders involved in the decision-making process understand and accept the impacts and points of view around which the criteria are built. For nonexpert stakeholders it can be difficult to recognize different impacts. Consequently, we have approached the problem through people's own experiences. For each stakeholder the worst-case scenario of each alternative being considered is presented. Stakeholders are asked why some groups desire this kind of situation and what the disadvantages would be. Next, they are asked to describe and justify their most desirable alternative. In addition to the inquiry technique, visualization techniques can be used for discovering the points of view (see, e.g., Tuovinen 1992). After expressing the different points of view on a questionnaire, participants switch to studying the material collected by experts describing alternatives and impacts. During this phase, the participants may come up with new impacts.

All the material obtained is then put together and the criteria are formed. The final set of criteria should meet the following requirements (Keeney and Raiffa 1976):

1. Completeness: all the important points of view of the problem are covered.
2. Operationality: the set of criteria can be measured and used meaningfully in the analysis.
3. Nonredundancy: two or more criteria should not measure the same thing.
4. Minimality: the dimension of the problem should be kept to a minimum.

Let us consider how the set of criteria in a real-life application meets these requirements. Table 2 shows the final set of criteria in the Savonlinna waste treatment plant application (Hokkanen and Salminen 1997b). Completeness is satisfied, because these are exactly the criteria the stakeholders wanted to consider. The operationality requirement is well satisfied for criteria in the economy category, and some other criteria can be assessed fairly well based on earlier similar projects. Still, some criteria, such as manageability of plant waters and cultural history had to be evaluated by experts using discrete scales, which were assumed to be cardinal. Because the DMs understood and accepted these measurements, they can be considered operational in this sense. The nonredundancy requirement is not easy to satisfy in real-life problems. When trying to achieve completeness, it is often difficult to avoid partial overlapping among criteria. In the Savonlinna case, for example, the criteria on recreational use and effects on the standards of housing are slightly overlapping. Overlapping could be reduced by introducing a larger set of more restricted criteria, but this would contradict the minimality requirement. The final set of 14 criteria is a good compromise among the requirements.

Table 2. Final set of criteria in Savonlinna waste treatment plant application

Category	Criteria
Economy	g_1 = operating costs
	g_2 = building costs
	g_3 = transportation costs
Technology	g_4 = manageability of plant waters
	g_5 = linking with the existing infrastructure
Environment	g_6 = effects on ground water
	g_7 = effects on surface water
	g_8 = ecological effects
	g_9 = effects on the landscape
Man and the built-up environment	g_{10} = recreational use
	g_{11} = effects on the standards of housing
	g_{12} = cultural history
	g_{13} = health
	g_{14} = noise

Measuring the Criteria

Usually the criteria are measured as aggregates of primary factors, which may consist of, for example, emission levels for individual chemicals, size of affected population, noise distribution in certain areas, etc. The number of primary factors can be very large as they comprise every point of view considered by different stakeholders. In later phases of the planning process the assessment level can be used to describe each impact very precisely, e.g., at emission component or species levels. Conceptually, it is possible to carry out the comparison of the alternatives directly at the assessment level. However, due to the large number of different factors and the fact that several factors may measure essentially the same impact, criteria are used to aggregate related factors together.

The impacts of the chosen alternatives will be realized in the future, and therefore it may be impossible to measure the impacts accurately in the decision situation. As is well known, even the costs of a project are often estimated incorrectly; the same holds true for more difficult environmental criteria. However, the decisions must be made under this inherent uncertainty. When the inaccuracy or uncertainty of criteria values is considerable, it should be represented explicitly using, for example, confidence intervals, probability distributions, pseudocriteria, etc.

Sometimes the criteria measurements are based on expert judgements. In such cases the attainable scales for criteria may be cardinal or ordinal. On a cardinal scale, the differences between values are meaningful. On an ordinal scale only the order of values is meaningful. Some criteria may be so vague that the experts are only able to provide ordinal judgements for them. Sometimes real DMs prefer ordinal criteria to cardinal criteria. Examples of such vague criteria are technical reliability, landscape, and innovation. Sometimes ordinal measures are chosen if they can provide sufficient accuracy while allowing considerable costs and time savings. No matter how vague ordinal criteria may sound, if they describe the DMs' subjective reality in the problem, the analyst has to accept them.

Unfortunately, MCDA tools do not widely support problems where some or all criteria information is ordinal. If the MCDA method requires cardinal scales, the analyst faces the difficult problem of mapping ordinal values onto a cardinal scale. The SMAA-O method (Miettinen and others 1999) is capable of handling mixed cardinal and ordinal information, and we have used it in three real-life applications, as presented in Table 1. SMAA-O handles ordinal criteria by simulating all consistent ordinal to cardinal mappings.

Choosing the Decision Aid Method

A principled problem in choosing a decision aid method for a real-life problem is that different methods may provide different results with the same data, and there is usually no means to objectively identify the best alternative or method. Therefore, the choice of method should be well justified in real applications, although this is rarely done. There are some requirements for the MCDA method to be used in public environmental problems:

1. The method should be well defined and easy to understand, particularly regarding its central elements, such as modeling of criteria and definition of weights.
2. The technique must be able to support the necessary number of DMs.
3. The method must be able to manage the necessary number of alternatives and criteria.
4. The method should be able to handle the inaccurate or uncertain criteria information.
5. Due to time and money constraints, the need of preference information from the DMs should be as small as possible.

These constraints cover the typical factors through which the practical relevance of decision support methods is usually evaluated (Goicoechea and others 1982, Hobbs 1984, Hobbs and others 1992, Simpson 1996).

It is very difficult for any decision-aid method to satisfy all these requirements in the ranking problem. All methods have their own inherent weaknesses. The large number of DMs, alternatives, and criteria often present in public environmental problems emphasizes the last requirement. The planners usually do not have enough time or economic resources for assessing value/utility functions or performing pairwise comparisons of alternatives and criteria with every DM. The nature of environmental problems can also make it too difficult for most DMs to compare the significance of different criteria. For example, specifying a tradeoff ratio between greenhouse gases and employment may just be too difficult.

Several different multicriteria methods have been applied to environmental problems. The main approaches can be classified based on the type of decision model they apply:

(1) value or utility function based methods, such as multiattribute utility theory (MAUT) (Keeney and Raiffa 1976), SMART, the analytic hierarchy process (AHP) (Saaty 1980), interval AHP (Salo and Hämäläinen 1992), and the stochastic multicriteria acceptability analysis methods SMAA (Lahdelma and others 1998) SMAA-2 (Lahdelma and Salminen 1997, 2000, Hokkanen and others 1998b), SMAA-D (Lahdelma and others 1999), and SMAA-O (Miettinen and others 1999); and (2) outranking methods such as Electre II (Roy and Bertier 1971), Electre III (Roy 1978) Electre IV (Roy and Hugonnard 1982), Promethee I and II methods (Brans and Vincke 1985), and SMAA-3 (Hokkanen and others 1998a).

Cost–benefit analysis (CBA) could also be classified as a multicriteria method. However, currently its use has decreased in environmental problems in Finland. CBA is still used in road planning for example, but not in problems in our context where we are interested in different valuations of criteria by different stakeholders.

Another classification can be made based on the use of preference information in the method. Most of the methods require preference information in the form of precise weights. Methods that do not require DMs' preference information are acceptability analysis (Bana e Costa 1986 1988), SMAA methods, data envelopment analysis (DEA) (Charnes and others 1978), and Electre IV. Some methods can also be used with partial weight information. DEA, SMAA, and interval AHP can handle weight intervals. SMAA and the method of Butler and others (1997) can also be used with arbitrary weight distributions.

The advantage of preference-information-free methods in real problems is that the DMs avoid many difficult questions, and the theoretical problem of combining conflicting weights from multiple DMs is avoided. However, preference-information-free methods cannot generally provide conclusive solutions to the problems. For example, Electre IV is often not able to produce a single best alternative, and it requires definition of difficult parameters by the analyst. DEA can only separate efficient alternatives from inefficient ones; the efficiency score should not in general be used for ranking the alternatives. SMAA methods provide the most detailed information describing what kind of preferences correspond to the choice of each alternative. SMAA provides this information in the form of so-called acceptability indices that measure the variety of different preferences supporting each alternative, and central weights describing the preferences of a typical DM supporting a certain alternative. SMAA can be used for identifying good compromise alternatives that are acceptable to many stakeholders with different preferences. It important to note that such alternatives are likely to remain good solutions in the future also, subject to changing preferences, new stakeholders, and changing or more accurate criteria.

In utility-function-based methods, the uncertainty and inaccuracy of the problem data can be modeled using intervals or stochastic distributions. In general, stochastic models must be analyzed numerically using Monte Carlo simulation. In outranking approaches, the inaccuracy can be modeled through the indifference and preference thresholds (so-called pseudocriteria). Of course, threshold values must be assessed for each criterion and for each problem separately. The SMAA methods can be used with any decision model that uses weights. Thus, the uncertainty can be modeled using either stochastic criteria (SMAA, SMAA-2, and SMAA-D) or pseudocriteria (SMAA-3). With stochastic criteria, SMAA provides so-called confidence factors, which measure explicitly whether the data are accurate enough for making informed decisions.

The use of pseudocriteria in association with outranking methods may result in many mutually indifferent or incomparable alternatives (incomparability may occur only with the so-called distillation process, which may be used in the aggregation phase of Electre methods). Thus, no complete ranking of the alternatives is obtained. The incomparability between some alternatives can be considered a weakness of the method when it is not able to rank the alternatives completely. Incomparability can also be seen as a way to represent decision situations where the DM indeed is unable to compare some alternatives. If there is no basis to compare two alternatives reliably, they should be accepted as being incomparable. This is also one way to protect stakeholders' points of view in environmental planning processes.

The decision model determines the compensation between the criteria (see, e.g., Bouyssou 1986). A linear value/utility model provides full compensation between the criteria, i.e., a poor value on any criterion can be compensated by a sufficiently good value on another criterion. Compensation can be decreased by using nonlinear utility models. However, this leads to the difficult problem of determining the correct shape. Outranking methods typically do not provide full compensation. Due to the thresholds used, not all differences among criteria values affect the analysis.

Providing Preference Information

Commonly, in multicriteria problems a number is assigned for each criterion describing its importance. These numbers are called weights, and they model the DMs' subjective preferences. The interpretation of the weights depends completely on the decision model. Therefore, it is essential that the decision model be chosen prior to collecting weights (see, e.g., Vincke 1992). In decision models based on utility theory, the weights are used for aggregating criteria values into a single number describing the overall goodness or utility of each alternative. The interpretation of the weights depends on the shape of the utility function. The most commonly used linear utility function uses the weights to compute the utilities as weighted (arithmetic) averages of suitably scaled criteria. The weights can then be interpreted as price-coefficients for criteria, and ratios between weights represent tradeoff ratios between criteria. An additive utility function first maps criteria values by partial utility functions onto the interval [0, 1] and then computes the overall utilities as a weighted average of the partial utilities. As the partial utility functions may be nonlinear, the weights then correspond to nonconstant price functions for criteria, and weight ratios represent variable tradeoff ratios between criteria. The interpretation of weights in more complex utility functions becomes exceedingly difficult. In the outranking approach the interpretation of weights is completely different; the weights are considered as votes for certain criteria (Roy 1991).

Weight information can be more or less accurate. When exact weights cannot be obtained or agreed on, weight intervals or weight distributions can be used. Sometimes only partial priority information between criteria is available. The DMs may also refuse to provide any weight information. When the number of DMs is small, it is possible to use weight-assessing techniques with several consistency checks. When the number of

DMs is large, the search for the right weights is particularly difficult.

In the public decision-making context, the number of DMs is often so large that there is no possibility of obtaining preferences from DMs more than once. This is a problem, because new information is continuously obtained during the planning and decision-making process and consequently the DMs' preferences also evolve. This is true particularly in situations where the planning is completed several months before the decision making, as in environmental impact assessment (EIA) projects.

Several techniques for eliciting weights are presented in literature. These vary from direct assessment to pairwise comparison methods such as AHP (Saaty 1980) and Macbeth (Bana e Costa and Vansnick 1994). Once again, there exist no right weights that would allow comparisons between different procedures. The weights obtained depend on the technique used.

After weight information has been obtained from a group of DMs, there is the difficult problem of aggregating conflicting weights into a single set of weights that would represent the overall preferences of the group. Various averaging procedures may produce weights and lead to solutions that no one wants. In fact, the overall preferences of a group cannot, in general, be represented by any single set of weights. Here only the use of weight intervals or weight distributions may give a sound starting point.

Often it is not possible to obtain any preference information from the DMs. Reasons for this may be that: (1) the DMs do not have enough time to study the problem carefully, (2) the analysts do not have resources enough to reveal the preferences of a large group, (3) the DMs are not able to provide any weights due to the difficulty of the problem, (4) the DMs do not want to confine themselves to any preference statements in a long process, (5) the DMs are afraid to express their preferences in public because votes from supporters and opponents of a project are valuable later on, and (6) the sometimes group of DMs is not clearly identified and therefore it is difficult to decide whose preferences should be taken into account.

For these cases one can not apply methods requiring precise weight information. Instead, the preference-information-free multicriteria methods can be used for describing the potential alternatives and the preferences (weights) that support each alternative. This will normally not result in a single solution. Instead, the list of alternatives will be reduced, but the final decision is left to the DMs.

Concluding Remarks

It is important to identify stakeholders' points of view in environmental decision problems. The information obtained from the stakeholders helps identify context-specific impacts that the experts may fail to recognize. In real-life problems, the experts have been able to develop new alternatives where the number of harmful impacts has been decisively reduced (Salminen and others 1996, Hokkanen and Salminen 1997a, Hokkanen and others 1998a).

The multicriteria planning process as described in this paper has enabled bidirectional learning between experts and interest groups. One of the benefits of MCDA methods is thus that all stakeholders learn to understand the problem better. The decision problem immediately becomes clearer after it has been formalized in terms of alternatives and criteria. The MCDA formulation provides a comprehensive framework for storing all relevant problem information, makes the requirements for new information explicit, and thus supports allocation of resources.

The MCDA approach has also increased discussion between different stakeholders, activated nonparticipants, and focused the discussion to relevant topics. Stakeholders have started to examine problems comprehensively, not just from their own points of view. Stakeholders have also learned to recognize conflicts based on misunderstandings and solve them. This is proven by the fact that the emphasis of the discussions has changed from alternatives to impacts: what kinds of impacts are people really willing to accept?

One problem with the meetings organized for different stakeholders is that they usually reach only the active part of the population consisting mainly of supporters and opponents of the project, the opponents being generally in the majority. The participants' views are usually considerably different from the views of the less active population, who nevertheless form the largest group when all stakeholders are considered. Approximately 60%–70% of all those who are affected by a certain alternative belong to nonparticipant and guardian groups. Although the meetings help to recognize impacts that are important for decision-making, they cannot be used as the only source of preference information. Therefore, to clarify the preferences of all interest groups, inquiries with larger samples should be used.

It is important that the points of view significant for different interest groups be conveyed to the DMs. After the criteria have been constructed and accepted, the conclusions should be based on the criteria. Therefore, methods restricting the number of criteria should not be used in public decision-making.

The role of the planner is emphasized in the choice of the multicriteria method to be used in aiding the decision process. As is widely known, different methods may give different solutions to the same problem, and DMs are rarely able to compare the methods. (This may happen only when the requirements of the method exceed what DMs consider realistic.) However, it is not possible to compare different methods reliably in a real-life problem. More insight into this problem will be gained when the number of real-life applications of different MCDA methods increases. Currently real-life MCDA applications are rare, but the number is increasing quite rapidly.

It should be noted that although the actual use of an MCDA method takes only a short time relative to the entire process, it defines the phases of the decision process through its data requirements. For example, our EIA procedures have each lasted about one year (except the Helsinki harbor application, which lasted two years), but the actual application of the MCDA method takes typically only a few weeks.

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