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Collaborative environmental planning in river management: An application of multicriteria decision analysis in the White River Watershed in Vermont

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Abstract

Multicriteria decision analysis (MCDA) provides a well-established family of decision tools to aid stakeholder groups in arriving at collective decisions. MCDA can also function as a framework for the social learning process, serving as an educational aid in decision problems characterized by a high level of public participation. In this paper, the framework and results of a structured decision process using the outranking MCDA methodology preference ranking organization method of enrichment evaluation (PROMETHEE) are presented. PROMETHEE is used to frame multi-stakeholder discussions of river management alternatives for the Upper White River of Central Vermont, in the northeastern United States. Stakeholders met over 10 months to create a shared vision of an ideal river and its services to communities, develop a list of criteria by which to evaluate river management alternatives, and elicit preferences to rank and compare individual and group preferences. The MCDA procedure helped to frame a group process that made stakeholder preferences explicit and substantive discussions about long-term river management possible.

Keywords: Outranking PROMETHEE; Participatory process; MCDA

1. Introduction

Throughout much of the 20th century, environmental planning decisions have been made primarily by state and federal governments in the United States. Federal agencies such as the Army Corps of Engineers, Bureau of Land Management, and the US Forest Service have had a great deal of power and influence in local land management decisions. However, greater public input became the norm following a wave of environmental legislation in the late 1960s and early 1970s, in particular with the requirement of environmental impact assessments of the National Environmental Policy Act of 1969. In a recent national survey, the vast majority (83%) of participants said that they should have more influence on environmental management decisions (Steel and Weber, 2001). The demand for greater public involvement emerged in part from an increased understanding of the linkages between human welfare and the environment, of the need for management at local scales, and a general backlash against federal power in local decision making (Troy, 2007).

While public input became a requirement of much environmental planning in late-20th century America, the process of eliciting and incorporating public advice has varied widely. Too often public input has followed a process of public officials vetting already well-developed management plans in order to inform, but not seek advice, from any who might listen. This one-way flow of information has frustrated many decision processes, resulting in decisions

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that have weak public support and subsequent implementation barriers (Moote et al., 1997; Rowe and Frewer, 2000; Renn et al., 1995; Germain and Floyd et al., 2001).

In more recent years, due in part to the failures of the past, public input could be more aptly described as public participation, with two-way communication becoming more routine. A new era of environmental management has arisen with the expanding roles of well-organized and funded advocacy groups, as well as the emergence of citizens groups, citizen advisory boards, and watershed partnerships (Lubell et al., 2002; Sellers, 2002; Thomson, 2001). However, while the role of the public has expanded as both stakeholders and decision makers, it has in no way been a panacea for sound planning and management. While the process itself can be mandated or emerge on demand, results can be disappointing, frustrating, untenable, and unsustainable. Common flaws include the lack of structure, quantifiable goals, and a clearly defined process to achieve them (Rhoades, 2000; Webler, 2001). In particular, processes that do not adequately engage group members typically fail either because too few opinions are cast on the decision at hand, or too much information is presented without the capacity to synthesize and inform opinions.

This paper examines how collaborative processes can be structured in order to achieve efficient stakeholder participation and perhaps avoid some of these pitfalls. The organization of group process around an analytical framework is explored as a means to increase understanding of the issues, provide greater stakeholder participation in the process, and improve stakeholder satisfaction and buy-in with the end result. The study context is a structured group process with a small citizens group organized to envision and deliberate over river management alternatives in the White River watershed of central Vermont in the northeastern United States. Alternatives were framed around the social, economic, and environmental impacts of river channelization—the artificial straightening of rivers to accommodate roads, railways, settlements, and other human investments such as farms and logging operations in floodplains.

To assess and evaluate tradeoffs of the costs and benefits of design alternatives to continued channelization, stakeholders participated in a multicriteria decision analysis (MCDA) group process. The primary objectives were to (1) structure an informed community discussion and process for ranking river management alternatives; (2) evaluate stakeholder preferences for characteristics of river management alternatives; and (3) investigate how individual stakeholder preferences are formed and modified as disparate information is synthesized during the group decision process.

2. River channelization and public participation in the White River Watershed

The White River is one of the last free-flowing rivers in Vermont. With its headwaters in the Green Mountains, the main stem travels 56 miles to its confluence with the Connecticut River (see Fig. 1). The White is a significant cultural, recreational, and aquatic habitat resource for Vermont but, like many northeastern US rivers, its health suffers from a legacy of channelization. The channeling (or straightening) of rivers over the last 100 years of development has made way for roads, rail, cities, towns, and farms resulting in significantly reduced floodplains and diminished river stability. The direct impacts include increased severity of flood events, exacerbated erosion and sediment deposition, and impaired aquatic and riparian habitat. These effects, in turn, damage property, public and private infrastructure, and generally increase conflicts between people and the river. Channelized rivers are also expensive to manage through intervention measures such as gravel removal, channel armoring, realignment, and post-flood remediation projects (Kline and Cahoon, 2003).

In response to mounting externalities from a century-long legacy of channelization, the White River Partnership (WRP) was formed in 1996 as "a locally led and community driven collaborative between communities, citizens, conservation groups, and federal and state agencies" (White River Partnership (WRP), 2004). Their mission is "to help local communities balance the long-term cultural, economic, and environmental health of the watershed through active citizen participation" (WRP, 2004). In 1996 the WRP held a series of public forums where concerns identified included riverbank erosion, water quality problems, wildlife and habitat loss, sedimentation, decline of native fisheries, and flood damage. The WRP formed six stream teams around the six main sub-watersheds in the basin to address these concerns (highlighted in Fig. 1). The Upper River Stream Team (URST, also referred to here as 'the stakeholder group') has been among the most active with river restoration projects. Comprised of 30 members (with approximately twenty core members) they primarily represent local government,

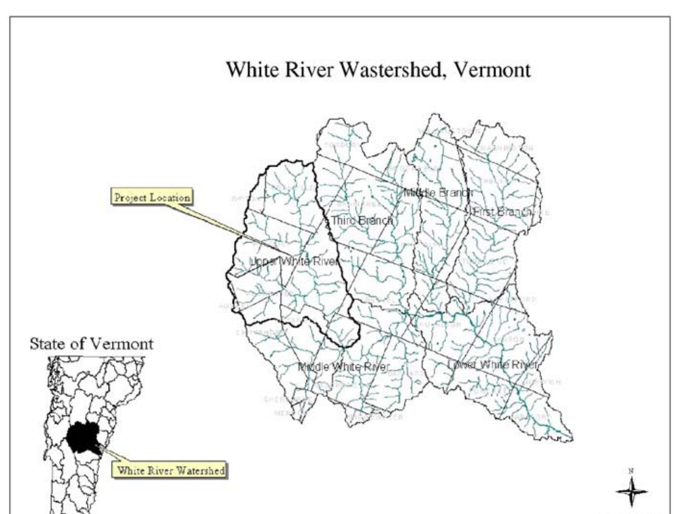

Fig. 1. White River Watershed.

private landowners, farmers, and US Forest Service interests, however all watershed citizens are welcome and encouraged to participate.

In recognition of the WRP's accomplishments in river restoration and commitment to public involvement, in 1999 they were designated a National Showcase Watershed by the Environmental Protection Agency, and in 2000 selected as one of only 12 US watersheds to receive a 5-year US Forest Service Community Based Watershed Restoration Grant. This commitment to and recognition of community-wide involvement is critical to successful river management for several reasons. Individual property owners, river users, and municipal governments in the watershed cannot effectively manage the White River independent of each other due to downstream and upstream externalities from any local action. Rivers do not follow political boundaries and watershed-based decisions require community, regional, state and federal cooperation. The financial cost of channelization have been borne primarily by the State of Vermont, however, it is expected that local municipalities' financial responsibility for flood damages will increase in the future (Kline and Cahoon, 2003).

In 2004, with a growing interest to take a more holistic approach to river restoration, the URST within the WRP undertook a community planning process to assess management alternatives for eight reaches (totaling 14 miles of river) of the Upper White River. The planning area passes through the rural towns of Granville, Hancock, Rochester and Stockbridge, with populations of 298, 377, 1183, and 684, respectively. Land use by cover type include forest (47.2%), agriculture (29%), residential (21.5%), wetland (1.6%), shrub (0.4%), and commercial (0.2%) (White River Partnership, 2003). At the core of deliberations was a River Management Program proposed by the Vermont Department of Environmental Conservation (DEC) to "find agreement for resolving conflicts between human investments and river dynamics in the most economically and ecologically sustainable manner" (Kline and Cahoon, 2003). The program identifies four alternatives to manage Vermont's rivers, including continued channelization, active geomorphic, passive geomorphic, and a combination of these alternatives (each defined in Table 1).

Analyzing these alternatives require deciphering and discussing complex information on river dynamics in a decision environment of high uncertainty and diverse stakeholder knowledge and values. Using the framework described below, the group formulated a vision for the Upper White River, evaluated the DEC river management alternatives, discussed next steps and priorities, and have begun to compose a management plan based on their assessment. The plan will position the citizens of the Upper White River and WRP to apply for implementation funding, assist towns in their planning efforts, and, in the event of a major flood event, apply for Federal Emergency Management Agency assistance. Issues of group selection and representation, description of the general MCDA decision framework and process, and details of the specific outranking methodology used are discussed in the next section, followed by results, discussion, and concluding remarks.

3. Methodology

3.1. Group selection, representation, and facilitation

Critical to any group process is the selection of group members to represent interests, and a fair and open group facilitation (Carpenter and Kennedy, 2001). For group selection the research team was at a disadvantage since the URST had already been formed based on past interest and active participation in river restoration activities. The WRP is a membership organization that uses community-wide newsletters, annual meetings, and seasonal events (such as fall harvest festivals) to recruit new members and seek broad community input. Representation of key stakeholder interests such as agriculture, recreation, riparian land owners, and state and federal agencies were recruited through direct invitation by staff of the WRP. Participation was voluntary but encouraged throughout the process

Table 1
River corridor management alternatives for resolving historic and ongoing conflicts between river dynamics and land use expectations (Kline and Cahoon, 2003)

Channelization Maintain rivers in a channelized state through dredging and bank armoring applications. Active revegetation and long-term protection of a wooded riparian buffer is important to this alternative
Active geomorphic Restore or manage rivers to a state of dynamic equilibrium by designing and constructing a stable planform in a relatively short period of time. This may include human-constructed meanders, floodplains, and bank stabilization techniques. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative
Passive geomorphic Allow rivers to return to a state of dynamic equilibrium through a passive approach that involves the removal of constraints from a river corridor thereby allowing the river, utilizing its own energy and watershed inputs to re-establish its meanders, floodplains, and self-maintaining, sustainable equilibrium condition over an extended time period. Active riparian buffer revegetation and long-term protection of a river corridor is essential to this alternative
Combinations of the above alternatives Use a combination of alternative approaches to accommodate the varying constraints that typically occur along a project reach.

by constant communication in person, by phone, letter, and e-mail.

The participatory process consisted of monthly workshops, held over a 10-month period, structured by the MCDA framework described below. A professional facilitator, experienced in environmental facilitation, was used in each meeting to ensure that the proceedings were fair and democratic. Before this process, the group's common process was to engage in informal, unstructured conversations to make group decisions.

In their capacity as stewards of the river, the group acted as both a decision-making body and special interest group. The group strived to represent the diverse interests of the local communities, and in fact designed and helped to facilitate a public opinion survey toward the end of the process to compare their knowledge and values with those of the general public. The survey, implemented at a local harvest festival in the fall of 2004, did suggest that their knowledge and direct experience with the river was higher than the average watershed citizen and also more clearly on one side or another of the issues. Table 2 captures the survey results of public opinion across a number of issue statements, highlighting a fair degree of neutrality or uncertainty about many of the more contentious issues discussed by the group. Statements with at least 20% of those polled expressing neutral opinions include issues of public access, rights of land owners, economic impacts of conservation, public ownership, environmental impacts of growth and development, passive management, pollution perception, private or not-for-profit conservation, and erosion protection.

3.2. Outranking MCDA

Natural resource decision problems generally involve the evaluation of several possible solutions across multiple criteria in order to achieve a specific goal or objective. Such problems are rarely a matter of choosing a solution based on the optimization of a single, well-defined criterion (Guitouni and Martel, 1998). In addition, ignorance and uncertainty among stakeholders is often the case (especially when there is a high level of public participation), as well as a high level of data imprecision and incompleteness (Faber et al., 1992). For examples of the use of MCDA in water resources, see Abu-Taleb and Mareschal (1995), Hyde et al. (2005), Flug and Seitz (2000), and Joubert et al. (2003).

To explicitly account for multiple criteria, objective and subjective measurement, and the role of ignorance and uncertainty in preference development, an outranking MCDA approach was used to structure and evaluate the deliberations of the URST. Preference refers to the economic connotation of factors that dictate an individual's demand for a good or service. Outranking refers to the performance of an alternative against the other alternatives with three possible outcomes: (1) Alternative *a* outperforms or outranks alternative *b* on a given

Table 2
Results of public values survey from harvest festival ($n = 121$)

Survey statement	Agree (%)	Neutral (%)	Disagree (%)
Landowners should be given incentives to enhance streamside habitats	87	11	2
It is important to provide erosion protection for prime agricultural soils, regardless of the cost	75	20	5
It is important for river banks to be naturally stable and shaded by self-sustaining vegetation	93	6	1
Pollution from septic systems, fertilizers, and manure spread on fields next to the river is a problem in the river	63	24	13
The river should have deep pools that are naturally created and maintained by a meandering river	82	15	2
The river should be allowed to run its natural meandering course to guard against long term flood damage/risks, even if that negatively affects private landowners	56	26	22
Land adjacent to the river should be conserved by private landowners and not-for-profit organizations to ensure the health of the river over the long term	73	21	6
Land along the river should be in public ownership wherever possible	43	32	35
Zoning should be in place to prevent development in the floodplain	74	18	8
Availability of outdoor, river-related recreation is important to our communities	94	5	1
There are not enough public access points to the river	33	41	25
Individually owned properties are part of a much larger natural system and when making decisions about the river, downstream and upstream effects of these decisions must be considered	85	12	3
Both ecology and economics should be considered when making decisions about natural resources	91	6	3
Landowners should be permitted to do as they please with their land	27	34	39
Growth and development are threatening the natural, historic, and scenic resources of the White River	64	28	8
Efforts to conserve the natural and scenic resources of the White River are threatening growth and development in the watershed	10	35	54

criterion; (2) alternative *a* is outranked or outperformed by alternative *b*; and (3) alternative *a* does not outrank, nor is it outranked by alternative *b*. As such, outranking MCDA tools for preference elicitation do not emphasize Pareto optimal solutions or utility maximization, but aid the decision process by ranking alternatives across multiple criteria. Partial or incomplete rankings of alternatives may result by explicitly incorporating uncertainty, ignorance, and stakeholder indifference between available alternatives (Bouyssou et al., 2000; Bender and Simonovic, 2000).

There are two families of outranking MCDA methods that include Elimination et Choix Traduisant la Realite (ELECTRE) (Roy, 1985) and preference ranking organization method of enrichment evaluation (PROMETHEE) (Brans and Mareschal, 2005). PROMETHEE was chosen for the collaborative process over the ELECTRE methods for several reasons. PROMETHEE theory and methodology are easier for stakeholders to understand (Klauer et al., 2002). We also found PROMETHEE to be more amenable to stakeholder involvement at every stage of the process through, for example, changing criteria weights or testing different preference functions (Brans and Mareschal, 2005; Pomerol and Barba-Romero, 2000; Mahmoud and Garcia, 2000). In addition, Brans et al. (1986) found PROMETHEE rankings to be more stable than ELECTRE rankings.

The PROMETHEE family includes PROMETHEE I, II, V, and VI. The main differences are PROMETHEE I gives a partial ranking of the alternatives, version II also allows a complete ranking, version V includes segmentation constraints, and version VI is used when precise weights are not allocated. We used PROMETHEE II in order to estimate both partial and complete rankings for the alternatives, as well as accommodate a large number of stakeholders, criteria, and alternatives. We found this version particularly well suited for use in large groups with diverse opinions. In this capacity, outranking was used as a group process that supported the development of a shared understanding of different perspectives and facilitated the social learning of the group as a whole. If stakeholders are not able to communicate around a common framework, collaboration becomes very difficult as they instead operate from their individual frames of reference (Gray, 2004).

In order to use PROMETHEE to evaluate river management alternatives two major components were required: (1) the development of an evaluation or performance matrix showing how the alternatives perform on the selected criteria; and (2) a measurement of each individual stakeholder's preferences. Preferences consist of three elements: (1) the minimization or maximization of each criterion; (2) the degree of preference for different amounts of a criterion (intra-criterion preference); and (3) relative importance between each criterion (inter-criterion preference). The approach of PROMETHEE as developed by Brans and Mareschal (2005) is outlined in Appendix A. The next section discusses the process of developing these key components to the MCDA.

3.3. *Group process*

The monthly workshops followed the PROMETHEE structure as ideas were formulated into values and then criteria. Stakeholders' preferences for the criteria were then elicited and discussed. The quantification of these preferences is what set this process apart from typical discursive group processes.

As a first step, the stakeholder group was educated about river dynamics and ecology and river management alternatives by DEC scientists. The group then collaborated on a creating a future vision of the Upper White River a generation from now. In tandem with this, the group brainstormed a list of what they valued about the river. Table 3 describes the vision and values generated by the stakeholders.

This collaborative vision and values were then broken down by the group into achievable objectives and 18 criteria (Table 4). These criteria were measures against which the river management alternatives might be assessed in terms of achieving the stakeholders' objectives and were divided into economic, social/cultural, and environmental indicators.

At this juncture, the 18 criteria were reduced into five measurable criteria through deliberations of an expert group, with consultation and final approval by the larger stakeholder group. The expert group consisted of the WRP coordinator, Forest Service scientists, Vermont DEC scientists, and the MCDA researcher. The stakeholder group, of which all members of the expert group were a part of with the exception of the MCDA researcher, felt that the process of coming up with five *measurable* criteria from the list of 18 was beyond the capacity of the group and that it would take too much time. The task of defining the criteria was given to the expert group. Indeed, the expert group struggled with the development of the quantifiable criteria and it took a great deal of time to develop the final list of five criteria. Although PROMETHEE can handle a large number of criteria, five were chosen due to the constraints presented by the use of conjoint analysis to enhance the PROMETHEE process. Conjoint analysis was used to elicit and quantify the preferences of the stakeholders. For a detailed description of conjoint analysis and its use in this project, please see Hermans (2005a).

The final five criteria are described in Table 5. Driving the development of the criteria was the desire to focus on environmental and socioeconomic criteria and to represent the larger group's values. From the list of measures, the most important and representative of the other measures were chosen. For example, of the six indicators of a socioculturally healthy river, *number of high quality pools* was chosen as a proxy for recreation opportunities (swimming and fishing) and it is also an environmental indicator for a healthy river. Educational opportunities, community commitment to stewardship, and mileage of trails were not

Table 3
Vision and values for the river identified by stakeholders

Vision for the Upper White River

This vision describes our dream for how the community will relate to the White River over the long-term. In thirty years, we will have a peaceful relationship with the river. It will have regained the sinuosity and access to floodplain necessary to slow erosion and reduce damage during flood events, while areas of hard armoring exist only where necessary to protect infrastructure. The community understands river dynamics and limits the way in which they constrain it through public and private investments. A corridor for the river has been established along the entire 12 miles of the main stem and riparian buffers from 35 to 200 feet in width are growing along the whole river. Meanders will create deep, self-maintaining pools that provide outstanding swimming opportunities as well as habitat for a healthy, naturally regenerating trout population. Agriculture is flourishing, with many new enterprises having come to the valley once the river conflicts were minimized. More people are able to make their living in the town in which they live, because of our healthy local economy that includes value added products, agriculture, forestry and tourism. The river is a focal point for the community, with educational programs in the schools incorporating it into their curriculum on a regular basis

River values

In 30 years, we hope for…

- A river that creates and maintains its own swimming and fishing holes
- A river that has high water quality, a healthy trout population, and banks actively vegetating as much as possible
- A corridor with thriving recreational opportunities for residents and visitors, including swimming, fishing, canoeing, pedestrian/biking trails, picnicking, hiking, biodiverse forest, and wilderness areas
- A sustainable working landscape with active agricultural, forestry, recreation, and tourist economies—to support residents in earning their living without having to leave the Valley or allow big box stores, strip malls, and housing developments to alter the landscape
- A healthy, functioning river without human/river conflicts, where all human/river conflicts have been resolved
- A community that retains local authority and power to decide best management of the river, without intrusive restrictions (e.g. externally driven wilderness designations)
- Local decision-making processes that integrate human/river needs and are informed by better maps, information, education, and a commitment to the river corridor stewardship
- A community that understands river dynamics, river risks, floodplains, belt-width, flood damages and costs, etc.—and strives to develop land and manage the river in ways that minimize the risks of flood damage and costs (e.g. discouraging new housing and commercial development in floodplains)
- A community that realizes Mother Nature will alter landscape at unpredictable times and in unforeseen ways, and responds to flood events in ways that encourage the river to seek equilibrium and hold down long-term costs
- A community that invests adequate resources in river restoration and corridor protection efforts and has funding available to respond to opportunities as they arise
- A community that balances human and river needs effectively and is looked to by other communities as a model for river management
- A community that educates its children about river history and river dynamics, and creates opportunities for school involvement in river stewardship

Table 4
Measures of a healthy river

Indicators of an economically healthy river

1. Acreage in agricultural use (maintained or increasing)
2. Acres of prime agricultural soil conserved (maintained or increasing)
3. Number of residents employed within the valley, not having to commute elsewhere
4. Number of residents employed in agriculture, forestry, and recreation jobs
5. Number of visitors attracted to the valley for recreation/tourism
6. Reduction in flood hazards/economic damage/repair and maintenance costs

Indicators of a socially/culturally health river

7. Number and depth of swimming/fishing holes
8. Number of recreation opportunities (fishing, canoeing, trails, etc.)
9. Mileage of trails
10. Acreage within local control for decision-making about future use
11. Evidence of community commitment to river stewardship in local decision making
12. Number of opportunities for children to learn river history and dynamics/number opportunities for school involvement in river stewardship

Indicators of an environmentally health river

13. Water quality data
14. Number/size/variety of fish
15. Percentage of river with meanders
16. Percentage of river with access to floodplains
17. Percentage of river with riparian vegetation
18. Measures of biodiversity/wildlife habitat

Table 5
Criteria developed from original measures

Maximum acceptable amount of land taken out of agriculture or development over 30-year period	Different management strategies for the river will result in different amounts of land taken out of agriculture or development, providing room for the river to meander and to have access to the floodplain. This will reduce flood damage and erosion, and will improve the habitat of the river. This land is measured in acres.
Maximum acceptable cost borne by local taxpayers to manage one mile of the river	Different management strategies for the river will have different costs of implementation and maintenance. These costs can include average maintenance and land acquisition costs, as well as one time construction costs, depending on the management strategy employed. They do not include flood damage costs. Long and short-term river management costs are taken together here over a 30-year period. These costs are paid by you with taxpayer dollars. In the future, these costs may likely be incurred locally. (These do not include the costs that might be added or avoided from management decisions made upstream and downstream.)
Desired number of high quality pools	High quality pools provide deep water for recreational opportunities and fish habitat. These pools are typically formed along the outside of a steam's meander bend. Under various management scenarios, the number of pools will increase or stay the same over time.
Desired percentage of the river section that minimizes flood damage through meandering and river access to floodplain	A meandering river, with access to the floodplain, is more stable, resulting in less erosion and reduced flood impacts. Public and private investment is minimized in the river corridor and the floodplain.
Desired percent of river section with more than 35 feet of vegetative buffer	All river management alternatives result in at least a 35 foot buffer. The wider the buffer the more benefits you get from the buffer. Buffers are an important feature of a healthy river. They stabilize the river bank and protect against erosion. They offer quality wildlife habitat, provide shade to keep water temperature down, and are an indication of high animal and plant diversity.

Table 6
Data estimations for rural 1-mile stretch of the river

	Channelization	Active geomorphic	Passive geomorphic
Economic			
Acreage lost	1 acre	38 acres	75 acres
Cost of river management/year	\$80	\$100	\$20
Social/cultural			
Percent of high quality pools	Does not change	Increases	Increases
Environment			
% Meander	22	75	75
Width of buffer	35 feet	35 feet	150 feet

immediately dependent on the three management alternatives being evaluated.

To represent the economic indicators, the indicators *land taken out of agriculture* and *cost borne by local community* were chosen. This was driven, in part, from a lack of data on tourism in the valley and the uncertainty in assessing future monetary damages resulting from various degrees of flooding. The group felt that the amount of land taken out of agriculture was the best way to represent the effect of the management alternatives on prime agricultural land and agricultural employment. The cost of the management alternatives was an important factor, although, as evident by the results, it was considered by many to be the least important criterion.

3.4. Data estimation and preference elicitation

Data estimations for the performance of each river management alternative on the five criteria were developed by experts. This was also a difficult and crucial part of the MCDA process. Estimations were based on data collected by WRP over the last 10 years, and projected into the future under the three alternatives. In order to attempt to capture the uncertainty of the data estimations and future river form under the alternatives, qualitative variables were used in the data matrix and ranges were used in the conjoint analysis survey. The conjoint survey is reproduced in Appendix B. Table 6 shows the data estimated for each alternative.

In order to capture the stakeholder group's opinions and preferences for the criteria for input into the PROMETHEE model, a detailed survey was administered to the stream team. The survey estimated stakeholder preferences as intra-criteria importance weights through a conjoint analysis survey and a 100-point allocation question to check for consistency. Unlike typical weighting exercises in MCDA, conjoint analysis reveals implicit weightings by having respondents rank hypothetical bundles (see Appendix B), thereby minimizing strategic bias. Attribute weights are then deduced through regression analysis. For a review of conjoint analysis, see Kuhfeld (2005) and Green and Srinivasan (1990). Respondents were also asked whether they wanted to minimize or maximize each criterion, as well as a variety of opinion questions on land ownership and conservation strategies. The quantification of preferences during facilitated group discussion provided for tangible results and points of discussion for the group to defend or clarify their positions.

The next step in the process was to run the PROMETHEE model using the river management alternatives, criteria, intra-criteria weights, and minimize/maximize information for each individual stakeholder. This model can be run in real time, with each stakeholder in front of a computer, participating in the analysis. However, due to meeting constraints, the analysis was completed by the MCDA analyst and then presented and discussed at a monthly meeting. Using PROMETHEE DecisionLab 2000 software, rankings of alternatives were established for each individual stakeholder and for the group as a whole (assuming equal equity weights between group members).

At the last meeting of the group (in this stage of their work), the conjoint analysis portion of the survey was re-administered to the team to capture changes in stakeholders' weights that occurred during the stakeholder discussions. The purpose of the second survey was to measure changes in individual respondents' preferences as a result of the group discussions. Results are reported in Hermans (2005b). The final step of this 11-month process trial was then to put a 'next phase' into place. Discussions about applying the management alternatives to specific sections of the river began with the intention of charting out management alternatives for the entire Upper White.

4. Results and discussion

The MCDA analyst beginning this process assumed that the results most interesting to the group would be the rankings of the alternatives. The PROMETHEE procedure and associated software is able to quantify and visualize the decision space and where each stakeholder stands in this space, relative to each other. It was hypothesized that group discussion would center around the alternative rankings, as that had been a contentious topic in prior discussions. Stakeholders came into this process divided into two predictable camps—pro-channelization and pro-active management. The outcome for the overall group ranking actually indicated passive management as the preferred alternative, a result we assumed would generate a great deal of discussion. Additionally, many of the members who publicly advocated for a continued channelization approach had a preference for active or passive management according to the PROMETHEE results.

However, group deliberations focused less on the outcome of the rankings, and more on the preferences for the five criteria. The quantification of stakeholder's preferences allowed stakeholders to understand and discuss where both conflicts and agreement in preferences existed. Stakeholders were interested in discussing why they held these preferences and not necessarily the alternative rankings they produced. Between 14 and 18 stream team members participated in the majority of workshops over the 10-month period and 16 members took the survey. Fig. 2 highlights the diversity in individual stakeholders' preference weights for the different criteria, with each bar for each attribute representing each of the 16 respondents. Fig. 3 highlights the percentage of respondents who preferred to maximize or minimize the individual criterion.

From the respondents' weights and the performance estimations of the management alternatives, individual stakeholder preferences for the management alternatives were estimated. Five stakeholders favored adopting a channelization approach over the active and passive geomorphic approaches. These members were all riparian landowners, and two of them farm their land extensively up to the river. They attach a high level of importance to minimizing the amount of land taken out of agriculture.

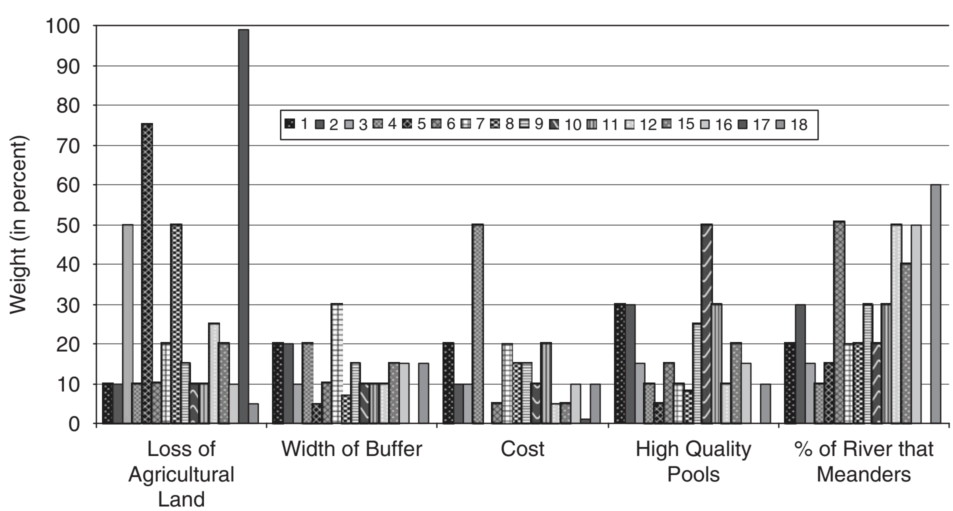

Fig. 2. Variability in individual stakeholders' weights for river characteristics.

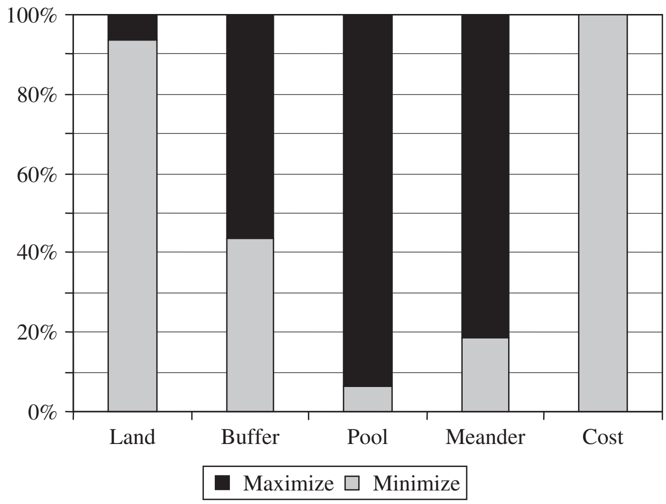

Fig. 3. Stakeholder maximization or minimization of criteria.

Nine members favored a passive geomorphic approach, and two members preferred an active geomorphic approach. Members that favored a passive geomorphic approach preferred a meandering river with wide buffers. Many of these members, before the quantification of their preferences, had advocated for a channelization approach or channelization with some active geomorphic management. However, none of them disagreed with the PROMETHEE rankings. Instead they seemed to accept that their preferences indicated a different approach than expected. The aggregate ranking for the group (assuming equal equity weights for each individual) was passive management over channelization over active management.

During the ensuing discussions over differences in criteria preferences, members discussed the implications of these various preferences on their willingness to ascribe to a particular management alternative. The group expressed a general feeling that they did not have a full understanding of their individual preferences before these exercises, which had affected their capacity to make group decisions. The quantification of preference differences allowed stakeholders not only to understand others' opinions, but to also better understand their own. Stakeholders were thus better able to articulate their own preferences to the group. This proved to be a key outcome of the process. The fact that each member better understood their position made communication about river management much more productive, and some even changed their preferences as a result. The same conjoint survey was administered following the group process. The results are speculative because only seven of the 12 members who completed the pre-process survey were able to complete the post-process survey, however, some significant individual changes in preference weights and orderings were measured while some stayed nearly the same (reported in Hermans, 2005b).

The importance of the MCDA process for this group was not in the actual decision results, but in the process itself and the education that took place for the group. From a theoretical discussion of their preferences for different criteria and management alternatives, the stream team began a practical discussion of how to apply this new information. Based on their quantified preferences, discussions centered on members' opinions about public ownership of riparian land, tensions between protecting the river and individual economic needs, and the importance of community-wide education on river system dynamics. Survey results indicated that most stream team members are opposed to public land ownership as a strategy to protect the river, but are comfortable with local zoning and public access approaches. Discussions centered on river management strategies that increase the sense of local ownership, local control, local decision making, and local benefit.

Survey results also suggest that members are in conflict over the desire to manage the river for social benefits over protection of individual landowners' economic needs and way of life. Stream team members felt that it is important to conserve riparian land and to take into account the impact of individual actions on the larger system. However, they also felt that individual property rights, especially the right to protect one's economic livelihood and traditional ways of life, are important. Members felt that the establishment of wide riparian buffers and river meanders may further limit people's ability to farm. Discussion centered on how to reconcile these two opposing needs and how to ensure long-term river system health while protecting riparian landowner's property. Deliberations led to several options to address these concerns, including:

- establishment of a river conservation district,
- state recognition of a river corridor plan as a tax abatement program,
- state compensation to landowners for buffer and meander establishment,
- revenue generation through the purchase of a 35-foot access zone paid for by fishing license fees,
- experimenting with small sections of the river to determine the degree of meandering sufficient to begin taking pressure off downstream sections where land is needed for farming and
- planting low-profile species such as willows to slow erosion instead of bank-top riparian buffer plantings that obstruct viewsheds and land use.

To further explore and potentially adopt these specific strategies, the stream team discussed the need for community-wide education to increase residents' understanding of river dynamics. They believed the community needs to have demonstrable concrete results of the three river management strategies. They felt WRP should measure results from existing projects, such as pool depth and quality and channel width, and create public placards and posters raising awareness in high visibility and high traffic areas in the watershed. The stream team agreed to begin discussions on how to predict where river pools and meanders might form in the future under the three management alternatives.

During the final discussions of the process, these deliberations led to the identification of several next steps:

- Map possible management strategies on a reach-by-reach basis.
- Identify and prioritize opportunities according to various criteria such as: upstream to downstream prioritization, viable areas for pool establishment, feasible areas for meander placements, river sections where projects would take significant pressure off lower reaches, areas where projects are achievable based on landowner cooperation, and appropriate areas for “middle ground” strategies (like tree-plantings).
- Identify areas where the river needs to remain channelized and define infrastructure that should be protected.
- Develop new language to help residents reevaluate the issues—e.g. “sediment storage” instead of “gravel build-up”.

In comparing the structured decision process to unstructured discussions that took place before this process, PROMETHEE served to facilitate dialog between members about how to manage the river and consequently made the communication process more productive. Stakeholders felt that the PROMETHEE process and results served to raise awareness, generated new ways of thinking, revitalized the stream team, produced a solidly informed group, created a common language, and generated a high degree of optimism. Stakeholders appreciated that they were involved throughout the process and were able to understand how their preferences were measured and used in the ranking of the alternatives. The hired professional facilitator, unfamiliar with this method, was impressed by its ability to encourage involvement and discussions. In fact, she was initially hesitant to facilitate the PROMETHEE process with the MCDA analyst, commenting that facilitated discourse was an adequate enough structure and that quantifying the process would deter stakeholders. However, during debriefings she later expressed that the quantification of preferences and the analytical rendering of rankings was key to moving the group forward. This is, of course, anecdotal evidence. A major constraint in evaluating discursive processes is that there is no easy metric for evaluation. Therefore, we had to rely on the stakeholders’ experience of the group before and during the structured process.

The goal of this group was to educate themselves about what contributes to a healthy, sustainable river and to evaluate proposed river management alternatives. This was a very large, loosely defined goal. There is potential for this process to aid consensus-based decision-making processes, although this was not the primary objective of the group. Instead, the process was used primarily as a social learning tool. For a group striving to reach consensus or make a definitive decision, the structure for the process would be similar, however the use of the results of the MCDA process would be different. Instead of using the outcomes of the process for *discussion,* results would be used for achieving *consensus.* Here the function of facilitator is critical. In this study, we were careful to not make consensus an explicit goal given the apprehension of the group about making formal decisions. However, a side benefit is that they now feel more comfortable in making river management decisions.

5. Conclusion

The use of an analytical decision framework offered a structured and deliberative analysis of the river management problem. For this particular group, they felt the use of PROMETHEE improved their discussions and ability to move ahead, compared to their discussions before the process. Typical conflict resolution and consensus-building methods are not analytical. Due to their qualitative and discursive nature, it is very difficult to compare with analytical processes such as PROMETHEE. We hesitate to state that this method produced better results than if a discursive conflict resolution or consensus building method had been used, we can only report on impressions of the stakeholder group and facilitator.

Quantifying stakeholder preferences provided a focus for stream team discussions and enabled the group to move beyond having conversations about river management alternatives to analyzing the use of the alternatives on different reaches of the river. Science became a larger part of the conversation as the focus shifted from opinions to the facts of river system dynamics and river health. Additionally, this group went from ignoring and downplaying their differences to being able to discuss them in a non-threatening, productive way.

Compared to some MCDA methods, a major strength of PROMETHEE in collaborative processes lies in the design of eliciting preferences from each individual stakeholder. For example, methods from multi-attribute utility theory such as the analytical hierarchy process or simple additive weighting require a global preference to be established for the entire group (Hermans and Erickson, 2007). The method is also easy to understand with a high degree of transparency. The Decision Lab software in particular provides excellent visualization of stakeholders’ relative preferences. PROMETHEE is adaptable to additions or subtractions of alternatives, criteria or stakeholders, and is transparent with respect to the evaluation of the impact that such changes have on preferences and rankings. All these factors make it a good choice for structuring a group process.

In any collaborative decision-making process education is vital, especially if the subject is complex as with river system dynamics. We found the PROMETHEE method to be effective in framing the education of the stakeholders through the development of a vision, values, criteria, and the evaluation of preferences. Together with conjoint analysis, this MCDA procedure allowed the quantification of stakeholder preferences, which in turn contributed to the social learning of the group. The development of criteria and alternatives evaluation provided a basis for future discussions, a way to operationalize the stream team's vision for the Upper White River, and a measure of whether the vision is being achieved. This process is now being considered for use in other areas of the White River watershed as well as in other watersheds in Vermont.

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Appendix A

In the first step of PROMETHEE the outranking degree or multicriteria preference for each pair of alternatives is calculated (Brans and Mareschal, 2005). This is the measure of the preference for one alternative over another on all criteria. For alternative *a* in terms of alternative *b* the outranking degree is determined as follows:

$$\prod_{(a,b)} = \sum_{j=1}^{n} w_j P_j(a,b),$$

where w_j is the weight of criterion *j*, $P_j(a,b)$ is preference of alternative *a* in regard to alternative *b*.

If alternative *a* outranks alternative *b* on criterion *j*, it is preferred to alternative *b* and $P_j(a,b) = 1, P_j(b,a) = 0$. If neither alternative performs better than the other, $P_j(a,b) = 0$ and $P_j(b,a) = 0$.

For each criterion, PROMETHEE can accommodate indifference and strict and weak preferences for various levels of the criterion through the use of six possible preference functions. PROMETHEE does not assign alternatives an absolute utility value. Instead preference measurements are obtained through a pairwise comparison of each pair of alternatives on each criterion. The PROMETHEE preference structure examines the degree of preference (or *deviation*) for one alternative over another on a given criterion. Stakeholders can have a weak preference or strong preference for one alternative over another, or be indifferent to either one. For example, a stakeholder might indicate that he/she is indifferent between two alternatives on a criterion up to a certain threshold (called the *indifference threshold*). Above that indifference threshold, the stakeholder might strictly prefer one alternative over another; however he/she might indicate that they weakly prefer one alternative over another up to a certain point. Once that point is reached, they will strictly prefer one alternative over the other (called the *strict preference threshold*). Fig. A.1 illustrates these preference functions and the differences in preference or *deviations.*

For this study a usual preference function was assumed for all stakeholders on all criteria on a (0,1) scale (Fig. A.1). A usual preference function was used because the criteria used in this study did not lend themselves well to indifference and strict preference thresholds. We also felt that, given the complexity of the criteria, it would be too difficult for stakeholders to define thresholds. With usual preference, alternative *a* is strictly preferred to alternative *b* for a single unit difference in criterion *j*, $P_j(a,b) = 1$, and $P_j(b,a) = 0$. Usual preference is denoted by (1) and no preference is denoted by (0).

From the outranking degrees for each alternative, entering and leaving flows are calculated. These flows measure the strength of each alternative against the other

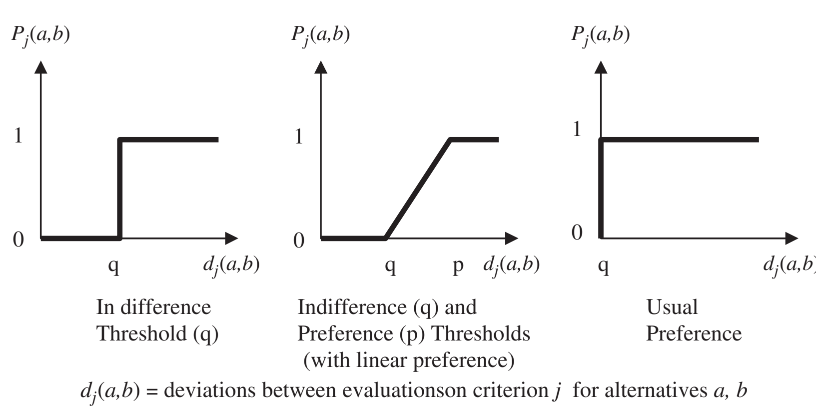

Fig. A.1. PROMETHEE preference function graphs.

alternatives and are calculated as follows:

$$\phi_a^+ = \sum_{a \in K} \prod (a, b),$$

$$\phi_a^- = \sum_{b \in K} \prod (b, a).$$

The leaving flow (ϕ_a^+) is the sum of all outranking degrees for alternative *a* against all alternatives in the *K* set of alternatives and is a measure of the strength of alternative *a*. The entering flow (ϕ_a^-) is the sum of all outranking degrees where alternative *a* is outranked or 'out-performed' by all the other alternatives in the set of *K* alternatives. The higher that the leaving flow is and the lower the entering flow is or the greater the difference between the two flows, the more the alternative outranks or is preferred over the others. From these flows, a partial or complete ranking of the alternatives is achieved. A partial ranking captures any incomparability between alternatives. For example, alternative *a* may perform well on several of the criteria, and be outperformed by alternative *b* on other criteria. Alternative *b* may perform well on several criteria and be outperformed by alternative *a* on the other criteria. Neither alternatives *a* nor *b* is clearly preferred, instead they are incomparable. For a complete ranking a net flow is computed by subtracting the entering flow from the leaving flow for each alternative ($\phi_a = \phi_a^+ - \phi_a^-$). The flows are also a measure of the strength of the ranking of alternatives. The greater the difference in flows between alternatives, the stronger the ranking.

The ranking of alternatives can be done for each individual member as well as for the group as a whole. Members each have their own weights and preferences for each criterion and do not have to agree on a common set of weights. PROMETHEE also allows these individual weights and preferences to be changed, if desired, by members. This leads to a better understanding of the perspectives of individual members and facilitates the decision process. Additionally, it ensures that each member's preferences are elicited and addresses the issue of an equal distribution of individual stakeholder power in the decision process.

Appendix B. Conjoint analysis survey

	1 Amount of land taken out of agriculture	2 Number of high quality pools in the river section	3 Width of riparian buffer	4 Percentage of the river section that minimizes flood damage through meandering	5 Annual per capita average cost borne by local taxpayers to manage 1 mile of the river—in current dollars	** Ranking 1 = best choice 8 = worst choice
A	11–20 acres	Increases over time	150 feet	10	$100	**
B	1–10 acres	Does not change	150 feet	10	$100	**
C	11–20 acres	Increases over time	50 feet	75	$100	**
D	11–20 acres	Does not change	150 feet	75	$20	**
E	11–20 acres	Does not change	50 feet	10	$20	**
F	1–10 acres	Increases over time	150 feet	75	$20	**
G	1–10 acres	Increases over time	50 feet	10	$20	**
H	1–10 acres	Does not change	50 feet	75	$100	**

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