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COLLECTIVE DECISION MAKING ON LOCALLY UNDESIRABLE LAND USES

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ABSTRACT

We use "fuzzy" analysis to give more language flexibility to outcomes of collective decision making about locally undesirable land uses (LULUs). We briefly review methods of collective decision making on LULUs for examples of decision environments which use public participation and expert opinion to moderate the conflicts found on this type of issue. We then present the strengths and weaknesses of one such decision environment, the Public Value Forum (PVF), where the traditional analytical and diagnostic tools of multiattribute utility theory and value free analysis are used. Using a scenario of stakeholders deciding on the appropriate use for a hazardous waste facility, we contrast the outcomes of the PVF with those that could be obtained if fuzzy analysis were used. Fuzzy analysis can provide a more transparent outcome of the decision process than the PVF because its use of linguistic variables offers decision makers final expressions of preferences over alternative choices that go beyond that of reject or accept.

INTRODUCTION

Locally undesirable land uses (LULUs) can be sources of conflict in a community. The siting of hazardous waste facilities is a common example. Other examples include the location of halfway houses, minimum security prisons, and rehabilitative housing units. These types of land uses often involve threats or risks to health or well-being. Other concerns include the loss of property value. Local community opposition to LULUs from various groups of stakeholders nearby often plays a major role in preventing the unwanted use. We briefly review

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selected literature for examples of public involvement in environmental decisions and for the role of risk communication and expert opinion in such examples. We then focus on the decision environment of the Public Value Forum (PVF) which also allows for compromise and moderation of views. We discuss its usefulness in conflict diagnosis and its limitations. We broaden the scope of our discussion with a synopsis of basic elements of fuzzy systems analysis and describe how fuzzy systems analysis can contribute to the use of the PVF in conflict management. Our general objective is to broaden the expression of the results of a traditional hierarchical process of collective decision making, with specific application to environmental policy issues over land use, such as those listed above.

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Public participation in environmental decision making can be limited to simply informing the affected members of the public about decisions that affect them. Or it can be as broad as having public involvement in citizen advisory groups mandated by federal or state law [1], in "legal" or "quasi-legal" arenas [2] such as the mediation or arbitration of disputes [3], in city council meetings, or in focus groups [4]. Technical expertise is usually combined with, or even pitted against, public input. In New York, for example, expert consultants have helped members of the public navigate their way through scientific terminology and explanations of technology [1]. Expert knowledge also may come in the form of testimony provided to decision making authorities, e.g., legislators, city officials, and regulators. Heath and Nathan [5] and Young [6] document the importance of this information in environmental issues. Such testimony may be looked upon with suspicion by the public, who view it as an attempt by decision makers to provide information supporting certain technologies.

However, the conflicts over environmental issues cannot be simply attributed to the lack of factual information, or even the existence of certain factual information, as important as this information may be. Value conflicts, emotional concerns, fears of long-lasting hazards to health, and the private interest of obtaining profits are also present. Keeney et al. [7] combine the necessary elements of public involvement, expression of preferences and the use of expert knowledge in the form of the Public Value Forum (PVF). In this article, the PVF is used to create an environment in which multiple stakeholders reveal their preferences with respect to the decision factors that describe alternative energy paths. We argue that the PVF has a moderating influence on the preferences of opposing stakeholders. The PVF uses value tree analysis as a descriptive and diagnostic tool.

The first stage of this decision process is to construct a value tree, which displays a hierarchy of generated values with general values and concerns at the top and the decision factors and their attributes at the bottom. Each stakeholder group identifies decision factors which would allow for differentiation between the alternatives. In this way all the decision factors are specified and values are identified.

The second stage requires a moderator to assist PVF participants in arriving at a value score for each alternative. Multiattribute utility/Multiattribute value theoretical models (MAUM, MAVM) form the basis of models used to formally evaluate alternatives shown on the value tree, and a MAU model is constructed for each participant. First of all, to measure the impact of various alternatives on the decision factors, a scale is identified or constructed to measure each of the decision factors. Then the possible impact of each alternative is estimated in terms of these scales. How much of one decision factor one is willing to give up in exchange for achieving more of another decision factor is ascertained by determining which criteria are more important than others and how much more important. This is the process of weighting the decision factors.

Ratings and weights are combined and an aggregate utility or a value score is calculated for each of the alternatives in the third and final stage. Alternatives can be evaluated using a weighted additive model. The MAUT method results in each group choosing the alternative with the highest value score. The advantage of this decision environment is that the problem is presented in a structured form with identified stakeholders. Stakeholder multiattribute utility models can be compared for differences and agreements; compromise options can be assessed on the basis of the decision tree; and the final decision using the model can be compared, and perhaps reconciled, with the rankings of the alternatives by the stakeholders before the decision making exercise was carried out. Individual and institutional decision making authorities can use the outcomes from this kind of decision process or "environment" to assist them in negotiations with stakeholders (see Figure 1).

ISSUES OF LANGUAGE

Although many controversial issues surround LULUs, the final decision outcome is still expected to be a simple yes/no, thumbs-up/thumbs-down choice. Less attention is paid to other problems of judgment in the decision process. For instance, participants in a decision environment where value tree analysis is used may have difficulty in conveying in a precise way the information needed to calculate value scores and preference weights. Uncertainty in scale responses is very common in a decision maker's choice environment. Multiattribute models may not be sufficient to capture the representation of preferences in an imprecise way. Vatn mentions the difficulty of reducing the many attributes of an environmental decision, filtering these attributes through the web of the decision maker's preferences to a single weight measure [8].

The objective of multiattribute utility analysis is prescriptive in nature—i.e., to maximize a utility function. A review of the decision made is limited to sensitivity

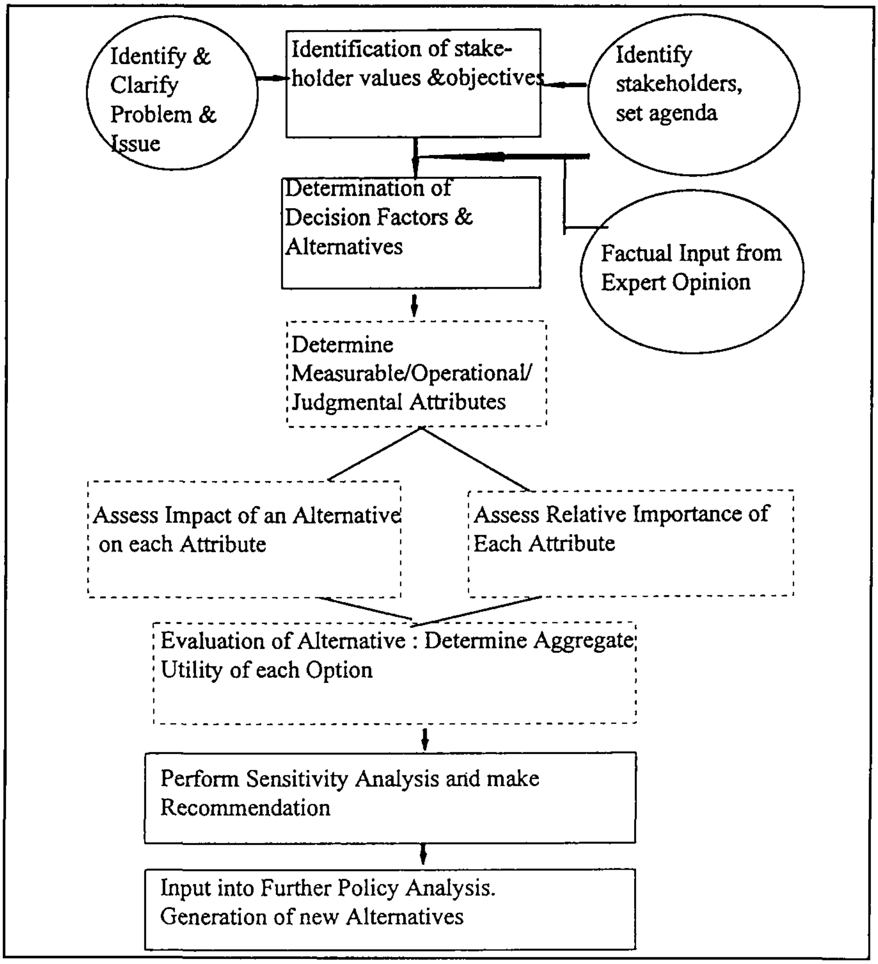

Figure 1. Flow chart of public forum decision process. Solid rectangles show diagnostic elements of the value tree, dotted rectangles show analytical elements of the decision tree. All rectangles show traditional value tree analysis. Circles show unique elements provided by PVF decision environment.

analysis, which indicates the extent to which a particular stakeholder may be "swayed" either by other alternatives or by changes in weights, or an attempt by moderators to have the stakeholders reconcile the decision from the model with their direct rankings of the alternatives.

Finally, the collective choice problem is, after all, about advancing common ways of understanding how people collectively arrive at decisions on pertinent issues. Collective choice depends on a reliable representation of the expression of individual preferences, even though individual preferences cannot be made on the basis of a simple aggregation of individual preferences alone [9]. Some organizational models [10] can deal with acceptable levels of an objective or goal. If preference functions need not be exactly quantified, then models of this type could allow a broader description of acceptable outcomes of the decision process. Further, because the new function of decision environments is not solely to come to a decision about a HWF, but to moderate the conflict, we incorporate fuzzy set theory which allows for a much more flexible expression of preferences over decision factors that describe the choices that have to be made by the decision makers (input) and a much more flexible expression of the outcomes of this type of decision environment (output). We now provide a brief review of fuzzy sets.

SOME CONCEPTS REGARDING FUZZY SETS

A central concept of fuzzy-set theory is the membership function, which represents the degree to which an element belongs to a set. A *fuzzy subset* A of a universe of discourse U is characterized by a membership function μ_A.

That is,

$$\mu_A\text{:}U \rightarrow [0,1]; \tag{1}$$

this function associates with each element x of U a number $\mu_{A(x)}$ in the interval [0,1]. $\mu A(x)$ is the membership of x in A; that is, μ_A serves as the membership function by which a fuzzy set A is defined [11].

This fuzzy set A can be formally written as:

$$A = \{x_1/\mu(x_1), x_2/\mu(x_2), \ldots, x_n/\mu(x_n)\}; \tag{2}$$

To illustrate this concept, let A designate the set of "high" risk decisions. The concept "high" is presented in Figure 2. The risk index is arbitrarily set between 0 and 10.

We could express the set of "high" risk projects as in (2):

$$A = \{5/0, 6/0.25, 7/0.5, 8/0.7, 9/0.8, 10/1.0\}.$$

We can note that a decision with an index value equal or greater than 10 is in general considered "high" risk. Also we note that a decision with a value less than 5 is definitely "not high" risk, i.e., it might be "medium" risk. Also, we note from Figure 2 that there are degrees of membership to the set of "high risk." A decision that ranks 6 would have a "risk" to a degree of 0.22, and another decision with a value of 8 would have a "risk" to another degree, 0.65. Therefore, different decision risk indices can be "high" to a different degree [12].

In the next section we use an example to demonstrate how consensus is measured using fuzzy analysis.

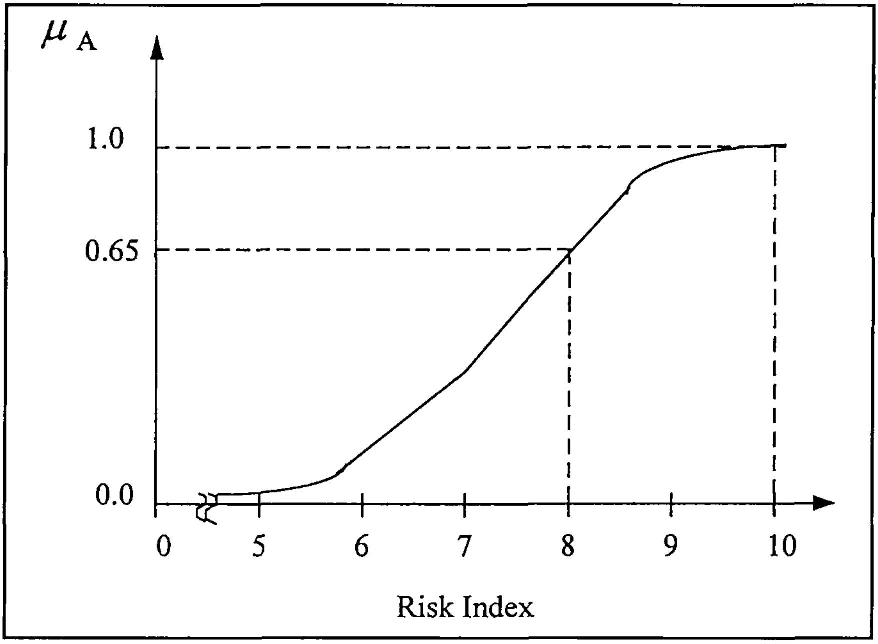

Figure 2. Illustration of membership function.

USE OF FUZZY ANALYSIS IN ENVIRONMENTAL DECISIONS

This section discusses an example used in Temponi and Charles which broadened the decision making methodology of the PVF using fuzzy analysis [13]. Fuzzy sets rely on subjective judgments which are put together by an "objective" aggregation of rules. Fuzzy sets have been shown to be an excellent representation of linguistic expressions, especially in situations surrounded by uncertainty [14, 15]. The decision is whether or not to accept the alternative use of a site for the burning of hazardous waste based on the degree of acceptability each stakeholder may have on each measure of the decision factors. Acceptability is a fuzzy linguistic variable. Thus the term may be qualified by "Low," "Medium," and "High." When the linguistic variable and the fuzzy restrictions are combined, the result is a fuzzy set—for example "Low acceptability" is a fuzzy set [16]. Typically there are three perspectives to consider: the community's decision, the local authority's decision, and the developer's view. There was only one developer in the case study in [13], but many developers could be included in the process; stakeholders defined not only the meaning of acceptability, but also the guidelines of what was acceptable for each decision factor. Table 1 summarize the guidelines for each decision factor.

Each stakeholder had to also assign a relative weight of importance to the attributes. An example of these relative weights can be found in Table 2. A well known method, the Analytic Hierarchy Process [17], can be used to estimate these weights. The Analytic Hierarchy Process (AHP), consists of comparing pairs of decision factors, let us say decision factors i and j. Information resulting from the paired comparisons reflect the qualitative judgment among decision factors. A rating is assigned to the preference based on the linguistic measures of preference developed by Saaty [17] and presented in Table 2.

In [13], importance weights were also expressed in a non-traditional manner, using linguistic terms instead of the traditional numeric format. Finally, the outcome of the decision process was described so that each one of the stakeholders could express his opinions and thoughts in natural language and information could be processed in a similar fashion. The final "output" could well be a compromise of the parties involved, with less friction and more possibilities for a successful and fair decision for all. We extend this use of fuzzy analysis to consensus measurement as a by-product of its ability to capture fuzzily defined expressions and/or linguistic expressions commonly found in conflicts over LULUs. The use of a fuzzy linguistic term makes it possible to move beyond the limitations in the description language of the decision factors used in the PVF,

Table 1. Guidelines for an Acceptable Decision

Decision Factor	Requirement
Monetary Impact	Good Economic Benefits
Risk Reduction	Many Risk Reduction Measures in Place
Risk Reference	Good History of Reducing Hazards
Health	Low Impact on Health
Environment Quality	Low Impact on the Environment

Table 2. Measures of Linguistic Preference

Intensity of Importance	Definition
1	Equal Preference or Indifference
3	Weak Preference
5	Strong Preference
7	Demonstrated Preference
9	Absolute Preference
2, 4, 6, 8	Intermediate Values

and from outcome expectations of simply a moderation of views to a consensus of view.

OUTCOMES OF THE FUZZY ANALYSIS APPROACH

Now let us place the framework of the previous section in the context of the traditional utility-theoretic approach of the PVF. We want to contrast the way in which the outcomes of the PVF are expressed and analyzed with the way in which it is possible to express outcomes using fuzzy analysis. Final reports of the PVF would compare the final rank ordering of different decision factors by different stakeholder groups. For instance, there may be some difference between the final rank ordering given to Environmental and Health concerns by the community's interests and that assigned by the local authority, but the difference in ranking may not be that great. Perhaps the local authority's concerns ranked the Environment over Health concerns. The Forum facilitator would explore the possibility that this group may have become convinced of the developer's claim, and that of expert opinion, that the alternative use of the facility would not present any greater health risk than the present use of the facility. This would be verified by comparing their initial direct rankings on the decision factors with their final rankings. A large change from their initial direct rankings might indicate that they were convinced by the persuasive arguments of the developer, or by expert opinion. The weights would not be the only discriminators between stakeholder groups. Differences among stakeholder perceptions might also be seen in the value scores of the two alternatives on a particular decision factor. Finally, since during the PVF there may have been strong disagreements in judgments within a particular stakeholder group on rankings, the Forum facilitator would perform sensitivity analysis to see to what extent a change in this group's rankings would change the overall evaluation of an alternative.

The overall evaluation may not result in a clear choice of a winning alternative. However, traditional analysis is expected to yield an output or outcome of yes or no, reject or accept, or one of consensus or no-consensus, based on the value score of the alternative. As we can see from the previous paragraph, conflict management will occur to the degree to which rankings and value scores can be reconciled or the differences accounted for. On the other hand, inclusion of fuzzy systems analysis into the Public Value Forum decision making environment will build on the degree of acceptability each stakeholder may have. Final output would be, in this case, a spectrum with dichotomous ends of consensus/no-consensus. The fact that stakeholder A1 may design low degree of acceptability to the project and stakeholders A2 and A3 assign relatively high degrees of acceptability to the project does not require a decision on the project to be simply consensus/no-consensus; instead, it will allow the outcome of the decision on the project to be "a relatively high consensus." Likewise, the project could end with all stakeholders conveying a "low consensus" due to their preferences translated as low acceptability through the decision factors. Our discussion assumes equal importance weight from each stakeholders; however, the process could be established for varying impact from each decision maker. A final decision in this type of analysis is now reached with a more thorough impact from each decision maker. A final decision in this type of analysis is now reached with a more thorough understanding of the voice of the participants involved. For instance, the language of the outcome of the decision process may be expressed in the following way: Acceptability is low on Alternative 1, so we recommend that the local authority not proceed with this Alternative. In this way, the local authority has flexibility in the language of the outcome of the decision process, which would be more useful in future negotiation and resolution of community conflict, and can decide whether or not to accept the risk of following the recommendation.

We note that precautions must be taken to limit strategic behavior by participants, since the nature of locally undesirable land use and the stakeholders involved both lend themselves to the presence of hidden agendas. Further, the complexity of the problem requires that care be taken during the elicitation stage to clearly identify the problem and clarify the values being addressed. The credibility of any recommendations emerging from the forum will rest on clear problem identification and value clarification during the initial stages of the PVF. As useful as fuzzy systems analysis and the PVF can be as analytical and diagnostic tools, they can never substitute for the cooperation among decision makers on what can be very time consuming and costly decision making process.

SUMMARY AND CONCLUSION

Our analysis proposes the use of fuzzy analysis to broaden the language in which outcomes are expressed as a result of the PVF decision environment which is already designed to be flexible, accommodating, and inclusive of all the participants involved. We have suggested ways to enhance the hierarchical decision making process used in the PVF with fuzzy analysis in a way which preserves public involvement and risk communication through expert opinion, but which allows for outcome descriptors which are more expressive about the outcome of the decision on a land-use project. We believe that when there is a more thorough understanding of the voice of the participants involved, the outcome of the decision process can be expressed in language which is more transparent, contributing to the management of conflict seen in policy issues involving LULUs. Further work would be required to refine the methodological and analytical tools and techniques for collecting preference information from Forum participants and for calculating statistics, such as average weights and average utilities, for comparing stakeholder (or other) groups.

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