AN APPLICATION OF MULTIATTRIBUTE ANALYSIS IN STATE ENERGY PROGRAM SELECTION

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by

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INTRODUCTION

Despite recent declines in the price of oil, the design, selection, and implemention of energy programs remains an important planning activity for state governments. The recent transfer to states of $2.1 billion of Exxon oil overcharge funds is the latest impetus to energy planning.[1] The long-term instability of oil prices and the likelihood that oil prices will rebound sometime in the next few months to five years provides continuing impetus for energy planning.

The State of Wisconsin is in the midst of a major effort to design and ultimately select and implement promising energy programs. To date, five programs have been evaluated, with one of those implemented and two others, that were operational, discontinued. Because Wisconsin has received $37 million of Exxon oil overcharge funds, a large number of new programs are being recommended to the Wisconsin Division of State Energy and Coastal Management (DSE), located within the Department of Administration. The primary source of recommendations are coming from a set of Energy Advisory Committees (Industrial, Commerical, Residential, Transportation, and Low Income) established as part of the Governor's Energy Efficiency Plan.[2]

The problem faced by DSE is how to choose among the large number of programs being proposed in the context of multiple conflicting objectives. Programs with the largest energy savings are likely to be larger and more costly to the state budget. Achieving large energy savings is more easily achieved with a few large energy users than with many small users. Thus maximizing energy savings may conflict with reaching the greatest number of citizens. Somehow, conflicting objectives must be considered and trade-offs made in deciding which programs are the best and which, if any, should be funded. Multiattribute utility theory can be used to make these difficult trade-offs in comparing and ranking programs. At the request of DSE, members of the Energy Systems and Policy Research Program and the Department of Urban and Regional Planning at the University of Wisconsin-Madison (UW) worked with DSE staff in developing a multiobjective decision analytic framework for program evaluation.[3] This framework is an aid to decision-making, not a substitute for decision-making.

The next section of this paper provides a brief overview of the decision framework and its application, which is followed by a section discussing the preferences of energy decision-makers in Wisconsin. These preferences are different than what had been anticipated by the DSE, and has led to some important insights into the operation of the DSE and the difficulties in having the decision analysis framework accepted by some personnel in the DSE. The fourth section of the paper presents the results of the evaluation of five programs. The paper concludes with observations on the usefulness of the framework to date and its role in the upcoming evaluation of programs proposed for the Exxon funds.

MULTIATTRIBUTE DECISION ANALYSIS FRAMEWORK AND APPLICATION

A multiattribute decision analysis procedure was selected as the framework for evaluation of the programs. This evaluation procedure has two main components: 1) the quantitative estimation of the "impacts" (economic, physical, environmental, etc.) of each of the programs under evaluation; 2) the quantification of a "preference" model for evaluating these impacts, based upon a value system deduced from interviews with energy decision- and policy-makers. This approach has the advantage of using multiple units of measure of program impact and of being able to incorporate the preferences of decision-makers such as legislators, the Governor's staff, and other state officials and program managers.

Decision analysis is a systematic procedure for analyzing complex, multi-objective problems. The methodology has been applied to numerous energy related problems[4,5,6,7,8,9] and was judged to be superior in this particular situation to alternative approaches[10] such as cost-benefit analysis which utilizes a single unit of measure. A decision analysis procedure was familiar to DSE in that it had been used in designing state energy conservation plans.[11]

Multiattribute Utility Theory

Before describing the specific decsion framework and application, utility theory is briefly reviewed. Utility theory is used to compare alternatives with multiattribute consequences and logically determine which is most preferred. For a set of attributes $\underline{X} = (X_1, X_2, ..., X_n)$, where x_i represents a specific level of X_i, the consequence of any alternative can be represented by a vector of levels $\underline{x} = (x_1, x_2, ..., x_n)$ for the attributes. Attributes correspond to objectives and are measures by which the achievement of a given objective can be quantified. Utility theory provides a method for assessing a decision-maker's utility (or preference) function, U, which assigns a number $U(\underline{x})$ to each possible consequence, $\underline{x}$. The utility function has two important properties:

* $U(\underline{x}) > U(\underline{x}')$ if and only if $\underline{x}$ is preferred to $\underline{x}'$, and
* In situations involving uncertainty, the expected value of U is the appropriate index with which to evaluate alternatives

If preferential and utility independence conditions hold for a decision-maker, then the multiattribute utility function $U(\underline{x})$ can be broken into a series of single attribute utility functions $U_i(x_i)$ and scaling constants k_i.[5,12] Two useful forms of the utility function are:

$$U(\underline{x}) = \sum_{i=1}^{n} k_i U_i(x_i) \qquad [1]$$

if $\sum k_i = 1$, and

$$1 + kU(\underline{x}) = \prod_{i=1}^{n} [1 + kk_i U_i(x_i)] \qquad [2]$$

if $\sum k_i \neq 1$

where $U(\underline{x})$ and $U_i(x_i)$ are scaled from zero to one, the k_i are scaling constants between zero and one, and $k > -1$ is a nonzero scaling constant calculated from the k_i, where

$$1 + k = \prod_{i=1}^{n} (1 + kk_i) \qquad [3]$$

Equation 1 defines the additive utility function and Eq. 2 defines the multiplicative utility function.

A multiattribute utility function is used to rank programs. A program's performance or rank relative to other programs is determined by how well the program performs for all of the attributes.

Defining Objectives and Attributes

A series of brainstorming sessions with DSE and UW staffs were held in April 1985 to define a set of State energy program objectives. From these sessions it was determined that the overall objective of state renewable energy and conservation programs and policies is to foster the development and use of renewable energy systems and conservation. Four main objectives emerged from the sessions:

* Catalyze or facilitate renewable energy use and conservation
* Foster economic development
* Generate and provide information
* Minimize program costs

These objectives were further broken into subobjectives. These subobjectives were narrowed to a list of thirteen by eliminating those for which the choice of program would not be altered if a particular subobjective were excluded. The four objectives and thirteen subobjectives are listed in Table 1.

Table 1. Objectives and Subobjectives for Renewable Energy and Conservation Programs

Catalyze Efficient Energy Use	Foster Economic Development	Generate and Provide Information	Minimize Program Cost
1. encourage projects that would otherwise not be done 2. encourage widespread application	3. minimize net energy cost 4. maximize energy savings 5. maximize job creation 6. increase energy source diversity 7. maximize number of applications	8. provide new information 9. provide usable information 10. minimize environmental impact	11. minimize fiscal cost to state 12. maximize administrative efficiency 13. promote equity

Once these subobjectives had been identified, attributes for them were defined. Attributes are measures by which the achievement of each subobjective can be assessed. Attributes can be continuous as in the case of energy savings which are measured in Btu's (British thermal units) or they can be a discrete numerical index where a description of conditions can be associated with each point of the index. Table 2 describes the thirteen attributes, corresponding to the subobjectives, developed for use in the evaluation.

Table 2. Attributes and Ranges

Catalyzing/Facilitating the Role of the Program

1. Importance of the program to development and completion:
   Little Help Some Help Significant Help
2. Probability for technological breakthrough or innovative application gaining widespread use as a result of the program: (Percentage probability = 0 - 100%) ["Widespread" defined as 10% of potential applications within 10 years]

Economic Consequences to the State

3. Net cost of energy provided to user: [\$ 1985/10^6 Btu] (\$1.00 - \$30.00)
4. Potential maximum energy savings (or production) within ten years: (.01 to 1 x 10^{12} Btu/yr)
5. Potential state-wide long term direct job creation: (1 - 500 net jobs)
6. Increase in energy source diversity:
   High - Utilizes Wisconsin energy resource without displacing other productive use of resource (e.g., use of biomass that does not displace actual or potential agricultural use) and has potential for widespread use.
   Medium - Utilizes Wisconsin energy resource that may displace other productive use of resource and/or >=25% energy conservation of traditional fuel in application demonstrated. Potential for widespread use.
   Low - Utilizes Wisconsin energy resource that may displace other productive use of resource or <25% energy conservation of traditional fuel in application demonstrated. Low potential for widespread use.
   Zero to Negative - No use of Wisconsin energy resources or energy conservation.
7. Potential state-wide applications to individuals and firms within ten years: (10 - 500,000 applications)

Information Gained and Provided

8. Provide new unbiased information to Wisconsin energy users (those contacted). (100 - 50,000)
9. Value of information gained from program:
   High - Either demonstrated widespread practicality of promising new energy technology or infeasibiity of a promising new technology for practical application in Wisconsin. Provided new information for consumer use.
   Medium - Mixed results. Added limited new information about technology for use by energy users. Reinforced existing information.
   Low - Produced no definitive results of use to energy users or added no new information about technology demonstrated.
10. Potential net in-state environmental impacts associated with program:
   Major positive impact - Major reduction in human health, property, or eco-system damage. For example, damage reduced by up to one million dollars per year, emissions of criteria pollutants decreased more than 5% in any urban area, or person days lost state-wide decreased by more than 1,000.
   Moderate positive impact - Moderate reduction in human health, property, or eco-system damage. For example, damage reduced by up to one million dollars per year, emissions of criteria pollutants decreased up to 5% in any urban area, or person days lost state-wide decreased by not more than 1,000.
   No or slight impact - No significant net environmental impact.
   Moderate negative impact - Moderate increase in human health, property, or eco-system damage. For example, damage increased by up to one million dollars per year, emissions of criteria pollutants increased up to 5% in any urban area, or person days lost state-wide increased by up to 1,000.
   Major negative impact -Major human health, property, or eco-system damage. For example, damage in excess of one million dollars per year, emissions of criteria pollutants increased more than 5% in any urban area, or person days lost state-wide increased more than 1,000.

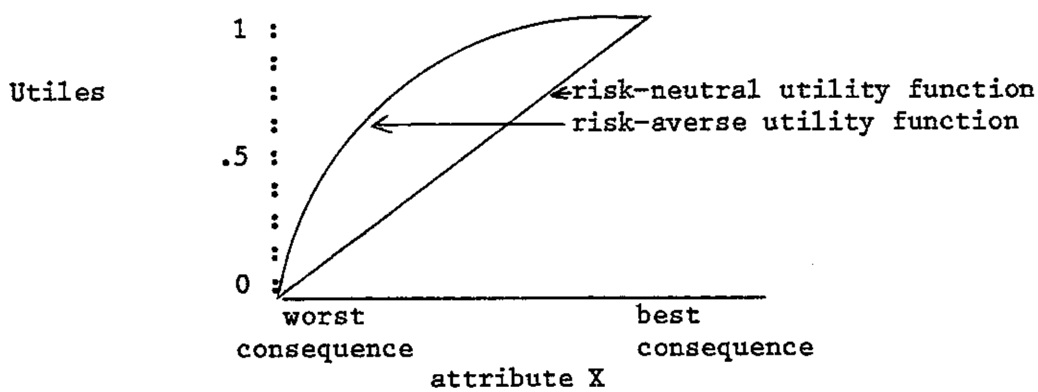
Minimizing Program Costs

11. Program cost to state: (\$50,000 - \$4,000,000 per year)
12. State employees needed to administer: (1 - 10 FTE employees)
13. Mean income of program beneficiaries: (\$5,000 - \$30,000 per year)

Decision Framework and Assessment Procedures

A simplified version of the additive multiattributre utility function, based on the method of Edwards,[13] was chosen for the decision analysis framework. This framework assumes a linear or risk-neutral utility function over the range of each attribute as shown in Figure 1. The relative importance of the attributes is determined by a weighting procedure where a decision-maker is asked to set the weight of the most important attribute to 100 and scale the rest of the attributes relative to this standard. These simplifications allow for a far more rapid although probably less accurate assessment of decision-maker preferences[13]. The procedure is also more amenable to assessing groups.

Figure 1. Example Utility Function



To implement the decision analysis framework for DSE, five state level decision-makers for energy programs were asked to participate by providing their preferences. These preferences would then be used in ranking energy conservation or renewable energy programs. The five individuals were selected because of their leadership positions in state energy policy. The five individuals were:

- Roy Christianson - Director, Wisconsin Division of State Energy and Coastal Management, Department of Administration
- Ness Flores - Chair, Wisconsin Public Service Commission
- Peter McAvoy - Executive Assistant to the Secretary of the Department of Administration (aide to the Governor on energy matters)
- Thomas Seery - Representative in the Wisconsin Assembly and Chair of the Assembly Energy Committee
- Joseph Strohl- Senator in the Wisconsin Senate and Chair of of the Senate Energy Committee

Each decision-maker was asked in a letter to participate in the energy program evaluation by providing their preferences as elicited by the assessment procedure. While the preferences of a given individual would not be identified, it was understood that the preference structures would be revealed and used in ranking energy programs. The rankings were constructed for each individual and for the group by equally weighting the five decision-makers' preferences. All five decision-makers agreed to participate. All the assessments were conducted by the author.

The specific steps of the assessment which occurred in the office of each decision-maker are:

Step 1. The purpose of the overall project and the assessment was reviewed. The stated purpose was to develop a rigorous, defensible process for energy program evaluation. Their preferences were being elicited to establish the relative importance of various objectives of the programs. The decision-makers were reminded that there were no "right" or "wrong" answers.

Step 2. The four objectives and thirteen subobjectives (See Table 1) were described to the decision-maker. These were listed on a sheet of paper as a visual aid. The decision-maker was told that the objectives and subobjectives were derived in a series of meetings with DSE and UW staff. After determining that all of these items were understood, the decision-maker was asked if any items were missing from the list that would make a difference in choosing between conservation or renewable energy programs. One of the decision-makers identified minimizing the impact of programs on existing energy providers as being a possible subobjective. The decision-makers indicated satisfaction with the objectives generated in the project.

Step 3. The need to measure the performance of programs in meeting decision-maker objectives was introduced as a concept. The attributes list in Table 2 was provided to the decision-maker. The order of the attributes coincided with the order in which the subobjectives were presented in Step 2. The attribute list was discussed item by item, with emphasis given to describing the range of the attributes. For attributes where the range might be abstract, the range was related to levels that would be meaningful. For example, the range in attribute 4, potential energy savings, was related to state-wide energy use.

The ranges were determined using the minimum and maximum consequences that would result from programs currently under consideration at DSE. It is possible that in the future a new program may be considered that ranges beyond the minimum or maximum ranges shown in Table 2. For example, a conservation device that provides an energy equivalent of $.40 per million Btu would be below the minimum cost of $1.00 shown in Table 2.

Step 4. The decision-maker was then asked to rate the relative importance of the attributes. The most important attribute was to be given a weight of 100. Other attributes were then given values of 0 to 100. Specific directions were given that ties were possible and that if, in the process of moving through the comparisons, another attribute was found to be more important than the "most important," that attribute could be given a weight of more than 100. The decision-maker was then told that the assessor would leave the room for 10 minutes to allow the decision-maker some privacy in working out the initial weights. The decision-maker recorded the weights on a piece of paper with a column of numbers from one to thirteen, corresponding to the attributes in Table 2. This procedure is a modification of the Edward's method in that attributes are weighted relative to the most important rather than the least important attributes.

Step 5. Upon returning to the decision-maker's office, the initial weightings were briefly discussed to see if there were any questions. Then the weightings were reconsidered using a graphical technique intended to focus the discussion on the ranges of the attributes. The graphical technique compared each of the attributes to the most important attribute as follows:

```
  another          :
 attribute         :
            best   :
     consequence   :
                   :
                   :
                   :
           worst   :
     consequence   :______________________________

     worst                 best
             consequence               consequence
                  most important attribute
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The decision-maker was then asked to identify equally desirable points, one on each axis, see for example the figure above. Setting the points was confusing for some decision-makers. In these cases, a "100" was written at the end of the axis of the most important attribute. The decision-maker was then asked to place a value at the top of the y-axis. In four of the five assessments, the reconsideration by this technique resulted in changes in the weightings. All of the decision-makers indicated that the second consideration and related discussion with the assessor was helpful in arriving at the final weights.

Step 6. The last step was to send the decision-makers a copy of Table 3, after all the assessments were completed, with the opportunity to alter their weights. Only the decision maker's own weights were identified. None of the decision-makers chose to alter their weights.

THE PREFERENCES OF WISCONSIN ENERGY DECISION-MAKERS

The relative importance of the thirteen objectives, as measured by the attributes in Table 2, to the five decision-makers is shown in Table 3. The relative weights revealed a considerable amount of agreement among the decision-makers. All felt that attribute 4, energy savings, was the most important. Other important attributes for which there was agreement were attributes 3, energy cost, attribute 10, environmental impact, and attribute 13, mean income of program beneficiaries. While there was divided opinion on attribute 1, the importance of the program to development or completion of projects or actions, it was also heavily weighted. Attributes 2, 11 and 12; gaining widespread use of a technological breakthrough, program cost, and number of state employees, were viewed as relatively unimportant aspects of the programs by all decision-makers. Attributes 5 and 9, net job creation and value of information, revealed the greatest disagreement among these decision-makers.

Table 3. Attribute Weights for Five State Energy Decision-makers

Attribute	Decision Maker					Group
	A	B	C	D	E	Weighting
1. Program Importance	0.12	0.13	0.07	0.14	0.02	0.10
2. Probability of Breakthrough	0.03	0.03	0.05	0.03	0.01	0.03
3. User's Energy Cost	0.13	0.11	0.11	0.08	0.14	0.11
4. Potential Energy Savings	0.14	0.14	0.14	0.15	0.14	0.14
5. Net State-wide Jobs	0.05	0.03	0.11	0.12	0.11	0.08
6. Increase in Energy Diversity	0.12	0.11	0.04	0.11	0.10	0.10
7. Applications	0.06	0.09	0.07	0.06	0.12	0.08
8. Information Contacts	0.04	0.07	0.04	0.03	0.01	0.04
9. Value of Information	0.11	0.03	0.11	0.03	0.03	0.06
10. Environmental Impacts	0.07	0.12	0.13	0.14	0.12	0.11
11. Cost to State	0.03	0.01	0.03	0.03	0.04	0.03
12. State Employees	0.00	0.01	0.03	0.02	0.05	0.02
13. Mean Income of Beneficiaries	0.10	0.11	0.07	0.08	0.12	0.10
TOTALS	1.00	1.00	1.00	1.00	1.00	1.00

For DSE staff, the most surprising result of the policy-makers' preferences is the consistently low weightings given to program cost. It must be stressed that the weightings are for the range of costs of $50,000 to $4,000,000 per year. A higher range of costs, e.g., $10 to $50 million, would result in a heavier weighting.

Nevertheless, the low weightings for program cost and number of employees run counter to DSE staff expectations. This in part is because their bureaucratic environment, in a time of cutbacks in federal funds for conservation and renewable energy, has conditioned them to anticipate decreasing funding and staffing levels. In addition, the State of Wisconsin faces a budget shortfall in the current biennium. Not surprisingly, DSE staff has been focusing on programs that have small budgets and require minimal staff. This contrasts with the revealed preferences of the five decision-makers in Table 3, which favor programs that: provide large energy savings, provide low cost energy, do not harm the environment, encourage projects that would not otherwise be done, increase energy diversity, and help low income individuals. The clear message is that the performance of energy programs on these attributes is far more important than costs in the range up to $4 million per program and state employees up to 10 per program. The sum of the weights of the six most important attributes (attributes 4,3,10,1,6, and 13) using the group weight is .66, while the sum of the weights for program cost to the state and state employees (attributes 11 and 12) is only .05.

EVALUATION OF FIVE ENERGY PROGRAMS

An initial set of five programs were evaluated in conjunction with the decision framework. Space permits only the briefest description of the programs:

*Renewable Energy Refund Program (RERP). This program was legislated in 1977 and, at the point of evaluation in 1985, provided a refund of 10% for systems costing up to $7500. To qualify, systems had to have a payback of 15 years or less. This refund was in addition to federal tax credits for renewable systems. In excess of 11,500 systems had been certified by the end of 1984.

*Revised Renewable Energy Refund Program (RRERP). The program is an alternative to the previous program. The main distinguishing feature was that the refund is $100 per million btu (British thermal unit) saved per year. The refund provides an incentive to utilize the most efficient systems and could result in subsidies of up to 46% or higher of the cost of the system.

*Energy Development and Demonstration Program (EDD). The grant program was established to support the development and demonstration of energy conservation and renewable energy projects appropriate to Wisconsin. During three program cycles since 1979, the program has awarded $620,000 to 43 projects across the state. The focus of the program in on new technologies.

*Wood Energy Capitalization Program. This proposed program provides low cost, readily available capital for small to medium sized institutional and industrial facilities which are converting to wood energy systems. The program would provide loans at 2% below commercial rates.

*Oil Burner Inspection and Tune Up Program. This proposed program provides a $50 certificate to certified contractors who perform oil furnace or boiler tune ups for a large set of eligible clients. The objective of the program is to improve the efficiency of existing burners and educate the recipients as to the economic benefits of regular oil burner maintenance.

The programs represented a diverse set of options for initially applying the framework. In addition, these are programs for which decisions have been or will be made, as will be described later.

The application of the multiattribute decision framework resulted in the following rankings, for the decision-makers as a group, on a utility scale of 0 to 1.0:

Wood Capitalization	.52
Oil Burner	.42
EDD Program	.41
RRERP	.38
RERP	.29

The value in the rankings is being able to compare programs across the thirteen attributes in Table 2 and being able to evaluate, on an attribute by attribute basis, why one program is preferred to another as shown in Table 4. The entries in Table 4 are the utility achieved for the indicated program for each attribute. The utility is the product of the group weight given to the attribute (from Table 3) and the performance of the program in utiles (Figure 1). While a utility value of .293 cannot be interpreted as being so low that a program should not be funded, it is interesting to note that the RERP program was discontinued in favor of the revised RRERP program. While the legislative action that resulted in the new program occurred prior to the completion of this analysis, preliminary evaluation had been completed and was made available to key legislators during the legislative process. The major advantages of the new program over the old program (RERP) was that that the new incentive structure would provide for a larger refund, an important feature with the federal program being discontinued. Both the greater anticipated numbers of systems and their more efficient nature were important advantages for the revised program as shown in Table 4, attributes 1,3, and 4.

Table 4. Program Utility by Attribute:Rankings for Decision-Maker Group

Attribute	EDD Program	RERP Program	RRERP Program	Wood Capitalization	Oil Burner
1. Program Importance	.00	0.00	0.05	0.07	0.10
2. Probability of Breakthrough	0.01	.00	.00	0.01	0.00
3. User's Energy Cost	0.05	0.04	0.06	0.08	0.11
4. Potential Energy Savings	0.05	0.01	0.03	0.14	0.01
5. Net State-wide Jobs	0.01	.00	.00	0.05	0.00
6. Increase in Energy Diversity	0.07	0.10	0.10	0.10	0.03
7. Applications	0.01	0.01	0.01	.00	0.02
8. Information Contacts	0.02	0.04	0.04	.00	0.02
9. Value of Information	0.05	0.00	0.00	0.00	0.00
10. Environmental Impacts	0.06	0.06	0.06	0.03	0.06
11. Cost to State	0.03	0.03	0.01	0.01	0.03
12. State Employees	0.02	0.02	0.02	0.02	0.02
13. Mean Income of Beneficiaries	0.02	0.00	0.00	0.02	0.04
Total Utility/Ranking	0.41	0.29	0.38	0.52	0.42

The EDD program, which ranked above RRERP, was killed in the legislature. While this runs counter to the rankings, the application of the decision framework shed some light on the outcome. First of all, the EDD program directly affected only 43 projects. The vast majority of the effects in terms of the attributes were assumed by project staff to be the result of consumers taking action as a result of seeing the demonstration. These effects are very difficult to predict, in fact, they may not occur, or they might have occurred regardless. Legislators may have seen the effects very differently than project staff which struggled with estimating the effects. Thus, the framework focuses attention on the important consideration, i.e., what does or will

the program actually do in regard to the things that matter.
The Wood Capitalization Program and the Oil Burner Tune Up Program compare favorably to the three programs considered up to this point. As shown in Table 4, both programs perform well in terms of attributes 1 (encouraging projects that would not otherwise be done), and 3 (providing low cost energy). The Wood Capitalization also does very well in providing savings of commercial energy, attribute 4, generating jobs in Wisconsin, attribute 5, and providing energy diversity, attribute 6. The oil burner program did not do well on these attributes, but does well in terms of attributes 7, 10, 11, and 13. These programs are under consideration at the present time.

USEFULNESS OF THE DECISION FRAMEWORK

The experience with the framework at this point is that it is useable and useful. What is yet to be determined is whether the framework will be used by DSE for their planning and in working with legislators. With the recent arrival of the Exxon oil overcharge funds and the various committees appointed by the Governor working on generating program ideas, the setting would seem ideal. In addition, a mid-level manager at DSE worked with the UW staff in developing the framework and initial application. Thus, transfer of the framework has taken place through an individual which is a key strategy for successful methods transfer.[14]

There are, however, some remaining obstacles which may stand in the way of the framework being used as an aid in selecting programs to be funded by the Exxon funds or in subsequent program selection activities. Some DSE staff believe that the framework is too complex to apply in the face of over 100 program proposals.[15] This is in part related to the valid concern that projecting program performance for the thirteen attributes is a complex task.

While predicting future consequences of an action is a difficult task, it cannot be avoided whether this or any other tool, such as benefit-cost analysis, is used. Even if the only objective of a legislator is to satisfy constituents, one has to project how the constituents will react to a given vote.

The initial application of the framework appeared useful in evaluating and designing energy programs. Most importantly, it focused attention on what the programs will and will not accomplish, and which of those accomplishments are the most important. Whether the framework will be used in ongoing program evaluations remains to be seen. I have recommended to DSE that they initially assess twenty or thirty of the intuitively most promising program suggestions for the Exxon funds, using quick judgmental estimates of program performance over the attributes. This exercise will focus attention on the pros and cons of the programs and reveal which programs may provide what Wisconsin energy decision-makers are looking for. The alternative is to leave the decision to unstructured intuition.

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