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APPLICATION OF MULTIPLE ATTRIBUTE DECISION MAKING TO THE OST PEER REVIEW PROGRAM

PHASE 1: METHODOLOGY

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EXECUTIVE SUMMARY

For the last several years, the Office of Science and Technology (OST) of the U.S. Department of Energy (DOE) has used the services of the American Society of Mechanical Engineers (ASME) and the Institute for Regulatory Science (RSI) to peer review various projects and technologies that OST supports. During the initial phases of the peer review program, it became clear that the number of projects was too large for the program to review every one of them annually or even periodically. In conjunction with these activities, a study known as Triage was initiated to screen all projects and provide a numeric value for various attributes of each project. In February 2000, RSI was contacted by the OST Peer Review Coordinator who asked if RSI would be willing to continue the Triage study and bring it to a successful conclusion. RSI responded affirmatively and suggested that the first phase of the study be the evaluation and possible expansion of the existing methodology.

This report consists of this first phase. The first part of this report contains a brief description of the Multiple Attribute Decision Making (MADM). The second part includes a description of attributes used previously; it also describes the application of MADM to the expansion of the previously-used attributes.

Recognizing the existence of extensive information collected in support of the current Triage process, it appears to be reasonable to enhance its applicability. Accordingly, the three attributes (investment, relevance, and availability) may be used as maximum attributes to generate a single score for a given project using the MADM technique.

As a modification of the current Triage process, three new attributes are considered in order to generate a composite index. Because not all relevant data are always available, a hierarchical approach is proposed. The first hierarchical level uses the attributes: total cost, timing, relevance, and availability. The second hierarchical level may be used when additional data are available. In addition to the four attributes used by the first hierarchical level, the second hierarchical level uses the benefit margin.

INTRODUCTION

For the last several years, the Office of Science and Technology (OST) of the U.S. Department of Energy (DOE) has used the services of the American Society of Mechanical Engineers (ASME) and the Institute for Regulatory Science (RSI) to peer review various projects and technologies that OST supports. During the initial phases of the peer review program, it became clear that the number of projects was too large for the program to review every one of them annually or even periodically. Therefore, OST decided to establish guidelines for Focus Area managers and others to concentrate on those projects and those phases of projects that needed peer review for the subsequent critical decisions.

In conjunction with these activities, a study known as Triage was initiated to screen all projects and provide a numeric value for various attributes of each project. These efforts resulted in a report (Wilkey et al. 1999). This report uses three attributes for assessment: investment, relevancy, and availability. This report provided numeric values for these three attributes for four Focus Areas. The authors acknowledged that one Focus Area was missing.

In February 2000, RSI was contacted by the OST Peer Review Coordinator who asked if RSI would be willing to continue the Triage study and bring it to a successful conclusion. RSI responded positively and recommended a three-phase program. The first phase of the study was suggested to be the evaluation and possible expansion of the existing process.

This report consists of this first phase. The first part of this report contains a brief description of the Multiple Attribute Decision Making (MADM). The second part includes a description of attributes used by Wilkey et al. (1999); it also describes the application of MADM to the expansion of the previously-used attributes.

PART I. MULTIPLE ATTRIBUTE DECISION MAKING

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Decision makers often deal with problems that involve multiple, usually conflicting, criteria. These problems may range from those affecting common households, such as the purchase of an automobile, to those affecting nations, as the national defense spendings. For example, in purchasing a car, the following multiple attributes are usually considered: price, comfort, fuel efficiency, safety, maintenance cost, insurance cost, and depreciation. U.S. News & World, in its annual edition of “America’s Best Colleges”, ranks academic institutions based on: academic reputation, student selectivity, faculty resources, financial resources, graduation rate, and alumni satisfaction (Yoon and Hwang 1995). In the U.S. Army, each year about one in six majors is selected for promotion to lieutenant colonel based on: military education level; civil education level; physical readiness and military bearing; officer qualifications; duty performance; and office potential (Yoon and Hwang 1995). Multiple Attribute Decision Making (MADM) refers to making preference decisions (such as evaluation, prioritization, selection) over the available alternatives that are characterized by multiple, usually conflicting, attributes (Hwang and Yoon 1981).

MADM is a branch of Multiple Criteria Decision Making (MCDM) which also includes Multiple Objective Decision Making (MODM) (Hwang and Masud 1979). In contrast to MADM problems, MODM problems involve designing the best alternative given a set of conflicting objectives. For example, automobile manufacturers must design a car that maximizes riding comfort and fuel efficiency, but minimizes production and maintenance costs. The alternatives are created through the design process.

A MADM method is an algorithm that specifies how attribute information is to be used in order to arrive at a choice. There are two major approaches in attribute information processing (Hwang and Yoon 1981):

1. Noncompensatory models. These models do not permit tradeoffs between attributes. A disadvantage or unfavorable value in one attribute cannot be offset by an advantage or favorable value in another attribute. The methods which belong to this category (dominance, maximin, maximax, conjunctive constraint, disjunctive constraint, lexicographic) are credited for their simplicity and should be used when the decision maker has limited knowledge.
2. Compensatory models. These models allow for disadvantages in one attribute to be offset by advantages in another attribute. A single number is usually assigned to each multidimensional characterization of a given alternative.

An alternative in MADM is usually described by quantitative and qualitative attributes. There are three types of scales that can be employed for these attributes: ordinal scales, interval scales, and ratio scales (Torgerson 1958; Stevens 1959). An ordinal scale sorts the competing alternatives according to their rank, but provides no information with respect to the relative distances among them. An interval scale provides the distances of the competing alternatives with respect to an arbitrary origin (e.g., Fahrenheit scale, Celsius scale). A ratio scale provides the distances of the competing alternatives with respect to a non-arbitrary origin (e.g., Kelvin scale). Most MADM methods use either ordinal or interval scales. The transformation of a qualitative attribute into an ordinal scale is much easier than into an interval scale. One of the most common methods for converting a qualitative attribute into an interval scale is to utilize the bipolar scale (MacCrimmon 1968). We may choose a 10-point scale and calibrate it giving 10 points to the best value and zero points to the worst value. The midpoint would also be a basis for calibration, because it should be the breakpoint between values that are favorable and values that are unfavorable.

The MADM problems share the following characteristics (Yoon and Hwang 1995):

1. Alternatives. A finite number of alternatives are screened, prioritized, selected, or ranked. The term “alternative” is synonymous with “candidate”, “option”, “policy”, and “action”.

2. Multiple Attributes. Each problem has multiple attributes. A decision maker must generate relevant attributes for each problem setting. The term "attributes" is synonymous with "criteria", and "goals".
3. Incommensurable Units. Each attribute may have different units of measure.
4. Attribute Weights. Almost all MADM methods require information regarding the relative importance of each attribute, which is usually supplied through an ordinal or cardinal scale. Weights can be assigned directly by the decision maker.
5. Decision Matrix. A MADM problem can be concisely expressed in a matrix format, where columns indicate attributes considered in a particular problem, and rows list competing alternatives. Therefore a typical element x_{ij} of the decision matrix indicates the performance rating of the i^{th} alternative (A_i) with respect to the j^{th} attribute (X_j).

A classic piece of advice on MADM was given by Benjamin Franklin (1772) in a letter to Joseph Priestley: "...[M]y way is to divide half a sheet of paper by a line into two columns; writing over the one Pro, and over the other Con. Then, during three or four days consideration, I put down under the different heads short hints of the different motives, that at different times occur to me, for or against the measure. When I have thus got them all together in one view, I endeavor to estimate their respective weights; and where I find two, one on each side, that seem equal, I strike them both out. If I find a reason pro equal to some two reasons con, I strike out the three. If I judge some two reasons con, equal to three reasons pro, I strike out the five; and thus proceeding I find at length where the balance lies; and if, after a day or two of further consideration, nothing new that is of importance occurs on either side, I come to a determination accordingly. And, though the weight of the reasons cannot be taken with the precision of algebraic quantities, yet when each is thus considered, separately and comparatively, and the whole lies before me, I think I can judge better, and am less liable to make a rash step, and in fact I have found great advantage from this kind of equation, and what might be called moral or prudential algebra."

In 1988, a significant budget reduction at the University of Wyoming left the Athletic Department approximately $700,000 short on operating funds compared to its previous budget (Swenson and McMahon 1991). The alternatives capable of realizing the proposed budget cuts included the elimination of the men's and women's ski programs (A_1), the baseball program (A_2), and the women's golf team (A_3). In order to evaluate these alternatives, the Athletic Department decided to use the following attributes: the number of people directly affected (X_1), money saved by the department (X_2), and miscellaneous (X_3). For X_1 the values were calculated by adding the number of participants and coaches. For X_2 the values represent money saved in the first year after the program is dropped. For X_3 a five-point scale (very high=1, high=2, average=3, low=4, very low=5) was used to account for facility proximity, fan support, past success, and required facility. The decision matrix as indicated in Table 1 is as follows:

Table 1. The decision matrix (Swenson and McMahon, 1991).

Alternatives	Attributes		
	X_1	X_2	X_3
A_1	30	$174,140	3
A_2	29	$74,683	4
A_3	12	$22,496	5

A similar example is presented by Yoon and Hwang (1985) for a manufacturing plant location. Table 2 contains a list of the first applications of the MADM.

Table 2. First applications of the MADM.

Reference	Comments
Davos et al. (1979)	Nuclear facility siting in California.
Keeney (1979)	Evaluates 10 sites for the pumped storage hydroelectric generation facility. Attributes: first year cost, transmission line distance, forest lost, community lost due to the construction.
Nakayama et al. (1979)	Assess the residential environment in Kyoto using 12 attributes: proportion of green area, proportion of park area, population density, medical facilities, bad odor, traffic accidents, sulphurous acid gas, soot and smoke, factories, accessibility to downtown, offices of the business affecting public morals, and land price.
Dinkel and Erickson (1978)	Evaluate environmental program effectiveness using: number of serious pollution incidents, number of less serious pollution incidents, number of complaints, comparison of environmental quality, compliance index, and number of non-monitored industries.
Moscarola (1977)	Selection of candidates for business school admission. Attributes: high school average grade, improvement, experience, motivation, professional interest.
Einhorn and McCoach (1977)	Evaluate player performance in the National Basketball Association. Eight attributes: field goal percentage, free throw percentage, rebounds, assists, steals, personal fouls, points per minute played, blocked shots. The resulting ranking predicted correctly the NBA all-star team.
Hirschberg (1977)	Graduate student selection policies. A linear regression is robust.
Gros et al. (1976)	Nuclear facility siting in New England. Four attributes: number of units at a given site, cost, population within ten kilometers of a given site, incremental water temperature at peak ambient water temperature period of year.
Litchfield et al. (1976)	Analyses of a hypothetical advanced nuclear waste management system.
Hill and Alterman (1974)	Nuclear facility siting in Israel.
Green and Carmone (1974)	Graduate business students' evaluation of (hypothetical) assistant professors for tenured positions. Uses a regression model with three criteria (research and publication, teaching, institutional contribution).
Easton (1973)	Compares three evaluation rules (geometric mean, arithmetic mean, quadratic mean) for the selection of a sales manager.

Table 2. (cont'd.)

Reference	Comments
Ellis and Keeney (1972)	Evaluate two air pollution control strategies for New York City. Attributes: per capita increase in the number of days of remaining lifetime, per capita decrease in the number of days of bed disability per year, per capita annual net costs to low-income residents, per capita annual net costs to other residents, daily sulfur dioxide concentration, total annual net cost to city government, subjective index of political desirability.
Klee (1971)	Alternatives for wood removal in salvaging the metal from railroad cars. Attributes: capital cost, ability to salvage the wood removed, time needed to develop the process, contribution to air pollution, operating cost.
Dawes (1971)	University committee admitting Ph.D. students. Attributes: GRE, GPA, and quality of undergraduate school attended.
Klahr (1969)	College admission officers' preferences. Attributes: alumni interview, campus interview, college board score, extracurricular activities, high school grade average, high school recommendation, IQ level, rank in senior class.
Smith and Greenlaw (1967)	Simulation model for the hiring of company employees.

It has become increasingly more complicated for a decision maker to make the right decision at the right time. To select a candidate to fill a certain position is difficult because there may be many qualified applicants. The sequential procedures of decision making include the preparatory phase, the screening phase, the evaluating phase, and the selection phase. The preparatory phase includes advertizing very specifically for what is desired. The screening phase consists of using various methods to eliminate the unqualified candidates. The evaluating phase includes reviewing the qualified candidates. Finally, the committee members may come with a recommendation to the manager or they may provide a list of pros and cons of each eligible candidate and let the manager decide. Mathematical solutions have been provided for the evaluation and selection phases. Probably the most commonly used evaluation techniques are ranking, rating, scoring and utility function, all of which indicate preferences with respect to a group of candidates. The ordinal approach, which involves the ranking of candidates, has been investigated among others by Souder (1973a; 1973b), Cook and Seiford (1978; 1982a), Franz et al. (1981). The cardinal approach, which involves the scoring of candidates, has been investigated among others by Eckenrode (1965), Dean and Nishry (1965), Fishburn (1966), Souder (1972), Minnehan (1973), Keeney and Kirkwood (1975), Dyer and Miles (1976), Hwang and Yoon (1981).

The advantage of the ordinal approach is that the assignment technique can be used quite easily. The Borda score (i.e., the sum of the committee members scores) used in the ordinal approach is very popular. As an example, we mention the weekly poll made by AP or UPI for the top 20 college basketball U.S. teams. The advantage of the cardinal approach is that it may take into account the distances among the different candidates and the relative closeness of the top candidate with respect to the ideal candidate.

The entropy method

Entropy has become an important concept in physics as well as in the social sciences (Capocelli and De Luca 1973; Nijkamp 1977). Additionally, entropy has a useful meaning in information theory where it is used as a measure of the expected information content of a given message. In the information theory entropy is also used as a measure for the uncertainty of a discrete probability density function (Shannon and Weaver 1949;

Jaynes 1957):

$$S(p_1,\ldots,p_n) = -k\sum_{i=1}^{n} p_i \cdot \ln(p_i)$$

Because this definition is similar to the one used in statistical mechanics, this measure of uncertainty is labeled entropy. When all probabilities are equal, the entropy reaches its maximum.

The decision matrix for a set of alternatives contains a certain amount of information. Entropy can therefore be used as a tool in attribute evaluation (Zeleny 1974; Nijkamp 1977). Entropy is particularly useful to investigate contrasts among data sets. An attribute is not very useful when all alternatives have similar values for that attribute. Furthermore, if all values are the same, that attribute should be eliminated.

The entropy of each attribute is:

$$E_j = -\frac{1}{\ln(m)}\sum_{i=1}^{m} p_{ij} \cdot \ln(p_{ij})$$

where:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad , x_{ij} > 0 \quad \forall\, i, j$$

and x_{ij} is the numerical outcome of the ith alternative with respect to the jth attribute.

The degree of diversification of the information provided by the outcomes of attribute j is:

$$d_j = 1 - E_j$$

If the decision maker has no reason to prefer one attribute over another, the Principle of Insufficient Reason (Starr and Greenwood 1977) suggests that each one should be equally preferred. Then the best weight set that can be used is:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}$$

A review of other weight assessment techniques may be found in Eckenrode (1965), Hobbs (1980), Stillwell et al. (1981), Hwang and Yoon (1981) and Voogd (1983).

Technique for order preference by similarity to ideal solution

A MADM problem with m alternatives that are evaluated by n attributes may be visualized as a set of m points in an n-dimensional space. There is an ideal level of attributes for the alternative of choice (Coombs 1958; Coombs 1964). The decision maker's utility decreases monotonically when an alternative moves away from this ideal (or utopia) point (Yu 1985). Because the ideal is dependent on the current economic and technical limits and constraints, a perceived ideal is utilized to implement the choice rationale. The positive-ideal solution is defined as the hypothetical alternative with the supremum (for maximum attributes) and infimum (for minimum attributes) ratings for the m alternatives. The negative-ideal solution is defined as the hypothetical alternative with the supremum (for minimum attributes) and infimum (for maximum attributes) ratings for the m alternatives. The Technique for Order Preference by Similarity to Ideal Solution (Yoon 1980; Yoon and Hwang 1980; Hwang and Yoon 1981; Zeleny 1982; Yoon 1987; Hall 1989; Hwang et al. 1993; Yoon and Hwang 1995) is based on the fact that the selected alternative should have the shortest distance with respect to the positive-ideal solution and the longest distance with respect to the negative-ideal solution (Dasarathy 1976).

The normalized decision matrix is computed based upon the decision matrix. The vector normalization is used to compute the normalized ratings (r_{ij}) based upon the numerical outcome of the ith alternative with respect to the jth attribute (x_{ij}):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad , \quad i = 1,\ldots,m \quad j = 1,\ldots,n$$

The weighted normalized decision matrix is computed based upon the normalized decision matrix and the weights vector, where w_j is the weight of the jth attribute:

$$v_{ij} = w_j \cdot r_{ij} \quad , \quad i = 1,\ldots,m \quad j = 1,\ldots,n$$

The positive-ideal solution A^+ and the negative-ideal solution A^- are defined with respect to the weighted normalized decision matrix as follows:

$$A^+ = \{v_1^+,\ldots,v_n^+\} = \{(\max_i v_{ij} | j \in J_1), (\min_i v_{ij} | j \in J_2) | i = 1,\ldots,m\}$$

$$A^- = \{v_1^-,\ldots,v_n^-\} = \{(\min_i v_{ij} | j \in J_1), (\max_i v_{ij} | j \in J_2) | i = 1,\ldots,m\}$$

where J_1 is the set of maximum attributes and J_2 is the set of minimum attributes. The positive-ideal solution identifies the most preferable alternative, and the negative-ideal solution identifies the least preferable alternative. The separation of each alternative from the positive-ideal solution is S_i^+ :

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \quad , \quad i = 1,\ldots m$$

Similarly, the separation of each alternative from the negative-ideal solution is S_i^- :

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad , \quad i = 1,\ldots m$$

The similarity of each alternative to the positive-ideal solution (i.e., the relative closeness of each alternative with respect to the positive-ideal solution) is S_i :

$$S_i = \frac{S_i^-}{(S_i^+ + S_i^-)} \quad , \quad i = 1, \ldots, m$$

The alternatives should be ranked in accordance to their similarities. The ranking process can be expressed through the indifference curves defined as:

$$s = \frac{S^-}{(S^+ + S^-)}$$

The indifference curve equation can be rewritten as:

$$s \cdot S^+ - (1 - s) \cdot S^- = 0$$

This equation indicates that the indifference curve is a variation of a hyperbola where the difference between two weighted distances (i.e., s and (1-s)) with respect to two focal points (i.e., the positive-ideal solution and the negative-ideal solution) is zero. A decision maker is expected to give equal preference to all alternatives located on the same indifference curve.

PART II. APPLICATION OF MADM TO OST PEER REVIEW PROCESS

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In their report, Wilkey et al. (1999) required a number of input data from each project as follows:

1. F_n = the funding in actual $ for each FY between 1989 and 1999
2. N_1 = the number of needs addressed by the project and having priority 1
3. N_2 = the number of needs addressed by the project and having priority 2
4. N_3 = the number of needs addressed by the project and having priority 3
5. The list of needs addressed by the project and having priority 1
6. The list of needs addressed by the project and having priority 2
7. The list of needs addressed by the project and having priority 3
8. Availability date (optional)

From each Focus Area, the following input data were requested:

1. N_{1FA} = the number of needs having priority 1
2. N_{2FA} = the number of needs having priority 2
3. N_{3FA} = the number of needs having priority 3
4. The earliest and latest needs dates (optional)

In addition, the following general input data were requested:

1. CIR_n = the composite inflation rate for each year between 1989 and 1999.

SCORES COMPUTATION

For each project the scores for the three attributes are computed as follows:

1. Investment:

$$F = \sum_{1989}^{1999} F_n \cdot CIR_n$$

2. Relevance:

$$R = [\frac{3N_1 + 2N_2 + N_3}{3N_{1FA} + 2N_{2FA} + N_{3FA}}] \cdot 100$$

3. Availability:

Score = 5 available on or before earliest needs date
= 4 available after earliest but on or before latest needs date
= 3 indeterminate, only needs dates known
= 2 indeterminate, only technology availability known
= 1 indeterminate, needs dates and technology availability known

Analysis of the current triage process

The Triage presented by Wilkey et al. (1999) appears to be a multiple attribute decision making process. The authors clearly specify the three attributes (investment, relevance, and availability), but they do not specify how the solution is selected. Moreover, they do not clearly specify the nature (maximum or minimum) of the three attributes. Apparently, all three are maximum attributes.

The input data are readily available and the computations can be easily performed.

The investment attribute may be misleading. It takes into account in constant U.S. $ the amount already invested, but it does not take into account the expected future expenses. This way, projects that are nearing completion are favored (and maybe it is too late to implement any corrections) over projects that are in an incipient stage (and maybe need review in order to identify and implement the required corrections).

The relevance attribute does not take into account the financial characteristics of different needs. All needs receive the same treatment.

The potential financial benefit that may be generated by a project is not taken into account.

Enhancement of the applicability of the current triage process

Recognizing the existence of extensive information collected in support of the current Triage process, it is reasonable to attempt to enhance its usefulness. Accordingly, the MADM technique may be used to generate a single score for a given project. It is proposed that investment, relevance, and availability as defined by Wilkey et al. (1999) be used as maximum attributes. Despite the shortcomings of the current attributes as noted above, the resulting single score will provide OST with a useful tool to enhance the applicability of the current Triage process.

Proposed modifications of the current triage process

In order to provide OST with a tool for the decision making process, the scores of the attributes should be used to generate a composite index for a given project using the MADM technique. Because not all relevant data are available, a hierarchical approach is proposed.

The **first hierarchical level** uses the following attributes:

1. Total cost (Maximum)
2. Timing (minimum)
3. Relevance (Maximum)
4. Availability (Maximum)

The **second hierarchical level** may be used when additional data are available. The second hierarchical level uses the following attributes:

1. Total cost (Maximum)
2. Timing (minimum)
3. Relevance (Maximum)
4. Availability (Maximum)
5. Benefit margin (Maximum or minimum)

For the first hierarchical level two new attributes are considered as follows:

1. Total Cost:

   For the years 2000-2010 the composite inflation rate may be estimated as the geometric average of the values reported for the years between 1989 and 1999. The total cost is computed as follows:

$$T = \sum_{1989}^{2010} F_n \cdot CIR_n$$

2. Timing:

If the best moment to review a project is when x% of the Total Cost has been spent, then the Timing attribute is computed as follows:

$$t = \left| \frac{100}{x} \frac{F}{T} - 1 \right|$$

For example, if the best moment to review a project is when 50% of the Total Cost has been spent, then:

$$t = \left| \frac{100}{50} \frac{F}{T} - 1 \right| = \left| 2 \frac{F}{T} - 1 \right|$$

Alternatively, the Timing attribute may be expressed as a function of the Gate process. For example, if projects at Gate 2 and projects at Gate 4 should be preferred, then the Timing attribute is computed as follows:

$$t = [(Gate - 2) \cdot (Gate - 4)]^2$$

In addition, in order to cover all cases, the Availability attribute of Wilkey et al. (1999) is expanded as follows:

Score	= 5	available on or before earliest needs date
	= 4	available after earliest but on or before latest needs date
	= 3	indeterminate, only needs dates known
	= 2	indeterminate, only technology availability known
	= 1	indeterminate, needs dates and technology availability known
	= 0	available after the latest needs date

The second hierarchical level requires additional data. For each technology, take as moment zero the start of its development. Compute PVT, the present value of the technology development. Compute PVFPT, the present value of the future projects using the new technology. Compute PVFPB, the present value of the same projects using the base technology. Compute the benefit margin as follows:

$$PM = \frac{PVFPB - PVFPT - PVT}{PVFPB}$$

In addition to the four attributes used by the first hierarchical level, the second hierarchical level uses the benefit margin. If the approach is financially conservative (i.e., losses are avoided), this attribute should be used as a minimum attribute. If the approach is financially aggressive (i.e., benefits are maximized), this attribute should be used as a maximum attribute.

Table 3 presents a hypothetical case: using the baseline technology, in 2010 the cost will be $10,000,000. As an alternative, a new technology can be developed spending $100,000 per year for 2001-2009, and the cost will be $8,000,000. Using a discount rate of 7%, the present value of the two cases is $5,439,337.43 (baseline technology) and $5,048,599.79 (new technology).

Using the new technology may provide a benefit of $390,737.63, i.e. 7.1% of the present value of the baseline technology case.

The projects should be ranked using the first hierarchical level. For those projects for which additional information is available, the ranking may be refined using the second hierarchical level. As long as only attributes 1-4 are used, the data are readily available and the computations can be easily performed. Adding attribute 5 may be beneficial, but the data are likely to be difficult to obtain.

The benefit margin may also be used to accept or reject new projects.

Table 3. Present Value Calculations.

Year	Baseline Technology		New Technology	
	Portfolio	Annual Spending	Portfolio	Annual Spending
2001	$ 5,439,337.43	$ -	$ 5,048,599.79	$ 100,000.00
2002	$ 5,820,091.05	$ -	$ 5,295,001.78	$ 100,000.00
2003	$ 6,227,497.42	$ -	$ 5,558,651.90	$ 100,000.00
2004	$ 6,663,422.24	$ -	$ 5,840,757.53	$ 100,000.00
2005	$ 7,129,861.79	$ -	$ 6,142,610.56	$ 100,000.00
2006	$ 7,628,952.12	$ -	$ 6,465,593.30	$ 100,000.00
2007	$ 8,162,978.77	$ -	$ 6,811,184.83	$ 100,000.00
2008	$ 8,734,387.28	$ -	$ 7,180,967.77	$ 100,000.00
2009	$ 9,345,794.39	$ -	$ 7,576,635.51	$ 100,000.00
2010	$10,000,000.00	$10,000,000.00	$ 8,000,000.00	$ 8,000,000.00

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