CAPITAL BUDGETING MODEL FOR A NUCLEAR POWER PLANT USING MULTIATTRIBUTE DECISION ANALYSIS

by

Michael G. Pinion

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APPROVED:

Dr. Roderick J. Reasor, Chairman

Dr. C. P. Koelling

Dr. Benjamin S. Blanchard

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Michael G. Pinion

Committee Chairman: Dr. Roderick J. Reasor

Industrial Engineering and Operations Research

(Abstract)

Managers of nuclear power plants are frequently faced with complex decisions which are further complicated by potentially conflicting objectives. The capital budgeting process is one area involving these complex decisions. This paper provides a capital budgeting model for a nuclear power plant. The capital budgeting process requires allocating limited resources in an attempt to satisfying a set of potentially conflicting objectives. An analytic hierarchy structure was developed to rank the projects by priority of the goals.

A tool used in solving this capital budgeting problem was a form of linear programming known as integer programming with contingent constraints. The computer software used in this analysis was the integer programming provided in STORM Personal Version 2.0. The project alternative priority preference (APP) assignments derived from the analytic hierarchy process were used as the coefficients in the objective function. Multiattribute decision analysis is a useful tool available to managers of

nuclear power plants that can be applied to the capital budgeting process. An important aspect of this process is the methodical definition of the factors or attributes that are important to the organization.

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INTRODUCTION

The Nuclear Regulatory Commission identified the basic requirements for nuclear utilities to meet a number of Three Mile Island related activities (U.S. Nuclear Regulatory Commission, 1982). The requirements and guidance included the coordination and integration of the Nuclear Regulatory Commission's initiatives dealing with Safety Parameter Display Systems, Control Room Design Reviews, Emergency Response Facilities, and Emergency Operating Procedures. The list of requirements for short and long term modifications and improvements had grown to such lengths that it had often been difficult to sort out the essential and important from the unessential and trivial. Therefore, as part of their response to the Nuclear Regulatory Commission in the early 1980's, nuclear utilities were required to provide an integrated plan for capital budgeting projects.

A more recent trend that emphasizes the need for nuclear utilities to control the capital budgeting process was reported in December 1989 by Electric Light & Power magazine. The average cost to produce electricity in 1988 decreased at coal fired plants and increased at nuclear plants. The national average cost increases at nuclear facilities included fuel costs increases (0.016 to 0.022

cents per kilowatt hour) as well as non-fuel operating and maintenance cost increases (0.017 cents per kilowatt hour).

The managers of the nuclear power plants, in an attempt to comply with the regulatory mandates and economic pressures, are faced with complex capital budgeting decisions which are further complicated by potentially conflicting objectives. The conflicting objectives are in response to the utilities' general environment which consists of the economic, political, social, and technological shareholders of the industry (Chung, 1986).

The capital budgeting process requires allocating limited resources in an attempt to satisfying a set of objectives. A tool useful in solving this capital budgeting problem is a form of linear programming known as integer programming with contingent constraints.

REVIEW OF LITERATURE

General Capital Budgeting With Multiple Objectives

A great deal has been written on multiattribute decision analysis (Canada and Sullivan, 1989; Electric Power Research Institute, 1982a, 1982b, 1982c; Hillier and Lieberman, 1986; Keeney and Raiffa, 1976; Saaty, 1980; Zeleny, 1982). In addition, a great deal has been written on multiattribute decision analysis as it applies to the capital budgeting process (Deckro, Spahr, and Hebert, 1985; Ignizio; Weingartner, 1963). One paper on the subject is by James P. Ignizio, titled "An Approach to the Capital Budgeting Problem with Multiple Objectives." A synopsis of Ignizio's paper is provided as an overview of the goal programming approach to capital budgeting.

Ignizio presented a discussion of goal programming to solve the capital budgeting problem, a basic branch and bound algorithm for solving the problem, and a heuristic algorithm to solve problems with more than fifty variables. The capital budgeting problem, as defined by Ignizio, "is one in which the decision-maker must select a subset of programs... from among a given, finite set. The objective is to maximize the return from these programs while still satisfying all yearly budget limits for the life of the programs." The methods used previous to Ignizio's paper to solve this capital budgeting problem included "dynamic programming, branch and bound, zero-one programming and heuristic programming." Ignizio identified a shortcoming of these methods as the inability to formulate a more realistic model of the capital budgeting problem using a multiple objective function. However, for the multiple objective function, if "one can establish preemptive priorities, then the problem is of a class known as goal programming."

Ignizio provided a brief summary and mathematical formulation of the goal programming process for the capital budgeting problem. This process includes:

1. Defining a minimization objective function containing preemptive priorities to be solved by a linear programming method,
2. Defining the constraints of the problem and include the "Goal Deviations" (Canada and Sullivan, 1989), and
3. Solving for the optimum solution.

An important assumption of the goal programming process is the concept of preemptive priority. Ignizio defined this as "the set of objectives at a given priority level [which] is immeasurably preferred to the satisfaction of any other set of objectives at any lower priority level."

In summary to Ignizio's paper, the emphasis of the paper was on the methodology and not on a specific capital budgeting model. This is typical of much of the literature referenced.

Electric Utility Capital Budgeting

An equally large, but varied number of reports have been written concerning electric utility capital decision analysis (Electric Power Research Institute, 1984, 1985a, 1985b, 1985c, 1985d, 1985e, 1985f, 1985g, 1986a, 1986b, 1986c, 1987). While some of these references repeat the multiattribute decision analysis methods discussed earlier, and others look at pure economic analysis methods (Electric Power Research Institute, 1984, 1986a), none of them specifically address a capital budgeting model for a nuclear power plant. Many of the reports provided methods to select the single best project of technically feasible options in lieu of selecting the best portfolio of projects as required in the capital budgeting process. Several of these reports will be used as a source of electric utility related objectives and attributes to be applied to a capital budgeting model for a nuclear power plant.

The report by Electric Power Research Institute (1984) provided an electric utility strategic planning model (behavioral simulation) to evaluate a range of investment strategies including (1) conventional baseload capacity expansion; (2) plant life extension; (3) smaller, shorter-lead time plants; (4) peak-load shifting; and (5) no investment in capacity until future time. This strategic planning model focused on six qualitative performance measures: (1) reserve margin; (2) price; (3) interest coverage; (4) earnings per share; (5) market price per share; and (6) market-price-to-book value ratio. Subsequently the model performed a quantitative ranking of the options using the present value of the three performance measures: (1) net cash flow; (2) dividends per share; and (3) price per kilowatt-hour to the consumer.

The reports by Electric Power Research Institute (1985a, 1985b, 1985c) utilized the technology choice model (TCM) to integrate environmental, health and safety, socioeconomic, and other considerations with traditional economic analyses in considering several generation options to meet anticipated increases in electricity demand. The objectives used included: (1) customer cost, (2) shareholder return; (3) decision difficulty, (4) corporate image; (5) environmental impact; (6) water usage, (7) transportation impact, (8) community disruption, (9) local employment, (10) visual impact, (11) local tax revenue; (12) mortality, (13) morbidity; (14) public attitudes; and (15) feasibility.

One additional report (Electric Power Research Institute, 1985d) utilized the technology choice model (TCM), but in this case it was used in considering several methods for management of spent nuclear fuel. The objectives used included: (1) construction land use, (2) operation land use, (3) construction water use, (4) operation water use, (5) construction waste water, (6) visual impact; (7) spent resin low-level waste, (8) compressible low-level waste, (9) occupational dose, (10) public dose, (11) public dose (transportation); (12) occupational transportation accident fatalities, (13) public transportation accident fatalities, (14) occupational transportation accident injuries, (15) public transportation accident injuries; (16) present value to Tennessee Valley Authority, and (17) present value to the Department Of Energy.

MATERIALS AND METHODS

Analytic Hierarchy Process

The analytic hierarchy process, developed by Thomas Saaty (1980), has been used in transportation planning, portfolio selection, corporate planning, marketing, and others fields (Canada and Sullivan, 1989). This process structures a complex multiattribute problem into a multi-level problem with a pairwise comparison of elements at a given level. The structuring allows the elements or attributes to be prioritized based on the strength of importance relative to higher level elements. The process translates into priority assignments for comparison of alternatives. Saaty's (1980) functional hierarchy is described as follows:

> The top level, called focus, consists of only one element-the broad, overall objective. Subsequent levels may each have several elements, although their numbers is very small-between 5 and 9. Because the elements in one level are to be compared with one another against a criteria in the next higher level, the elements in each level must be of the same order of magnitude. (p. 28)

A basic three-level analytic hierarchy structure is shown in Figure 1. If any attribute was further divided into sub-attributes, those sub-attributes would constitute a new level.

The prioritization process of the analytic hierarchy structure involves assigning a preference number to each pairwise comparison of elements on a given level with respect to the related elements in the level just above. The numbers suggested by Canada and Sullivan (1989) to express the degree of preference is provided in Table 1.

Even numbers (2, 4, 6, 8) can be used to define additional levels of preference. For inverse comparisons such as y to x, the reciprocal of the preference number for x to y is used. The next step in developing a priority assignment is to tabulate the comparisons into a matrix as shown in Table 2. The next step is to compute a vector of priorities for the elements in the matrix. This vector of priorities (eigenvector) of the matrix, is then normalized to a sum of 1 or 100%. The larger the value of the attribute preference, the higher the priority (more important) of the attribute or alternative. For each attribute in a pairwise comparison, this preference shall be called the principal vector element (PV). A sample of this process is shown in Table 3.

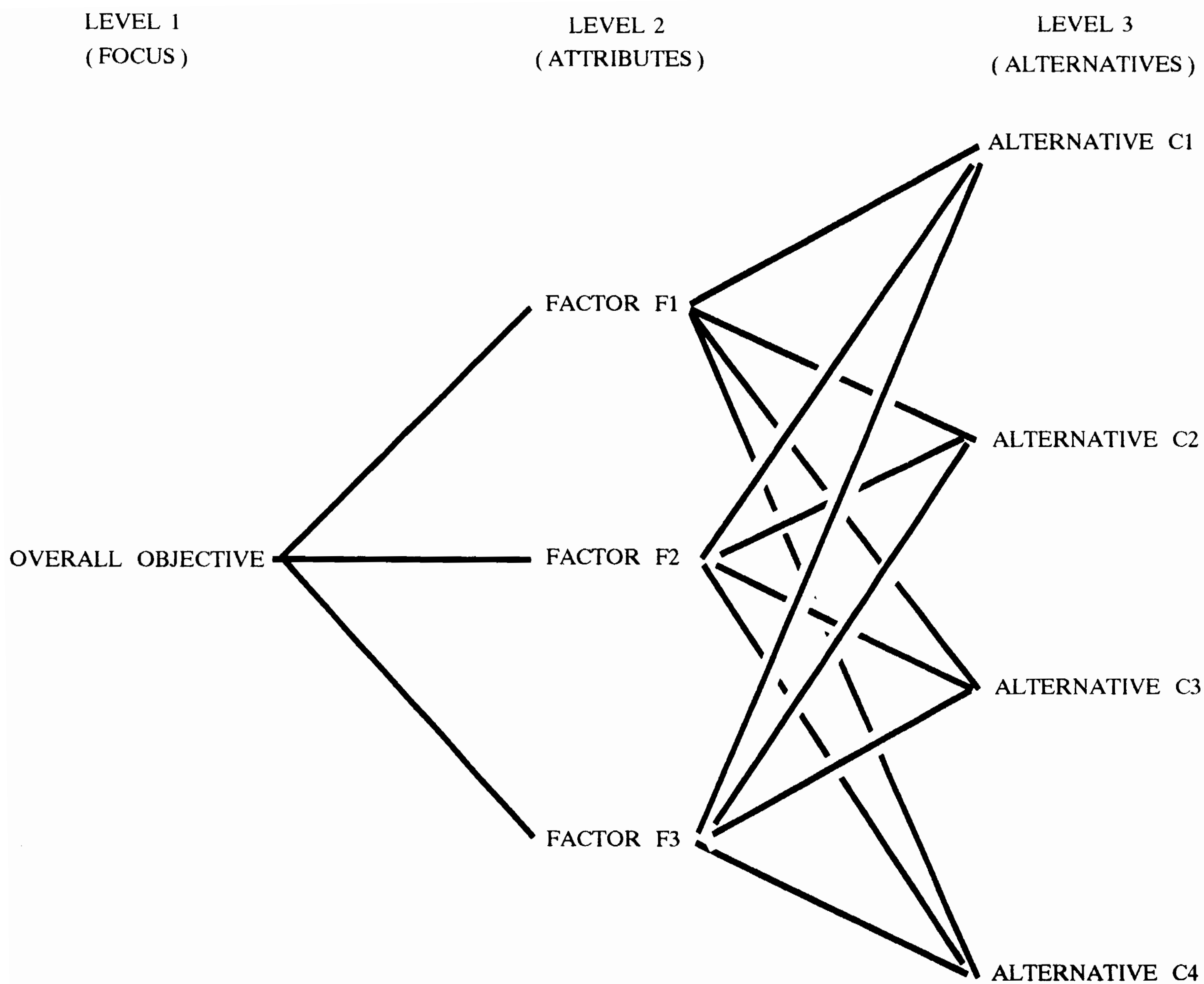

Figure 1. The basic analytic hierarchy structure.

TABLE 1
Pairwise Comparison Preference Assignment

If x is ... than y,	then the preference number to assign is:
equally important	1
weakly more important	3
strongly more important	5
very strongly more important	7
absolutely more important	9

TABLE 2
Preference Comparison Matrix

Attribute	F1	F2	F3
F1	1	3	9
F2	1/3	1	7
F3	1/9	1/7	1

TABLE 3
Attribute Prioritization

Attribute	F1	F2	F3
F1	1	3	9
F2	1/3	1	7
F3	1/9	1/7	1
Column Σ	1.44	4.14	17

Attribute	F1	F2	F3	Row Σ	Priority (Row Average) Σ Row / 3
F1	1/1.44	3/4.14	9/17	1.95	0.65
F2	0.33/1.44	1/4.14	7/17	0.88	0.29
F3	0.11/1.44	1/4.14	1/17	0.17	0.06
Column Σ	1	1	1		1

Canada and Sullivan called the average normalized attribute preference the "principal vector ... [,an] approximate priority weight (1989, p. 265)." However, a note of caution is in order concerning the usage of the term "weight." Weight implies a linear relationship of importance. For a pairwise comparison of only two elements with a weakly more important preference, an "approximate priority weight" of 0.75 and 0.25 is derived as shown in Table 4. The qualitative comparison selected was only weakly more important; however, the quantitative "approximate priority weight" derived was three times larger for factor F4 as compared to F5. Therefore, the term alternative priority preference (APP) shall be used for the capital budgeting model to prevent misinterpretation of the numbers derived in the principal vector.

An important check on the pairwise comparisons should be performed to verify a consistent assignment of preference. For example if F1 is assigned a preference over F2, F2 is assigned a preference over F3, and F3 is assigned a preference over F1, this would not be consistent. An explanation of the pairwise comparison consistency check used by Saaty (1980) shall follow.

TABLE 4
Attribute Prioritization for a Single Pairwise Comparison

Attribute	F4	F5
F4	1	3
F5	1/3	1
Column Σ	1.33	4.00

Attribute	F4	F5	Row Σ	Priority (Row Average) Σ Row / 3
F4	1/1.33	3/4	1.50	0.75
F5	0.33/1.33	1/4	0.50	0.25
Column Σ	1	1		1

Pairwise Comparison Consistency Check

The consistency ratio (CR) is an approximate indicator of the consistency of the pairwise comparisons. It is a function of the maximum eigenvalue (λ_{MAX}) of the comparison matrix and the size of the matrix. The size of an N by N matrix, for the purpose of this function, is the value N. The results of this function is called the consistency index (CI). The consistency index (CI) is then compared to similar empirical values of random pairwise comparisons called the random index (RI). This ratio is called the consistency ratio (CR).

To perform this consistency check, first multiply the matrix of the pairwise comparisons (in Table 2), call it matrix [A] by the attribute preference vector (right-hand column of Table 3), call it matrix [B] to obtain a new vector [C].

$$\begin{array}{ccccc} [A] & X & [B] & = & [C] \\ \begin{vmatrix} 1 & 3 & 9 \\ 0.33 & 1 & 7 \\ 0.11 & 0.14 & 1 \end{vmatrix} & X & \begin{vmatrix} 0.65 \\ 0.29 \\ 0.06 \end{vmatrix} & = & \begin{vmatrix} 2.04 \\ 0.91 \\ 0.17 \end{vmatrix} \end{array}$$

The second step is to divide each element in vector [C] by its corresponding element in vector [B] to find a vector [D].

$$[D] = \left| \frac{2.04}{0.65} \quad \frac{0.91}{0.29} \quad \frac{0.17}{0.06} \right| = [\ 3.15 \quad 3.08 \quad 3.01\ ]$$

Next, the average of the numbers in vector [D] is calculated. This is an approximation of the maximum eigenvalue (λ_{MAX}).

$$\lambda_{MAX} = \frac{3.15 + 3.08 + 3.01}{3} = 3.08$$

The consistency index for a matrix of size N is given by the following formula.

$$CI = \frac{\lambda_{MAX} - N}{N - 1} = \frac{3.08 - 3}{3 - 1} = 0.04$$

The consistency index (CI) is then compared to similar empirical values of random pairwise comparisons called the random index (RI). The random indexes provided in Table 5 for various matrix sizes, N, were approximated by Saaty (based on large numbers of simulation runs). The ratio of the consistency index versus random index is called the consistency ratio (CR).

TABLE 5
Random Index for Matrix Size N

N	RI
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
...	...

$$CR = CI / RI_3 = 0.04 / 0.58 = 0.07$$

Based on Saaty's empirical suggestion that a CR $\leq$ 0.10 is acceptable, implies that the pairwise comparisons to obtain attribute weights were reasonably consistent (Canada and Sullivan, 1989).

For multi-level attributes, the alternative priority preference (the larger the value of the alternative priority, the higher the importance) of the alternative is defined as the sum of the products of the attribute preference of a factor at a given level times the evaluation rating for an alternative at the next lower level. For example, for the basic analytic hierarchy structure (in Figure 1), the preference of the attributes (or principal vector element) for F1, F2, and F3 (in Table 3) as they relate to the overall objective are assigned to the applicable attributes and shown in Figure 2. The preferences shown in Figure 2 for the alternatives C1, C2, C3, and C4 as they relate to each attribute of the previous level were derived (but not shown) by similar pairwise comparisons. The alternative priority preference for the alternatives C1, C2, C3, and C4 are calculated as follows:

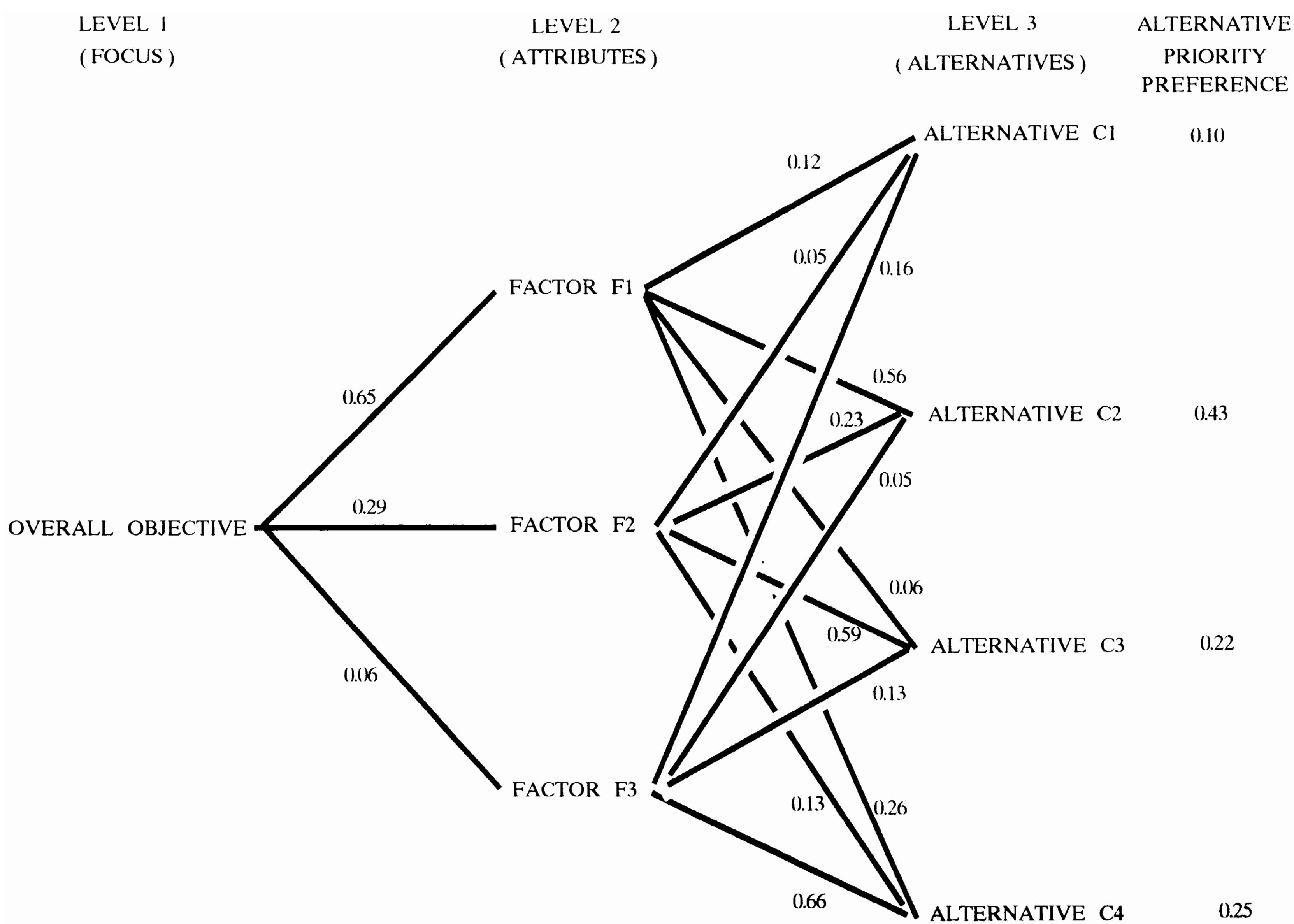

Figure 2. The basic analytic hierarchy structure with preference assingments.

$$APP_{C1} = (PV_{F1FO} \cdot PV_{C1F1}) + (PV_{F2FO} \cdot PV_{C1F2}) + (PV_{F3FO} \cdot PV_{C1F3})$$

where

APP_{C1} = Alternative Priority Preference of Alternative 1

PV_{F1FO} = Principal Vector element of Factor 1 as it relates to the Focus Objective

PV_{F2FO} = Principal Vector element of Factor 2 as it relates to the Focus Objective

PV_{F3FO} = Principal Vector element of Factor 3 as it relates to the Focus Objective

PV_{C1F1} = Principal Vector element of Alternative 1 as it relates to Factor 1

PV_{C1F2} = Principal Vector element of Alternative 1 as it relates to Factor 2

PV_{C1F3} = Principal Vector element of Alternative 1 as it relates to Factor 3

When the principal vector elements shown in Figure 2 are used, the alternative priority preference for the alternatives C1, C2, C3, and C4 are:

$$APP_{C1} = (PC_{F1FO} \cdot PC_{C1F1}) + (PC_{F2FO} \cdot PC_{C1F2}) + (PC_{F3FO} \cdot PC_{C1F3})$$
$$0.10 = (0.65 \cdot 0.12) + (0.29 \cdot 0.05) + (0.06 \cdot 0.16)$$

$$APP_{C2} = (PC_{F1FO} \cdot PC_{C2F1}) + (PC_{F2FO} \cdot PC_{C2F2}) + (PC_{F3FO} \cdot PC_{C2F3})$$
$$0.43 = (0.65 \cdot 0.56) + (0.29 \cdot 0.23) + (0.06 \cdot 0.05)$$

$$APP_{C3} = (PC_{F1FO} \cdot PC_{C3F1}) + (PC_{F2FO} \cdot PC_{C3F2}) + (PC_{F3FO} \cdot PC_{C3F3})$$
$$0.22 = (0.65 \cdot 0.06) + (0.29 \cdot 0.59) + (0.06 \cdot 0.13)$$

$$APP_{C4} = (PC_{F1FO} \cdot PC_{C4F1}) + (PC_{F2FO} \cdot PC_{C4F2}) + (PC_{F3FO} \cdot PC_{C4F3})$$
$$0.25 = (0.65 \cdot 0.26) + (0.29 \cdot 0.13) + (0.06 \cdot 0.66)$$

The alternatives in order of preference and their associated alternative priority preference are alternative C2 (0.43), alternative C4 (0.25), alternative C3 (0.22), and alternative C1 (0.10). These alternative priority preferences shall be used in the objective function of an integer program to select the best portfolio of alternatives to maximize the selection of highest priority alternatives.

Integer Programming Method

Integer programming is simply linear programming with the restriction that the variables must have integer values. One additional restriction shall be added to the integer program. This restriction is called contingent constraints. The contingent constraints are used to tie successive lower priority alternatives to the next higher priority alternative thereby insuring the lower priority alternative is not selected unless the higher priority alternative is selected. For example alternative C2 with an alternative priority preference of 0.43 is infinitely more important than alternative C4 with an alternative priority preference of 0.25. This is equivalent to preemptive priorities in goal programming.

The integer linear program is defined as follows:

Maximize the objective function

$$Z = \sum_{n=1}^{N} APP_{Cn} \cdot X_n$$

subject to the constraints

$$\sum_{n=1}^{N} A_{in} \cdot X_n \leq B_i \qquad \text{for } i = 1, 2, \ldots m$$

$$X_n = 0 \text{ or } 1 \qquad \text{for } n = 1, 2, \ldots N$$

where

N = the number of alternatives

APP_{Cn} = alternative priority preference of alternative n

X_n = decision variable for alternative n

A_{in} = coefficient of constraint i for alternative n

B_i = limit for constraint i

m = total number of constraints

The integer linear program with contingent constraints for the basic analytic hierarchy structure shown in Figure 2 is defined as follows:

Maximize the objective function

$$Z = 0.10\ X_1 + 0.43\ X_2 + 0.22\ X_3 + 0.25\ X_4$$

subject to the constraints

(some given set of technological or budget constraints)

$$\begin{aligned}
100\ X_1 + 110\ X_2 + 1000\ X_3 + 500\ X_4 &\leq 1600 \\
200\ X_1 + 150\ X_2 + 10\ X_3 + 100\ X_4 &\leq 450 \\
100\ X_1 + 210\ X_2 + 500\ X_3 + 1500\ X_4 &\leq 2600
\end{aligned}$$

(a set of priority contingent constraints)

$$\begin{aligned}
X_1 - X_3 &\leq 0 \\
+ X_3 - X_4 &\leq 0 \\
- X_2 + X_4 &\leq 0
\end{aligned}$$

(and decision variables)

$$X_n = 0 \text{ or } 1 \qquad \text{for } n = 1, 2, 3, 4$$

The initial results of this integer program selects alternatives X_2 and X_4 in the order of priority and does not select X_3 or X_1 due to a constraint coefficient requirement of 1000 for X_3 with only 900 units of slack available for the first technological or budget constraint. If the contingent constraint that makes X_1 contingent on X_3 is eliminated, and the integer program is rerun, then alternative X_1 can be selected (or any lower priority alternative subject to technological or budget constraints).

In the event that there is a tie between two or more alternative's alternative priority preference in the objective function the contingent constraints are slightly altered. For instance, if in the previous example alternatives X_3 and X_4 had the same alternative priority preference the initial contingent constraints would be:

$$
\begin{array}{lcccl}
X_1 & - & X_3 & & \leq 0 \\
X_1 & & - & X_4 & \leq 0 \\
 & - 2X_2 & + X_3 & + X_4 & \leq 0
\end{array}
$$

The same iterative process with contingent constraint removal (as required) can be used to solve for the optimum solution of the alternative portfolio selection.

The use of the integer linear program provides flexibility for the addition of various constraints to the solution process. Constraints such as budget constraints, manpower constraints, space constraints or any other technological constraint can be added.

THE CAPITAL BUDGETING MODEL

The first step in developing a multiattribute decision analysis capital budgeting model is to define the independent attributes to be considered in a comparison of alternatives as defined in the analytic hierarchy process. A second step would be to rank attributes in order of preference. This will quantify the relative importance of each attribute to the decision maker. An important source of this type of information for a given analysis is from the advice of "experts" in a given field. The Delphi method is often used as a source to obtain the information. However, if this source is not readily available, insight can be gained from documented sources such as industry reports, published company annual reports, internal company documents such as management goals (Table 6), and existing budget data. For the purpose of developing a capital budgeting model for a nuclear power plant, the following data and excerpts are provided from an electric utility.

Attribute Selection and Prioritization

The nuclear power plant under review is one of several production facilities for "The Company." "The Company" is a holding company principally involved in the electric power business. It is also active in natural gas, real estate, and the investment management business. The holding company's core electric power business includes operation of one of the nation's largest electric utilities and interests in a wide range of nonutility power production projects throughout the country.

1988 Annual Report

Letter To Shareholders from Chairman of the Board, Chief Executive Officer and President

> "The Company's" objective is to achieve higher returns than are possible in the regulated electric business while providing continued reliable service at low cost to our utility customers. Our strategy has two major elements. To meet our utility customers' growing needs for generating capacity, we will choose the best combination of capacity purchases in competitive markets and construction by "The Company." To improve returns on your investment, we will develop, through nonregulated subsidiaries, generating units to serve the needs of utilities other than "The Company."

TABLE 6
Vice President Nuclear Operation Goals 1990

Weight	Performance
.20	Nuclear Regulatory Commission perception
.08	Other Assessment Organizations' perception
.13	Human Resources Goals
.08	Accomplish Planned Projects
.17	Nuclear Capacity Factor, Heat Rate & Trips
.06	Personnel Radiation Exposure
	Profitability
.12	Control Operating & Maintenance Expenditures
.13	Control Capital Expenditures
.03	Limit Average Inventories
1.00	Total weight

General Review of Existing Capital Budget

The two unit nuclear power plant total capital budget under review is shown in Figure 3. All dollar values shown are in "1990 Dollars" using company specified rates. The budgeted capital shown in Figure 3 for years 1987 through 1990 was determined from an existing selection process of proposed projects at the beginning of each of the respective years. The actual capital for years 1987 through 1989 was determined from each end-of-year expenditure.

Analysis of the Existing Decision-Making System

The existing capital budgeting process involves an unweighted prioritization of all proposed projects. This process can be grouped into the seven categories listed in Table 7. After the projects are prioritized, a beginning of year budgeted project list is developed based on highest priority and the available capital. The actual projects worked and the amount of work performed during the year may differ from the beginning of year budgeted projects due to mid-year unforeseen priority projects. The results of the classification of the projects are shown in Figures 4 through 10. Based on the data provided in Figures 3 through 10, Table 8 provides a tabulation of the project categories identifying the percentage of the total budget expended.

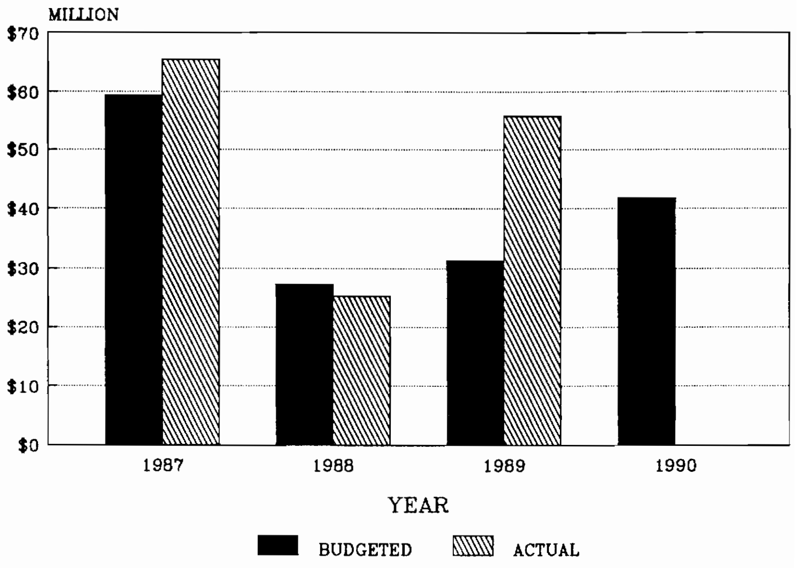

FIGURE 3. Total capital budget.

TABLE 7
Existing Project Priority Categories

Priority	Project Category
1	Maintaining Power Production
2	Regulatory Modifications
3	Health Physics Modifications
4	Maintenance Modifications
5	Required Surveillance Modifications
6	Efficiency Modifications
7	General Plant Support

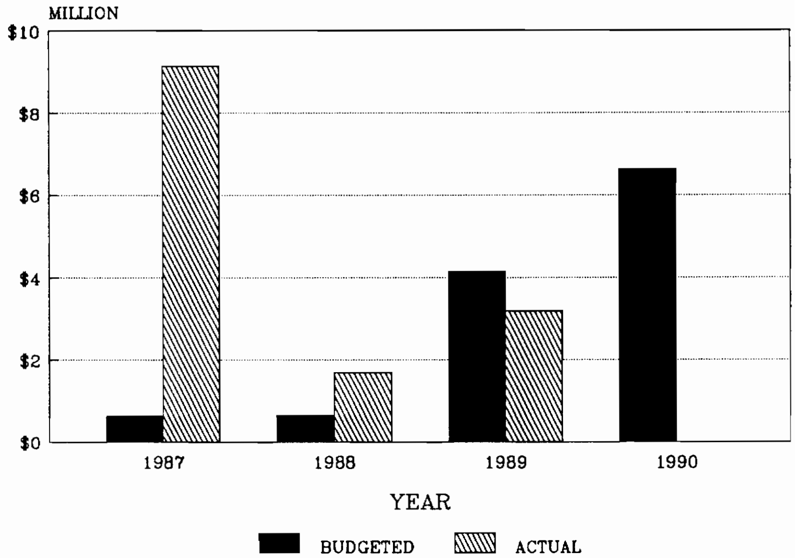

FIGURE 4. Maintaining power production budget.

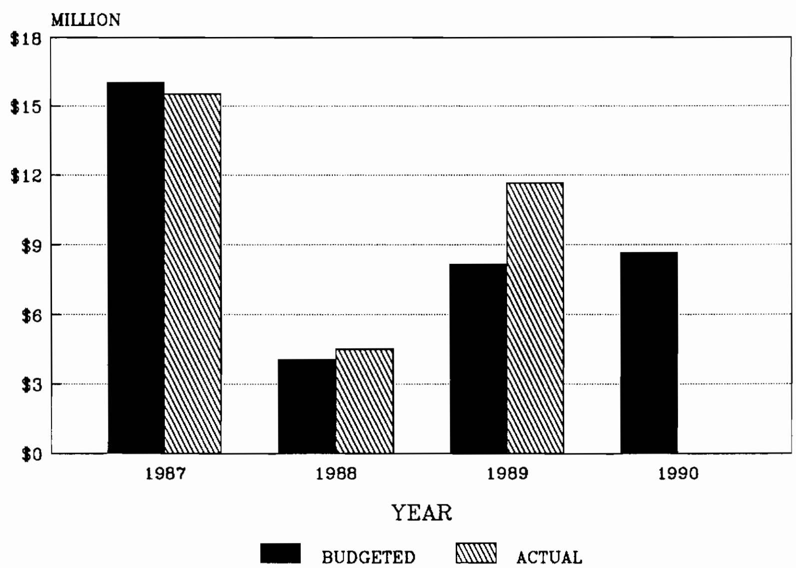

FIGURE 5. Regulatory capital budget.

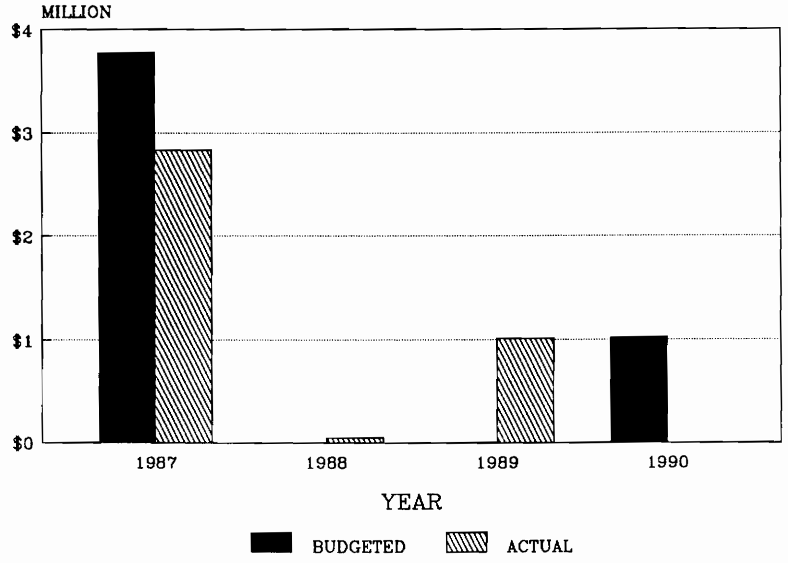

FIGURE 6. Health physics capital budget.

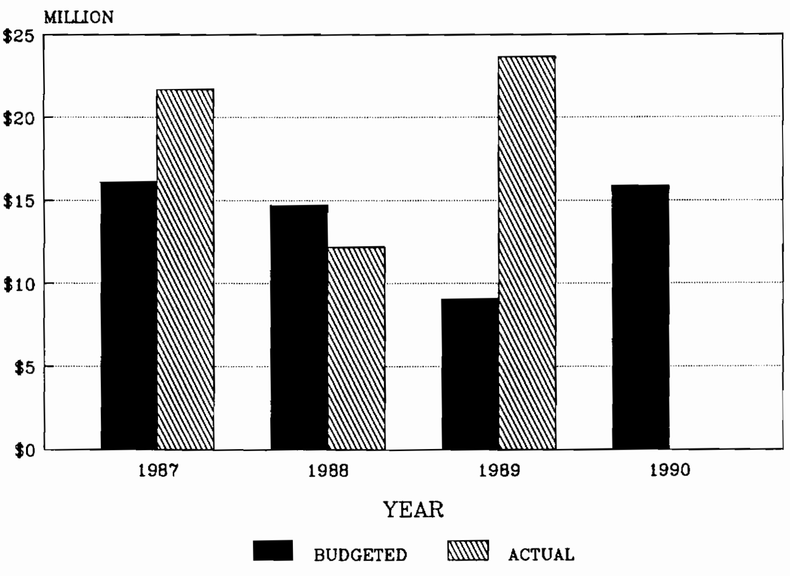

FIGURE 7. Maintenance capital budget.

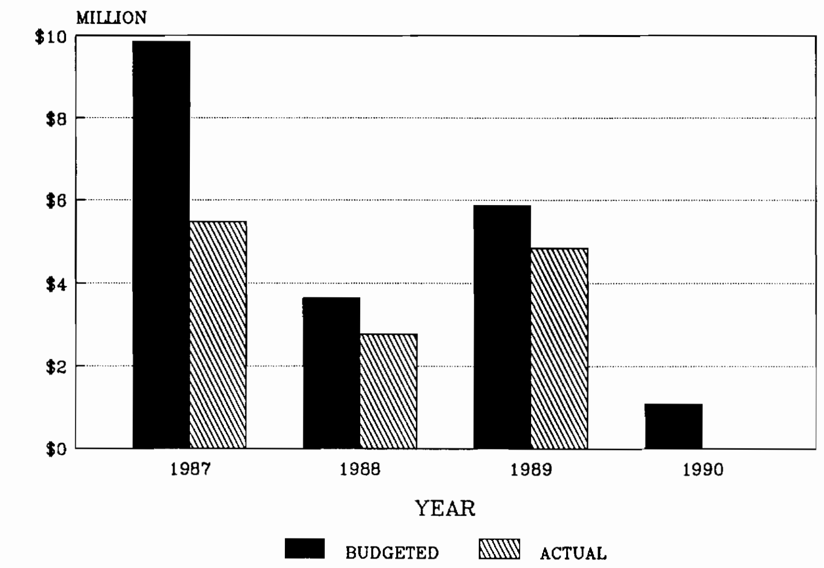

FIGURE 8. Surveillance capital budget.

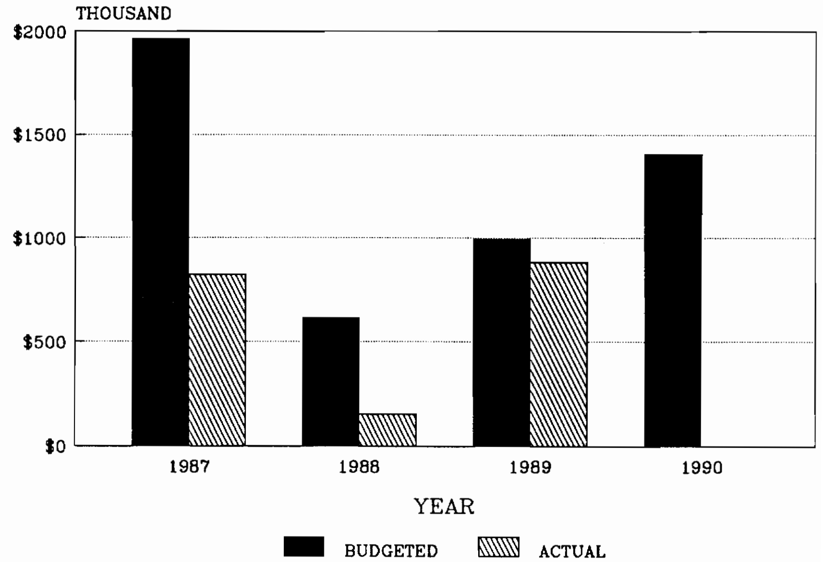

FIGURE 9. Efficiency capital budget.

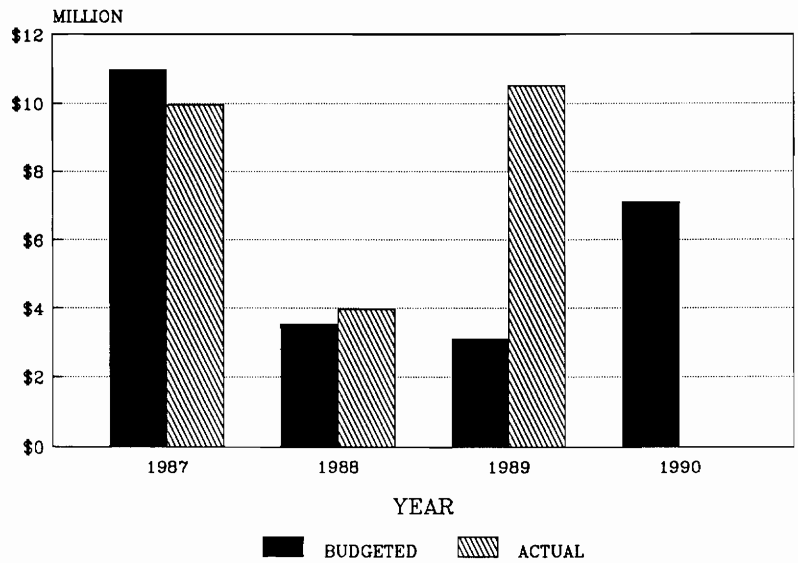

FIGURE 10. General support capital budget.

TABLE 8
Actual Project Category Percentage of Total Budget

Percentage	Project Grouping
.10	Maintain Power Production
.20	Regulatory Modifications
.02	Health Physics Modifications
.40	Maintenance Modifications
.09	Required Surveillance Modifications
.02	Efficiency Modifications
.17	General Plant Support

Note: The values are subject to error due to the authors limited information concerning actual classification of the projects.

RESULTS

Analytic Hierarchy Process

The proposed analytic hierarchy structure is shown in Figure 11. This structure is based on a review of the referenced industry reports, published company annual reports, internal company documents, and existing budget data. The multi-level attribute pairwise comparisons, the calculations of the attribute alternative priority preference, and the verification of consistency for each comparison are shown in Tables 9 through 14. The project classification (intermediate) alternative priority preference is shown in Table 15. The intermediate alternative priority preference of the project classifications is defined as the sum of the products of the attribute alternative priority preference of a factor at a given level times the evaluation rating for a choice at the next lower level. For example as listed in Table 15:

$$\text{FORCED OUTAGE} = [(\text{SERVICE} \times \text{POWER}_{\text{SERVICE}}) + (\text{ECONOMIC} \times \text{POWER}_{\text{ECONOMIC}})] \times \text{OUTAGE}_{\text{POWER}}$$

$$0.48 = [(0.75 \times 0.65) + (0.25 \times 0.72)] \times 0.72$$

The project pairwise comparisons, the calculations of the project alternative priority preference, and the verification of consistency are shown in Tables 16 through 23.

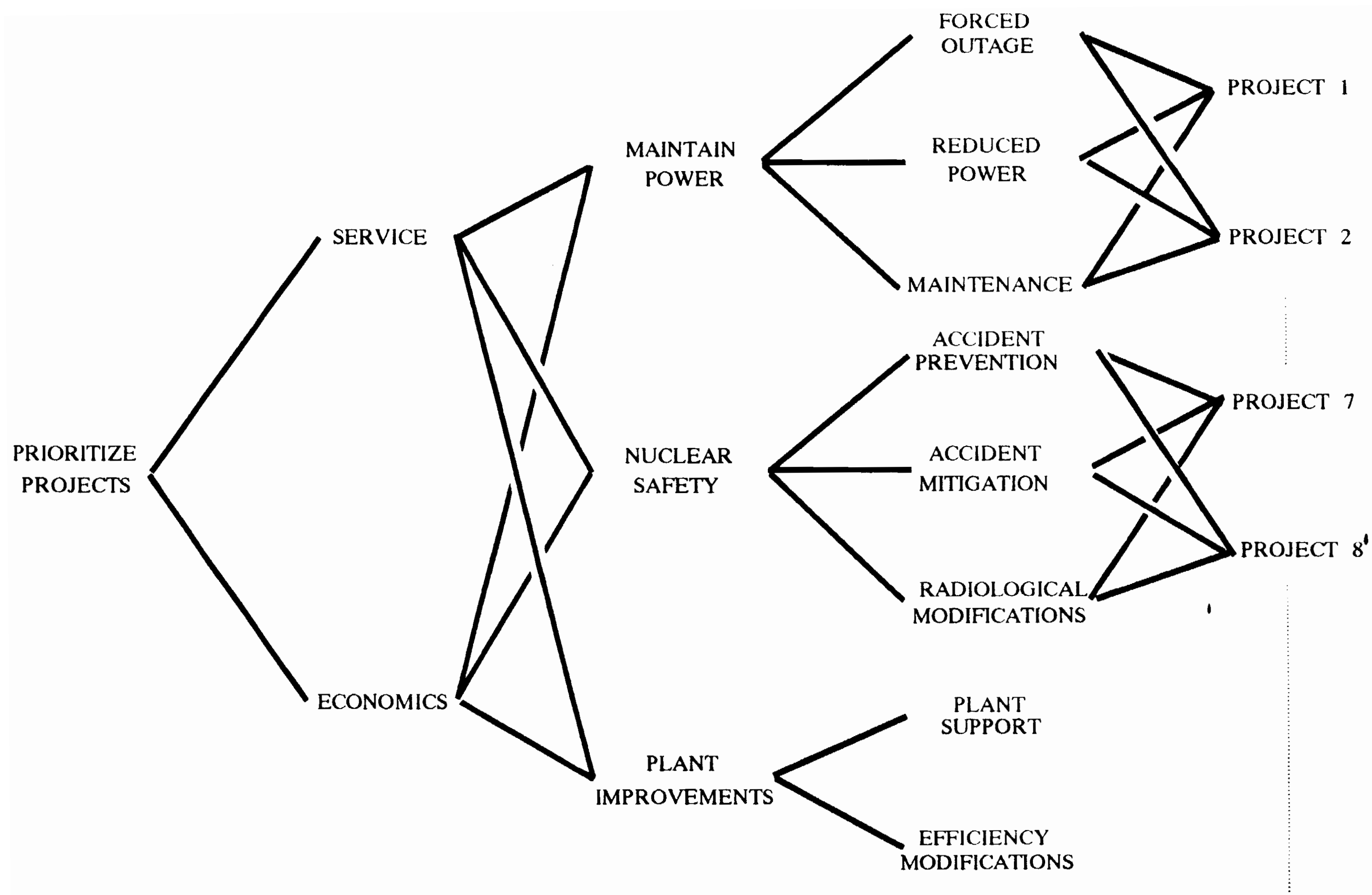

Figure 11. Capital budget analytic hierarchy.

TABLE 9
Level 1 Objective Pairwise Comparison

	[A] Serv	Econ
Service	1.00	3.00
Economic	0.33	1.00
Sum	1.33	4.00

	Serv	Econ	Sum	Ave
Service	0.75	0.75	1.50	0.75
Economic	0.25	0.25	0.50	0.25
Sum	1.00	1.00		1.00

TABLE 10
Level 2 Service Pairwise Comparison

	Pow	[A] Safe	Impr		[B]		[C]
Power	1.00	3.00	9.00		0.65		2.04
Safety	0.33	1.00	7.00	X	0.29	=	0.91
Improvement	0.11	0.14	1.00		0.06		0.17
Sum	1.44	4.14	17.00				

[D] =[3.15 3.08 3.01]

Lamda Max = 3.08
Const Index= 0.04
Const Ratio= 0.07

	Pow	Safe	Impr	Sum	Ave
Power	0.69	0.72	0.53	1.95	0.65
Safety	0.23	0.24	0.41	0.88	0.29
Improvement	0.08	0.03	0.06	0.17	0.06
Sum	1.00	1.00	1.00		1.00

TABLE 11
Level 2 Economic Pairwise Comparison

$$
\begin{array}{llll}
 & & [A] & \\
 & \text{Pow} & \text{Safe} & \text{Impr} \\
\text{Power} & \left| 1.00 \right. & 5.00 & \left. 7.00 \right| \\
\text{Safety} & \left| 0.20 \right. & 1.00 & \left. 3.00 \right| \\
\text{Improvement} & \left| 0.14 \right. & 0.33 & \left. 1.00 \right| \\
\text{Sum} & 1.34 & 6.33 & 11.00
\end{array}
\;\; X \;\;
\begin{array}{c}
[B] \\
\begin{vmatrix} 0.72 \\ 0.19 \\ 0.08 \end{vmatrix}
\end{array}
\;\; = \;\;
\begin{array}{c}
[C] \\
\begin{vmatrix} 2.27 \\ 0.59 \\ 0.25 \end{vmatrix}
\end{array}
$$

[D] =[3.14 3.04 3.01]

Lamda Max = 3.07
Const Index= 0.03
Const Ratio= 0.06

	Pow	Safe	Impr	Sum	Ave
Power	0.74	0.79	0.64	2.17	0.72
Safety	0.15	0.16	0.27	0.58	0.19
Improvement	0.11	0.05	0.09	0.25	0.08
Sum	1.00	1.00	1.00		1.00

TABLE 12
Level 3 Power Pairwise Comparison

	[A] Out	Red	Main		[B]		[C]
Outage	1.00	5.00	7.00		0.72		2.27
Reduction	0.20	1.00	3.00	X	0.19	=	0.59
Maintenance	0.14	0.33	1.00		0.08		0.25
Sum	1.34	6.33	11.00				

[D] =[3.14 3.04 3.01]

Lamda Max = 3.07
Const Index= 0.03
Const Ratio= 0.06

	Out	Red	Main	Sum	Ave
Outage	0.74	0.79	0.64	2.17	0.72
Reduction	0.15	0.16	0.27	0.58	0.19
Maintenance	0.11	0.05	0.09	0.25	0.08
Sum	1.00	1.00	1.00		1.00

TABLE 13
Level 3 Safety Pairwise Comparison

	[A] Prev	Mitg	Rad		[B]		[C]
Preventive	1.00	3.00	7.00		0.64		2.01
Mitigation	0.33	1.00	5.00	X	0.28	=	0.87
Radiological	0.14	0.20	1.00		0.07		0.22
Sum	1.48	4.20	13.00				

[D] =[3.12 3.06 3.01]

Lamda Max = 3.07
Const Index= 0.03
Const Ratio= 0.06

	Prev	Mitg	Rad	Sum	Ave
Preventive	0.68	0.71	0.54	1.93	0.64
Mitigation	0.23	0.24	0.38	0.85	0.28
Radiological	0.10	0.05	0.08	0.22	0.07
Sum	1.00	1.00	1.00		1.00

TABLE 14
Level 3 Improvement Pairwise Comparison

	[A] Supp	Eff
Support	1.00	2.00
Efficiency	0.50	1.00
Sum	1.50	3.00

	Supp	Eff	Sum	Ave
Support	0.67	0.67	1.33	0.67
Efficiency	0.33	0.33	0.67	0.33
Sum	1.00	1.00		1.00

TABLE 15
Level 4 Project Classification Alternative Priority Preference

Forced Outage	0.48
Power Reduction	0.13
Maintenance	0.06
Accident Prevention	0.17
Accident Mitigation	0.08
Radiological	0.02
Support	0.04
Efficiency	0.02
Sum	1.00

TABLE 16
Level 5 Outage Project Pairwise Comparison

	P5673	P5740
P5673	1.00	1.00
P5740	1.00	1.00
Sum	2.00	2.00

	P5673	P5740	Sum	Ave
P5673	0.50	0.50	1.00	0.50
P5740	0.50	0.50	1.00	0.50
Sum	1.00	1.00		1.00

TABLE 17
Level 5 Reduced Power Project Pairwise Comparison

	P5744
P5744	1.00

TABLE 18
Level 5 Maintenance Project Pairwise Comparison

A

MAINT/PROJ PAIRWISE	P4865	P5675	P5716	P5720	P5724	P5735	P5771	P5774	P5781	P5795
P4865	1.00	0.33	3.00	0.50	4.00	6.00	5.00	1.00	2.00	0.25
P5675	3.00	1.00	5.00	0.67	6.00	8.00	7.00	3.00	4.00	0.50
P5716	0.33	0.20	1.00	0.25	2.00	4.00	3.00	0.33	0.50	0.17
P5720	2.00	1.50	4.00	1.00	5.00	7.00	6.00	2.00	3.00	0.33
P5724	0.25	0.17	0.50	0.20	1.00	3.00	2.00	0.25	0.33	0.14
P5735	0.17	0.13	0.25	0.14	0.33	1.00	0.50	0.17	0.20	0.11
P5771	0.20	0.14	0.33	0.17	0.50	2.00	1.00	0.20	0.25	0.13
P5774	1.00	0.33	3.00	0.50	4.00	6.00	5.00	1.00	2.00	0.25
P5781	0.50	0.25	2.00	0.33	3.00	5.00	4.00	0.50	1.00	0.20
P5795	4.00	2.00	6.00	3.00	7.00	9.00	8.00	4.00	5.00	1.00
Sum	12.45	6.05	25.08	6.76	32.83	51.00	41.50	12.45	18.28	3.08

X

	B		C
P4865	0.10		1.01
P5675	0.18		1.98
P5716	0.05		0.46
P5720	0.16		1.70
P5724	0.03	=	0.32
P5735	0.02		0.17
P5771	0.02		0.23
P5774	0.10		1.01
P5781	0.07		0.68
P5795	0.28		3.05

D =	10.55	10.80	10.18	10.77	10.11	10.30	10.16	10.55	10.34	10.75
Lamda Max	10.45									
Const Index	0.05									
Const Ratio	0.03									

Weight	P4865	P5675	P5716	P5720	P5724	P5735	P5771	P5774	P5781	P5795	Sum	Ave
P4865	0.08	0.06	0.12	0.07	0.12	0.12	0.12	0.08	0.11	0.08	0.96	0.10
P5675	0.24	0.17	0.20	0.10	0.18	0.16	0.17	0.24	0.22	0.16	1.83	0.18
P5716	0.03	0.03	0.04	0.04	0.06	0.08	0.07	0.03	0.03	0.05	0.46	0.05
P5720	0.16	0.25	0.16	0.15	0.15	0.14	0.14	0.16	0.16	0.11	1.58	0.16
P5724	0.02	0.03	0.02	0.03	0.03	0.06	0.05	0.02	0.02	0.05	0.32	0.03
P5735	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.04	0.17	0.02
P5771	0.02	0.02	0.01	0.02	0.02	0.04	0.02	0.02	0.01	0.04	0.23	0.02
P5774	0.08	0.06	0.12	0.07	0.12	0.12	0.12	0.08	0.11	0.08	0.96	0.10
P5781	0.04	0.04	0.08	0.05	0.09	0.10	0.10	0.04	0.05	0.06	0.66	0.07
P5795	0.32	0.33	0.24	0.44	0.21	0.18	0.19	0.32	0.27	0.32	2.84	0.28
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00

TABLE 19
Level 5 Accident Prevention Project Pairwise Comparison

PREVT/PROJ PAIRWISE	P4870	P4874	P4875	P5612	A P5663	P5679	P5737	P5754	P5757	P5765	
P4870	1.00	4.00	0.20	3.00	5.00	0.25	2.00	0.33	2.00	0.50	
P4874	0.25	1.00	0.13	0.50	2.00	0.14	0.33	0.17	0.33	0.20	
P4875	5.00	8.00	1.00	7.00	9.00	2.00	6.00	3.00	6.00	4.00	
P5612	0.33	2.00	0.14	1.00	3.00	0.17	0.50	0.20	0.50	0.25	
P5663	0.20	0.50	0.11	0.33	1.00	0.13	0.25	0.14	0.50	0.17	X
P5679	4.00	7.00	0.50	6.00	8.00	1.00	5.00	2.00	5.00	3.00	
P5737	0.50	3.00	0.17	2.00	4.00	0.20	1.00	0.25	1.00	0.33	
P5754	3.00	6.00	0.33	5.00	7.00	0.50	4.00	1.00	4.00	2.00	
P5757	0.50	3.00	0.17	2.00	2.00	0.20	1.00	0.25	1.00	0.33	
P5765	2.00	5.00	0.25	4.00	6.00	0.33	3.00	0.50	3.00	1.00	
Sum	16.78	39.50	3.00	30.83	47.00	4.92	23.08	7.84	23.33	11.78	

	B		C
P4870	0.07		0.77
P4874	0.02		0.24
P4875	0.29		3.12
P5612	0.03		0.34
P5663	0.02	=	0.19
P5679	0.21		2.26
P5737	0.05		0.51
P5754	0.15		1.61
P5757	0.05		0.47
P5765	0.11		1.12

D =	10.36	10.14	10.75	10.10	10.28	10.81	10.18	10.73	10.33	10.56
Lamda Max	10.42									
Const Index	0.05									
Const Ratio	0.03									

Weight	P4870	P4874	P4875	P5612	P5663	P5679	P5737	P5754	P5757	P5765	Sum	Ave
P4870	0.06	0.10	0.07	0.10	0.11	0.05	0.09	0.04	0.09	0.04	0.74	0.07
P4874	0.01	0.03	0.04	0.02	0.04	0.03	0.01	0.02	0.01	0.02	0.24	0.02
P4875	0.30	0.20	0.33	0.23	0.19	0.41	0.26	0.38	0.26	0.34	2.90	0.29
P5612	0.02	0.05	0.05	0.03	0.06	0.03	0.02	0.03	0.02	0.02	0.34	0.03
P5663	0.01	0.01	0.04	0.01	0.02	0.03	0.01	0.02	0.02	0.01	0.18	0.02
P5679	0.24	0.18	0.17	0.19	0.17	0.20	0.22	0.26	0.21	0.25	2.09	0.21
P5737	0.03	0.08	0.06	0.06	0.09	0.04	0.04	0.03	0.04	0.03	0.50	0.05
P5754	0.18	0.15	0.11	0.16	0.15	0.10	0.17	0.13	0.17	0.17	1.50	0.15
P5757	0.03	0.08	0.06	0.06	0.04	0.04	0.04	0.03	0.04	0.03	0.46	0.05
P5765	0.12	0.13	0.08	0.13	0.13	0.07	0.13	0.06	0.13	0.08	1.06	0.11
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00

TABLE 20
Level 5 Accident Mitigation Project Pairwise Comparison

MITIGATE PAIRWISE	P5782	P6186 (A)	P5759	P5773	P5783	P7004		B		C
P5782	1.00	3.00	0.33	7.00	0.50	5.00		0.18		1.15
P6186	0.33	1.00	0.20	5.00	0.25	3.00	X	0.09	=	0.58
P5759	3.00	5.00	1.00	9.00	2.00	7.00		0.39		2.50
P5773	0.14	0.20	0.11	1.00	0.13	0.33		0.03		0.16
P5783	2.00	4.00	0.50	8.00	1.00	6.00		0.26		1.70
P7004	0.20	0.33	0.14	3.00	0.17	1.00		0.05		0.30
Sum	6.68	13.53	2.29	33.00	4.04	22.33				

D =	6.42	6.20	6.42	6.09	6.48	6.04
Lamda Max	6.28					
Const Index	0.06					
Const Ratio	0.04					

Weight	P5782	P6186	P5759	P5773	P5783	P7004	Sum	Ave
P5782	0.15	0.22	0.15	0.21	0.12	0.22	1.08	0.18
P6186	0.05	0.07	0.09	0.15	0.06	0.13	0.56	0.09
P5759	0.45	0.37	0.44	0.27	0.49	0.31	2.34	0.39
P5773	0.02	0.01	0.05	0.03	0.03	0.01	0.16	0.03
P5783	0.30	0.30	0.22	0.24	0.25	0.27	1.57	0.26
P7004	0.03	0.02	0.06	0.09	0.04	0.04	0.29	0.05
Sum	1.00	1.00	1.00	1.00	1.00	1.00		1.00

TABLE 21
Level 5 Radiological Project Pairwise Comparison

RADIOLOGICAL PAIRWISE	P4005	P5665 (A)	P5791	P7128		B		C
P4005	1.00	0.20	3.00	0.33		0.12		0.49
P5665	5.00	1.00	7.00	3.00	X	0.56	=	2.36
P5791	0.33	0.14	1.00	0.20		0.06		0.23
P7128	3.00	0.33	5.00	1.00		0.26		1.10
Sum	9.33	1.68	16.00	4.53				

D =	4.04	4.22	4.04	4.17
Lamda Max	4.12			
Const Index	0.04			
Const Ratio	0.04			

Weight	P4005	P5665	P5791	P7128	Sum	Ave
P4005	0.11	0.12	0.19	0.07	0.49	0.12
P5665	0.54	0.60	0.44	0.66	2.23	0.56
P5791	0.04	0.09	0.06	0.04	0.23	0.06
P7128	0.32	0.20	0.31	0.22	1.05	0.26
Sum	1.00	1.00	1.00	1.00		1.00

TABLE 22
Level 5 General Support Project Pairwise Comparison

A

SUPPT/PROJ PAIRWISE	P1101	P2548	P2549	P2550	P2551	P4884	P5661	P5694	P5725	P5734
P1101	1.00	1.00	1.00	1.00	1.00	0.33	3.00	4.00	0.50	3.00
P2548	1.00	1.00	1.00	1.00	1.00	0.33	3.00	4.00	0.50	3.00
P2549	1.00	1.00	1.00	1.00	1.00	0.33	3.00	4.00	0.50	3.00
P2550	1.00	1.00	1.00	1.00	1.00	0.33	3.00	4.00	0.50	3.00
P2551	1.00	1.00	1.00	1.00	1.00	0.33	3.00	4.00	0.50	3.00
P4884	3.00	3.00	3.00	3.00	3.00	1.00	5.00	6.00	2.00	5.00
P5661	0.33	0.33	0.33	0.33	0.33	0.20	1.00	2.00	0.25	1.00
P5694	0.25	0.25	0.25	0.25	0.25	0.17	0.50	1.00	0.20	0.50
P5725	2.00	2.00	2.00	2.00	2.00	0.50	4.00	5.00	1.00	4.00
P5734	0.33	0.33	0.33	0.33	0.33	0.20	1.00	2.00	0.25	1.00
Sum	10.92	10.92	10.92	10.92	10.92	3.73	26.50	36.00	6.20	26.50

X

	B		C
P1101	0.10		0.98
P2548	0.10		0.98
P2549	0.10		0.98
P2550	0.10		0.98
P2551	0.10	=	0.98
P4884	0.25		2.56
P5661	0.04		0.38
P5694	0.03		0.26
P5725	0.17		1.69
P5734	0.04		0.38

D =	10.13	10.13	10.13	10.13	10.13	10.21	10.04	10.08	10.21	10.04
Lamda Max	10.13									
Const Index	0.01									
Const Ratio	0.01									

Weight	P1101	P2548	P2549	P2550	P2551	P4884	P5661	P5694	P5725	P5734	Sum	Ave
P1101	0.09	0.09	0.09	0.09	0.09	0.09	0.11	0.11	0.08	0.11	0.97	0.10
P2548	0.09	0.09	0.09	0.09	0.09	0.09	0.11	0.11	0.08	0.11	0.97	0.10
P2549	0.09	0.09	0.09	0.09	0.09	0.09	0.11	0.11	0.08	0.11	0.97	0.10
P2550	0.09	0.09	0.09	0.09	0.09	0.09	0.11	0.11	0.08	0.11	0.97	0.10
P2551	0.09	0.09	0.09	0.09	0.09	0.09	0.11	0.11	0.08	0.11	0.97	0.10
P4884	0.27	0.27	0.27	0.27	0.27	0.27	0.19	0.17	0.32	0.19	2.51	0.25
P5661	0.03	0.03	0.03	0.03	0.03	0.05	0.04	0.06	0.04	0.04	0.38	0.04
P5694	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.03	0.03	0.02	0.26	0.03
P5725	0.18	0.18	0.18	0.18	0.18	0.13	0.15	0.14	0.16	0.15	1.65	0.17
P5734	0.03	0.03	0.03	0.03	0.03	0.05	0.04	0.06	0.04	0.04	0.38	0.04
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00

TABLE 23
Level 5 Efficiency Project Pairwise Comparison

EFFIC/PROJ PAIRWISE	P5756	P5766	P7236	P5600	A P5670	P5685	P5686
P5756	1.00	4.00	6.00	7.00	1.00	9.00	3.00
P5766	0.25	1.00	3.00	4.00	0.25	6.00	0.50
P7236	0.17	0.33	1.00	2.00	0.14	4.00	0.25
P5600	0.14	0.25	0.50	1.00	0.14	3.00	0.20
P5670	1.00	4.00	7.00	7.00	1.00	9.00	3.00
P5685	0.11	0.17	0.25	0.33	0.11	1.00	0.14
P5686	0.33	2.00	4.00	5.00	0.33	7.00	1.00
Sum	3.00	11.75	21.75	26.33	2.98	39.00	8.09

	B		C
P5756	0.31		2.32
P5766	0.11		0.80
P7236	0.06		0.39
P5600	0.04		0.28
P5670	0.31	=	2.38
P5685	0.02		0.16
P5686	0.15		1.15

D =	7.56	7.38	7.13	7.04	7.58	7.11	7.54
Lamda Max	7.34						
Const Index	0.06						
Const Ratio	0.04						

Weight	P5756	P5766	P7236	P5600	P5670	P5685	P5686	Sum	Ave
P5756	0.33	0.34	0.28	0.27	0.34	0.23	0.37	2.15	0.31
P5766	0.08	0.09	0.14	0.15	0.08	0.15	0.06	0.76	0.11
P7236	0.06	0.03	0.05	0.08	0.05	0.10	0.03	0.39	0.06
P5600	0.05	0.02	0.02	0.04	0.05	0.08	0.02	0.28	0.04
P5670	0.33	0.34	0.32	0.27	0.34	0.23	0.37	2.20	0.31
P5685	0.04	0.01	0.01	0.01	0.04	0.03	0.02	0.16	0.02
P5686	0.11	0.17	0.18	0.19	0.11	0.18	0.12	1.07	0.15
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00

Sensitivity Analysis of Alternative Priority Preferences

A sensitivity analysis was performed to determine the changes in relative ranking of projects by altering the pairwise comparison preferences.

The first sensitivity analysis was performed by altering the Level 2 Service versus Economics pairwise comparison. The preferences were changed from:

"Service is weakly more important than Economics."

to

"Economics is weakly more important than Service."

It is my opinion that it would be difficult to justify a larger preference change at this level. As shown in Table 24, a change in ranking of the projects averaged less than 1 position change with a variance of 4. A change of +1 in Table 24 means that the relative ranking of priority for the particular project increased to a higher priority (preferred), while a change of -1 in Table 24 means that the relative ranking of priority for the particular project decreased to a lower priority (less preferred).

The second sensitivity analysis was performed by altering the Level 3 attributes Power versus Safety in relation to Service. The preferences were changed from:

TABLE 24

Level 5 Project Alternative Priority Preference Assignment And Sensitivity Analysis

	Initial Analysis	First Sensitivity Analysis For Level 2		Second Sensitivity Analysis For Level 3		Third Sensitivity Analysis For Level 4	
Project	APP	APP	Rank Change	APP	Rank Change	APP	Rank Change
P1101	0.0041	0.0049	2	0.0041	-2	0.0041	-1
P2548	0.0041	0.0049	2	0.0041	-2	0.0041	-1
P2549	0.0041	0.0049	2	0.0041	-2	0.0041	-1
P2550	0.0041	0.0049	2	0.0041	-2	0.0041	-1
P2551	0.0041	0.0049	2	0.0041	-2	0.0041	-1
P4005	0.0024	0.0020	-2	0.0048	4	0.0024	0
P4865	0.0053	0.0056	1	0.0032	-5	0.0053	2
P4870	0.0128	0.0104	-2	0.0254	2	0.0056	-9
P4874	0.0041	0.0033	-2	0.0081	7	0.0018	-7
P4875	0.0502	0.0408	2	0.0997	1	0.0221	-3
P4884	0.0106	0.0128	1	0.0106	-2	0.0106	1
P5600	0.0008	0.0010	2	0.0008	4	0.0008	0
P5612	0.0059	0.0048	-2	0.0116	8	0.0026	-6
P5661	0.0016	0.0019	1	0.0016	3	0.0016	1
P5663	0.0032	0.0026	-3	0.0063	5	0.0014	-6
P5665	0.0111	0.0090	-3	0.0220	2	0.0111	1
P5670	0.0066	0.0080	3	0.0066	-11	0.0066	2
P5673	0.2414	0.2550	-2	0.1454	0	0.2414	0
P5675	0.0102	0.0108	2	0.0061	-10	0.0102	1
P5679	0.0362	0.0294	-2	0.0720	1	0.0159	-4
P5685	0.0005	0.0006	1	0.0005	3	0.0005	0
P5686	0.0032	0.0039	2	0.0032	0	0.0032	1
P5694	0.0011	0.0013	1	0.0011	3	0.0011	0
P5716	0.0025	0.0027	-3	0.0015	-3	0.0025	0
P5720	0.0088	0.0093	1	0.0053	-10	0.0088	-1

-Continued-

TABLE 24
-Continued-
Level 5 Project Alternative Priority Preference Assignment And Sensitivity Analysis

Project	Initial Analysis APP	First Sensitivity Analysis For Level 2 APP	First Sensitivity Analysis For Level 2 Rank Change	Second Sensitivity Analysis For Level 3 APP	Second Sensitivity Analysis For Level 3 Rank Change	Third Sensitivity Analysis For Level 4 APP	Third Sensitivity Analysis For Level 4 Rank Change
P5724	0.0018	0.0019	-2	0.0011	-1	0.0018	1
P5725	0.0070	0.0084	3	0.0070	-1	0.0070	2
P5734	0.0016	0.0019	1	0.0016	3	0.0016	1
P5735	0.0009	0.0010	1	0.0006	2	0.0009	0
P5737	0.0086	0.0070	-3	0.0172	5	0.0038	-9
P5740	0.2414	0.2550	0	0.1454	0	0.2414	0
P5744	0.1289	0.1362	0	0.0776	-1	0.1289	0
P5754	0.0259	0.0210	0	0.0515	2	0.0114	-4
P5756	0.0065	0.0079	3	0.0065	-1	0.0065	2
P5757	0.0079	0.0064	-3	0.0157	5	0.0035	-9
P5759	0.0297	0.0241	-2	0.0589	1	0.0675	2
P5765	0.0184	0.0149	-3	0.0365	1	0.0081	-8
P5766	0.0023	0.0028	2	0.0023	2	0.0023	0
P5771	0.0013	0.0013	-3	0.0008	0	0.0013	0
P5773	0.0020	0.0017	-4	0.0041	5	0.0047	9
P5774	0.0053	0.0056	1	0.0032	-5	0.0053	2
P5781	0.0037	0.0039	1	0.0022	-3	0.0037	1
P5782	0.0137	0.0111	-1	0.0272	2	0.0311	5
P5783	0.0200	0.0162	-1	0.0396	1	0.0454	3
P5791	0.0011	0.0009	-1	0.0022	7	0.0011	0
P5795	0.0158	0.0167	2	0.0095	8	0.0158	0
P6186	0.0071	0.0058	-3	0.0141	5	0.0161	11
P7004	0.0037	0.0030	-2	0.0074	7	0.0085	11
P7128	0.0052	0.0043	-1	0.0104	8	0.0052	2
P7236	0.0012	0.0014	1	0.0012	3	0.0012	0
Sum	1.0000	1.0000		1.0000		1.0000	
		Average	-0.16		0.94		-0.20
		Variance	4.17		18.86		17.32
		Standard Deviation	2.04		4.34		4.16

"Power is weakly more important than Safety." "Power is absolutely more important than Improvements."
"Safety is very strongly more important than Improvements."
to
"Safety is weakly more important than Power."
"Safety is absolutely more important than Improvements."
"Power is very strongly more important than Improvements."

Once again, it is my opinion that it would be difficult to justify a larger preference change at this level for the dominant factors Power and Safety. As shown in Table 24, the ranking of the projects averaged less than 1 position change with a variance of 19. Three projects (Projects P5670, P5675, and P5720) had a change of at least 10 positions.

Project P5670 which was not categorized under the Power or Safety attributes, scored the same alternative priority preference value of 0.0066 for the initial calculation and second sensitivity analysis. However, with the altering of other project scores, the relative position was reduced by 11 positions.

Projects P5675 and P5720, which were categorized under the attribute Power and under the lower subattribute Maintenance, scored different alternative priority preference values for the initial calculation and second sensitivity analysis. These projects were some of the higher priority projects under the subattribute Maintenance.

The third sensitivity analysis was performed by altering the Level 4 attribute Accident Prevention versus Accident Mitigation pairwise comparison in relation to Safety. The preferences were changed from:

"Accident Prevention is weakly more important than Mitigation."
"Accident Prevention is very strongly more important than Radiological Protection."
"Accident Mitigation is strongly more important than Radiological Protection."

to

"Accident Mitigation is weakly more important than Prevention."
"Accident Mitigation is very strongly more important than Radiological Protection."
"Accident Prevention is strongly more important than Radiological Protection."

As shown in Table 24, the ranking of the projects averaged less than 1 position change with a variance of 17. Six projects (Projects P4870, P5737, P5757, P5765, P6186, and P5720) had a change of at least 8 positions.

Projects P4870, P5737, P5757, and P5765 had a relative reduction of 8 positions. These were categorized under subattribute Accident Prevention. Projects P6186 and P7004 had a relative increase of 11 positions. These were categorized under subattribute Accident Mitigation.

Integer Programming Method

Integer programming with contingent constraints was used to select the optimum portfolio of projects. The computer software used in this analysis was the integer programming provided in STORM Personal Version 2.0.

The project alternative priority preferences provided in Table 24 were used as the coefficients in the objective function after using a scalar factor of 10000. The total budget constraint for each project was divided into five separate constraints; material dollars, internal engineering dollars, external engineering dollars, internal craft dollars, and external craft dollars. The actual budgeted dollars for these five constraints were not available; however, for the purpose of this model, the values were simulated. The contingent constraints were used to define the preemptive priorities. A complete listing of the model is provided in Table 25.

The software package STORM Personal Version 2.0 limits the number of constraints to 40. Therefore, for this model the 15 highest priority projects were eliminated from the evaluation. The budget constraints were reduced accordingly.

TABLE 25

Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	P1101	P2548	P2549	P2550	P2551
OBJ COEFF	41.	41.	41.	41.	41.
MATERIAL	1913.	377.	70.	140.	33.
INT ENGR	478.	0.	0.	0.	0.
OUT ENGR	0.	0.	0.	0.	0.
INT CRAFT	2392.	42.	8.	16.	4.
OUT CRAFT	0.	0.	0.	0.	0.
TOTAL BUDG	4783.	419.	78.	156.	37.
CONSTR 7	0.	0.	0.	0.	0.
CONSTR 8	0.	0.	0.	0.	0.
CONSTR 9	0.	0.	0.	0.	0.
CONSTR 10	0.	0.	0.	0.	0.
CONSTR 11	0.	0.	0.	0.	0.
CONSTR 12	0.	0.	0.	0.	0.
CONSTR 13	0.	0.	0.	0.	0.
CONSTR 14	0.	0.	0.	0.	0.
CONSTR 15	0.	0.	0.	0.	0.
CONSTR 16	0.	0.	0.	0.	0.
CONSTR 17	0.	0.	0.	0.	0.
CONSTR 18	0.	0.	0.	0.	0.
CONSTR 19	0.	0.	0.	0.	0.
CONSTR 20	0.	0.	0.	0.	0.
CONSTR 21	0.	0.	0.	0.	0.
CONSTR 22	0.	0.	0.	0.	0.
CONSTR 23	0.	0.	0.	0.	0.
CONSTR 24	-1.	-1.	-1.	-1.	-1.
CONSTR 25	1.	0.	0.	0.	0.
CONSTR 26	0.	1.	0.	0.	0.
CONSTR 27	0.	0.	1.	0.	0.
CONSTR 28	0.	0.	0.	1.	0.
CONSTR 29	0.	0.	0.	0.	1.
CONSTR 30	0.	0.	0.	0.	0.
CONSTR 31	0.	0.	0.	0.	0.
CONSTR 32	0.	0.	0.	0.	0.
CONSTR 33	0.	0.	0.	0.	0.
CONSTR 34	0.	0.	0.	0.	0.
CONSTR 35	0.	0.	0.	0.	0.
CONSTR 36	0.	0.	0.	0.	0.
CONSTR 37	0.	0.	0.	0.	0.
CONSTR 38	0.	0.	0.	0.	0.
CONSTR 39	0.	0.	0.	0.	0.
CONSTR 40	0.	0.	0.	0.	0.
VARBL TYPE	0-1	0-1	0-1	0-1	0-1
LOWR BOUND	.	.	.	.	.
UPPR BOUND	.	.	.	.	.
INIT SOLN	0.	0.	0.	0.	0.

TABLE 25
-Continued-
Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	P4005	P4865	P4870	P4874	P4875
OBJ COEFF	24.	53.	128.	41.	502.
MATERIAL	472.	329.	157.	212.	1.
INT ENGR	0.	329.	157.	212.	3.
OUT ENGR	0.	494.	392.	848.	8.
INT CRAFT	52.	165.	0.	0.	0.
OUT CRAFT	0.	494.	78.	848.	1.
TOTAL BUDG	524.	1811.	784.	2120.	13.
CONSTR 7	0.	0.	0.	0.	0.
CONSTR 8	0.	0.	0.	0.	0.
CONSTR 9	0.	0.	0.	0.	0.
CONSTR 10	0.	0.	0.	0.	0.
CONSTR 11	0.	0.	0.	0.	0.
CONSTR 12	0.	0.	0.	0.	0.
CONSTR 13	0.	0.	0.	0.	0.
CONSTR 14	0.	0.	0.	0.	0.
CONSTR 15	0.	0.	0.	0.	0.
CONSTR 16	0.	0.	0.	0.	0.
CONSTR 17	0.	0.	0.	0.	0.
CONSTR 18	-1.	0.	0.	0.	0.
CONSTR 19	1.	0.	0.	0.	0.
CONSTR 20	0.	0.	0.	0.	0.
CONSTR 21	0.	0.	0.	0.	0.
CONSTR 22	0.	0.	0.	0.	0.
CONSTR 23	0.	0.	0.	0.	0.
CONSTR 24	0.	0.	0.	-1.	0.
CONSTR 25	0.	0.	0.	0.	0.
CONSTR 26	0.	0.	0.	0.	0.
CONSTR 27	0.	0.	0.	0.	0.
CONSTR 28	0.	0.	0.	0.	0.
CONSTR 29	0.	0.	0.	0.	0.
CONSTR 30	0.	0.	0.	1.	0.
CONSTR 31	0.	-1.	0.	0.	0.
CONSTR 32	0.	0.	0.	0.	0.
CONSTR 33	0.	1.	0.	0.	0.
CONSTR 34	0.	0.	0.	0.	0.
CONSTR 35	0.	0.	0.	0.	0.
CONSTR 36	0.	0.	0.	0.	0.
CONSTR 37	0.	0.	0.	0.	0.
CONSTR 38	0.	0.	0.	0.	0.
CONSTR 39	0.	0.	0.	0.	0.
CONSTR 40	0.	0.	0.	0.	0.
VARBL TYPE	0-1	0-1	0-1	0-1	0-1
LOWR BOUND	.	.	.	.	.
UPPR BOUND	.	.	.	.	.
INIT SOLN	0.	0.	0.	0.	0.

TABLE 25
-Continued-
Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	P4884	P5600	P5612	P5661	P5663
OBJ COEFF	106.	8.	59.	16.	32.
MATERIAL	385.	14.	328.	61.	0.
INT ENGR	385.	7.	109.	30.	32.
OUT ENGR	385.	28.	328.	122.	130.
INT CRAFT	385.	0.	0.	30.	0.
OUT CRAFT	385.	21.	328.	61.	0.
TOTAL BUDG	1925.	70.	1093.	304.	162.
CONSTR 7	0.	-1.	0.	0.	0.
CONSTR 8	0.	1.	0.	0.	0.
CONSTR 9	0.	0.	0.	0.	0.
CONSTR 10	0.	0.	0.	0.	0.
CONSTR 11	0.	0.	0.	0.	0.
CONSTR 12	0.	0.	0.	0.	0.
CONSTR 13	0.	0.	0.	-1.	0.
CONSTR 14	0.	0.	0.	0.	0.
CONSTR 15	0.	0.	0.	1.	0.
CONSTR 16	0.	0.	0.	0.	0.
CONSTR 17	0.	0.	0.	0.	0.
CONSTR 18	0.	0.	0.	0.	0.
CONSTR 19	0.	0.	0.	0.	0.
CONSTR 20	0.	0.	0.	0.	-1.
CONSTR 21	0.	0.	0.	0.	0.
CONSTR 22	0.	0.	0.	0.	1.
CONSTR 23	0.	0.	0.	0.	0.
CONSTR 24	0.	0.	0.	0.	0.
CONSTR 25	0.	0.	0.	0.	0.
CONSTR 26	0.	0.	0.	0.	0.
CONSTR 27	0.	0.	0.	0.	0.
CONSTR 28	0.	0.	0.	0.	0.
CONSTR 29	0.	0.	0.	0.	0.
CONSTR 30	0.	0.	0.	0.	0.
CONSTR 31	0.	0.	0.	0.	0.
CONSTR 32	0.	0.	-1.	0.	0.
CONSTR 33	0.	0.	-1.	0.	0.
CONSTR 34	0.	0.	1.	0.	0.
CONSTR 35	0.	0.	0.	0.	0.
CONSTR 36	0.	0.	0.	0.	0.
CONSTR 37	0.	0.	0.	0.	0.
CONSTR 38	0.	0.	0.	0.	0.
CONSTR 39	0.	0.	0.	0.	0.
CONSTR 40	0.	0.	0.	0.	0.
VARBL TYPE	0-1	0-1	0-1	0-1	0-1
LOWR BOUND	.	.	.	.	.
UPPR BOUND	.	.	.	.	.
INIT SOLN	0.	0.	0.	0.	0.

TABLE 25
-Continued-
Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	P5665	P5670	P5673	P5675	P5679
OBJ COEFF	111.	66.	2414.	102.	362.
MATERIAL	73.	161.	4.	87.	153.
INT ENGR	37.	0.	4.	0.	38.
OUT ENGR	146.	242.	8.	29.	115.
INT CRAFT	37.	161.	4.	29.	38.
OUT CRAFT	73.	242.	0.	0.	76.
TOTAL BUDG	366.	806.	20.	145.	420.
CONSTR 7	0.	0.	0.	0.	0.
CONSTR 8	0.	0.	0.	0.	0.
CONSTR 9	0.	0.	0.	0.	0.
CONSTR 10	0.	0.	0.	0.	0.
CONSTR 11	0.	0.	0.	0.	0.
CONSTR 12	0.	0.	0.	0.	0.
CONSTR 13	0.	0.	0.	0.	0.
CONSTR 14	0.	0.	0.	0.	0.
CONSTR 15	0.	0.	0.	0.	0.
CONSTR 16	0.	0.	0.	0.	0.
CONSTR 17	0.	0.	0.	0.	0.
CONSTR 18	0.	0.	0.	0.	0.
CONSTR 19	0.	0.	0.	0.	0.
CONSTR 20	0.	0.	0.	0.	0.
CONSTR 21	0.	0.	0.	0.	0.
CONSTR 22	0.	0.	0.	0.	0.
CONSTR 23	0.	0.	0.	0.	0.
CONSTR 24	0.	0.	0.	0.	0.
CONSTR 25	0.	0.	0.	0.	0.
CONSTR 26	0.	0.	0.	0.	0.
CONSTR 27	0.	0.	0.	0.	0.
CONSTR 28	0.	0.	0.	0.	0.
CONSTR 29	0.	0.	0.	0.	0.
CONSTR 30	0.	0.	0.	0.	0.
CONSTR 31	0.	0.	0.	0.	0.
CONSTR 32	0.	0.	0.	0.	0.
CONSTR 33	0.	0.	0.	0.	0.
CONSTR 34	0.	0.	0.	0.	0.
CONSTR 35	0.	-1.	0.	0.	0.
CONSTR 36	0.	1.	0.	0.	0.
CONSTR 37	0.	0.	0.	0.	0.
CONSTR 38	0.	0.	0.	0.	0.
CONSTR 39	0.	0.	0.	0.	0.
CONSTR 40	0.	0.	0.	0.	0.
VARBL TYPE	0-1	0-1	0-1	0-1	0-1
LOWR BOUND	.	.	.	.	.
UPPR BOUND	.	.	.	.	.
INIT SOLN	0.	0.	0.	0.	0.

TABLE 25
-Continued-
Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	P5685	P5686	P5694	P5716	P5720
OBJ COEFF	5.	32.	11.	25.	88.
MATERIAL	49.	2584.	79.	103.	1163.
INT ENGR	24.	0.	26.	34.	0.
OUT ENGR	73.	861.	0.	69.	69.
INT CRAFT	0.	0.	52.	34.	0.
OUT CRAFT	98.	861.	105.	103.	103.
TOTAL BUDG	244.	4306.	262.	343.	1335.
CONSTR 7	1.	0.	0.	0.	0.
CONSTR 8	0.	0.	0.	0.	0.
CONSTR 9	0.	0.	-1.	0.	0.
CONSTR 10	0.	0.	1.	0.	0.
CONSTR 11	0.	0.	0.	0.	0.
CONSTR 12	0.	0.	0.	0.	0.
CONSTR 13	0.	0.	0.	0.	0.
CONSTR 14	0.	0.	0.	0.	0.
CONSTR 15	0.	0.	0.	0.	0.
CONSTR 16	0.	0.	0.	0.	0.
CONSTR 17	0.	0.	0.	0.	0.
CONSTR 18	0.	0.	0.	0.	0.
CONSTR 19	0.	0.	0.	-1.	0.
CONSTR 20	0.	-1.	0.	2.	0.
CONSTR 21	0.	1.	0.	0.	0.
CONSTR 22	0.	0.	0.	0.	0.
CONSTR 23	0.	0.	0.	0.	0.
CONSTR 24	0.	0.	0.	0.	0.
CONSTR 25	0.	0.	0.	0.	0.
CONSTR 26	0.	0.	0.	0.	0.
CONSTR 27	0.	0.	0.	0.	0.
CONSTR 28	0.	0.	0.	0.	0.
CONSTR 29	0.	0.	0.	0.	0.
CONSTR 30	0.	0.	0.	0.	0.
CONSTR 31	0.	0.	0.	0.	0.
CONSTR 32	0.	0.	0.	0.	0.
CONSTR 33	0.	0.	0.	0.	0.
CONSTR 34	0.	0.	0.	0.	0.
CONSTR 35	0.	0.	0.	0.	0.
CONSTR 36	0.	0.	0.	0.	0.
CONSTR 37	0.	0.	0.	0.	0.
CONSTR 38	0.	0.	0.	0.	0.
CONSTR 39	0.	0.	0.	0.	0.
CONSTR 40	0.	0.	0.	0.	-1.
VARBL TYPE	0-1	0-1	0-1	0-1	0-1
LOWR BOUND	.	.	.	.	.
UPPR BOUND	.	.	.	.	.
INIT SOLN	0.	0.	0.	0.	0.

TABLE 25
-Continued-
Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	P5724	P5725	P5734	P5735	P5737
OBJ COEFF	18.	70.	16.	9.	86.
MATERIAL	2878.	192.	45.	105.	7.
INT ENGR	411.	48.	15.	26.	2.
OUT ENGR	0.	144.	30.	53.	4.
INT CRAFT	822.	0.	15.	0.	0.
OUT CRAFT	0.	96.	45.	79.	9.
TOTAL BUDG	4111.	480.	150.	263.	22.
CONSTR 7	0.	0.	0.	0.	0.
CONSTR 8	0.	0.	0.	-1.	0.
CONSTR 9	0.	0.	0.	2.	0.
CONSTR 10	0.	0.	0.	0.	0.
CONSTR 11	0.	0.	0.	0.	0.
CONSTR 12	0.	0.	0.	0.	0.
CONSTR 13	0.	0.	-1.	0.	0.
CONSTR 14	-1.	0.	1.	0.	0.
CONSTR 15	-1.	0.	0.	0.	0.
CONSTR 16	1.	0.	0.	0.	0.
CONSTR 17	0.	0.	0.	0.	0.
CONSTR 18	0.	0.	0.	0.	0.
CONSTR 19	0.	0.	0.	0.	0.
CONSTR 20	0.	0.	0.	0.	0.
CONSTR 21	0.	0.	0.	0.	0.
CONSTR 22	0.	0.	0.	0.	0.
CONSTR 23	0.	0.	0.	0.	0.
CONSTR 24	0.	0.	0.	0.	0.
CONSTR 25	0.	0.	0.	0.	0.
CONSTR 26	0.	0.	0.	0.	0.
CONSTR 27	0.	0.	0.	0.	0.
CONSTR 28	0.	0.	0.	0.	0.
CONSTR 29	0.	0.	0.	0.	0.
CONSTR 30	0.	0.	0.	0.	0.
CONSTR 31	0.	0.	0.	0.	0.
CONSTR 32	0.	0.	0.	0.	0.
CONSTR 33	0.	0.	0.	0.	0.
CONSTR 34	0.	0.	0.	0.	0.
CONSTR 35	0.	0.	0.	0.	0.
CONSTR 36	0.	-1.	0.	0.	0.
CONSTR 37	0.	1.	0.	0.	0.
CONSTR 38	0.	0.	0.	0.	0.
CONSTR 39	0.	0.	0.	0.	-1.
CONSTR 40	0.	0.	0.	0.	1.
VARBL TYPE	0-1	0-1	0-1	0-1	0-1
LOWR BOUND	.	.	.	.	.
UPPR BOUND	.	.	.	.	.
INIT SOLN	0.	0.	0.	0.	0.

TABLE 25
-Continued-
Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	P5740	P5744	P5754	P5756	P5757
OBJ COEFF	2414.	1289.	259.	65.	79.
MATERIAL	11.	3.	63.	69.	103.
INT ENGR	7.	1.	21.	23.	52.
OUT ENGR	7.	8.	63.	46.	103.
INT CRAFT	0.	10.	0.	0.	52.
OUT CRAFT	11.	0.	63.	92.	206.
TOTAL BUDG	36.	22.	210.	230.	516.
CONSTR 7	0.	0.	0.	0.	0.
CONSTR 8	0.	0.	0.	0.	0.
CONSTR 9	0.	0.	0.	0.	0.
CONSTR 10	0.	0.	0.	0.	0.
CONSTR 11	0.	0.	0.	0.	0.
CONSTR 12	0.	0.	0.	0.	0.
CONSTR 13	0.	0.	0.	0.	0.
CONSTR 14	0.	0.	0.	0.	0.
CONSTR 15	0.	0.	0.	0.	0.
CONSTR 16	0.	0.	0.	0.	0.
CONSTR 17	0.	0.	0.	0.	0.
CONSTR 18	0.	0.	0.	0.	0.
CONSTR 19	0.	0.	0.	0.	0.
CONSTR 20	0.	0.	0.	0.	0.
CONSTR 21	0.	0.	0.	0.	0.
CONSTR 22	0.	0.	0.	0.	0.
CONSTR 23	0.	0.	0.	0.	0.
CONSTR 24	0.	0.	0.	0.	0.
CONSTR 25	0.	0.	0.	0.	0.
CONSTR 26	0.	0.	0.	0.	0.
CONSTR 27	0.	0.	0.	0.	0.
CONSTR 28	0.	0.	0.	0.	0.
CONSTR 29	0.	0.	0.	0.	0.
CONSTR 30	0.	0.	0.	0.	0.
CONSTR 31	0.	0.	0.	0.	0.
CONSTR 32	0.	0.	0.	0.	0.
CONSTR 33	0.	0.	0.	0.	0.
CONSTR 34	0.	0.	0.	-1.	0.
CONSTR 35	0.	0.	0.	1.	0.
CONSTR 36	0.	0.	0.	0.	0.
CONSTR 37	0.	0.	0.	0.	0.
CONSTR 38	0.	0.	0.	0.	-1.
CONSTR 39	0.	0.	0.	0.	1.
CONSTR 40	0.	0.	0.	0.	0.
VARBL TYPE	0-1	0-1	0-1	0-1	0-1
LOWR BOUND	.	.	.	.	.
UPPR BOUND	.	.	.	.	.
INIT SOLN	0.	0.	0.	0.	0.

TABLE 25
-Continued-
Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	P5759	P5765	P5766	P5771	P5773
OBJ COEFF	297.	184.	23.	13.	20.
MATERIAL	6.	30.	271.	30.	1036.
INT ENGR	4.	12.	0.	0.	345.
OUT ENGR	2.	12.	181.	20.	690.
INT CRAFT	2.	0.	0.	50.	0.
OUT CRAFT	6.	6.	452.	0.	1381.
TOTAL BUDG	20.	60.	904.	100.	3452.
CONSTR 7	0.	0.	0.	0.	0.
CONSTR 8	0.	0.	0.	0.	0.
CONSTR 9	0.	0.	0.	0.	0.
CONSTR 10	0.	0.	0.	0.	0.
CONSTR 11	0.	0.	0.	0.	0.
CONSTR 12	0.	0.	0.	-1.	0.
CONSTR 13	0.	0.	0.	2.	0.
CONSTR 14	0.	0.	0.	0.	0.
CONSTR 15	0.	0.	0.	0.	0.
CONSTR 16	0.	0.	0.	0.	-1.
CONSTR 17	0.	0.	-1.	0.	1.
CONSTR 18	0.	0.	1.	0.	0.
CONSTR 19	0.	0.	0.	0.	0.
CONSTR 20	0.	0.	0.	0.	0.
CONSTR 21	0.	0.	0.	0.	0.
CONSTR 22	0.	0.	0.	0.	0.
CONSTR 23	0.	0.	0.	0.	0.
CONSTR 24	0.	0.	0.	0.	0.
CONSTR 25	0.	0.	0.	0.	0.
CONSTR 26	0.	0.	0.	0.	0.
CONSTR 27	0.	0.	0.	0.	0.
CONSTR 28	0.	0.	0.	0.	0.
CONSTR 29	0.	0.	0.	0.	0.
CONSTR 30	0.	0.	0.	0.	0.
CONSTR 31	0.	0.	0.	0.	0.
CONSTR 32	0.	0.	0.	0.	0.
CONSTR 33	0.	0.	0.	0.	0.
CONSTR 34	0.	0.	0.	0.	0.
CONSTR 35	0.	0.	0.	0.	0.
CONSTR 36	0.	0.	0.	0.	0.
CONSTR 37	0.	0.	0.	0.	0.
CONSTR 38	0.	0.	0.	0.	0.
CONSTR 39	0.	0.	0.	0.	0.
CONSTR 40	0.	0.	0.	0.	0.
VARBL TYPE	0-1	0-1	0-1	0-1	0-1
LOWR BOUND	.	.	.	.	.
UPPR BOUND	.	.	.	.	.
INIT SOLN	0.	0.	0.	0.	0.

TABLE 25
-Continued-
Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	P5774	P5781	P5782	P5783	P5791
OBJ COEFF	53.	36.	137.	200.	11.
MATERIAL	331.	445.	472.	456.	107.
INT ENGR	66.	148.	157.	228.	0.
OUT ENGR	132.	0.	472.	684.	0.
INT CRAFT	0.	223.	0.	0.	27.
OUT CRAFT	132.	0.	472.	912.	0.
TOTAL BUDG	661.	816.	1573.	2280.	134.
CONSTR 7	0.	0.	0.	0.	0.
CONSTR 8	0.	0.	0.	0.	0.
CONSTR 9	0.	0.	0.	0.	-1.
CONSTR 10	0.	0.	0.	0.	0.
CONSTR 11	0.	0.	0.	0.	1.
CONSTR 12	0.	0.	0.	0.	0.
CONSTR 13	0.	0.	0.	0.	0.
CONSTR 14	0.	0.	0.	0.	0.
CONSTR 15	0.	0.	0.	0.	0.
CONSTR 16	0.	0.	0.	0.	0.
CONSTR 17	0.	0.	0.	0.	0.
CONSTR 18	0.	0.	0.	0.	0.
CONSTR 19	0.	0.	0.	0.	0.
CONSTR 20	0.	0.	0.	0.	0.
CONSTR 21	0.	-1.	0.	0.	0.
CONSTR 22	0.	-1.	0.	0.	0.
CONSTR 23	0.	1.	0.	0.	0.
CONSTR 24	0.	0.	0.	0.	0.
CONSTR 25	0.	0.	0.	0.	0.
CONSTR 26	0.	0.	0.	0.	0.
CONSTR 27	0.	0.	0.	0.	0.
CONSTR 28	0.	0.	0.	0.	0.
CONSTR 29	0.	0.	0.	0.	0.
CONSTR 30	0.	0.	0.	0.	0.
CONSTR 31	-1.	0.	0.	0.	0.
CONSTR 32	1.	0.	0.	0.	0.
CONSTR 33	0.	0.	0.	0.	0.
CONSTR 34	0.	0.	0.	0.	0.
CONSTR 35	0.	0.	0.	0.	0.
CONSTR 36	0.	0.	0.	0.	0.
CONSTR 37	0.	0.	0.	0.	0.
CONSTR 38	0.	0.	0.	0.	0.
CONSTR 39	0.	0.	0.	0.	0.
CONSTR 40	0.	0.	0.	0.	0.
VARBL TYPE	0-1	0-1	0-1	0-1	0-1
LOWR BOUND	.	.	.	.	.
UPPR BOUND	.	.	.	.	.
INIT SOLN	0.	0.	0.	0.	0.

TABLE 25
-Continued-
Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	P5795	P6186	P7004	P7128	P7236
OBJ COEFF	158.	71.	37.	52.	12.
MATERIAL	409.	706.	36.	0.	153.
INT ENGR	68.	177.	27.	25.	0.
OUT ENGR	0.	530.	18.	62.	0.
INT CRAFT	204.	0.	0.	0.	17.
OUT CRAFT	0.	353.	9.	0.	0.
TOTAL BUDG	681.	1766.	90.	87.	170.
CONSTR 7	0.	0.	0.	0.	0.
CONSTR 8	0.	0.	0.	0.	0.
CONSTR 9	0.	0.	0.	0.	0.
CONSTR 10	0.	0.	0.	0.	-1.
CONSTR 11	0.	0.	0.	0.	-1.
CONSTR 12	0.	0.	0.	0.	1.
CONSTR 13	0.	0.	0.	0.	0.
CONSTR 14	0.	0.	0.	0.	0.
CONSTR 15	0.	0.	0.	0.	0.
CONSTR 16	0.	0.	0.	0.	0.
CONSTR 17	0.	0.	0.	0.	0.
CONSTR 18	0.	0.	0.	0.	0.
CONSTR 19	0.	0.	0.	0.	0.
CONSTR 20	0.	0.	0.	0.	0.
CONSTR 21	0.	0.	0.	0.	0.
CONSTR 22	0.	0.	0.	0.	0.
CONSTR 23	0.	0.	-1.	0.	0.
CONSTR 24	0.	0.	6.	0.	0.
CONSTR 25	0.	0.	0.	-1.	0.
CONSTR 26	0.	0.	0.	-1.	0.
CONSTR 27	0.	0.	0.	-1.	0.
CONSTR 28	0.	0.	0.	-1.	0.
CONSTR 29	0.	0.	0.	-1.	0.
CONSTR 30	0.	0.	0.	-1.	0.
CONSTR 31	0.	0.	0.	2.	0.
CONSTR 32	0.	0.	0.	0.	0.
CONSTR 33	0.	0.	0.	0.	0.
CONSTR 34	0.	0.	0.	0.	0.
CONSTR 35	0.	0.	0.	0.	0.
CONSTR 36	0.	0.	0.	0.	0.
CONSTR 37	0.	-1.	0.	0.	0.
CONSTR 38	0.	1.	0.	0.	0.
CONSTR 39	0.	0.	0.	0.	0.
CONSTR 40	0.	0.	0.	0.	0.
VARBL TYPE	0-1	0-1	0-1	0-1	0-1
LOWR BOUND	.	.	.	.	.
UPPR BOUND	.	.	.	.	.
INIT SOLN	0.	0.	0.	0.	0.

TABLE 25
-Continued-
Integer Programming Data

STORM DATA SET LISTING
DETAILED PROBLEM DATA LISTING FOR
Capital Budgeting Model With MultiAttributes CAPBUD1

ROW LABEL	CONST TYPE	R H S	RANGE
OBJ COEFF	XXXX	XXXX	XXXX
MATERIAL	<=	16912.	.
INT ENGR	<=	3768.	.
OUT ENGR	<=	7608.	.
INT CRAFT	<=	4871.	.
OUT CRAFT	<=	8201.	.
TOTAL BUDG	<=	41360.	.
CONSTR 7	<=	0.	.
CONSTR 8	<=	0.	.
CONSTR 9	<=	0.	.
CONSTR 10	<=	0.	.
CONSTR 11	<=	0.	.
CONSTR 12	<=	0.	.
CONSTR 13	<=	0.	.
CONSTR 14	<=	0.	.
CONSTR 15	<=	0.	.
CONSTR 16	<=	0.	.
CONSTR 17	<=	0.	.
CONSTR 18	<=	0.	.
CONSTR 19	<=	0.	.
CONSTR 20	<=	0.	.
CONSTR 21	<=	0.	.
CONSTR 22	<=	0.	.
CONSTR 23	<=	0.	.
CONSTR 24	<=	0.	.
CONSTR 25	<=	0.	.
CONSTR 26	<=	0.	.
CONSTR 27	<=	0.	.
CONSTR 28	<=	0.	.
CONSTR 29	<=	0.	.
CONSTR 30	<=	0.	.
CONSTR 31	<=	0.	.
CONSTR 32	<=	0.	.
CONSTR 33	<=	0.	.
CONSTR 34	<=	0.	.
CONSTR 35	<=	0.	.
CONSTR 36	<=	0.	.
CONSTR 37	<=	0.	.
CONSTR 38	<=	0.	.
CONSTR 39	<=	0.	.
CONSTR 40	<=	0.	.
VARBL TYPE	XXXX	XXXX	XXXX
LOWR BOUND	XXXX	XXXX	XXXX
UPPR BOUND	XXXX	XXXX	XXXX
INIT SOLN	XXXX	XXXX	XXXX

To evaluate the model the following budget cuts where applied.

20% Material Dollars

10% Internal Engineering Dollars

25% External Engineering Dollars

10% Internal Craft Dollars

25% External Craft Dollars

20% Total Budget

Table 26 lists the first optimum solution. The limiting project is P5686. To determine what additional lower priority projects could be implemented with the remaining capital, the contingent constraints tied to P5686 were eliminated. The results of the new constraints are provided in Table 27. This process was repeated as listed in Tables 28 and 29. Table 29 is the final optimum solution. Table 30 provides a summary of the final optimum solution in order of priority.

TABLE 26

Integer Programming Solution Limited by P5686

Capital Budgeting Model With MultiAttributes CAPBUD3
OPTIMAL SOLUTION - SUMMARY REPORT

Variable	Value	Cost	Lower bound	Upper bound
P1101	1	41.0000	0	1
P2548	1	41.0000	0	1
P2549	1	41.0000	0	1
P2550	1	41.0000	0	1
P2551	1	41.0000	0	1
P4005	0	24.0000	0	1
P4865	1	53.0000	0	1
P4874	1	41.0000	0	1
P5600	0	8.0000	0	1
P5612	1	59.0000	0	1
P5661	0	16.0000	0	1
P5663	1	32.0000	0	1
P5670	1	66.0000	0	1
P5685	0	5.0000	0	1
P5686	0	32.0000	0	1
P5694	0	11.0000	0	1
P5716	0	25.0000	0	1
P5720	1	88.0000	0	1
P5724	0	18.0000	0	1
P5725	1	70.0000	0	1
P5734	0	16.0000	0	1
P5735	0	9.0000	0	1
P5737	1	86.0000	0	1
P5756	1	65.0000	0	1
P5757	1	79.0000	0	1
P5766	0	23.0000	0	1
P5771	0	13.0000	0	1
P5773	0	20.0000	0	1
P5774	1	53.0000	0	1
P5781	1	36.0000	0	1
P5791	0	11.0000	0	1
P6186	1	71.0000	0	1
P7004	1	37.0000	0	1
P7128	1	52.0000	0	1
P7236	0	12.0000	0	1

TABLE 26
-Continued-
Integer Programming Solution Limited by P5686

Capital Budgeting Model With MultiAttributes CAPBUD3
OPTIMAL SOLUTION - SUMMARY REPORT

Constraint	Type	RHS	Slack
MATERIAL	<=	11220.0000	4605.0000
INT ENGR	<=	2269.0000	541.0000
OUT ENGR	<=	3375.0000	225.0000
INT CRAFT	<=	3684.0000	621.0000
OUT CRAFT	<=	4068.0000	1156.0000
TOTAL BUDG	<=	24533.0000	7065.0000
CONSTR 7	<=	0.0000	0.0000
CONSTR 8	<=	0.0000	0.0000
CONSTR 9	<=	0.0000	0.0000
CONSTR 10	<=	0.0000	0.0000
CONSTR 11	<=	0.0000	0.0000
CONSTR 12	<=	0.0000	0.0000
CONSTR 13	<=	0.0000	0.0000
CONSTR 14	<=	0.0000	0.0000
CONSTR 15	<=	0.0000	0.0000
CONSTR 16	<=	0.0000	0.0000
CONSTR 17	<=	0.0000	0.0000
CONSTR 18	<=	0.0000	0.0000
CONSTR 19	<=	0.0000	0.0000
CONSTR 20	<=	0.0000	1.0000
CONSTR 21	<=	0.0000	1.0000
CONSTR 22	<=	0.0000	0.0000
CONSTR 23	<=	0.0000	0.0000
CONSTR 24	<=	0.0000	0.0000
CONSTR 25	<=	0.0000	0.0000
CONSTR 26	<=	0.0000	0.0000
CONSTR 27	<=	0.0000	0.0000
CONSTR 28	<=	0.0000	0.0000
CONSTR 29	<=	0.0000	0.0000
CONSTR 30	<=	0.0000	0.0000
CONSTR 31	<=	0.0000	0.0000
CONSTR 32	<=	0.0000	0.0000
CONSTR 33	<=	0.0000	0.0000
CONSTR 34	<=	0.0000	0.0000
CONSTR 35	<=	0.0000	0.0000
CONSTR 36	<=	0.0000	0.0000
CONSTR 37	<=	0.0000	0.0000
CONSTR 38	<=	0.0000	0.0000
CONSTR 39	<=	0.0000	0.0000
CONSTR 40	<=	0.0000	0.0000

Objective Function Value = 1093

NOTE: The Storm solution to the objective function does not include the 15 highest priority projects.

TABLE 27

Integer Programming Solution Limited by P5766

Capital Budgeting Model With MultiAttributes CAPBUD4
OPTIMAL SOLUTION - SUMMARY REPORT

Variable	Value	Cost	Lower bound	Upper bound
P1101	1	41.0000	0	1
P2548	1	41.0000	0	1
P2549	1	41.0000	0	1
P2550	1	41.0000	0	1
P2551	1	41.0000	0	1
P4005	1	24.0000	0	1
P4865	1	53.0000	0	1
P4874	1	41.0000	0	1
P5600	0	8.0000	0	1
P5612	1	59.0000	0	1
P5661	0	16.0000	0	1
P5663	1	32.0000	0	1
P5670	1	66.0000	0	1
P5685	0	5.0000	0	1
P5686	0	32.0000	0	1
P5694	0	11.0000	0	1
P5716	1	25.0000	0	1
P5720	1	88.0000	0	1
P5724	0	18.0000	0	1
P5725	1	70.0000	0	1
P5734	0	16.0000	0	1
P5735	0	9.0000	0	1
P5737	1	86.0000	0	1
P5756	1	65.0000	0	1
P5757	1	79.0000	0	1
P5766	0	23.0000	0	1
P5771	0	13.0000	0	1
P5773	0	20.0000	0	1
P5774	1	53.0000	0	1
P5781	1	36.0000	0	1
P5791	0	11.0000	0	1
P6186	1	71.0000	0	1
P7004	1	37.0000	0	1
P7128	1	52.0000	0	1
P7236	0	12.0000	0	1

TABLE 27
-Continued-
Integer Programming Solution Limited by P5766

Capital Budgeting Model With MultiAttributes CAPBUD4
OPTIMAL SOLUTION - SUMMARY REPORT

Constraint	Type	RHS	Slack
MATERIAL	<=	11220.0000	4030.0000
INT ENGR	<=	2269.0000	507.0000
OUT ENGR	<=	3375.0000	156.0000
INT CRAFT	<=	3684.0000	535.0000
OUT CRAFT	<=	4068.0000	1053.0000
TOTAL BUDG	<=	24533.0000	6198.0000
CONSTR 7	<=	0.0000	0.0000
CONSTR 8	<=	0.0000	0.0000
CONSTR 9	<=	0.0000	0.0000
CONSTR 10	<=	0.0000	0.0000
CONSTR 11	<=	0.0000	0.0000
CONSTR 12	<=	0.0000	0.0000
CONSTR 13	<=	0.0000	0.0000
CONSTR 14	<=	0.0000	0.0000
CONSTR 15	<=	0.0000	0.0000
CONSTR 16	<=	0.0000	0.0000
CONSTR 17	<=	0.0000	0.0000
CONSTR 18	<=	0.0000	1.0000
CONSTR 19	<=	0.0000	0.0000
CONSTR 20	<=	0.0000	0.0000
CONSTR 21	<=	0.0000	1.0000
CONSTR 22	<=	0.0000	0.0000
CONSTR 23	<=	0.0000	0.0000
CONSTR 24	<=	0.0000	0.0000
CONSTR 25	<=	0.0000	0.0000
CONSTR 26	<=	0.0000	0.0000
CONSTR 27	<=	0.0000	0.0000
CONSTR 28	<=	0.0000	0.0000
CONSTR 29	<=	0.0000	0.0000
CONSTR 30	<=	0.0000	0.0000
CONSTR 31	<=	0.0000	0.0000
CONSTR 32	<=	0.0000	0.0000
CONSTR 33	<=	0.0000	0.0000
CONSTR 34	<=	0.0000	0.0000
CONSTR 35	<=	0.0000	0.0000
CONSTR 36	<=	0.0000	0.0000
CONSTR 37	<=	0.0000	0.0000
CONSTR 38	<=	0.0000	0.0000
CONSTR 39	<=	0.0000	0.0000
CONSTR 40	<=	0.0000	0.0000

Objective Function Value = 1142

NOTE: The Storm solution to the objective function does not include the 15 highest priority projects.

TABLE 28

Integer Programming Solution Limited by P5771

Capital Budgeting Model With MultiAttributes CAPBUD7
OPTIMAL SOLUTION - SUMMARY REPORT

Variable	Value	Cost	Lower bound	Upper bound
P1101	1	41.0000	0	1
P2548	1	41.0000	0	1
P2549	1	41.0000	0	1
P2550	1	41.0000	0	1
P2551	1	41.0000	0	1
P4005	1	24.0000	0	1
P4865	1	53.0000	0	1
P4874	1	41.0000	0	1
P5600	0	8.0000	0	1
P5612	1	59.0000	0	1
P5661	1	16.0000	0	1
P5663	1	32.0000	0	1
P5670	1	66.0000	0	1
P5685	0	5.0000	0	1
P5686	0	32.0000	0	1
P5694	0	11.0000	0	1
P5716	1	25.0000	0	1
P5720	1	88.0000	0	1
P5724	0	18.0000	0	1
P5725	1	70.0000	0	1
P5734	1	16.0000	0	1
P5735	0	9.0000	0	1
P5737	1	86.0000	0	1
P5756	1	65.0000	0	1
P5757	1	79.0000	0	1
P5766	0	23.0000	0	1
P5771	0	13.0000	0	1
P5773	0	20.0000	0	1
P5774	1	53.0000	0	1
P5781	1	36.0000	0	1
P5791	0	11.0000	0	1
P6186	1	71.0000	0	1
P7004	1	37.0000	0	1
P7128	1	52.0000	0	1
P7236	0	12.0000	0	1

TABLE 28
-Continued-
Integer Programming Solution Limited by P5771

Capital Budgeting Model With MultiAttributes CAPBUD7
OPTIMAL SOLUTION - SUMMARY REPORT

Constraint	Type	RHS	Slack
MATERIAL	<=	11220.0000	3924.0000
INT ENGR	<=	2269.0000	462.0000
OUT ENGR	<=	3375.0000	4.0000
INT CRAFT	<=	3684.0000	490.0000
OUT CRAFT	<=	4068.0000	947.0000
TOTAL BUDG	<=	24533.0000	5744.0000
CONSTR 7	<=	0.0000	0.0000
CONSTR 8	<=	0.0000	0.0000
CONSTR 9	<=	0.0000	0.0000
CONSTR 10	<=	0.0000	0.0000
CONSTR 11	<=	0.0000	0.0000
CONSTR 12	<=	0.0000	0.0000
CONSTR 13	<=	0.0000	2.0000
CONSTR 14	<=	0.0000	0.0000
CONSTR 15	<=	0.0000	0.0000
CONSTR 16	<=	0.0000	1.0000
CONSTR 17	<=	0.0000	1.0000
CONSTR 18	<=	0.0000	1.0000
CONSTR 19	<=	0.0000	0.0000
CONSTR 20	<=	0.0000	0.0000
CONSTR 21	<=	0.0000	1.0000
CONSTR 22	<=	0.0000	0.0000
CONSTR 23	<=	0.0000	0.0000
CONSTR 24	<=	0.0000	0.0000
CONSTR 25	<=	0.0000	0.0000
CONSTR 26	<=	0.0000	0.0000
CONSTR 27	<=	0.0000	0.0000
CONSTR 28	<=	0.0000	0.0000
CONSTR 29	<=	0.0000	0.0000
CONSTR 30	<=	0.0000	0.0000
CONSTR 31	<=	0.0000	0.0000
CONSTR 32	<=	0.0000	0.0000
CONSTR 33	<=	0.0000	0.0000
CONSTR 34	<=	0.0000	0.0000
CONSTR 35	<=	0.0000	0.0000
CONSTR 36	<=	0.0000	0.0000
CONSTR 37	<=	0.0000	0.0000
CONSTR 38	<=	0.0000	0.0000
CONSTR 39	<=	0.0000	0.0000
CONSTR 40	<=	0.0000	0.0000

Objective Function Value = 1174

NOTE: The Storm solution to the objective function does not include the 15 highest priority projects.

TABLE 29

Integer Programming Optimum Solution Limited by Budget

Capital Budgeting Model With MultiAttributes CAPBUD8
OPTIMAL SOLUTION - SUMMARY REPORT

Variable	Value	Cost	Lower bound	Upper bound
P1101	1	41.0000	0	1
P2548	1	41.0000	0	1
P2549	1	41.0000	0	1
P2550	1	41.0000	0	1
P2551	1	41.0000	0	1
P4005	1	24.0000	0	1
P4865	1	53.0000	0	1
P4874	1	41.0000	0	1
P5600	1	8.0000	0	1
P5612	1	59.0000	0	1
P5661	0	16.0000	0	1
P5663	1	32.0000	0	1
P5670	1	66.0000	0	1
P5685	0	5.0000	0	1
P5686	0	32.0000	0	1
P5694	1	11.0000	0	1
P5716	1	25.0000	0	1
P5720	1	88.0000	0	1
P5724	0	18.0000	0	1
P5725	1	70.0000	0	1
P5734	1	16.0000	0	1
P5735	1	9.0000	0	1
P5737	1	86.0000	0	1
P5756	1	65.0000	0	1
P5757	1	79.0000	0	1
P5766	0	23.0000	0	1
P5771	0	13.0000	0	1
P5773	0	20.0000	0	1
P5774	1	53.0000	0	1
P5781	1	36.0000	0	1
P5791	1	11.0000	0	1
P6186	1	71.0000	0	1
P7004	1	37.0000	0	1
P7128	1	52.0000	0	1
P7236	1	12.0000	0	1

TABLE 29
-Continued-
Integer Programming Optimum Solution Limited by Budget

Capital Budgeting Model With MultiAttributes CAPBUD8
OPTIMAL SOLUTION - SUMMARY REPORT

Constraint	Type	RHS	Slack
MATERIAL	<=	11220.0000	3527.0000
INT ENGR	<=	2269.0000	433.0000
OUT ENGR	<=	3375.0000	45.0000
INT CRAFT	<=	3684.0000	424.0000
OUT CRAFT	<=	4068.0000	803.0000
TOTAL BUDG	<=	24533.0000	5149.0000
CONSTR 7	<=	0.0000	1.0000
CONSTR 8	<=	0.0000	0.0000
CONSTR 9	<=	0.0000	0.0000
CONSTR 10	<=	0.0000	0.0000
CONSTR 11	<=	0.0000	0.0000
CONSTR 12	<=	0.0000	0.0000
CONSTR 13	<=	0.0000	1.0000
CONSTR 14	<=	0.0000	0.0000
CONSTR 15	<=	0.0000	1.0000
CONSTR 16	<=	0.0000	1.0000
CONSTR 17	<=	0.0000	1.0000
CONSTR 18	<=	0.0000	1.0000
CONSTR 19	<=	0.0000	0.0000
CONSTR 20	<=	0.0000	0.0000
CONSTR 21	<=	0.0000	1.0000
CONSTR 22	<=	0.0000	0.0000
CONSTR 23	<=	0.0000	0.0000
CONSTR 24	<=	0.0000	0.0000
CONSTR 25	<=	0.0000	0.0000
CONSTR 26	<=	0.0000	0.0000
CONSTR 27	<=	0.0000	0.0000
CONSTR 28	<=	0.0000	0.0000
CONSTR 29	<=	0.0000	0.0000
CONSTR 30	<=	0.0000	0.0000
CONSTR 31	<=	0.0000	0.0000
CONSTR 32	<=	0.0000	0.0000
CONSTR 33	<=	0.0000	0.0000
CONSTR 34	<=	0.0000	0.0000
CONSTR 35	<=	0.0000	0.0000
CONSTR 36	<=	0.0000	0.0000
CONSTR 37	<=	0.0000	0.0000
CONSTR 38	<=	0.0000	0.0000
CONSTR 39	<=	0.0000	0.0000
CONSTR 40	<=	0.0000	0.0000

Objective Function Value = 1209

NOTE: The Storm solution to the objective function does not include the 15 highest priority projects.

TABLE 30

Rank Order of Optimum Solution

Project	Selected	Alternative Priority Preference	Rank
P5673	Yes	2414	1
P5740	Yes	2414	1
P5744	Yes	1289	2
P4875	Yes	502	3
P5679	Yes	362	4
P5759	Yes	297	5
P5754	Yes	259	6
P5783	Yes	200	7
P5765	Yes	184	8
P5795	Yes	158	9
P5782	Yes	137	10
P4870	Yes	128	11
P5665	Yes	111	12
P4884	Yes	106	13
P5675	Yes	102	14
P5720	Yes	88	15
P5737	Yes	86	16
P5757	Yes	79	17
P6186	Yes	71	18
P5725	Yes	70	19
P5670	Yes	66	20
P5756	Yes	65	21
P5612	Yes	59	22
P5774	Yes	53	23
P4865	Yes	53	23
P7128	Yes	52	24
P1101	Yes	41	25
P2548	Yes	41	25
P2549	Yes	41	25
P2550	Yes	41	25
P2551	Yes	41	25
P4874	Yes	41	25
P7004	Yes	37	26
P5781	Yes	36	27
P5663	Yes	32	28

TABLE 30
-Continued-
Rank Order of Optimum Solution

Project	Selected	Alternative Priority Preference	Rank
P5686	No	32	28
P5716	Yes	25	29
P4005	Yes	24	30
P5766	No	23	31
P5773	No	20	32
P5724	No	18	33
P5661	No	16	34
P5734	No	16	34
P5771	No	13	35
P7236	Yes	12	36
P5694	Yes	11	37
P5791	Yes	11	37
P5735	Yes	9	38
P5600	Yes	8	39
P5685	No	5	40

CONCLUSIONS

This paper has provided a capital budgeting model for a nuclear power plant. The capital budgeting process requires allocating limited resources in an attempt to satisfying a set of potentially conflicting objectives. The first step in developing the multiattribute decision analysis capital budgeting model was to define the independent attributes to be considered in a comparison of alternatives as defined in the analytic hierarchy process. A second step was to rank and assign an alternative priority preference factor to the attributes. This quantified the relative importance of each attribute to the decision maker. The analytic heirachy structure used to rank the projects was based on a review of industry reports, published company annual reports, internal company documents, and existing budget data.

A sensitivity analysis was performed to determine the changes in relative ranking of projects by altering the pairwise comparison preferences. The area of sensitivity analysis and the effects of the analytic hierarchy structure on the alternative priority preference is one area that provides many possibilities for further research.

A tool used in solving this capital budgeting problem was a form of linear programming known as integer programming with contingent constraints. The computer software used in this analysis was the integer programming provided in STORM Personal Version 2.0.

The project alternative priority preference (APP) assignments derived from the analytic hierarchy process were used as the coefficients in the objective function. The software package STORM Personal Version 2.0 limits the number of constraints to 40 and the number of projects to 50. Therefore, for capital project programs requiring larger or more complex analysis, the professional version of STORM, or some other suitable software package is recommended. One additional alternative would be to apply the derived objective function into a true goal programming program.

Multiattribute decision analysis is a useful tool available to managers of nuclear power plants that can be applied to the capital budgeting process. An important aspect of this process is the methodical definition of the factors or attributes that are important to the organization.

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VITA

Michael G. Pinion was born on October 24, 1954 in Bethesda, Maryland. He attended Virginia Polytechnic Institute & State University, Blacksburg, Virginia and received his Bachelors of Science degree with a major in Electrical Engineering in June of 1977.

After graduation, he worked for the Department Of Defense for several years designing internal communication systems for U.S. Naval surface ships. Then he worked for Raytheon Service Company for several years designing, installing, and testing numerous projects involving electrical and electronic systems and their auxiliary systems for U.S. Naval ship and shore facilities. For the last nine years, he has worked for Virginia Electric and Power Company in the Nuclear Operations Department, Nuclear Engineering Department and Electrical Engineering Department in various technical and supervisory positions.

Mr. Pinion began his graduate work in Systems Engineering at Virginia Polytechnic Institute and State University in September, 1985. He plans to expand his career with Virginia Electric and Power Company.

Michael G. Pinion