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THESIS

**BENEFIT ANALYSIS
OF PROPOSED
INFORMATION SYSTEMS**

by

Mark H. Besore

March, 1991

Thesis Advisor: William J. Haga

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Different benefit comparison and user satisfaction methods are reviewed for their particular advantages and disadvantages. A discussion is given on how selected methods of each approach may be used within the federal government for the evaluation of alternatives. Suggestions are made for ways of conducting a more complete analysis of alternatives through incorporating present value analysis, benefit comparison of non-cost factors, and analysis of user satisfaction, into one comprehensive analysis.

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Benefit Analysis of Proposed Information Systems

by

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ABSTRACT

This thesis reviewed two different approaches to benefit analysis, benefit comparison and user satisfaction, that could be applied to the evaluation of proposed information systems which are under consideration for acquisition by the federal government. Currently the General Services Administration only recommends that present value analysis methods be used in the analysis of alternatives even though the GSA specifies that non-cost factors should be evaluated in such an analysis.

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I. INTRODUCTION

A. BACKGROUND

The need for benefit analysis methods capable of being applied to the evaluation of proposed information systems has long been recognized. Twenty years ago Chervany and Dickson (Chervany and Dickson,1970) asserted then that it was time to re-evaluate the decision-making process involving the development of information system alternatives. In the mean time the demand for information systems, and hence the demand for benefit analysis of these systems, has grown substantially. Abdel-Hamid and Madnick (Abdel-Hamid and Madnick,1989) estimate the increase in demand at a hundredfold over the last two decades. Kitfield (Kitfield, 1989) estimated the demand for avionic software was increasing 25 percent per year. This trend may be even more true for the Department of Defense (DoD) as one expert has described what he calls the "military software crisis" (Kitfield,1989). Kitfield describes this crisis as, "runaway demand and a profound shortage of software programmers" (Kitfield,1989). The problem of selecting an information system alternative may now be focused more on which alternative to invest in first. This situation reinforces the need for benefit analysis to prioritize software projects.

B. OBJECTIVES

The objective of this thesis, is to determine what methodologies can be used to analyze the benefits to be gained from a proposed information system. More specifically the objective is to examine what current benefit analysis methods can be used in the evaluation of different competitive bids submitted in response to a solicitation from the federal government for a proposed information system. Of special interest is how intangible benefits of advanced information technology are treated in such an analysis.

C. RESEARCH QUESTIONS

The research concerns of this thesis are really two fold. First, which benefit analysis methods can be employed to compare the benefits of two competing proposed information systems to determine the alternative that is the most advantageous to the government. Secondly, which benefit analysis methods are capable of calculating a monetary value of the benefits from a complex information system prior to that system's development.

D. SCOPE AND LIMITATIONS

This study will focus on benefit analysis methods that can be used in the evaluation of alternatives which is conducted in the process of a federal acquisition of an information system. Benefit analysis methods will also be examined that can be incorporated into a larger cost-benefit analysis. The subject of risk assessment, in relation to information systems, is included under benefit analysis of proposed information systems for the purpose of this thesis.

II. METHODOLOGY

A. SELECTING STUDIES OF BENEFIT ANALYSIS

1. Choosing a Medium from which to Select Studies

Published articles were chosen as the source of studies on benefit analysis in both existing and proposed information systems. Studies on existing systems were included to gain a better insight into the subject of benefit analysis of proposed information systems. Only articles of benefit analysis in English-language journals, in the field of management information systems and the related field of management science, were surveyed.

2. Choosing a Time Span of the Studies to Survey

The work on this literature review began in June, 1990 and was completed in January, 1991. The last articles that were excepted for inclusion were published in the calendar year of 1990. The year 1970 was selected as the starting point for the bibliographical search of this literature review. However, a time limit was not placed on articles or supporting publications that could be incorporated into the research based on references in articles found in the main bibliographical search or books that supported the underlying concepts of an article.

3. Search for Key Words

a. The Initial Bibliographical Search

An initial search was conducted manually of Harvard Business Review and Management Information Systems Quarterly to find key words that could be used in the search of on-line bibliographic data. These journals were used because of their history of articles published in the field of management information systems. The table of contents of every issue between 1970 and 1990 was manually reviewed. If a title appeared relevant to the subject of benefit analysis of information systems then the article was reviewed. After reading the article and determining that indeed it did pertain to the subject, the article was then copied and saved for later referral.

b. Key Words Found

The search for key words identified 19 articles from these two journals. From the initial search it could also be concluded that the authors of the 19 articles chose diverse key words to describe their articles. Key words included:

- Cost/Benefit Analysis
- Cost/Benefit Calculations
- Information Economics
- Information System Investment
- Information Technology Investment
- Value Analysis

As the dissimilarity of key words found in the initial search was discovered, it was determined that a single on-line search with a single set of key words would not sufficiently identify the number of articles desired on the subject of benefit analysis of information systems. The problem was that the key words that were found were just to diverse for the on-line system to be effective.

4. Manual Bibliographical Search

As a result of the difficulties with key words, a manual bibliographical search was undertaken as opposed to an on-line search. This main search was conducted in the same manner as the preliminary search. A list of eight additional journals was gathered based on their reputation for publishing studies in the field of management information systems. The journals searched manually were:

- Communications of the ACM *
- Data Base
- Decision Sciences
- Harvard Business Review
- Information and Management
- Journal of Management Information Systems
- Management Science
- Management Information Systems Quarterly
- Omega
- Sloan Management Review

* ACM: Association for Computing Machinery

a. ***Conduct of the Manual Search***

Once the list of journals was established the search was conducted systematically. Journal by journal, the table of contents for each issue available, during the time period of 1970 to 1990, was examined for a possible article relevant to the subject of interest. Articles with fitting titles were copied for latter reference if after being reviewed it was concluded that they were appropriate.

b. ***Other Sources of Literature***

Other sources of reference were considered to clarify certain points brought up in the articles that had been initially collected and reviewed. The references of the articles located in the main search were used to identify further articles that could pertain to the subject of this study. These sources were located through on-line bibliographical searches by either author, title, or subject. The on-line search was useful to locate these additional sources within the library for in this instance very specific: author names, and titles, were used to query the on-line system for exact locations of individual works. A final source of literature that comprises the foundation of this thesis came from the courses that this author was exposed to at the Naval Postgraduate School. A comprehensive inventory of the literature found and used for this thesis is presented in the bibliography.

B. SORTING THE WORKS ON BENEFIT ANALYSIS

In combination, the preceding search methods yielded a total of 50 references that were considered for possible contribution to the study of benefit analysis of proposed information systems. These references were organized into three groups: benefit comparison, user satisfaction, and miscellaneous literature.

1. Benefit Comparison

The articles in this group are distinguished from the others by the condition that they present methods of analyzing benefits by assessing various system attributes. The methods discussed under benefit comparison are: the additive weight model, the eigenvector model, and the multi-attribute utility model. Chapter IV is dedicated to benefit comparison.

2. User Satisfaction

The references in this group, in contrast to the groups previously mentioned, propose to analyze benefits not through an objective indicator, but through a survey to determine the subjective satisfaction that users have with their respective information system. The procedures of this method incorporate various formulas and models to interpret the responses of user satisfaction questionnaires. User satisfaction is the subject of Chapter V.

3. Miscellaneous Literature

The last group that references were organized into was miscellaneous. This group contained articles on the importance of information systems and their predominance throughout the business world and DoD. Articles were also placed in this group that stressed the value of information and the need for benefit analysis of information systems. Articles on the competitive advantage to be gained from information systems were also placed in the miscellaneous group. In spite of the expressed need for benefit analysis, the group of miscellaneous literature did not contribute to any specific benefit analysis technique. As such, the references in this group were largely used as background material that stressed the importance of information system benefit analysis and that put benefit analysis in perspective in relation to analysis of alternatives and the rest of the development life cycle for information systems.

III. BACKGROUND

A. GUIDELINES FOR FEDERAL ADP ACQUISITIONS

The Brooks Act, public law 89-306, established the U.S General Services Administration (GSA) as the procurement authority for ADP equipment acquisitions within the federal government. The Act instructs the GSA to "provide for the economic and efficient purchase, lease, and maintenance of automated data processing equipment by federal agencies" (U.S. GSA,1990). This authority was increased through the enactment of public law 99-500 to also include the federal acquisition of such things as; software, firmware, and computer related contracted services to include programming and support services. In fulfillment of their responsibility the GSA publishes both procedural guides, such as A Guide for Requirements Analysis and Analysis of Alternatives, and the federal information resources management regulation (FIRMR). (U.S. GSA,1990)

The Warner Amendment, as enacted under public law 99-500, did release DoD from the jurisdiction of the Brooks Act for certain ADP functions that dealt with national security or military operations. However, the Warner Amendment did not release DoD from the conditions of the Brooks Act for ADP acquisitions that deal with a vast number of other functions such as logistics and administrative activities.

As such the DoD must abide by FIRMR when making a great number of ADP and information system acquisitions.

B. GSA POLICY FOR THE ANALYSIS OF ALTERNATIVES

In the process of making a federal acquisition of ADP equipment or systems the GSA requires that an analysis of alternatives be performed. The objective of this analysis is to determine the most advantageous alternative to the government. As a part of this analysis of alternatives the GSA has mandated that both cost and non-cost factors are to be evaluated. The specific cost and non-cost factors that should be considered in this type of analysis have been determined by the GSA and are listed, and described, in A Guide for Requirements Analysis and Analysis of Alternatives (U.S. GSA,1990). The cost factors are:

- conversion
- personnel
- supplies
- energy
- maintenance
- space
- administrative costs of contracting
- contract price

The cost factors above are all quite tangible and relatively easy to evaluate in the course of an analysis of alternatives. In fact the GSA has recommended three different methods for use in the analysis of cost factors:

present value analysis, net present value, and benefit-cost ratio. (U.S. GSA,1990)

C. ANALYSIS OF COST FACTORS

1. Description

Of the techniques recommended by GSA for the analysis of cost factors, present value analysis is common to capital investment and calculates the present worth of a monetary amount to be received in the future. Present value analysis takes into account the time value of money, or the concept that a dollar is worth more today than a year from today. There are several different approaches to present value analysis to included: present value of a single future payment, present value net benefits, and present value for competing alternatives.

a. *Present Value of a Single Future Payment*

In Garrison (1988), present value analysis is described in the context of a the receipt of a single amount, or benefit, in the future. The formula for calculating present value of a one time payment in the future is given in Formula 1. (Garrison,1988)

$$P=\frac{F_n}{(1+r)^n} \tag{1}$$

In Formula 1, P represents the present value of the benefit in monetary terms. F is the monetary value of the benefit to be received in the future. r is the interest rate and n is the number of years in the future that the benefit will be received. (Garrison,1988)

b. Present Value Net Benefits

Thompson (1980) examines present value analysis in terms of discovering the sum of all the systems results, both good and bad, or in other words both liabilities and assets. In his work Thompson uses the expression "present-valued compensating variation" when referring to the difference between the cost and benefit of a particular attribute. Thompson's formula for present-valued net benefits is given in Formula 2. (Thompson,1980)

$$P=\sum_{i=1}^{n}\sum_{j=1}^{m}\frac{CV_{ij}}{(1+d)^{y}} \qquad (2)$$

In Formula 2, CV_{ij} is the compensating variation for benefit j on the user i. d is the discount rate. y is the number of years until the user i is affected by benefit j. m is the number of different benefits. n is the number of users benefitted by the system. (Thompson,1980)

Thompson's present-valued net benefits method should not be confused with the net present value (NPV) method. As recommended by GSA, the NPV is equal to difference between the total present value of all of the benefits and the total present value of all of the costs.

NPV, unlike present-valued net benefits, does not attempt to sum the differences between costs and benefits of each characteristic of an information system. (U.S. GSA,1990)

c. Present Value for Competing Alternatives

In NAVDAC PUB 15 (Dec,1980) present value analysis is used to evaluate alternatives based on lowest cost. In this application of present value analysis, the benefits of all alternatives being considered must be equal and a selection is made by determining the lowest present value of the costs of the different alternatives. Also, by this method, the service lives of the alternatives must be finite and equal among alternatives, or be placed in equal terms. In computing present values the NAVDAC method uses standard tables of discount factors in which the present value of a dollar can be found for both a single cash flow and cumulative uniform cash flows. Uniform here being the same amount paid every year. This form of the present value may be easier to conceptualized if placed in the context of hardware acquisitions. (NAVDAC PUB 15,1980)

2. Example of Present Value Analysis

In this example two high capacity printers are under consideration for purchase. Both of the printers have the same exact capabilities, such as the same output speeds, font styles, and buffer sizes. One of the printers, alternative A, has a service life of six years. The other, alternative B, has a service life of three years. In this situation the NAVDAC method of present value analysis can be applied for the benefits are equal and the service lives can be placed in equal terms. (NAVDAC PUB 15,1980)

To further define the example, alternative A costs $10,000 to purchase and has annual reoccurring cost of $4,000. Alternative B costs $8,000 to purchase and has annual reoccurring costs of $5,000. Both alternatives are not expected to retain any value at the end of the economic lives. (NAVDAC PUB 15,1980)

a. ***Present Value Using a Six Year Service Life***

The present value for the two alternatives using a six year service life would be found as follows. For alternative A the purchase price would be added to the reoccurring expenses multiplied by the factor for a six year cumulative uniform series. In alternative B two printers have to be purchased so that their combined service life equals six years. The present value of alternative B is the purchase price for the first printer added to the reoccurring expenses multiplied by the factor for a six year cumulative uniform series and then added to the purchase price of the second printer multiplied by the factor for a single payment in three years. Algebraically the present values determination of the alternatives is shown below. (NAVDAC PUB 15,1980)

$$A = \$10,000 + (\$4,000 \times 4.570) = \$28,280$$

$$B = \$8,000 + (\$5,000 \times 4.570) + (\$8,000 \times .788) = \$37,154$$

b. Present Value Using a Three Year Service Life

Had a three year service life been used in the comparison only one purchase in alternative B would have to have been considered. However, as alternative A would have half of its service life remaining at the end of three years, then half of its purchase price, multiplied by the factor for a single cash flow in three years, would have to be deducted from the calculation to represent the remaining value. Also, the reoccurring expenses multiplied by the factor for a three year cumulative uniform series, not a six year series. Algebraically the present values determination of the alternatives using this three year service life is given below. (NAVDAC PUB 15,1980)

A = \$10,000 + (\$4,000 x 2.609) - (\$5,000 x .788)=\$16,496

B = \$8,000 + (\$5,000 x 2.609) = \$21,045

3. Advantages & Disadvantages of Present Value Analysis

A key advantage of the present value technique is that organizations are familiar with it for the technique is used to make other capital budgeting decisions (Garrison,1988). Another advantage is that present value analysis is a simple means of comparing alternatives when the benefits and project lives are the same (NAVDAC PUB 15,1980). Then possibly the most compelling advantage of present value analysis is that it is one of the three cost analysis methods recommended by the GSA for use in the analysis of alternatives. This analysis being required for each federal acquisition of ADP equipment or information systems.

Present value analysis alone is seen by some as ill suited for the analysis of some types of information systems, such as decision support systems (Keen,1981). The technique is not recommended in this situation for it is difficult to quantify the benefits of such a system capabilities such as AD-HOC analysis (Keen,1981). Present value analysis, as described above, is also criticized for it does not take into account risk or the probability of the benefit occurring (Couger et al,1982). Possibly for these, or similar reasons GSA has also required that non-cost factors be included in the analysis of alternatives.

D. ANALYSIS OF NON-COST FACTORS

The non-cost factors that the GSA has specified that are to be included in an analysis of alternatives have been separated by GSA into two groups; functional factors and risk factors. The functional factors include: (U.S. GSA,1990)

- obsolescence
- availability
- reliability
- maintainability
- expandability
- flexibility
- security

- privacy
- personnel impacts
- user acceptance
- accountability

The risk factors are: (U.S. GSA,1990)

- financial
- technical
- schedule

The inclusion of these functional and risk factors into an analysis of alternatives offsets the disadvantages of conducting an analysis solely on the basis of cost factors. Those disadvantages namely being; the lack of addressing risk, and the inappropriate nature of attempting to apply cost-benefit analysis methods to benefits that are difficult to quantify in dollar terms. As such, there should be a clear advantage of conducting an analysis of alternatives that incorporates both cost and non-cost factors. However, even though GSA does directs that the functional and risk factors be included in the analysis of alternatives, the GSA guides do not recommend or mension any non-cost analysis method which should be used in such an analysis. (U.S. GSA,1990)

IV. ANALYSIS METHODS FOR NON-COST FACTORS

There are existing benefit comparison methods that may well suited for fulfilling the GSA requirement for non-cost analysis. That analysis, of course, being part of an analysis of alternatives leading up to the federal acquisition of ADP equipment or information systems. These benefit comparison methods not only are useful in contrasting the benefits of the various alternatives, they can also be used for making a selection from proposed alternatives based on non-cost factors. The non-cost factors in this context may be described as attributes of information systems and may be analyzed as well as measured as such by the different benefit analysis methods. The supporters of objective quantification methods believe that analysts, who describe the benefits of information systems as completely intangible, are not putting forth the effort to find measures for the benefits (Couger et al,1982). The benefit comparison methods that will be addressed are: the additive weight model, the eigenvector model, and the multi-attribute utility model.

A. THE ADDITIVE WEIGHT MODEL

1. Description

The additive weight model consists of three steps; determining weights, scoring alternatives, and selecting the best alternative. Prior to using the model however, the benefits must be defined and broken down into the separate attributes or characteristics of the information system. Such attributes could include: memory capacity, calculation speed, or the manufacturer's reliability. These attributes can be divided by categories, such as hardware and software, or listed together in one group. The attributes are not required to be independent of each other (Shoval and Lugasi,1987). Defining the attributes establishes common references in which the additive weight model can be implemented by analysts and decision makers alike. (Shoval and Lugasi,1987)

a. ***The Three Steps of the Additive Weight Model***

The first step determines attribute weights for each attribute. These may be obtained through point allocation where a decision maker assigns a number between 0 and 1 to each attribute to reflect its relative importance (Schoemaker and Waid,1982). The sum of all the attribute importance weights must equal 1. If attributes are divided into categories then category importance weights must also be selected and their sum must also equal 1.

The second step, scores alternatives, by having the decision maker evaluate each alternative and assess a rating for each attribute. This is done one attribute at a time and only the attributes receive a rating, not the categories or the overall system. The final step, selection of the best alternative, is made by choosing the information system that maximizes the summation of attribute scores multiplied by the respective attribute and category weights. This step is expressed in Formula 3 and demonstrated in Table 3. (Shoval and Lugasi,1987)

b. The Additive Weight Formula

Formula 3 is the additive weight formula. When using this formula four conditions must hold true. First, the sum of the category weights must equal 1. Second, attribute weights range from 0 to 1. Third, attribute scores must be less than or equal to 1. Finally, the sum of the attribute importance weights must equal 1. (Shoval and Lugasi,1987)

The following notation is used in Formula 3 and Tables 1 through 3. Z_k expresses the category importance weights of m categories. W_i represents attribute importance weights of n attributes. Finally V_{ij} symbolizes the ith attribute score for alternative j. (Shoval and Lugasi,1987)

$$\max \sum_{k=1}^{m} \sum_{i=1}^{n_k} Z_k W_i V_{ij} \qquad (3)$$

2. Example of the Additive Weight Model

In Shoval and Lugasi (1987) an example of the additive weight model is given where there are four alternatives to select from and 14 attributes to be evaluated which were split into three categories. The four proposed systems are alternatives A through D. The three categories are hardware, software, and support. The attributes, listed by category, are given in Table 1 along with their respective importance weights. Alternative scores by attribute are given in Table 2. (Shoval and Lugasi,1987)

Table 1. Category and Attribute Importance Weights

Category	Attribute	Weight	
Z1	Hardware	.30	
	X1 Memory Capacity		.25
	X2 Calculation Speed		.25
	X3 I/O Speed		.07
	X4 Equipment Reliability		.25
	X5 Flexibility for Expansion		.18
Z2	Software	.30	
	X6 Availability for Scientific Software		.30
	X7 Flexibility to Changes		.30
	X8 Software Performance		.40
Z3	Support	.40	
	X9 Manufacturer's Reliability		.20
	X10 Supplier's Reliability		.20
	X11 Supply Time		.10
	X12 Quality of Hardware Support		.20
	X13 Quality of Software Support		.20
	X14 Quality of Documentation		.10

Table 2. Alternative Scores by Attribute

Attributes	Alternatives A	B	C	D
X1	0.8	0.8	0.8	1.0
X2	0.8	0.8	0.8	0.6
X3	0.8	0.8	0.8	1.0
X4	1.0	1.0	0.7	0.9
X5	1.0	0.9	0.9	0.8
X6	0.8	0.8	0.8	0.6
X7	1.0	1.0	1.0	1.0
X8	0.9	0.9	0.8	0.9
X9	1.0	1.0	0.8	0.9
X10	0.9	0.9	0.7	0.8
X11	0.9	0.7	1.0	0.9
X12	1.0	1.0	0.8	1.0
X13	0.9	0.9	1.0	0.8
X14	1.0	1.0	1.0	0.9

Table 3. Calculation of the Weighted Score for Alternative A

Attribute	Category Weight	x	Attribute Weight	x	Attribute Score	=	Weighted Score	
X1	0.3		.25		0.8		.0600	
X2	0.3		.25		0.8		.0600	
X3	0.3		.07		0.8		.0168	
X4	0.3		.25		1.0		.0750	
X5	0.3		.18		1.0		.0540	
								.2658
X6	0.3		0.3		0.8		.0720	
X7	0.3		0.3		1.0		.0900	
X8	0.3		0.4		0.9		.1080	
								.2700
X9	0.4		0.2		1.0		.0800	
X10	0.4		0.2		0.9		.0720	
X11	0.4		0.1		0.9		.0360	
X12	0.4		0.2		1.0		.0800	
X13	0.4		0.2		0.9		.0720	
X14	0.4		0.1		1.0		.0400	
								.3800
Total Weighted Score								.9158

From Formula 3 and Tables 1 through 3, alternative A, with a score of 0.9158, has the highest total weighted score of the four alternatives. Alternative A would thus be the information system selected by the additive weight model. The weighted scores of alternatives B, C, and D are 0.9024, 0.8399, and 0.8557 respectively. (Shoval and Lugasi,1987)

3. Advantages and Disadvantages of Additive Weight

Besides being simple in nature the additive weight model also has the advantage that sensitivity analysis, or receptiveness to change, can be measured for the weights assigned to the various attributes and categories. The disadvantage is that this model cannot check the consistency of evaluators; nor does it consider risk or uncertainty. Assigning weights and scoring alternatives is also a subjective appraisal of information system benefits. (Shoval and Lugasi,1987)

B. THE EIGENVECTOR MODEL

1. Description

Building on the additive weight model the eigenvector model provides a means for determining the attribute and category weights as well as scoring the alternatives. Final system selection in the eigenvector model is made using Formula 3 of the additive weight model. In the eigenvector model attribute weights are found by a process which starts with pairwise comparisons. A decision maker completes a matrix in which both the number of columns and rows equal the number of attributes being evaluated. For instance, if four attributes were being examined, then a 4x4 matrix would be required. Each cell of the matrix represents a comparison between two of the attributes. A nine-point scale is used in the model with 1 representing equality between attributes and 9 depicting absolute preference of one attribute over the other. In the matrix in Figure 1, attribute *x1* is favored 3/2 times to attribute *x5*. The consistency of the decision maker can be verified through an inspection of inverse relationships. Here *x5* is favored 2/3 times to *x1* so the decision maker is being consistent. (Shoval and Lugasi,1987)

Figure 1. Sample Matrix

	X1	X2	X3	X4	X5
X1	1	1	5/2	1	3/2
X2	1	1	5/2	1	3/2
X3	2/5	2/5	1	1/3	1/2
X4	1	1	3	1	3/2
X5	2/3	2/3	2	2/3	1

The eigenvector of this matrix is then computed for the maximum eigenvalue. This eigenvector is then normalized so that the sum of the elements in the vector equals 1. Computing and normalizing these eigenvectors can be done through the use of a computer package such as EISPACK, which is a package of fortran IV programs (Goos and Hartmanis,1977). The elements in this final form of the eigenvector are the respective attribute weights. Category weights are then determined in a similar fashion with the dimensions of the matrix equal to the number of categories. (Shoval and Lugasi,1987)

To score the alternatives by attribute, a matrix of pairwise comparisons is used. This time the number of matrices used is equivalent to the number of attributes. The dimensions of each of these matrices is set to the number of alternatives. The elements of the normalized eigenvector are the solution. Here they represent the scores of the alternatives for the respective attributes. (Shoval and Lugasi,1987)

2. **Example of the Eigenvector Model**

The situation used in this example is the same as that used above for the additive weight model: four alternatives, three categories, and 14 attributes. The four alternatives are still labeled A through D and the categories and attributes remain the same from Table 1 above. In Figure 2 of Appendix A the matrices for determining attribute weights are displayed. Figure 3 of Appendix A is the matrix of pairwise comparisons of the three categories. In Figure 4 of Appendix A the 14 matrices are presented that were used to define the alternative scores by attribute. Finally, Table 4 contains the category and attribute weights, and lists the weighted scores for the each alternatives which is used to produce their respective ranking as determined by the eigenvector model. (Shoval and Lugasi,1987)

Table 4. Scores and Ranking of Alternatives

Attribute	Weight	Alternatives A	B	C	D
Z1	.333				
X1	.244	.222	.222	.222	.333
X2	.244	.286	.286	.286	.143
X3	.091	.211	.211	.199	.378
X4	.253	.316	.316	.158	.210
X5	.169	.286	.286	.286	.143
Z2	.333				
X6	.400	.286	.286	.286	.143
X7	.200	.250	.250	.250	.250
X8	.400	.273	.273	.273	.182
Z3	.333				
X9	.352	.375	.250	.125	.250
X10	.235	.316	.284	.142	.258
X11	.062	.275	.347	.277	.102
X12	.139	.351	.351	.109	.189
X13	.139	.333	.333	.111	.222
X14	.072	.315	.315	.153	.216
Weighted Score		.295	.280	.213	.212
Ranking		1	2	3	4

3. Advantages & Disadvantages of the Eigenvector Model

The advantage of the eigenvector model is that it facilitates a review of a decision makers consistency throughout the analysis by conducting an inspection of inverse relationships between respective paired comparisons. However, the eigenvector model ignores attribute interdependence and does not reflect risk or uncertainty involved with the various alternatives in the analysis. In the course of a large scale analysis pairwise comparisons can also become quite difficult when the number of pairs is increased to a large number. (Shoval and Lugasi,1987)

C. THE MULTI-ATTRIBUTE UTILITY MODEL

1. Description

Like the additive weight and eigenvector models the multi-attribute utility model requires a list of applicable attributes to be evaluated. While benefits of information systems are not unidimensional, it is probable that dimensionality can be contained or at least reduced by including only the most relevant attributes to the systems being evaluated (Ahituv,1980). The multi-attribute utility model itself has two variations, an additive model and a multiplicative model (Formulas 4 and 5 respectively). The variants differ in the way they treat risk. (Shoval and Lugasi,1987)

a. *Multi-Attribute Utility Formulas*

$$U_j=\sum_{i=1}^{n} k_i U_{ij} \tag{4}$$

$$U_j=\frac{\left(\prod_{i=1}^{n}(1+kk_iU_{ij})\right)-1}{k} \tag{5}$$

In both Formulas 4 and 5, U_j depicts the utility of alternative j. U_{ij} refers to the utility of attribute i in alternative j and U itself is constrained to be between 0 and 1 by the constant k. Formula 6 below is used to determine k. k_i here portrays the weight of attribute i. (Shoval and Lugasi,1987)

$$1+k=\prod_{i=1}^{n}(1+kk_i) \qquad (6)$$

b. Model Selection

The use of either the additive or multiplicative model is dependent on the decision maker's outlook on risk. The decision aid for that determination is the summation of all the attribute weights. If this sum is equal to 1, then the decision maker is indifferent to risk and the additive model is selected. If the sum is greater than 1, then the multiplicative model is selected and k set between 0 and -1. When the summation of attribute weights is less than 1, then the multiplicative model is also used, yet in this case k is set to a value greater than 0. (Shoval and Lugasi,1987)

c. Application of the Multi-Attribute Utility Model

The multi-attribute utility model requires both utility and preference independence of the various attributes. Once the attribute independence has been confirmed the evaluation of the utility function for every attribute can then be based on two axioms, transitivity and continuity. The transitivity axiom states that if alternative a_i is favored over a_j, and a_j is favored over a_k, then alternative a_i is superior to alternative a_k. The continuity axiom refers to the state that if alternative a_i is favored over a_j, and a_j is favored over a_k, then a gamble on a_i and a_k can be performed so that there will be a point where the decision maker will be indifferent between choosing the gamble or being assured of receiving alternative a_j. If the axioms can be met then the utility function can be found through the multi-attribute utility model. (Shoval and Lugasi,1987)

d. *Forming the Utility Function*

To form the utility function for each attribute, with the above axioms previously being met, the two extreme points of the utility curve must be defined. The highest level for attribute i is designated as i^* and $U(i^*)$ is set to equal 1. The lowest level of attribute i is represented by $i^\#$ and $U(i^\#)$ is set to 0. *i* is designated as *i'* when conducting the gambling technique in evaluating the utility of a particular level of i. The decision maker is then presented with the following situation. Given two alternatives, A and B, with all attributes between the two alternatives, other than i, being equal. In alternative A there is a 100% probability that attribute i will be i'. Alternative B is the gamble with a probability of p that attribute i will be i^* and a probability of 1-p that i will be $i^\#$. The decision maker is then asked to determine at what level of p he would be indifferent between the two alternatives. When the decision maker is indifferent to the two alternatives the utility of alternative A equals the expected utility of alternative B, or in other words $U(i') = pU(i^*) + (1-p)U(i^0)$. The value of $U(i')$ is then known to be p, for $U(i^*)$ is 1 and $U(i^0)$ is 0. Other utility points for attribute i are found in the same manner by varying the level of i'. The utility curve for i is formed by connecting the utility points. A continuous curve is not required for it is suitable to evaluate only a range of relevant values for each attribute. (Shoval and Lugasi,1987)

e. Determining the Attribute Weights

The attribute weights, k_i, are found in the same way that the attribute utility points were found. To define the attribute weights the decision maker is given a situation with two alternatives, A and B. This time alternative A has attribute i at the highest level, or i^*, and the remaining attributes at their lowest level, or i^0. Alternative B is again a gamble with a probability of p that all of the attributes are at their respective highest level, and a probability of 1-p that all of the attributes are at their lowest level. The decision maker is then asked to choose between the two alternatives by answering the following question: "At what level of p would you be indifferent between the two alternatives?" The value of k_i is then known to be p by the same reasoning that $U(i')$ is equal to p. With the utility function and weights found for every attribute the appropriate version of the model can then be applied. (Shoval and Lugasi,1987)

2. Example of the Multi-Attribute Utility Model

The example cited here is from Shoval and Lugasi (Shoval and Lugasi,1987) and is the same situation as given in the examples for the additive weight and eigenvector models.

a. Determining Attribute Independence

Prior to the application of the multi-attribute utility model the attribute utility and preference independence had to be verified. The utility independence was confirmed through the repeated use of the gambling technique. In each trial the level of the attributes other than *i* were set to different levels. Utility independence was known to be true as *U(i')* remained constant throughout the trials. (Shoval and Lugasi,1987)

In a similar manner the preference independence was also found. Attributes were evaluated taking them two at a time. In the first alternative, the first attribute, quality of documentation, was set at 2 out of a five-point scale and the second attribute, memory capacity, was placed at 768K. The second alternative had quality of documentation at 4 and memory capacity at i'. All other attributes were at their highest respective levels. The decision maker was then asked to determine a value for *i'* where he would be indifferent between the two alternatives.

This process was repeated with all of the attributes other than quality of documentation and memory capacity set to their lowest respective levels. As i' was found not to change between the two trials, the preference between the two attributes was determined to be independent. The rest of the attribute pairs were examined in the same way and found to be preference independent. (Shoval and Lugasi,1987)

b. Determining Attribute Utility

In evaluating the utility of the attributes the categories were ignored and the 14 attributes were addressed in one list. Continuous utility curves were not calculated for it was determined that for each attribute only four values, one for each alternative, needed to be evaluated. To evaluate the memory capacity the decision maker was again given two alternatives. Alternative A is certain to receive 768K capacity. Alternative B is a gamble with the probability of *p* that the capacity will be 1060K and a probability of 1-*p* that the capacity will be 576K. The minimum acceptable memory capacity having previously been defined at 576K and the highest capacity between all alternatives being 1060K. After asking the decision maker for a value of *p* where he would be indifferent between the two alternatives he responded that *p* would have to be 0.3 for him to be indifferent. Thus the memory capacity of 768K has the utility value of 0.3. The utility values of all of the 14 attributes were found using this same method. The utilities found for each of the attributes of each of the four alternatives are presented in Table 5. (Shoval and Lugasi,1987)

c. *Determining Attribute Weights*

Attribute weights, k_i, were found as in the following example for memory capacity. The decision maker being provided with two alternative computer systems. One has a guaranteed capacity of 1060K and all the remaining attributes are at their lowest levels. The other alternative is the gamble with a probability of *p* that all attributes are at their highest levels and a probability of 1-p that all of the attributes are at their lowest levels. The decision maker was then asked for a value of *p* where he would feel indifferent between the two alternatives. The response was that *p* would have to be 0.08 for the decision maker to be indifferent. Thus the weight of the attribute memory capacity is 0.08. The weights for the other attributes were found in the same manner and are given in Table 5. (Shoval and Lugasi,1987)

d. *Implementing the Model*

As the sum of the weights was greater than 1 the multiplicative utility model, Formula 5, was used in this example. The constant *k* was found to be -0.44268 from Formula 6. The ranking of the alternatives is given in the last line of Table 4. (Shoval and Lugasi,1987)

Table 5. Utility Values and Weights

Attribute	Weight	Alternatives A	B	C	D
X1	0.08	0.6	0.6	0.6	0.1
X2	0.07	1.0	1.0	1.0	0.5
X3	0.04	0.9	0.9	0.8	1.0
X4	0.12	1.0	0.9	0.7	0.9
X5	0.07	1.0	0.9	1.0	0.8
X6	0.07	1.0	1.0	1.0	0.8
X7	0.15	1.0	1.0	1.0	1.0
X8	0.10	1.0	1.0	1.0	0.9
X9	0.15	1.0	0.9	0.7	0.8
X10	0.10	1.0	0.9	0.6	0.9
X11	0.05	0.8	0.7	1.0	0.9
X12	0.09	1.0	1.0	0.9	1.0
X13	0.08	1.0	1.0	0.7	0.8
X14	0.12	1.0	1.0	1.0	0.9
Utility		.973	.944	.882	.905
Ranking		1	2	4	3

3. Advantages & Disadvantages of Multi-Attribute Utility

There are three primary advantages of the multi-attribute utility model. First, the model is normative in that it is based on the axioms of transitivity and continuity which reveal the behavioral rules of the decision maker. Secondly, the model verifies attribute independence. Finally, the model differs from the additive weight and eigenvector models in that it has the capacity to take into account the issues of risk and uncertainty. (Shoval and Lugasi,1987)

The disadvantages of the multi-attribute utility model are two fold. First, the decision maker may have difficulty with the gambling technique in making a preference between the two alternatives. Secondly, the rules of attribute independence, necessary for the implementation of the model, are not always met. Thus there are situations were the model can not be used. (Shoval and Lugasi,1987)

D. SUMMARY

In summary the benefit comparison methods; additive weight, eigenvector, and multi-attribute utility, are all similar in nature. All three methods start by defining the various advantageous features, or non-cost factors, of an information system that are to be evaluated and separate those features into distinct attributes. Then each attribute is assigned either an importance weight or relative utility, dependent on the analysis method. A score, or utility, is next found for each alternative by attribute. From these scores the various formulas of the different methods can then be used to arrive at a final ranking of each alternative. The methods differ, of course, by the formulas used and if any special conditions have to be met, such as attribute independence in the multi-attribute utility model.

1. Advantages & Disadvantages of Benefit Comparison

All of the methods addressed in this chapter have their own merits. The additive weight model has the capacity for sensitivity analysis however, in the application of the model in the example, the model does not take into account risk or uncertainty. The eigenvector model has the capacity to verify a decision maker's consistency, yet it too does not consider risk or uncertainty. In addition, the eigenvector model overlooks the issue of attribute interdependence. The multi-attribute utility model has the advantages that it is; normative, it examines attribute independence, and it takes into account risk and uncertainty. The disadvantage of the multi-attribute utility model is that the gambling technique, used in the differentiation of alternatives, may be difficult for some decision makers. The multi-attribute utility model also can not be applied in all situations particularly when the rules of attribute independence can not be met.

2. Benefit Comparison and Non-Cost Factor Analysis

The different functional and risk factors recommended by GSA could be selected as the attributes to be evaluated in the application of a benefit comparison method for the analysis of the non-cost factors. However, by including the functional factor of user acceptance in any one of the models would require a scoring technique to assess user satisfaction with the proposed alternative. None of the benefit comparison methods discussed here address how such a score could be determined. Thus there remains a need for an analysis method or tool that can be applied in the evaluation of user acceptance with respect to the analysis of alternatives. Tools that have been recommended for quantifying user acceptance fall under the heading of measurements of user satisfaction, which is the subject of Chapter V.

V. MEASURING USER SATISFACTION

In the preceding chapter the measurement of user satisfaction was introduced as a means of augmentation to the benefit comparison methods so that all of the GSA stipulated non-cost factors may be evaluated in an analysis of alternatives in the acquisition of ADP systems for the federal government. The supporters of user satisfaction analysis techniques believe so strongly in their work that they consider that these techniques should be used more than just for augmentation of other evaluation methods (Baroudi,Ives,and Olson,1983). These defenders of user satisfaction regard the efforts to measure actual productivity benefits of information systems as difficult and even futile (Baroudi,Ives,and Olson,1983). Others insist that when dealing with information systems it is impossible to derive useful measures such as return on investment or pretax profits (Olson,and Weill,1989). User satisfaction, in the view of these authors, is measurable and for that fact should be used as the method of choice in the analysis of information systems benefit (Baroudi, Ives, and Olson,1983). Methods that can be used in the analysis of user satisfaction that will be addressed are: the Bailey and Pearson tool, the Electre model, and the multi-attribute linear value model.

A. USER SATISFACTION ANALYSIS METHODS

Primarily as a substitute to the objective methods of information system benefit analysis, such as net present value, a subjective measure of user satisfaction has been offered. The technique of user satisfaction, also known as user information satisfaction, centers around the use of surveys or questionnaires to measure the satisfaction level that the users have with their information system. Different types of surveys have been suggested, such as single item and multiple item. Surveys of single items or functions are of limited utility (Baroudi,Ives, and Olson,1983). Multiple item surveys, more broad in scope, take a better sample of the users opinions of the information system and therefore dominate as preferred measurement techniques of user satisfaction (Baroudi, Ives, and Olson,1983). Completed surveys are used to make inferences about the beneficial value of an information system as a whole. These deductions have been made in the past from numerical scales and formulas that have been devised by different developers of user satisfaction measurement tools.

B. THE BAILEY AND PEARSON TOOL

Bailey and Pearson (Bailey and Pearson,1983) present a multiple item survey and a respective scoring method to measure computer user satisfaction. They identified 39 different factors of user satisfaction (see Appendix B).

Each factor identified was assigned four distinct adjective pairs to assess the factor. The documentation factor, for instance, was assigned the distinct adjective pairs of:

- clear vs. hazy
- available vs. unavailable
- complete vs. incomplete
- current vs. obsolete

In addition to the four distinct pairs of each factor the adjective pair satisfactory - unsatisfactory was included as a consistency check on the other adjective pairs. Finally the adjective pair important - unimportant was included to assign weights of importance to the various factors (see Appendix B). (Bailey and Pearson, 1983)

1. Numerical Scales

To quantify the results of the survey Bailey and Pearson (Bailey and Pearson,1983) derived their own importance and satisfaction scales. The importance scale, used to designate weights of importance to the respective factors, was assigned a value range of 0.10 to 1.00 in 0.15 increments. The values were associated with importance and unimportance as shown below:

1.0	extremely important
.85	quite
.70	slightly
.55	equally
.40	slightly

.25 quite

.10 extremely unimportant

The satisfaction scale below was used to assign values to the first four adjective pairs of each factor (Bailey, and Pearson, 1983):

3 extremely satisfied

2 quite

1 slightly

0 equally

-1 slightly

-2 quite

-3 extremely dissatisfied

2. Bailey and Pearson's Formula

Through the use of the importance and satisfaction scales the perception of a user towards the respective information system can be captured as a numerical score. This value is obtained by first taking a simple arithmetic mean of the values I assigned to each of the first 4 adjective pairs k of each of the factors j using the satisfaction scale. Then the summation of the individual factorial scores multiplied by their respective weights W, from the importance scale, produces the overall measure of satisfaction S for each user i as seen in Formula 7. (Bailey, and Pearson, 1983)

$$S_i = \sum_{j=1}^{39} \frac{W_{ij}}{4} \sum_{k=1}^{4} I_{ijk} \qquad (7)$$

Formula 7 is then normalized to reduce the undesirable effects of any factors assessed as neutral or meaningless. Any factor is eliminated from consideration if all four of the respective distinct adjective pairs were evaluated as equal or zero. (Bailey, and Pearson, 1983)

3. Disadvantages of Bailey and Pearson's tool

The tool developed by Bailey and Pearson takes a broad look at the information system being evaluated and the organizational setting in which it was used. However, some problems have been identified with the manner in which the tool was developed. First, a sample size of only 29 was used to validate the tool. Second, each of the 29 subjects had participated in the development of the tool (Baroudi, Ives and Olson,1983). Baroudi, Ives and Olson (Baroudi, Ives and Olson,1983) also found that Bailey and Pearson's weighted and unweighted results were highly correlated and as such the adjective pair important - unimportant was unnecessarily included in the questionnaire. This means that questions concerning the importance of individual factors did not have a significant impact on the final results of the measurement tool. A key problem with the tool is that it violates measurement theory by treating ordinal measures, the adjective pairs, as interval measures such as distance (Galletta and Lederer,1989). In the application of Formula 7 Bailey and Pearson are conducting parametric statistical analysis on ordinal measures which is a breach measurement theory (Galletta and Lederer,1989).

C. THE MULTI-ATTRIBUTE LINEAR VALUE PROCEDURE

A procedure that has been employed in an attempt to assess the value of information systems is the multi-attribute linear value (MALV) technique (Epstein and King,1983). This application of MALV produces more than a ranking of alternatives, similar to the Bailey and Pearson tool, and though very objective sounding in name this use of MALV is in actuality a subjective measure of user satisfaction for the data manipulated by the procedure was gained through the user survey process (Epstein and King,1983).

1. Description

The application of the MALV procedure by Epstein and King uses a survey, numerical scales, and a formula in a similar manner as Bailey and Pearson's measurement tool of user satisfaction. MALV in this application receives data through the use of a ten item survey. Each item is a factor, or attribute, of information value. All ten attributes were selected by the model designer. The ten attributes are: (Epstein and King,1983)

- Reporting cycle
- Sufficiency

- Understandability
- Freedom from bias
- Reporting delay
- Reliability
- Decision relevance
- Cost efficiency
- Comparability
- Quantitativeness

2. **Epstein and King's Numerical Scales**

Epstein and King then used a scale to attach numerical scores to each of the attributes. The scale applied to the reporting cycle measures the frequency that information inputs have to be generated for user's decision making (Epstein and King,1983):

Reporting Cycle Attribute Scale

Greatest Satisfaction Possible	100
Extremely frequent	90
Fairly infrequent	70
Moderately frequent	50
Very frequent	30
Very infrequent	10
Lowest Satisfaction Possible	0

Relative importance weights are obtained by a graphic scale on the survey where the response positions are stressed and not the scale values. Survey evaluators can then quantify the weights by assigning values that match the distance ratios between points and the origin. (Epstein and King,1983)

3. MALV Formula

To find the overall value V of an information system the multi-attribute linear value model simply multiplies each attribute score V(a) by the respective importance weight W and adds together all of the results. Formula 8 summarizes this process. (Epstein,and King,1983)

$$V=\sum_{i=1}^{10} W_i V(a_i) \tag{8}$$

4. Subjectivity in Disguise

This application of MALV is essentially a subjective measure of user satisfaction as the data are acquired through the use of a ten item survey. The attribute scales and the formula of MALV conflict with measurement theory in the same manner as Bailey and Pearson's tool. The model fits adjectives to a numerical scale and then analyzes the results as if they were interval level measures. The validity of the model results are questionable in that they are derived from the manipulation of ordinal measures and the only legitimate statistical analysis on ordinal measures is nonparametric, such as rank ordering (Galletta and Lederer,1989).

D. THE ELECTRE MODEL

1. Description

A second analysis method of user satisfaction that can be used to evaluate completed user satisfaction surveys is the Electre model of multiple criteria decision making. This model is based on pairwise comparisons of alternatives, *i* and *j*, and employs two indexes to determine a final ranking of various alternatives (Zeleny,1982). The first index is the concordance index $C(i,j)$ which is the summation of the corresponding criteria weights for all criteria in which *i* out performs *j*, divided by the summation of all the criteria weights of the model (Bui,1981). The second index is the discordance index $D(i,j)$ which is found by taking the largest difference in evaluation scores for which *j* outranks *i* and dividing that value by the maximum range between highest and lowest possible scores (Bui,1981). The two indexes are then used in conjunction with threshold values selected arbitrarily by the user. The concordance threshold *P* ranges from 0.5 to 1.0 and increases in severity as it approaches 1. The discordance threshold *Q* ranges from 0 to 1 and increases in severity as it approaches 0. The final ranking of alternatives is made as follows (Bui,1981):

If	Then
$C(i,j) >= P$ and $D(i,j) <= Q$	*i* outranks *j*
$C(j,i) >= P$ and $D(j,i) <= Q$	*j* outranks *i*
i outranks *j* and *j* outranks *i*	*i* and *j* are equal
In all other cases	*i* and *j* are incomparable or the comparison is not determinable.

2. Example

a. Applying the Electre Model

If the Electre model were applied to the analysis of user satisfaction for three alternatives, the first issue to be settled would be to select the different criteria of user satisfaction that would be evaluated in the analysis. Along with the criteria, a weight of relative importance for each criterion must also be determined. For this example the following criteria and weights will be used:

- Understandability of system requests and responses (.2)
- Ease of learning the new system (.3)
- Key mapping, or function keys having the same use as in other applications used by the same user (.1)
- Availability of the system to the user (.1)
- System response time (.3)

A second requirement in setting up the Electre model is selecting a scale for use in the application of the model. For this example the following scale will be used:

Greatest Satisfaction Possible	100
Extremely Satisfied	90
Fairly Satisfied	70
Moderately Satisfied	50
Fairly Dissatisfied	30
Extremely Dissatisfied	10
Lowest Satisfaction Possible	0

With the criteria and scale established for the application of the model the scores from a user satisfaction survey can be put to use in determining a ranking of the various alternatives. Prior to ranking alternatives the concordance and discordance thresholds must be selected. Here the values of P=.6 and Q=.3 are used for the respective thresholds. For this example the scores for the different alternatives, given by criteria, are displayed in Table 6.

Table 6. Sample Criteria Score

Criteria	Alternative 1	2	3
Understandability	90	70	30
Ease of learning	70	70	50
Key mapping	70	50	10
Availability	30	50	50
Response time	50	30	50

b. *Ranking Alternatives*

From the example $C(1,2) = (.2 +.1 +.3)/1 = .6$ and $D(1,2) = 20/100 = .2$, therefor $C(1,2) = P$ and $D(1,2) < Q$ so that alternative one outranks alternative two. Likewise, $C(1,3) = P$ and $D(1,3) < Q$ so that alternative one also outranks alternative three. In the comparison of alternatives two and three, $C(2,3) = P$ and $D(2,3) < Q$ so that alternative two also outranks alternative three. The final ranking of alternatives is then: 1, 2, and 3. The concordance and discordance index figures for this example are given in Table 7.

Table 7. Concordance and Discordance Figures

(i,j)	*C(i,j)*	*D(i,j)*
(1,2)	.6	.2
(1,3)	.6	.2
(2,1)	.1	.2
(2,3)	.6	.2
(3,1)	.1	.6
(3,2)	.3	.4

E. SUMMARY

User satisfaction analysis is based on user satisfaction surveys or questionnaires as illustrated by Bailey and Pearson's questionnaire on computer user satisfaction. The results of such surveys are interpreted through the use of formulas or models such as Bailey and Pearson's formula, the Electre model, or MALV. Prior to the application of these formulas the responses to the surveys have to be quantified though the use of numerical scales such as the importance and satisfaction scales of the Bailey and Pearson tool. Measurement tools which may be applied objectively, may be subjective measures of user satisfaction if the data the tool is based on is obtained through surveys of user satisfaction.

1. Precautions of User Satisfaction Analysis Methods

Analysts employing measure of user satisfaction should be cautious for the results may be undesirable for the several reasons. First, the adjective pairs and the scales used with them have different meanings to the different respondents of the same questionnaire (Galletta and Lederer, 1989). Second, the overall score produced by some techniques through the summation of responses to specific functions of an information system is invalid (Galletta and Lederer,1989). The functions are assumed to be homogeneous when in fact they are heterogeneous which makes a score based on their summation illogical (Galletta and Lederer,1989). If the factors overlap, or are not independent of each other, then a tally of the various functions simply does not make sense. Overall scores are also arrived at without questioning the users' overall perception of the information system which reinforces a concern that measures of user satisfaction are unsound (Galletta and Lederer,1989). Analysts need to avoid methods that violate measurement theory by the mannor in which the methods call for parametric statistical analysis on ordinal measures such as adjective pairs used in surveys. Lastly, officials administering the survey can sway the resuits by influencing the setting or condition in which the survey is given (Galletta and Lederer,1989).

2. Benefits of User Satisfaction Analysis

Using the Electre model to rank alternatives is a legitimate use of ordinal measures. As such the results of the Electre model can augment the findings of other analysis methods in the analysis of the non-cost factors, particularly user acceptance. Thus there is a method that can be used for the analysis of user acceptance as required by GSA for the analysis of alternatives in the acquisition of federal ADP systems.

VI. DISCUSSION AND CONCLUSION

In the proceeding chapters different approaches to benefit analysis were discussed that could be used in the analysis of the different non-cost factors that are required by the GSA to be evaluated during an analysis of alternatives prior to the federal acquisition of an ADP system. The two approaches reviewed were benefit comparison and user satisfaction. Both of these strategies have their own advantages, disadvantages, and possible applications within the DoD and the federal government for the evaluation of proposed information systems.

A. BENEFIT COMPARISON

1. Advantages of Benefit Comparison

The benefit comparison methods reviewed were: additive weight, eigenvector, and multi-attribute utility models, and each have some capacity for sensitivity analysis. They also have the advantage that they are objective methods of benefit analysis as apposed to user satisfaction. As mentioned the multi-attribute utility model is normative as it is based upon different axioms.

2. Disadvantages of Benefit Comparison

A disadvantage of the benefit comparison methods is that additive weight and eigenvector models do not have the capacity to consider risk or uncertainty when utilized with the attributes given in Table 1. Yet even more critical is that these methods can not be used in all situations. As addressed, the multi-attribute utility model is incompatible with a situation where the attributes are interdependent. All of the benefit comparison methods also require that an investment of time and effort be made to defining the advantages to be gained from the various proposed system so that those desired advantages can be used as attributes in the analysis.

3. Feasible Applications of Benefit Comparison

Benefit comparison techniques are most applicable in situations where the users are willing and able to devote the time and expense of defining the desired benefits of a proposed information system. For a small application that can be developed in-house there may not exist the need for a detailed benefit analysis. Benefit comparison techniques may however, be quite suitable for the evaluation of large information systems dealing with administrative activities or logistics that are not excluded from the Brooks Act and where the GSA recommended non-cost factors must be evaluated in the analysis of alternatives for a federal acquisition of an ADP system. The GSA functional and risk factors can then be used as the attributes in the application of any one of the benefit comparison method discussed.

B. USER SATISFACTION

1. Advantages of User Satisfaction

The main advantage of the user satisfaction is that through this technique it is easy to collect data on the users' perceptions of an existing information system. This same concept can be applied to gaining information on prototypes of proposed information systems. The ease of data collection is in reference to the fact that it is easier to measure a respondent's answers to a questionnaire than finding and proving a cause and effect relationship between a system capability and any specific organizational benefit. The advantage of easy data collection, used in conjunction with such methods as the Electre model, enables an analyst to employ user satisfaction to rank order several competing alternatives, and to do all of this from a users point of view.

2. Disadvantages of User Satisfaction

A disadvantage of user satisfaction is that the technique has been used incorrectly, as in the Bailey and Pearson instrument. Analyst should be cautioned when using user satisfaction not to confuse ordinal measures, such as adjective pairs, as interval measures, such as time or distance. Analysts should also question methods that score alternatives through the summation of interdependent attributes.

Other disadvantages of the measures of user satisfaction include having the responses to the questionnaires affected by the manner in which the surveys were administered. Inaccurate responses may also be caused by what is seen to the respondent's as confusing wording used in the questionnaire. Another disadvantage centers around the evaluation of proposed system alternatives versus evaluating existing systems. Of the literature cited in Chapter V on user satisfaction all of the surveys used were intended for existing systems. While this technique may be selected by some to evaluate system effectiveness, the user satisfaction method of benefit analysis appears to be of little use in the analysis of proposed information systems unless the analysis is tailored so that it can be conducted on a prototype of the system.

3. Feasible Applications of User Satisfaction

One arena for the application of user satisfaction as a technique of evaluating proposed information systems is to survey test bed organizations working with prototypes of the different alternatives for new proposed system. These organizations could receive experience with the different prototypes and would be knowledgeable users who could make informed responses to surveys on the competing alternatives. Using measurements of user satisfaction in a test bed organization would be useful for systems that have a high degree of user interface, such as in decision support systems or avionic software. The members of these type of organizations can offer significant improvements to reduce ambiguity through their recommendations concerning: screens lay outs, system response messages, or on-line help. Due to the large number of units in the military that perform similar actions, this technique could be used to evaluate highly interactive systems, from the users perspective, prior to a large scale purchase. Again, avionic or some weapon system software is a good example where the economies of scale for the military could make this type of prototyping really pay off. This use of prototyping may help preclude the purchase of inappropriate or insufficient software.

C. CONNECTING BENEFITS TO ORGANIZATIONAL GOALS

Buss (Buss,1983) recommended taking into consideration how well an alternative is in line with the organizational objectives. This is a vital concern and should be addressed by analysts when conducting a benefit analysis. By initiating a benefit analysis with a review of organizational goals an analyst should be aware of the goals that recommendations should address and take into account. The organization's goals can also be used as a guide to narrow in on what system attributes need to be evaluated during the benefit analysis. In Seidmann and Arbel (Seidmann and Arbel,1984) a process was presented that hierarchically decomposed the problem of defining system attributes. First, the overall organizational objectives were reviewed to determine what type of systems are needed. In this example a business was examined and it was determined that it was in need of an accounting information system. Second, the organizational needs were studied in respect to the proposed system. This step looked at major functions of the planned system, such as accounts receivable, payroll, general ledger, and inventory control. Third, specific system operations were addressed that were required to support the major functions defined earlier. Here such operations were identified as file updating and report generation. Finally, the system attributes were defined that were required to support the specific system functions determined in the previous step. Some of the attributes identified in this step were: CPU capacity, main memory size, compatibility of software, and vendor support. (Seidmann and Arbel,1984)

D. DIFFERENT APPROACHES USED TOGETHER

There are advantages to using the different approaches to benefit analysis in concert with each other and capitalizing on the strong points of each. Where system capabilities could easily be measured in dollar values, present value analysis could be employed to take advantage of that method's widely understood methodology. Where system benefits are difficult to quantify in dollar term benefit comparison methods, such as additive weight, could be used to take advantage of their objective nature and capability for sensitivity analysis. The Electre model could be used to rank order the alternatives in the analysis of user acceptance of a prototype where not only are benefits difficult to quantify in dollar term, but where analysts need to be cautious with their use of ordinal measures in an analysis. By conducting an analysis that includes: present value analysis of cost factors, using the additive weight model to analyze non-cost factors, and using the Electre model to specifically analyze user acceptance, a more complete picture can be presented in the analysis of alternatives. This will allow for a more informed decision in the final selection of alternatives. Both the Eletre model and present value analysis could be applied toward this type combined analysis without modification. The additive weight model would only require slight changes from the example given previously.

E. ADDITIVE WEIGHT MODEL IN FEDERAL ACQUISITIONS

The functional and risk factor defined by the GSA would be used in the application of the additive weight model for the analysis of non-cost factors. The functional factor of user-acceptance would be excluded from analysis under the additive weight model and reserved for the Electre model so as to preclude the wrongful use of ordinal measures. The break down of non-cost factors in an additive weight analysis would resemble Table 8. Starting with these defined attributes and categories an analyst would then have to ask the decision maker to assign weights between 0 and 1 to each of the attributes and categories. The sum of the weights assigned to the two categories would have to equal 1 and the sum of the weights assigned to the attribute of each category would also have to equal 1. Sample weights are given in Table 8.

Table 8 . Sample Weights for Non-Cost Categories and Attributes

Category		Attribute		Weights	
Z1	Functional Factors			.60	
		X1	Obsolescence		.08
		X2	Availability		.08
		X3	Reliability		.11
		X4	Maintainability		.16
		X5	Expandability		.11
		X6	Flexibility		.10
		X7	Security		.16
		X8	Privacy		.07
		X9	Personnel Impacts		.06
		X10	Accountability		.07
Z2	Risk Factors			.40	
		X11	Financial		.20
		X12	Technical		.50
		X13	Schedule		.30

1. Sample Scores for the Additive Weight Model

The next step in applying the additive weight model is to score the alternatives one attribute at a time. A range of 0 to 1 is used for the individual attribute scores. If the first 13 attribute scores given in Table 2 are used as an example, in combination with the category and attribute weights stated in Table 8, then the total weighted score for alternative A would be 0.9272 as expressed in Table 9.

Table 9. Calculation of the Weighted Score for Alternative A

Attribute	Category Weight	x	Attribute Weight	x	Attribute Score	=	Weighted Score	
X1	0.6		.08		0.8		.0384	
X2	0.6		.08		0.8		.0384	
X3	0.6		.11		0.8		.0528	
X4	0.6		.16		1.0		.0960	
X5	0.6		.11		1.0		.0660	
X6	0.6		.10		0.8		.0480	
X7	0.6		.16		1.0		.0960	
X8	0.6		.07		0.9		.0378	
X9	0.6		.06		1.0		.0360	
X10	0.6		.07		0.9		.0378	
								.5472
X11	0.4		0.2		0.9		.0720	
X12	0.4		0.5		1.0		.2000	
X13	0.4		0.3		0.9		.1080	
								.3800
Total Weighted Score								.9272

2. **Advantage of this Application**

The additive weight's recognized weakness, that of not taking into account risk or uncertainty, is counteracted in this application of the model. The weakness is cancel because the three different risk factors; financial, technical, and schedule, are specifically addressed as attributes when using the GSA recommended non-cost factors. This application of the additive weight model has the advantages of being: conceptually simplistic, calculable on any standard spreadsheet application, and in accordance with the guidelines set forth by the GSA for federal ADP acquisitions. The results of this application of the additive weight model combined together with the results of present value analysis and user acceptance analysis, through the use of the Electre model, offer a more complete evaluation of alternatives than any of the methods could offer when used alone.

F. CONCLUSION

One method of benefit analysis is not suitable for all situations where proposed information systems are in need of evaluation. Nor is one method alone appropriate for the evaluation of all of the factors that must be taking into account during an analysis of alternative systems. Each analysis method has its own advantages and disadvantages. Gains can be made by combining methods to take advantage of the respective potentials of each. Using different methods together would also provide a more complete analysis as some methods used alone are inappropriate for certain applications, such attempting to use present value analysis in an evaluation that includes the measurement of user acceptance. System analysts conducting analysis of alternatives for a federal acquisition of information systems will have to be knowledgeable of the different benefit analysis methods. To obtain the required approval for development of information systems, and to abide by the GSA requirements for analysis of alternatives, system analysis will also have to know how to implement the right mix of benefit analysis methods so to fully evaluate both cost and non-cost factors.

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APPENDIX A: EIGENVECTOR MATRICES

Figure 2. Pairwise Comparison of Attributes by Categories

Hardware

	X1	X2	X3	X4	X5
X1	1	1	5/2	1	3/2
X2	1	1	5/2	1	3/2
X3	2/5	2/5	1	1/3	1/2
X4	1	1	3	1	3/2
X5	2/3	2/3	2	2/3	1

Software

	X6	X7	X8
X6	1	2	1
X7	1/2	1	1/2
X8	1	2	1

System Support

	X9	X10	X11	X12	X13	X14
X9	1	3/2	5	3	3	4
X10	2/3	1	3	2	2	3
X11	1/5	1/3	1	1/3	1/3	1
X12	1/3	1/2	3	1	1	2
X13	1/3	1/2	3	1	1	2
X14	1/4	1/3	1	1/2	1/2	1

Figure 3. Pairwise Comparison of Categories

	Z1	Z2	Z3
Z1	1	1	1
Z2	1	1	1
Z3	1	1	1

Figure 4. Comparison of Alternatives by Attributes

X1	A	B	C	D
A	1	1	1	2/3
B	1	1	1	2/3
C	1	1	1	2/3
D	3/2	3/2	3/2	1

X2	A	B	C	D
A	1	1	1	2
B	1	1	1	2
C	1	1	1	2
D	1/2	1/2	1/2	1

X3	A	B	C	D
A	1	1	6/5	1/2
B	1	1	6/5	1/2
C	5/6	5/6	1	2/3
D	2	2	3/2	1

X4	A	B	C	D
A	1	1	2	3/2
B	1	1	2	3/2
C	1/2	1/2	1	3/4
D	2/3	2/3	4/3	1

X5	A	B	C	D
A	1	1	1	2
B	1	1	1	2
C	1	1	1	2
D	1/2	1/2	1/2	1

X6	A	B	C	D
A	1	1	1	3
B	1	1	1	3
C	1	1	1	3
D	1/3	1/3	1/3	1

X7	A	B	C	D
A	1	1	1	1
B	1	1	1	1
C	1	1	1	1
D	1	1	1	1

X8	A	B	C	D
A	1	1	1	3/2
B	1	1	1	3/2
C	1	1	1	3/2
D	2/3	2/3	2/3	1

X9	A	B	C	D
A	1	3/2	3	3/2
B	2/3	1	2	1
C	1/3	1/2	1	1/2
D	2/3	1	2	1

X10	A	B	C	D
A	1	1	2	3/2
B	1	1	2	1
C	1/2	1/2	1	1/2
D	2/3	1	2	1

X11	A	B	C	D
A	1	3/2	1/2	3
B	2/3	1	3	2
C	2	1/3	1	3
D	1/3	1/2	1/3	1

X12	A	B	C	D
A	1	1	3	2
B	1	1	3	2
C	1/3	1/3	1	1/2
D	1/2	1/2	2	1

X13	A	B	C	D
A	1	1	3	3/2
B	1	1	3	3/2
C	1/3	1/3	1	1/2
D	2/3	2/3	2	1

X14	A	B	C	D
A	1	1	2	3/2
B	1	1	2	3/2
C	1/2	1/2	1	2/3
D	2/3	2/3	3/2	1

APPENDIX B: COMPUTER USER SATISFACTION QUESTIONNAIRE

Use the following scale in response to each pair of adjectives:

extremely	quite	slightly	equally	slightly	quite	extremely

1. **Top management involvement:** The positive or negative degree of interest, enthusiasm, support, or participation of any management level above the user's own level toward computer-based information systems or services or toward the computer staff which supports them.

strong								weak
consistent								inconsistent
good								bad
significant								insignificant
satisfactory								unsatisfactory
important								unimportant

2. **Organizational competition with the EDP unit:** The contention between the respondent's organizational unit and the EDP unit when vying for organizational resources or for responsibility for success or failure of computer-based information systems or services of interest to both parties.

productive								destructive
rational								emotional
low								high
harmonious								dissonant
satisfactory								unsatisfactory
important								unimportant

3. **Priorities determination:** Policies and procedures which establish precedence for the allocation of EDP resources and services between different organizational units and their requests.

fair								unfair
consistent								inconsistent
just								unjust
precise								vague
satisfactory								unsatisfactory
important								unimportant

4. **Charge-back method of payment for services:** The schedule of charges and the procedures for assessing users on a pro rata basis for the EDP resources and services that they utilize.

just								unjust
reasonable								unreasonable
consistent								inconsistent
known								unknown
satisfactory								unsatisfactory
important								unimportant

5. **Relationship with the EDP staff:** The manner and methods of interaction, conduct, and association between the user and the EDP staff.

harmonious								dissonant
good								bad
cooperative								uncooperative
candid								deceitful
satisfactory								unsatisfactory
important								unimportant

6. **Communication with the EDP staff:** The manner and methods of information exchange between the user and the EDP staff.

harmonious								dissonant
productive								destructive
precise								vague
meaningful								meaningless
satisfactory								unsatisfactory
important								unimportant

7. **Technical competence of the EDP staff:** The computer technology skills and expertise exhibited by the EDP staff.

current								obsolete
sufficient								insufficient
superior								inferior
high								low
satisfactory								unsatisfactory
important								unimportant

8. **Attitude of the EDP staff:** The willingness and commitment of the EDP staff to subjugate external, professional goals in favor of organizationally directed goals and tasks.

user-oriented								self-centered
cooperative								belligerent
courteous								discourteous
positive								negative
satisfactory								unsatisfactory
important								unimportant

9. **Schedule of products and services:** The EDP center timetable for production of information system outputs and for provision of computer-based services.

good								bad
regular								irregular
reasonable								unreasonable
acceptable								unacceptable
satisfactory								unsatisfactory
important								unimportant

10. **Time required for new development:** The elapsed time between the user's request for new applications and the design, development, and/or implementation of the application systems by the EDP staff.

short								long
dependable								undependable
reasonable								unreasonable
acceptable								unacceptable
satisfactory								unsatisfactory
important								unimportant

11. **Processing of change requests:** The manner, method, and required time with which the EDP staff responds to user requests for changes in existing computer-based information systems or services.

fast								slow
timely								untimely
simple								complex
flexible								rigid
satisfactory								unsatisfactory
important								unimportant

12. **Vendor support:** The type and quality of the service rendered by a vendor, either directly or indirectly, to the user to maintain the hardware or software required by that organizational status.

skilled								bungling
sufficient								insufficient
eager								indifferent
consistent								inconsistent
satisfactory								unsatisfactory
important								unimportant

13. **Response/turnaround time:** The elapsed time between a user-initiated request for service or action and a reply to that request. Response time generally refers to the elapsed time for terminal type request or entry. Turnaround time generally refers to the elapsed time for execution of a program submitted or requested by a user and the return of the output to that user.

fast								slow
good								bad
consistent								inconsistent
reasonable								unreasonable
satisfactory								unsatisfactory
important								unimportant

14. **Means of input/output with EDP center:** The method and medium by which a user inputs data to and receives output from the EDP center.

convenient								inconvenient
clear								hazy
efficient								inefficient
organized								disorganized
satisfactory								unsatisfactory
important								unimportant

15. **Convenience of access:** The ease of difficulty with which the user may act to utilize the capability of the computer system.

convenient								inconvenient
good								bad
easy								difficult
efficient								inefficient
satisfactory								unsatisfactory
important								unimportant

16. **Accuracy:** The correctness of the output information.

accurate								inaccurate
high								low
consistent								inconsistent
sufficient								insufficient
satisfactory								unsatisfactory
important								unimportant

17. **Timeliness:** The availability of the output information at a time suitable for its use.

timely								untimely
reasonable								unreasonable
consistent								inconsistent
punctual								tardy
satisfactory								unsatisfactory
important								unimportant

18. **Precision:** The variability of the output information from that which it purports to measure.

sufficient								insufficient
consistent								inconsistent
high								low
definite								uncertain
satisfactory								unsatisfactory
important								unimportant

19. **Reliability:** The consistency and dependability of the output information.

consistent								inconsistent
high								low
superior								inferior
sufficient								insufficient
satisfactory								unsatisfactory
important								unimportant

20. **Currency:** The age of the output information.

good								bad
timely								untimely
adequate								inadequate
reasonable								unreasonable
satisfactory								unsatisfactory
important								unimportant

21. **Completeness:** The comprehensiveness of the output information content.

complete								incomplete
consistent								inconsistent
sufficient								insufficient
adequate								inadequate
satisfactory								unsatisfactory
important								unimportant

22. **Format of output:** The material design of the layout and display of the output contents.

good								bad
simple								complex
readable								unreadable
useful								useless
satisfactory								unsatisfactory
important								unimportant

23. **Language:** The set of vocabulary, syntax, and grammatical rules used to interact with the computer systems.

simple								complex
powerful								weak
easy								difficult
easy-to-use								hard-to-use
satisfactory								unsatisfactory
important								unimportant

24. **Volume of output:** The amount of information conveyed to a user from computer-based systems. This is expressed not only by the number of reports or outputs but also by the voluminousness of the output contents.

concise								redundant
sufficient								insufficient
necessary								unnecessary
reasonable								unreasonable
satisfactory								unsatisfactory
important								unimportant

25. **Relevancy:** The degree of congruence between what the user wants or requires and what is provided by the information products services.

useful								useless
relevant								irrelevant
clear								hazy
good								bad
satisfactory								unsatisfactory
important								unimportant

26. **Error recovery:** The methods and policies governing correction and return of system outputs that are incorrect.

fast								slow
superior								inferior
complete								incomplete
simple								complex
satisfactory								unsatisfactory
important								unimportant

27. **Security of data:** The safeguarding of data from misappropriation or unauthorized alteration or loss.

secure								insecure
good								bad
definite								uncertain
complete								incomplete
satisfactory								unsatisfactory
important								unimportant

28. **Documentation:** The recorded description of an information system. This includes formal instructions for the utilization of the system.

clear								hazy
available								unavailable
complete								incomplete
current								obsolete
satisfactory								unsatisfactory
important								unimportant

29. **Expectations:** The set of attributes or features of the computer-based information products or services that a user considers reasonable and due from the computer-based information support rendered within the organization.

pleased								displeased
high								low
definite								uncertain
optimistic								pessimistic
satisfactory								unsatisfactory
important								unimportant

30. **Understanding of systems:** The degree of comprehension that a user possesses about the computer-based information system or services that are provided.

high								low
sufficient								insufficient
complete								incomplete
easy								hard
satisfactory								unsatisfactory
important								unimportant

31. **Perceived utility:** The user's judgement about the relative balance between the cost and the considered usefulness of the computer-based information products or services that are provided. The costs include any costs related to providing the resource, including money, time, manpower, and opportunity. The usefulness includes any benefits that the user believes to be derived from the support.

high								low
positive								negative
sufficient								insufficient
useful								useless
satisfactory								unsatisfactory
important								unimportant

32. **Confidence in the system:** The user's feelings of assurance or certainty about the systems provided.

high								low
strong								weak
definite								uncertain
good								bad
satisfactory								unsatisfactory
important								unimportant

33. **Feeling of participation:** The degree of involvement and commitment which the user shares with the EDP staff and others toward the functioning of the computer-based information systems and services.

positive							negative
encouraged							repelled
sufficient							insufficient
involved							uninvolved
satisfactory							unsatisfactory
important							unimportant

34. **Feeling of control:** The user's awareness of the personal power or lack of power to regulate, direct or dominate the development, alteration, and/or execution of the computer-based information systems or services which serve the user's perceived function.

high							low
sufficient							insufficient
precise							vague
strong							weak
satisfactory							unsatisfactory
important							unimportant

35. **Degree of training:** The amount of specialized instruction and practice that is afforded to the user to increase the user's proficiency in utilizing the computer capability that is unavailable.

complete							incomplete
sufficient							insufficient
high							low
superior							inferior
satisfactory							unsatisfactory
important							unimportant

36. **Job effects:** The changes in job freedom and job performance that are ascertained by the user as resulting from modifications induced by the computer-based information system and services.

liberating							inhibiting
significant							insignificant
good							bad
valuable							worthless
satisfactory							unsatisfactory
important							unimportant

37. **Organizational position of the EDP function:** The hierarchical relationship of the EDP function to the overall organizational structure.

appropriate								inappropriate
strong								weak
clear								hazy
progressive								regressive
satisfactory								unsatisfactory
important								unimportant

38. **Flexibility of systems:** The capacity of the information system to change or to adjust in response to new conditions, demands, or circumstances.

flexible								rigid
versatile								limited
sufficient								insufficient
high								low
satisfactory								unsatisfactory
important								unimportant

39. **Integration of systems:** The ability of systems to communicate/transmit data between systems servicing different functional areas.

complete								incomplete
sufficient								insufficient
successful								unsuccessful
good								bad
satisfactory								unsatisfactory
important								unimportant

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