Cost-Benefit Analysis in Information Systems Development and Operation*

JOHN LESLIE KING AND EDWARD L. SCHREMS

The URBIS Group, Public Policy Research Organization, University of California, Irvine, California 92717

Cost-benefit analysis of computer-based information systems is a major concern of managers in public and private organizations using computers. This paper introduces and reviews basic elements of cost-benefit analysis as applied to computerized information systems, and provides discussion of the major problems to be avoided.

Keywords and Phrases: cost-benefit analysis, management of computing, evaluating projects

CR Categories: 1.3, 2.40, 2.41, 2.49, 3.52, 3.53

INTRODUCTION

Major decisions concerning computer-based information systems are always made in light of some specific criteria, whether explicit or not. These criteria may range from the subjective preferences of top decision-makers to more rigorous criteria of decision analysis. Due to the expenses and difficulties associated with establishing or altering any large computer-based information system, most organizations prefer to conduct an "objective" cost-benefit analysis before coming to major decisions regarding their information systems. Presumably, the results of such analysis will guide decision-makers to more profitable decisions about their information systems. Unfortunately, conducting a rigorous cost-benefit analysis for information systems is not an easy task—a fact that results in reluctance to seriously undertake such analyses or, even worse, in poor analyses that are conveniently regarded as good.

This paper discusses cost-benefit analysis as it is used in evaluating information system decisions in public and private organizations. It consists of a description of the nature and use of cost-benefit analysis, the major techniques of analysis, and the major problems with cost-benefit analysis as it is usually performed for information systems. The paper is primarily intended as an introduction to cost-benefit analysis for managers, data processing professionals, and users who need a general understanding of the subject. It assumes that most such readers have little background in financial analysis, and

* This paper is a product of the URBIS Project, which studies the uses and effects of computers in US local governments. It is conducted by the Public Policy Research Organization at the University of California, Irvine, under Grant No. APR74-12158 A01 & A02 from the RANN Division of the National Science Foundation. The views herein are solely those of the authors, and not of the National Science Foundation.

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therefore will benefit from a discussion of the basic issues. Those who already have a strong background in cost-benefit analysis in information systems settings may find that this paper does not go beyond their present knowledge.

The paper deals extensively with five issues: 1) the definition of and uses for cost-benefit analysis; 2) the various perspectives taken in analysis; 3) the procedures and techniques commonly used to perform analyses; 4) the methods for basic financial analysis; and 5) the criteria for decision-making based on analysis. There is also discussion of special problems to be considered when performing cost-benefit analyses in information systems, such as the peculiarities of analysis in the public sector, the difficulties of accurately estimating benefits from proposed systems in multiuser environments, and the perplexities of intangible benefits. The paper does not deal with the related subjects of financing computer systems and allocation of computer resources through pricing for services, although these subjects should be kept in mind as important adjuncts. Where appropriate, footnotes and references lead the reader to sources that extend the discussion.

1. OVERVIEW

Cost-benefit analysis, in simple terms, seeks to estimate and compare the costs and benefits of an undertaking. It can be used in any or all of three ways:

1) As a planning tool for assistance in choosing among alternatives and allocating scarce resources among competing demands;
2) As an auditing tool for performing *post hoc* evaluations or follow-up studies of an existing project;
3) As a way to develop "quantitative" support in order to politically influence a decision.

While only the first two are economically justified uses for performing a cost-benefit analysis, the third use may be the most common.[1] Because of the greater rigor required, it is more difficult to perform effective cost-benefit analyses for decision and investment than it is to perform them for politics and advocacy purposes. This is true with information systems in both business and government.

We must first make a distinction between "cost-benefit" and "cost effectiveness." These two terms have often been confused; there has been no clear explanation of their differences (see [23], Chapter 5.2; [5]). The problem seems to arise from the difficulties of applying the ideals of welfare economics to the practicalities of life. Some authors, such as McRae, reserve the term cost-benefit analysis for the theoretical or ideal, and the term cost-effectiveness analysis for the practical [14]. Others distinguish the terms on the basis of ability to assign dollar values to benefits; cost-benefit analysis applies where benefits are quantifiable and cost effectiveness otherwise (see [20], pp. 18–19]. Because we believe that the two terms are

[1] Given the difficulty of complex cost-benefit analyses, the relatively small number of such analyses, and the fact that these analyses are most frequently done by those with the greatest interest in seeing a proposed project approved (or an existing one continued), the published results of most analyses show bias. A helpful overview of cost-benefit analysis can be found in [21].

nearly synonymous in common use, we will use "cost-benefit analysis" for both.

The "cost" of an object, project, or "benefit" is measured by the resources required to procure it. Costs can usually be expressed in dollars: the purchase price of equipment, wages for work, rent for space, and so on. A benefit is the consequence of an action that protects, aids, improves, or promotes the well-being of an individual or organization. Benefits take the form of cost savings, cost avoidance, improved operational performance, and "intangibles."

The most common examples of benefits in business computing are in reduction or avoidance of costs, lower error rates, more flexible production or operations, or increased speed for performing certain repetitive tasks like calculations and printing of bills. A less obvious but very important benefit in some industries is improved utilization of assets. It is, for example, of great interest to an airline to enter reservations and cancellations rapidly, to facilitate maximum utilization of available airplane capacity. Similar improvements in utilization of assets come from the ability to reduce inventories in manufacturing firms, thereby releasing capital for more profitable investment. These two results—reduced or avoided costs, and better utilization of assets—are the most commonly claimed benefits of computing in business.

Another commonly claimed benefit from computing is "improved information." It comes from the computer's ability to increase the volume of information available, to speed up the retrieval of information, to improve the accuracy of the information, and to combine old information in new ways. This helps most in planning and decision-making by reducing mistakes and increasing the reliability of estimates. Although improved information is often cited as a benefit, it is a more problematic one in analysis than the others, because it is less tangible. We will deal with some of the problems of intangible benefits later in the paper.

Variations of these benefits appear in government operations: improvements in record-keeping, financial control, list processing, billing, payments, and record searching. These benefits are apparent in such applications as public-assistance record-keeping and payments, utility and tax billing, maintenance of school records, budgetary reporting and monitoring, and automated recording of wants and warrants in law enforcement.

There are four issues of perspective in any cost-benefit analysis: the statement of purpose of the analysis, the time period considered by the analysis, the scope of the analysis, and the criteria of the analysis. The statement of purpose of the analysis specifies the intended use of the results—e.g., the analysis is to be used to provide background information for decisions, to be the basis of a decision, or to "influence" a decision toward some predetermined resolution.

The time period of the analysis can precede, overlap, or follow a project. Analysis can be conducted prior to a project to decide among alternative ways to do the project (or whether to do it at all); it can be conducted during the project to see if goals are being met; and it can be conducted afterward to evaluate the final outcome of the project and decide what to do next.

The scope of analysis is the breadth and depth of issues that the analysis will cover. It includes the range of alternatives and the level of detail within alternatives with which the analysis will deal. An analysis may deal broadly with major alternatives for performing a task, or may be confined narrowly to evaluating different ways of performing specific tasks within a larger project.

The criterion of the analysis is the standard, rule, or test on which a judgment or decision will be based. In the most general terms, a criterion is used as an analytical scale for weighing costs and benefits consistently over time. A more detailed discussion of cost-benefit criteria appears later in this paper.

2. THE TECHNIQUE OF COST-BENEFIT ANALYSIS

There are five principal steps in the technique of cost-benefit analysis: selecting an analyst, identifying alternatives, identifying and measuring costs and benefits, comparing costs and benefits, and analyzing all the alternatives. Each of these will be dealt with briefly.

Selecting the Analyst

There are usually three choices. The first is to do the analysis in-house with regular staff members. However, this may exceed the resources of smaller organizations. The second choice is to hire an outside consultant. Reputable consultants have the skills and experience required to perform a correct analysis, but they can be expensive, their work of variable quality, and their activities disruptive to normal operations. Moreover, there can be an incentive for a consultant to be "skillfully irresponsible" in telling a client only what he believes the client wishes to hear. The third choice is help from another organization. Small business can get assistance from other small businesses, local trade organizations, or the Small Business Administration. A subsidiary company may find help from its parent or from another subsidiary. Small governments may help one another. Obviously, the specific circumstances will determine which course is most satisfactory.

Identifying and Selecting the Alternatives

This step consists of specifying the objectives (e.g., improved customer billing, better inventory control) and determining how to attain them. This step requires discarding all alternatives unacceptable for political or other reasons, and determining acceptable levels of performance for the remaining alternatives. Sometimes this step is not necessary because all the acceptable alternatives have already been identified, or because the choice is limited by constraints to a few specific alternatives. It is helpful to remember that it is frequently impossible to study every conceivable alternative. While this implies a risk of missing the best possible solution, in most cases the alternatives are among a small number of understood options, and the risk is slight.

At this step it is important to have a clear understanding of the scope of the analysis. If the purpose of the analysis is to determine whether or not to undertake a large project, the acceptable alternatives may be quite different in character from the alternatives when the choice is among different ways of doing a minor task. In all cases, it must also be remembered that analysis can only select the best choice among given alternatives; it cannot reveal new alternatives.

Identifying and Measuring Benefits and Costs

Identifying the benefits and the costs is difficult. It is important to list the probable effects of the project, both positive and negative, and to specify all reasonable costs of the project.

Two sub-steps are involved in considering benefits: identifying the beneficial effects, and assigning a value to each. Table I illustrates possible benefits of changes in a computing system. An alternative method of classifying benefits is indicated by the parenthetical designations next to each entry. (See Leyland [10], Morris [17], and McRae [14].) The special problems presented by "intangible" benefits are discussed further on.

To determine costs, it is necessary to measure outside procurement as well as in-house expenditures. In-house expenditures may be difficult to calculate since market prices may not be available, and the indirect costs of using in-house personnel may be hard to establish. Nevertheless all costs must be accounted for. Table II is one possible breakdown of the costs to be considered. Leyland [10] and Morstein [18] provide further information. Useful examples of cost-estimation forms are provided by Rubin [22] and Benjamin [1].

Comparing Alternatives

This step consists of three tasks: converting the measures of costs and benefits to common units; establishing a discount rate for the undertaking; and calculating the present value of the alternatives.

TABLE I. POSSIBLE INFORMATION SYSTEM BENEFITS*

Benefits from contributions of calculating and printing tasks
Reduction in per-unit costs of calculating and printing (CR)
Improved accuracy in calculating tasks (ER)
Ability to quickly change variables and values in calculation programs (IF)
Greatly increased speed in calculating and printing (IS)
Benefits from contributions to record-keeping tasks
Ability to "automatically" collect and store data for records (CR, IS, ER)
More complete and systematic keeping of records (CR, ER)
Increased capacity for recordkeeping in terms of space and cost (CR)
Standardization of recordkeeping (CR, IS)
Increase in amount of data that can be stored per record (CR, IS)
Improved security in records storage (ER, CR, MC)
Improved portability of records (IF, CR, IS)
Benefits from contributions to record searching tasks
Faster retrieval of records (IS)
Improved ability to access records from large databases (IF)
Improved ability to change records in databases (IF, CR)
Ability to link sites that need search capability through telecommunications (IF, IS)
Improved ability to create records of records accessed and by whom (ER, MC)
Ability to audit and analyze record searching activity (MC, ER)
Benefits from contributions to system restructuring capability
Ability to simultaneously change entire classes of records (IS, IF, CR)
Ability to move large files of data about (IS, IF)
Ability to create new files by merging aspects of other files (IS, IF)
Benefits from contributions of analysis and simulation capability
Ability to perform complex, simultaneous calculations quickly (IS, IF, ER)
Ability to create simulations of complex phenomena in order to answer "what if?" questions (MC, IF)
Ability to aggregate large amounts of data in various ways useful for planning and decision making (MC, IF)
Benefits from contributions to process and resource control
Reduction of need for manpower in process and resource control (CR)
Improved ability to "fine tune" processes such as assembly lines (CR, MC, IS, ER)
Improved ability to maintain continuous monitoring of processes and available resources (MC, ER, IF)

* CR = Cost reduction or avoidance; ER = Error reduction; IF = Increased flexibility; IS = Increased speed of activity; MC = Improvement in management planning or control The classification of tasks is adapted from [9].

Converting the measures to common units usually means expressing all the costs in dollars. (While dollars are not the only units that can be used, they are a convenient, easily understood measure.) Expressing costs and benefits in dollars is simplest, when a competitive market value for the output exists or when it is possible to assess a value by finding the maximum price users are willing to pay. When the market does not determine costs, surrogate values must be found. Great care must be used in evaluating surrogate costs. For example, consider a computer system which dispatches fire companies. The purpose of this system is to reduce response time, thereby reducing fire losses. The difference between losses before and after the improvement may seem a reasonable surrogate value of the added protection. However, these losses are usually passed outside the community through fire insurance. Thus, a better measure of the value of improved fire protection under the automated dispatching system is the reduction in total fire insurance premiums paid by those in the community.

Sometimes the economy will provide a "pecuniary" benefit that approximates the value of the system benefit. An example is a computerized traffic-signal control system in a city. The objective of the system is to smooth traffic flows downtown. By facilitating access to merchants downtown, this system may make commercial real estate there more valuable. Because it was not among the objectives of the traffic computer to increase the value of commercial real estate, such an increase cannot be counted in the benefit–cost equations. However, such an increase in-

TABLE II. POSSIBLE INFORMATION SYSTEM COSTS

Procurement costs
Consulting costs
Actual equipment purchase or lease costs
Equipment installation costs
Costs for modifying the equipment site (air conditioning, security, etc.)
Cost of capital
Cost of management and staff dealing with procurement
Start-up costs
Cost of operating system software
Cost of communications equipment installation (telephone lines, data lines, etc.)
Cost of start-up personnel
Cost of personnel searches and hiring activities
Cost of disruption to the rest of the organization
Cost of management required to direct start-up activity
Project-related costs
Cost of applications software purchased
Cost of software modifications to fit local systems
Cost of personnel, overhead, etc., from in-house application development
Cost for interacting with users during development
Cost for training user personnel in application use
Cost of data collection and installing data collection procedures
Cost of preparing documentation
Cost of development management
Ongoing costs
System maintenance costs (hardware, software, and facilities)
Rental costs (electricity, telephones, etc.)
Depreciation costs on hardware
Cost of staff involved in information systems management, operation, and planning activities

directly indicates the value of improved traffic flow. Such surrogate and pecuniary benefits are more common in public-sector analyses than in the private sector.

Establishing a discount rate means determining the "time value" of the money invested in the project.[2] The discount rate in businesses is often already established by top management based on cost of capital for the business; that is, the interest costs and the return on investment to the equity owners. Because the cost of capital depends on the conditions and risk of the individual business, slightly different rates may be appropriate from business to business. Nevertheless, the cost of capital in business is always determined by the market. Business discount rates are discussed in texts on managerial finance (e.g., [27], Chs. 7 and 12).

There are three general ways that governments can establish a discount rate: they can use a market rate, they can use a normal corporate rate of return, or they can use a "social discount rate" [2, 16]. The market rate is the prevailing rate on government or corporate bonds.[3] The corporate rate, which runs about 8%, is useful because it approximates the cost of drawing funds away from business investment. The social discount rate is less definite,

[2] The time value of money is based on the concept that money today is worth more than money tomorrow—because money today can be invested, becoming worth more tomorrow. If the only profitable investment were a saving account at 5% interest a year, we would say that the discount rate on money to be had one year from now is 5% Thus the "discounted" (or present) value of $100 paid a year from now would be approximately $95.24. However, rates of return differ due to risk and other factors, so discount rates vary as well.

[3] A government may use as an indicator the rate on US government bonds, which approximates a riskless rate of return Some governments use the rate on municipal bonds as an indicator for discount rates. Neither strategy is recommended. Few governments within the United States are as "riskfree" for investment as the federal government; the federal standard should be considered a minimum. This rules out the interest rate on municipal bonds, which is low because of income tax preferences. The prevailing rates on corporate bonds are not good indicators because corporate rates vary considerably according to risk. *See* [23], pp. 13-15, and [16], pp. 112-140, regarding discount rates in the public sector.

being determined from hypotheses about social preferences for investment.[4] We believe that most governments will do well to follow the federal government's lead in establishing a discount rate based on a mixture of market indicators and the "public value" of social investment [23, 5, 14]. In early 1978, the federal rate was approximately 8%.

If there is great concern about the choice of an appropriate discount rate, it may be wise to use a sensitivity analysis to evaluate the effect of the discount rate. By choosing a range of rates, say 6%, 10%, and 15%, and performing the analysis using each, it will be more clear just how important the discount rate is for the final decision. If the decision is only minimally sensitive to the rate, there is a wide margin for error in setting the rate [15].

Discount rates are applied to decisions through a "present-value" calculation. Present value compares the long-range payoffs of alternatives by showing net time-adjusted benefits over time-adjusted costs. The present-value equation is:

$$PV = \sum_{t=0}^{n} \frac{a_t}{(1+d)^t}$$

where d is the discount rate, n is the number of time periods until the benefit is realized, and a_t is the future benefit or cost value in the tth period.

The equation for calculating the present value of a particular investment is:

$$PV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1 + d)^t}$$

where d is the discount rate, n is the life of the project in years, B_t is the value of benefits in period t, and C_t is the value of costs in period t.

[4] The social discount rate is favored by those who believe that individuals act differently when in groups Individuals, so the argument goes, undervalue public investment because it is open, and because benefits from public projects may not be realized for a long time. This theory is controversial, and its application is difficult. Even if social preferences differ from private preferences, the theory does not tell what the rate should be. *See* [15], Chapters 6 and 7, and [16], p. 126.

TABLE III Data for a Present-value Calculation when the Discount Rate is 8%

t	B_t	C_t	$(1+d)^t$
0	0	15,000	1 0000
1	1,000	500	1.0800
2	10,000	500	1.1664
3	12,000	500	1.2597

To illustrate this calculation, we suppose that the discount rate is 8% for a three-year project costing $15,000 to start and $500 per year to maintain. It is expected that this project will yield $1,000 in benefits the first year, $10,000 in benefits the second year, and $12,000 in benefits the third year. These data can be arranged as shown in Table III. Applying the present-value calculation, we find

$$-(15000/1) + 500/1.08 + 9500/1.1664 + 11500/1.2597 = \$2736.84$$

as the present value of the project.

This simple example omits several critical aspects of present-value calculations in practice. First, this analysis assumes that all costs and all benefits occur at the beginnings of their time periods. In practice, though, benefits and costs occur unevenly; aggregating them by time period is an approximation, which may cause skepticism about the analysis. Second, the figures shown for costs and benefits do not explicitly account for inflation. Normally, anticipated inflation can be included in the discount rate; however, this assumes that inflation affects all benefits and costs evenly. If inflation affects costs and benefits differently, the analysis can be inaccurate. In such cases inflation must be accounted for separately in the benefit and cost columns, and the discount rate must exclude inflation. Finally, the analysis terminates here after the third year; in practice, costs continue throughout the useful life of the system, and benefits may propagate indefinitely through future systems.

Performing the Analysis Itself

This step consists of selecting a criterion of comparison and applying it to the present values for the various alternatives. There are two important considerations;

1) The outcomes from alternative solutions should be "standardized" to enable a fair comparison. A common mistake is to compare the price per unit of two alternative solutions at different output levels. For example, one may notice that the per-unit cost of producing bills by hand quarterly exceeds the unit cost of producing bills monthly with a computer, and thus conclude that a computer is preferable. But this conclusion has not considered whether monthly billing by hand may be less costly than monthly billing by computer, or whether quarterly billing by computer may be more costly than monthly billing by hand. Prices must be compared at equivalent output levels.
2) This analysis requires that alternatives be compared in the same time period. To compare projects of unequal lives using present-value analysis, the time period should be that of the shortest project. A value can be assigned to the remainder of each longer project by considering it to be sold at its cash value. This residual cash value represents the added value of the longer useful life. There are other, more controversial ways of dealing with this problem; setting the "time horizons" (lives) of the projects equal is the simplest. (See [27], Ch. 12.)

Five criteria that may be used to compare alternatives when performing cost-benefit analyses are:

A) Maximize benefits for given costs;
B) Minimize costs of a given level of benefits;
C) Maximize the ratio of benefits over costs;
D) Maximize the net benefits (present value of benefits minus present value of costs);
E) Maximize the internal rate of return on the investment.

Notice that of a criterion of "maximize benefits for minimum costs" does not appear. It is meaningless: the best way to minimize costs is to spend nothing, whereas the best way to maximize benefits may require an enormous amount of money.

For most applications, the most sound and useful criterion is D—maximize the net benefit.[5] The other criteria suffer from various problems. Criteria A and B do not reflect incremental differences in costs or benefits that might have a significant effect on the outcome. For example, the assumption of fixed costs does not consider whether a substantially greater benefit may result from a small increase in cost. Criterion C—maximizing the ratio of benefits over costs—can be sensitive to small changes in costs and can give unreliable results. Moreover, there is a sticky problem of determining whether to treat an effect as a benefit or a cost. Criterion E—the internal rate of return—is difficult to apply and may not yield a unique solution.[6] Criterion D—maximization of net benefits—is easy to apply and does not suffer from these problems, as it recommends the alternative of highest net benefit. When an alternative is simply to be accepted or rejected, it recommends acceptance when the net benefit is greater than zero.

Applying the chosen decision criterion to the results of present-value analysis of the alternatives is the fifth and last step in a cost-benefit analysis. (Successful application may require additional reading; (we recommend [5], [11], [16], [17], [21], [22], [24]).

These steps constitute the usual procedure for a cost-benefit analysis. The flow chart of Figure 1 summarizes the steps. This is a broad overview; variations may be necessary or desirable in some situations.

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[5] Although the net-benefits criterion is usually the most appropriate, there are circumstances where others may apply. The net-benefits criterion in this case supposes that the levels of output under all alternatives have been established for comparison. We prefer this method. In a more complex analysis using variable output levels under different alternatives, the ratio of excess benefits over cost is an appropriate criterion. *See* [16], pp. 134–135.

[6] The internal rate of return is sometimes appropriate. However, our assumptions favor the net benefits criterion. Internal rate of return appears appropriate where investment and the payoff are widely separated in time. *See* [16], pp 128–131.

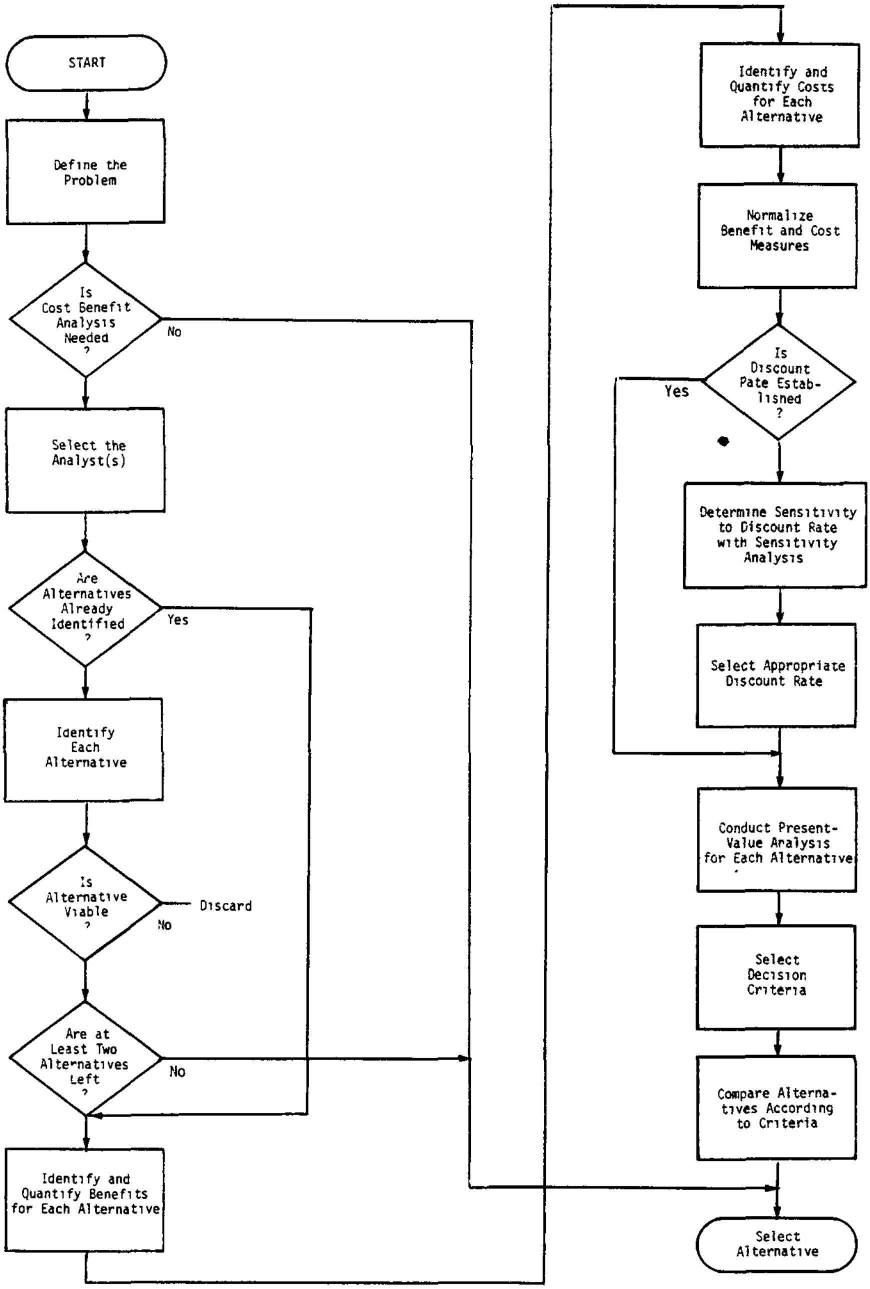

FIGURE 1. Flow chart of a common cost-benefit analysis procedure.

3. PROBLEMS

There are several important general considerations and potential difficulties in performing an analysis, or in making decisions based on it. They arise from incomplete identification of alternatives, cost accounting, assigning benefits, special characteristics of information systems, the cost of the analysis itself, and such realities as the local political or social environment. Before examining these in detail, we digress briefly to examine the characteristics of public agencies that pose further problems for using cost-benefit analysis in the public sector.

The Special Case of Public-Sector Analysis

Public agencies have special characteristics that make cost-benefit analysis more difficult than in the private sector. These characteristics tend to magnify the problems inherent in cost-benefit analysis. First, public agencies are primarily intended to render services. Their products, being intangible, cannot be precisely valued. How, for example, does one estimate the value of a community library service or the existence of a public park? Many of these services have no counterpart in the private sector: there is no surrogate that can be used.

Second, public agencies produce what economists call "public goods." Unlike private goods, which are consumed by their buyers, public goods are "consumed" by everyone in the community. In the private market, the buyer, himself, obtains the benefit. In the public market, some may receive far more than they ever could or would personally pay for, and necessarily "consume" the whole benefit.[7] It is the "indivisibility" of public goods that makes it difficult to accurately assess the benefits and costs of many public projects. However, computer projects in public agencies normally have a set of costs and benefits restricted to the bureaucratic organizations, making this problem less of an obstacle.

The third characteristic, perhaps the most significant, is the explicitly political environment of public agencies. Business leaders are responsible to their shareholders and customers; their long-term goal is a profitable enterprise. Elected public officials tend to be responsible to the short-term interests of the voters. Tenured bureaucrats are responsible only to themselves. Whereas business leaders must make sure their companies are effective in the rigorous, well circumscribed, competitive marketplace, political leaders actually need only the appearance of productivity and efficiency; because governments hold a monopoly over the "public goods" market, there is no pressure on them to be truly efficient or effective. Indeed, the terms "efficiency" and "effectiveness" are hard to apply to many public activities. Political values are not usually founded in criteria of efficiency; the utility of cost-benefit analysis in the public sector is consequently not related to "efficient" allocation of resources.[8]

These special characteristics of public agencies make cost-benefit analysis more difficult here than in the private sector. Although the taxpayers' money provides the public goods, the exact value of these goods is difficult to define because they are intangible and indivisible. The decision to provide one set of public goods or services instead of another is usually political, made by public officials who presumably act in the interest of their constituents. Decisions among alternatives are strongly influenced by factors well outside the criteria—economy and efficiency—to which cost-benefit analysis is best suited.

Incomplete Identification of Alternatives

This problem has two aspects. First is the difficulty of identifying all the acceptable alternatives; when computers are involved, there may be too many possible alternatives for one person to comprehend. Moreover, the cost of searching for new alternatives must be balanced by the benefits of a wider search. Everyone concerned should cooperate in identifying alternatives. Once a reasonable list of possible alternatives is created, it should be "edited" to exclude those which are clearly infeasible or disadvantageous.

The second aspect of this problem is the failure to specify the level of output that would make each alternative acceptable. The importance of this can be illustrated

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[7] Both [9], pp. 71-96, and [19], pp. 3-27, offer helpful examples of this point.

[8] This is not to say that public agencies do not make any efficient decisions; it is not always true that "business can do it better, cheaper." The point here is that public agencies deal with many things that *must* be resolved politically—and political considerations often bring on inefficiencies.

by a simple example. Suppose that we must decide whether to automate billing in a public utility, or to retain the current manual system of monthly bills. Suppose further that automated monthly billing has been proved cheaper than manual monthly billing. Two questions remain: Is automation the best overall *solution to the problem,* which is efficient collection of money from customers? Granted the decision to automate, is a *monthly* bill appropriate? Suppose that an incremental analysis reveals that automatic bimonthly billing is cheaper than any form of monthly billing, and that quarterly manual billing is cheaper still. In other words, the frequency of billing is as important as the method of preparing the bills. This example shows that incremental solutions, which account for such factors as the frequency of tasks, must be included among the alternatives or the decision may be suboptimal.[9]

Cost Accounting Problems

Cost accounting is always difficult. In computing it is even more difficult because the costs for certain expensive components, such as core memory, are difficult to account for equitably. There are four main problems in cost accounting within computing systems: double counting, omission of costs, hidden costs, and spillovers.

Double counting occurs when the same cost is included in two ways. A subtle but common form is to count a secondary cost already covered by a direct cost; for example, to count the reduction in a department's output on account of losing a person "purchased" by the proposed project, and to count the cost of the "purchase" itself (see [17], pp. 66–67). The danger of double-counting errors is greater for more complex analyses. Careful accounts of resources and their use will help avoid this problem.

Omitting significant costs is the opposite of double counting. Examples of costs easily overlooked are the costs of electricity, space, and change-overs when upgrading equipment. Omitting them can seriously distort the analysis. Accurate recordkeeping can help avoid such oversights and can provide data for cost projection.

Hidden costs are of two kinds. One kind consists of costs elsewhere in the organization that are part of the project. An example, which actually occurred in an analysis, is excluding analysts and programmers hired by departments which use the computing center. This omission makes salary costs for data processing appear lower than they actually are. Thus, one must always include the costs of personnel and other resources that are required by the entire system, even if they occur in other departments.

The second kind of hidden cost arises in assigning a share of overhead to a particular activity. This can be a serious problem in a computing center, where an application requiring large quantities of storage may wrongly be given the same share of overhead as an application requiring little storage. It is thus possible for the analysis to proceed as if the small user were subsidizing the big user. It is a tedious but often necessary task to assign each application its true share of the overhead.

Spillovers are secondary financial effects not directly related to the activity. Example: An organization's decision to automate brings income to computer companies; this decision gives certain technical personnel better chances for advancement. Such effects should not normally be taken into account in a cost-benefit analysis, although such spillovers may have a significant effect on training and hiring in the future.[10]

Problems of Determining Benefits

Many analysts consider the quantification of benefits to be the greatest obstacle to a cost-benefit analysis in an information system. This results both from inconsistencies among levels and kinds of outputs from information systems, and from the

[9] This example—billing frequency in utilities—is the subject of [25] and [26].

[10] Spillovers are also called external effects, or externalities *See* [9], p 19; [16], pp. 85-96

vague intangible benefits that information systems are said to bring.

Accurate comparison of benefits between existing and proposed systems requires a standardized scale for system outputs. It is a common mistake to compare the value of the level of output before the change with the value of a different level of output after the change. For example, it is improper to claim that a calculating and printing task should be automated because the unit costs of printing 1,000 notices automatically are lower than the unit costs of printing 100 manually. The proper comparison examines the value of a fixed level of automated output relative to the value of the same level of manual output.[11]

Measurement problems arise from the difficulty of assigning consistent and comparable values to benefits. These problems center on the basic worth of the various benefits. A benefit with a vague definition such as "improved operational performance" is, literally, of no value. Such a benefit must be broken down into a series of simple concrete benefits such as fewer errors in operations, faster response to client inquiries, faster and more thorough accessibility to important records, etc. Indeed, the value of *any* complex benefit is best determined from the simple, concrete benefits that constitute it.

Measurement problems become more perplexing in multiuser environments, since each group of users has its own opinions about expected benefits. This problem is less serious for hardware than for software, since the hardware should be chosen to maximize the net benefit of the total system, i.e., the sum of individual net benefits to each user or user group (note that this may produce a hardware configuration optimal for the organization as a whole, but suboptimal for some groups within the organization). For software, the sum of net benefits of independent users is a good measure, possibly weighted according to the importance of each user or group of users. If the users disagree about the net values of common benefits, an average of their assessments can be used in calculating the total benefit. If users disagree about the benefits, the total can be calculated as the sum of the net benefits perceived by each user.

If the computing center charges "hard" money for services, the analyst can treat the environment as a market when determining the value of benefits.[12] The users can be given a schedule of costs; they can exercise their own judgment about how to spend their money. (As long as users employ their own funds, it is reasonable to assume that they will choose the best alternatives for them.) This assumption is reliable only if users are charged in "hard" money; "soft" money, usually restricted for particular purposes, does not allow the user to make sound choices among alternative investment opportunities. This illustrates the importance of computer resource allocation policies within the organization, and of pricing and accounting.

These approaches are valid only to the extent that each user states the true value of his expected benefits. Users have a tendency to overestimate benefits; also, in some cases, "benefits" are disguised statements of political advantage. The decision-maker must use both administrative and political judgment to determine the truth in statements of benefit.

Intangible benefits are the most uncomfortable problem for cost-benefit analysts. How can they turn in an objectively accurate report based on "intangible" benefits? Many cost-benefit analyses list intangible benefits such as "improved decision-making," "enhanced morale," and "better service to clients." How does the analyst place a value on these things? (Note, however, that it *is* possible to place a value on some

[11] It is possible and sometimes necessary to treat outputs among alternatives variably. This is a much more difficult way to do cost-benefit analysis, since comparisons must be between the mathematical functions that describe the cost-benefit calculations for each alternative. The comparison could be made using graphs displaying cost-benefit calculation products for each alternative.

[12] "Hard money" refers to funds that can be spent at the discretion of user departments on a range of different items, whereas "soft money" (or "funny money") refers to budgeted funds assigned to one item that can be spent only on that item. Hard funds, therefore, are the effective disposable income for the department

intangible benefits, such as the speed with which a client's inquiry is handled.) It has been argued that the major difference between tangible and intangible benefits is the difficulty of evaluating them [4, 42].

The greatest problem with intangible benefits is assigning a value to information. All information has potential value—which is usually unknown until the information is used in a decision. Then the value of the information can be calculated as the difference in the expected value of the decision with and without the information. Even this simple notion is hard to apply because the values placed on the decisions may be unreliable.

Intangible benefits can be conveniently ignored if a proposed change shows clear tangible benefits, for then the intangible benefits are "icing on the cake." But in many cases the tangible benefits do not represent a clear advantage, and the intangible ones must be seriously considered. Nevertheless, it is wise to be continously aware that tangible benefits differ in measure from intangible ones, since the latter often cannot be expressed in "normalized" terms such as dollars, may not amount to the value predicted, and may not help their hoped-for beneficiaries. Consider, for example, the vague intangible "improved supervisory control." At what point does "improved control" by supervisors turn into "unnecessary surveillance" as perceived by subordinate employees? What seems an intangible potential benefit to some may appear to be an intangible cost to others.

Despite these traps, considering intangible benefits can be useful. It might be possible to set best- and worst-case boundaries on the value of the intangible benefits; this would provide a reliable *range* of predicted benefits to consider. Tradeoffs can be calculated, among the intangible benefits, for alternatives that involve similar tangible benefits. A sensitivity analysis using best guesses under pessimistic, realistic, and optimistic assumptions may be helpful. But it should always be remembered that intangible benefits are weak bases for rational judgments. Intangible benefits can be used in the context of the analysis, but they should not be used in the equations of the analysis itself.[13]

Finally, a break-even analysis can indicate a minimum value of intangible benefits that will make it possible for a project to survive. Break-even analysis is often applied where costs are known but benefits are unclear. For example, suppose that the portion of a system's cost not attributed to tangible benefits is $5000 per year, and that about five major decisions per year will be made using the data provided by the new system. In this case, the average increase in value per decision must be $1000 if the system is to break even, i.e., a total of $5000 in annual decision benefits beyond what would have been possible without the computerized assistance must be realized if the contribution of the computer to decision-making is to cover the difference between costs and tangible benefits. Although a manager may not be able to place an exact value on information for decisions, he frequently can decide whether the expected new benefits are worth at least the break-even value.

Special Characteristics of Information Systems

Accuracy, response time, security, reliability, and flexibility can significantly affect costs and benefits of an information system relative to a task. We recently evaluated an expensive on-line police vehicle dispatching system. The design specification called for an average response time, from the arrival of a call to the dispatching of an available police unit, to be about 15 seconds. When the dispatch

[13] We saw a report from a cost-benefit analysis of an information system in an organization that used a novel approach in dealing with "intangible" benefits. A rough calculation was made of the dollar value of these benefits, using a formula devised by the analysts, and the term "added value" was applied to these values In each instance of analysis, results were given in terms of both "value" (based on tangible costs and benefits) and in terms of "value" plus "added value" (total value). The reader could thereby choose the value of interest to him. The curious thing about this analysis, which was done by the data processing department itself, was the prominent use of total value in the conclusions section of the report The report recommended, not surprisingly, that the data processing center be given more money, more staff, and more equipment.

system had full use of the computer, it worked well. Unfortunately, this dispatching system shared a large computer in the city's finance department, used for everything from writing payroll checks to processing dog licenses. Despite efforts to give the police priority, the load on the system often caused serious delays—some response times were as long as 10 minutes. Fortunately, the police operators were re-

TABLE IV. SPECIAL CHARACTERISTICS OF INFORMATION SYSTEMS THAT AFFECT SYSTEM COSTS AND BENEFITS

Effect / *Characteristic*	*Kinds of Applications Affected*	*Steps that Can be Taken to Consider these Effects*
Accuracy	Any application where the actual values computed and assigned are critical to operations, and where error rates must be very low. Examples: structural engineering applications; law enforcement records, ballistic missile early warning system.	Evaluate the requirements for accuracy demanded by the system, and try to estimate the cost of errors. If the existing system seems to have an acceptable error rate, then the new system should at least equal that performance, provided no new levels of service are expected New levels of service may require improved accuracy.
Response time	On-line applications that affect ongoing operations that should not be delayed. Examples emergency vehicle dispatching; airline and other real-time reservation and ticketing systems; any system serving highly paid professionals who depend on the system.	Analyze the extent to which the task the application will assist requires fast response time. Slow response may simply be intolerable, rendering the system totally useless As above, the system should at least achieve the response time of the existing system Simulate the expected average operating conditions of the system to estimate probable average response times and the likely slow-response extremes.
Security	All systems that contain information considered secret or restricted, for whatever reason. Examples: military, national security, or police intelligence data; business or corporate financial data; proprietary industrial design information; electronic funds transfer systems.	The system, the data it contains, or both may be targets of abuse. Evaluate the kinds of data or systems involved, and imagine who might be interested in stealing, disrupting, or sabotaging operations. Try to estimate what level of security should be retained for a given cost. Consider taking the most sensitive information off the system except when being processed. Hire a reputable security consultant to evaluate your proposed system.
Reliability	Any system that supports the ongoing operation of crucial or at least expensive activities. Examples emergency vehicle dispatching; on-board or ground-based navigational systems for air or space craft; early warning systems; electronic funds transfer systems; vote counting systems.	Evaluate the effects of temporary down-time on operations If they are intolerable, consider backup systems and other reinforcement If they are merely costly and troublesome, try to estimate what each minute or hour of down-time costs under average conditions. Estimate the likely amount of down-time a system will have, perhaps based on performance of similar systems, and consider if the system is worth the probable cost of down-time.
Flexibility	Systems that need fairly frequent changes or overhauls to keep them current and efficient. Examples: systems designed to serve top management in planning and analysis; computer-aided instruction applications; any system designed to provide information to meet federal reporting requirements.	Consider the environment the system will operate in. If it is uncertain or changes frequently, flexibility will be an asset. Estimate the costs of making major changes of the kind likely to be encountered, and search for a system configuration that has low change costs as well as other characteristics desired.

sourceful: they shouted emergency calls across the room to the dispatchers. Under these conditions the net benefits of the system were deeply negative. The recommended solution was drastic: either buy a computer dedicated to dispatching, or return to the previous system. The net loss was estimated at $1 million.

This example shows that the expected benefits of a proposed system must be evaluated relative to the operating conditions which are likely to obtain. The value of the police dispatching system depended critically on the response time. A simulation of the dispatch system might have revealed that the required operating conditions would hold only rarely. When the system was in the planning stages, thought should have been given to the possibility of long response time.

In a similar way, accuracy, reliability, security, and flexibility should be analyzed for their contribution to benefits. Table IV provides some direction on dealing with these special characteristics of information systems.

The Cost of Cost-Benefit Analysis

A large-scale cost-benefit analysis is costly, and can disrupt normal operations. Sometimes, it is not cost-effective to conduct a full cost-benefit analysis! An experienced analyst can determine whether an analysis can be made on reasonable grounds.

Problems of Everyday Realities

Normal operations and existing conditions affect the utility of cost-benefit analyses. One problem is that a cost-benefit analysis is merely a tool; it cannot tell a manager what to do. No matter how well the analysis is done, it is only one input to the decision process. Because the results of cost-benefit analysis can be misunderstood, the analyst must present every analysis in perspective.

A second problem is the difficulty of performing an accurate yet useful cost-benefit analysis. Too detailed an analysis can be costly beyond its value, and can even mislead; too general an analysis may overlook critical factors. Allowances must be made for the shortcomings of analytic techniques in specific applications, and the analyst must be sure that the users of the analyses understand what allowances have been made.

A third problem is that inaccurate projections of costs and benefits show a predictable pattern of inaccuracy. Costs are usually underestimated, benefits overestimated. (This is surprisingly common: who ever head of "runaway benefits?") Runaway costs are endemic in major projects. The lesson is that costs are difficult to control and that benefits are difficult to achieve. Indeed, some organizations use a formula for adjusting projected costs upward and benefits downward. It seems sensible to assume that projections may be more accurate when analysts accustom themselves to thinking on the high side for costs and the low side for benefits.

A fourth problem is the political environment in organizations. Although a politically inspired cost-benefit analysis might be impartial, a policy-making body or advisory committee is not likely to release conclusions that are highly critical of its operations or proposals. Many cost-benefit studies have been conducted solely for proving a political point, e.g., that a system saves money (or that it wastes money), or that a system should be expanded (or done away with). Analysts should exercise care in accepting analyses under such political pressure: a few "staged" analyses can cast doubt about an analyst's responsible analyses or even reputation. Similarly, those who use cost-benefit analyses should consider whether political motivations underlie the conclusions of the analyses.

CONCLUSION

Cost-benefit analyses can be accurate, useful tools for guiding decisions about information systems in organizations. But there are problems: difficulties of assigning costs and benefits, failure to identify all alternatives, failure to specify the critical characteristics demanded of the system, and social and political realities. An analyst must be well informed about these problems. A user of an analysis must be aware of the analytic shortcomings.

ACKNOWLEDGMENTS

The authors would like to acknowledge the contributions of John Stowe, Kenneth Kraemer, Joseph Matthews, Peter Denning, and three anonymous reviewers of this paper.

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RECEIVED APRIL 4, 1977; FINAL REVISION ACCEPTED NOVEMBER 28, 1977