COST BENEFIT ANALYSIS OF INFORMATION SYSTEMS: A SURVEY OF METHODOLOGIES

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Abstract. *Cost justification has become one of the most important factors influencing the pace of business automation, particularly end user computing. The primary difficulty in cost justification is the evaluation of benefits. This paper identifies and discusses eight methodologies which have evolved to quantify the benefits of information systems. These are: decision analysis, cost displacement/avoidance, structural models, cost effectiveness analysis, breakeven analysis, subjective analysis, time savings times salary, and the work value model.*

1. Introduction.

Virtually all large organizations, and very many smaller ones, have by now invested in office information systems. Some have dabbled, some have experimented systematically, and some have made full scale commitments. The results might charitably be characterized as mixed. There have been more than a few disasters, at least some outright successes, and many mild disappointments.

What happened? In some cases, the systems did not function properly; in others, they simply weren't used. Costs frequently exceeded projections; and expected benefits didn't materialize. Top executives, always skeptical of the exaggerated productivity claims made for office systems, have become ever more cautious about approving new investments in end user computing. More frequently, they are demanding thorough and compelling cost justifications, as well as post-implementation audits, of end user information systems. In the capital budgeting process, these systems must now compete on equal grounds with most other investment proposals.

In the corporate environment, capital expenditure proposals live and die according to their financial analyses. Unfortunately, such analyses have become a weakness in information systems proposals: costs are always immediate, certain and tangible; but benefits are frequently distant, uncertain and intangible. Nonetheless, few I.S. managers doubt that there really are many financially sound opportunities for implementing end user computing in most organizations. The problem is in identifying such opportunities, and in financially justifying these systems to top management.

Thus, cost benefit analysis has assumed a pivotal position in the information revolution. For now, and for better or worse, cost benefit analysis is influencing the pace and mix of automation in the business sector.

In 1965, in a widely cited article, Prest and Turvey surveyed the field of cost benefit analysis. While water-supply projects, transport, land usage, health, education, R&D and defense were discussed as important areas of application, not surprisingly (at that early date) no mention was made of information systems . That oversight was rectified in 1978 by King and Schrems in an overview of the application of cost benefit analysis to information systems. While that paper was more an introduction to the topic than a survey, its breadth effectively summarized the then current state of the art.

A decade has since elapsed. Given the increasing importance of cost benefit analysis to business computing, it is again timely to assess the state of affairs. That is the purpose of this paper.

Much of the conventional wisdom of cost benefit analysis has withstood the passage of time. There was (as of 1978) and is today general agreement on many principals of cost benefit analysis. These include:

* the use of discounted cash flow analysis to account for the time value of money
* the use of life cycle cost analysis to identify and capture the gamut of relevant costs at each stage of a system's life
* the adoption of the with/without, rather than the before/after, paradigm to compare alternatives
* the use of incremental (or marginal) costs, rather than average costs

* the use of sensitivity, or "what if" analysis to explore the effects of different assumptions and parameters on results and conclusions
* the recognition of net present value as the best financial criterion for aggregating costs and benefits over time
*9Hthase of the corporate opportunity cost of capital as the appropriate discount rate in discounted cash flow calculations

There is little new to be added to these points, and no need to review them here.[2]

This paper focuses on benefit assessment methodologies - the theories, concepts and procedures for quantifying the benefits, or values, of information systems. These methodologies are the heart, and the most challenging aspect, of the process of cost justification. A number of such methodologies have evolved. The questions we pose are these: what are the benefit assessment methodologies used today, how do they work, when are they applicable, and what are their strengths and weaknesses?

Eight generic cost justification methodologies have been identified: decision analysis, structural models, breakeven analysis, subjective analysis, cost displacement/avoidance, cost effectiveness analysis, time savings times salary, and the work value model. For each, we present a description, describe the range of application, discuss strengths and weaknesses, and provide a set of references. Although in practice two or three of these methodologies might be used in tandem, for expositional purposes we have chosen to treat each approach independently.

2. Decision Analysis.

Decision analysis provides a structured approach to making choices. It is an application of operations research techniques - specifically Bayesian analysis and game theory - to business decisions. It usually involves the specification of an objective, a set of feasible choices, a set of possible "states," the probabilities of states occurring, and a set of possible outcomes (values of the objective) associated with each choice-state pair. In a decision analysis model, it is often convenient to represent probabilities and payoffs in matrix form. Because better information leads to better decisions, the value of an information system can be expressed as the improvement in the expected value of the objective due to the information system.

The decision analysis approach is useful for evaluating information systems designed to support routine decision making, such as credit decisions by a loan officer or hiring decisions by a personnel officer. The approach is flexible, accommodating both decision making under risk (where state probabilities are known) and decisions under uncertainty (where state probabilities are not known). It allows the projected benefits to be audited through tracking the pre- and post-implementation success ratios. One drawback, however, is the difficulty of determining the values of the probability-state matrices. Another drawback is that relatively few implementations of information systems fit neatly into the decision analysis framework. That is, few systems are used to support repetitive decisions with known payoffs for success and failure, and known prior and posterior probabilities. For these reasons, this approach is, while intellectually appealing, infrequently used.

[REFERENCES: Andrus, Emery, Kleijnen 1980A, Kliejnen 1980B]

3. Structural Models.

A structural model analytically represents a line of business or business function, and the impact of an information system on the costs and revenues of that function. It is a direct and intuitively satisfying approach to estimating the value of an information system. The approach involves modeling the organization's inputs, outputs and production process, modeling the projected changes attributable to the information system, and tracking the effects of the system to the organization's bottom line, frequently over time. Models may be as simple as one or two algebraic equations, or as complex as dynamic simulations involving dozens of equations and variables. Computer-based spreadsheets are convenient and common representations of such models.

A line of business is a profit center with distinct products, plans, costs and revenues. For example, the lines of business of a bank might include retail banking, corporate lending, trust services, investment banking, and brokerage services. In contrast, business functions are common across business lines. For example, business functions within a manufacturing company might include personnel, accounting, data processing, marketing, sales, production, warehousing and distribution. These functions would be carried out for each of the company's lines of business. Typical business function models include:

Billing. An improved billing system shortens the billing cycle and produces a one time increase in cash flow.
Inventory. An improved inventory system decreases the overall level of inventory and decreases the occurrences of orders against out-of-stock merchandise, thereby reducing carrying costs and avoiding the loss of orders.
Sales. Reducing paperwork and travel for a sales team increases selling time, sales and revenue.
An advantage of the structural modeling approach is directly linking the performance of the information system to the organization's bottom line, and explicitly identifying the intervening relationships, parameters and assumptions. This process helps expose unrealistic expectations about the anticipated performance and impacts of the system. Difficulties with this approach are many, however. First, it is usually difficult to use because the links between the information system and the bottom line frequently are tenuous and poorly understood. Second, the models tend to be unique - each one must be developed from scratch. This means the modeling process is time consuming and costly. Third, the data required usually extend beyond those which are readily available. Fourth, the details, if not the intent, of the models tend to be complex and difficult to communicate to management. And finally, if the models are *relative* (forecasting *changes* in revenues, profits or costs), there may be no usable audit trail. That is, a model which forecasts, say, a 10% increase in revenue is untestable, even in retrospect, since any subsequent revenue performance can be claimed to be 10% higher than it otherwise would have been.
[REFERENCES: Bender, Greer and Kropp, Kleijnen 1980B (chap. 8), Merkhofer, Scheer, Sassone and Schwartz 1985A, Strassman (chap. 8)]

4. Breakeven Analysis.

Breakeven analysis is a parametric assessment of benefits, where the parameter values are selected to equate costs and benefits. The technique is used when costs are quantifiable but some key benefits are uncertain or intangible. For example, suppose the benefits of a system which will cost $100,000 per year are uncertain. If the system is intended to displace clerks who cost $20,000 per year, the breakeven level of benefits is a displacement of 5 clerks.

Breakeven analysis is usually quickly and easily performed. It is useful when the calculated breakeven level is "extreme," that is, when it is outside the range of benefits that can reasonably be expected. If, in the preceding example, the reasonably expected displacement were between 1 and 3 clerks, the calculated breakeven level of 5 would permit a conclusion that the proposed system would be uneconomic. The opposite conclusion would be reached if the reasonable expectation were, say, a displacement of 6 to 8 clerks. If the reasonable expectation were in the neighborhood of 5, the breakeven analysis would not prove useful, and an independent estimation of benefits would be necessary.

5. Subjective Analysis

This approach asks the decision maker(s) to subjectively determine whether the prospective benefits of a system are worth the projected costs. Ordinarily, the subjective approach is used when the benefits are intangible, speculative or uncertain. The decision maker is asked to estimate the maximum amount he or she would pay to achieve the anticipated benefits, and that sum is compared with conventionally estimated system costs.

The quality of a subjective analysis depends critically on the knowledge and judgement of the managers polled. Managers who are, through experience or training, well informed about the capabilities, limitations, implementation and likely impacts of information systems may produce good subjective value estimates. On the other hand, managers who are not so well informed - and these would certainly constitute the majority - cannot be expected to produce meaningful value estimates. The subjective approach to cost justification is usually employed only when the more objective methods fail, and then with considerable caution.
[REFERENCES: Gallagher, Keen and Woodman, Keim and Janaro, Litecky, Matlin, R. Smith]

6. Cost Displacement/Avoidance.

Perhaps the most common, and most direct, approach to cost justifying information systems is by comparing their costs to the total of the current costs they will displace plus the projected costs they will avoid. In short, the justification is the substitution of lesser for greater costs. By focusing primarily on costs, this approach assumes that the benefits of the proposed information system are equal to or greater than the benefits of the current system. Of course, this approach is useful only when the proposed system will, in fact, substitute for some existing or expected costs. The cost displacement/avoidance approach initially gained popularity in, and is still best suited to, the cost justification of traditional data processing systems, where clerical labor is replaced by computer systems.

Because the cost displacement/avoidance methodology involves only estimates and

projections of costs (and not productivities, sales, revenues or profits), appropriate data and information on which to base the analysis are usually available. Furthermore, the analysis is conceptually straightforward, auditable, and easily conveyed to top management. These are strong points in support of this approach. On the other hand, the information systems being installed today are largely end-user systems - systems which complement, and do not displace, knowledge workers. Because these systems do not displace costs, but provide added value, the cost displacement/avoidance methodology is increasingly inapplicable to today's cost justification problems.
[REFERENCES: Axelrod (chap.4), Bair, Blinn and Cole, Edelman, IBM, Keim and Janaro, Mason and Sassone, Sassone 1981, D. Smith, R. Smith, Steele and Kalorkoti, Strassmann (chap. 6)]

7. Cost Effectiveness Analysis.

Cost effectiveness analysis (CEA) is used for choosing among similar information systems or system components. It does not explicitly address whether the benefits of any of the systems exceed their costs. While it is not, strictly speaking, a *cost* justification methodology, we have included it in our discussion for completeness, and because it often substitutes for a cost justification. CEA is a tool for estimating, comparing, and choosing among competing systems - given that some system is required. It is a relative rather than an absolute analysis. It attempts to identify the best among several options, without formally determining whether that best option is truly desirable. CEA is most useful when the benefits of a system are largely incommensurable, that is, when they are quantifiable in non-monetary dimensions.

CEA has three variants. One is to minimize cost for a given level of effectiveness, another is to maximize effectiveness for a given level of cost, and the last is to find the optimal effectiveness and cost combination. An example of the first would be a choice among several IBM-compatible PCs. Each may be equally effective, and the issue is to choose the one with the lowest expected life cycle cost. An example of the second variant would be a choice among spreadsheet programs, where the costs are identical but the features differ. An example of the last and most complex variant might be an R&D organization's selection of an engineering workstation: both performance features and costs might differ significantly among the candidate workstations.

Scoring models are non-pecuniary constructs frequently used to quantify "effectiveness" in cost effectiveness analyses. Scoring models identify the key performance criteria of the system or component, assign a score to each criterion for each candidate, and finally compute a weighted overall score for each candidate system.

Cost effectiveness analysis is a tractable approach to identifying the best option from among a set of similar alternatives. It supports good decisions by requiring the explicit identification, measurement and weighting of important decision factors. However, the cost effectiveness approach does not provide a general cost justification of an investment. In addition, in dealing with cost and performance trade-offs, it frequently relies on subjective assessments.
REFERENCES: Kleijnen 1980B (chap.4), Sharpe (chap. 9)]

8. The Time Savings Times Salary (TSTS) Approach.

An increasingly popular methodology for estimating the value of end user information systems is to estimate the percent of workers' time the system will save, and then to multiply that percentage by the workers' loaded salaries or wages. For example, if the system were implemented in a department of 100 workers where it was expected to save an average of 10% of each worker's time, and if each worker cost the company an average of $50,000 per year in salary, fringe benefits and direct overhead, then the annual value of the system is calculated as 100 x 10% x $50,000 = $500,000. $500,000 is the estimated value added (the value of the additional work performed) due to the system.

The TSTS approach evolved as an alternative, but close cousin, to the cost displacement/avoidance approach discussed above. The reasoning is intuitively appealing: if saving, say, 10% of workers' time does not result in cutting the work force by 10%; then it must result in 10% more work getting done; and this must be worth 10% of the cost of that work.

The theoretical basis[3] for this approach is an economic model of the firm which assumes (1) that the firm's management allocates resources efficiently, (2) that the firm's hiring is not effectively constrained by any budget limitations, (3) that the optimal numbers of each type of worker are employed, (4) that work comparable in value to current work remains to be done, and (5) that saved time will be allocated among a worker's productive activities according to a specific formula.

The time savings times salary approach has the merits of appearing intuitively plausible and of being relatively easy to carry out. It is used when the structural modeling approach is

not feasible and when the system will not displace or avoid significant costs. There are two problems with this methodology, however. First, the approach assumes that a person's value is equal to his or her cost to the organization. This may be true if the organization is not resource-constrained and it has hired the optimal number of employees. But, in general, the possibility that a worker's value exceeds his cost should not be automatically dismissed. If his value is greater than his cost, then this approach underestimates the true value of saved time. Second, and perhaps more importantly, this approach takes no account of how the saved time is used. Is the value the same whether the saved time is spent at the water cooler, or doing proportionally more of all activities, or devoting the saved time to the most important work? Clearly, the real value of the saved time would differ in each of these cases. This approach, however, implicitly assumes that saved time is reallocated among work activities according to a specific rule - a rule which has neither behavioral nor normative significance. Consequently, there is no reason to believe that that particular time allocation will materialize. Indeed, in actual practice, the TSTS approach tends to underestimate the true value of office systems, sometimes by a wide margin.
[REFERENCES: Axelrod (chap. 4), Boczany, Doswell (chap. 9), Ferenz, IBM, Potak, Sassone 1987, Tapscott (chap. 10)]

9. The Work Value Model.

The work value model was developed to overcome the shortcomings of the time savings times salary approach. It is motivated by the recognition that white collar workers routinely perform activities of different intrinsic value to the organization, and by the recognition that one of the major benefits of information systems is their capacity to restructure work patterns.[4] Thus, the benefits of information systems are not only increased efficiency (doing more of the same thing in the same, or less, time) but also increased effectiveness (doing more higher value work and less lower value work). The value of an information system, therefore, depends on both the intrinsic value of the activities workers perform and on how the system's capabilities are exploited to improve work patterns. The model is based on the premise that the values of workers' activities can be inferred from an analysis of the firm's resource allocation decisions.

A key concept in the work value model is the work profile matrix. The matrix characterizes an organization's allocation of its time, by level in the job hierarchy and by major type of activity. Job hierarchy levels might include senior, middle, and junior managers; senior, and junior professionals; technicians; administrators; secretaries and clerks. Major types of activities correspond to job titles. For example, general management, departmental management, and supervision might characterize the sets of activities proper to senior, middle and junior managers, respectively. Specialized and routine professional work are sets of activities which might characterize senior and junior professionals. Technical, administrative, secretarial and clerical work are other typical sets of organizational activities. The number of job levels and activity types (i.e. the dimensions of a work profile matrix) necessary to reasonably characterize the work of an organization will differ from case to case.

An example of a work profile matrix is given below. The matrix indicates that managers spend 50% of their time doing managerial work (e.g. planning, budgeting, directing projects, reporting to superiors, personnel matters), 20% of their time in professional work (e.g. analysis, writing technical reports, reading technical literature, preparing and giving technical presentations), and 20% of their time in clerical work (e.g. filing, copying, collating, distributing, retyping). The remaining 10% is non-productive time (e.g. travel, searching for information, waiting, walking to meetings, telephone tag). The other elements in the matrix are interpreted similarly.

	MANAGERIAL	PROFESSIONAL	CLERICAL	NON-PRODUCTIVE
MANAGERS	50%	20%	20%	10%
PROFESSIONALS		70%	20%	10%
SECRETARIES			80%	20%

A growing body of evidence (as well as casual empiricism) supports the assumption, embedded in the off-diagonal elements of the work profile matrix, that workers routinely perform activities which are "proper" to workers at other levels in the hierarchy. (See Doswell, chap. 9, which summarizes a half dozen studies on work patterns; Johnson; and Sassone and Schwartz, 1985B.)

Starting with the objective of quantifying the value of an information system in a white

collar environment, the work value model exploits the information content of firms' resource deployment decisions. By assuming that the observed allocations of labor resources reflect rational optimizing behavior, and by measuring those allocations and the costs of those resources, the marginal values of the kinds of work performed by managers and professionals can be inferred. These implicit marginal activity values can be used to estimate the value of restructuring office work patterns.

The model is useful for estimating the value of end user information systems supporting managers and professionals, especially when the cost displacement approach is inapplicable and when structural models are not feasible. The model is an extension of the time savings times salary approach, but avoids certain restrictive assumptions. As such, it produces more accurate estimates of benefits than that approach. The model has several advantages. First, by explicitly recognizing the restructuring of work patterns, it can faithfully reflect implementation plans. Second, by estimating pre- and post-implementation work profile matrices, the projected benefits can be audited.

A drawback associated with the model is the extensive information required about the organization's work patterns. If this information is collected through surveys or time logging, the process can be time consuming and expensive. Another drawback is the relative complexity of the approach, and the consequent difficulty of explaining it quickly in management briefings. [REFERENCES: IBM, Sassone 1984, Sassone and Schwartz 1985B, Sassone and Schwartz 1986, Sassone 1987]

10. Summary.

Cost justification is an increasingly important concern among users and vendors of end user information systems. Today, to win approval, such systems must hold their own in financial comparisons among the spectrum of corporate capital investment proposals. Gone, probably for good, are the days when such systems are justified on faith alone.

What does the future bode for cost justification? Four trends seem relevant. First, the spread of end user computing will continue. More powerful and less expensive hardware and software will bring electronic workstations to more managers and professionals. Second, there will be increased concern with developing and implementing strategic information systems - systems designed to provide competitive advantages to their organizations. Frequently cited examples of such systems include American's and United's Sabre and Apollo airline reservation systems, American Hospital Supply's distributed order entry system, and Merrill Lynch's cash management account. Third, the actual and potential uses of expert systems will expand rapidly. And fourth, computer integrated manufacturing systems (CIMS) will proliferate.

At some point, probably within five years, the cost justification of "conventional" end user computing will cease to be an issue. Enough studies will have been carried out, enough generalizations will have been made, and enough end user computing policies will have been implemented, that decisions will cease being taken on a case by case basis. Just as there are rules regarding who gets a company car, rules will guide much of the investment in desktop computing. However, for the next few years, the cost justification of end user computing will continue to be a central concern within the industry.

Strategic information systems, expert systems and CIMS are currently in the R&D stage for most users. As such, these pilot systems do not require *cost* justifications. However, as these systems move into the hands of users, and as they begin requiring large financial investments, cost justification will become an issue. For, just as with the end user systems which preceded them, the costs of these systems will be immediate and tangible; but the benefits will appear speculative, distant, and intangible.

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End Notes

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2. Readers interested in an overview of cost benefit analysis are directed to Prest and Turvey (1965), and to Sassone and Schaffer (1978). King and Schrems (1978) and Parker (1982) provide an introduction to and overview of the application of cost benefit analysis to information systems.
3. See Sassone (1987).
4. See Doswell, page 172.