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Cost Justification of an Expert System

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ABSTRACT

Expert systems are being developed and implemented by increasing numbers of businesses. Like other projects which spend corporate dollars, an expert system must be analyzed for its economic and strategic worth to the organization. Both traditional engineering economy project analysis and multi-variate holistic methods can be applicable. The fundamental strategy of the analyst is to decide upon the evaluation methodologies, gather cost and benefit data, study the project from various perspectives, and present the results and recommendations.

INTRODUCTION

Expert systems are new and intriguing avenues to solve a wide variety of business problems. The proliferation of powerful, but user friendly, software and the publicity attracted by successful systems have encouraged many organizations to consider their own development and implementation [4, 6, 13]. In most corporate settings, to commence with such an undertaking requires an analysis of worth to justify the anticipated dollar outlays.

Viewed as another project competing for limited funds, the expert system can be systematically and reasonably analyzed for costs and benefits. The recommended steps are (1) selecting justification methodologies, (2) quantifying and qualifying costs and benefits, (3) evaluating, summarizing and documenting these, and (4) interpreting and communicating results.

SELECTION OF JUSTIFICATION METHODOLOGIES

Traditional Indicators

Organizations vary in sophistication regarding measures of project worth [2, 11] and it behoves the analyst to know which methodologies are used by competing projects. The aim is to select a small, but comprehensive set of mutually exclusive criteria to base a judgement of the differences among projects [14]. Traditional measures from engineering economy and capital budgeting focus on cash inflows and outflows over the study period, and rank projects according to value [5, 11, 12, 15] (Table 1). Although these indicators lack the ability to effectively include nonmonetary or irreducible factors, they are widely accepted and are measures to which decision makers can attach both an intuitive and quantitative feel.

Indicators gauge different aspects of a project and therefore, while many are consistent, some will produce conflicting results — most companies use combinations. All are based upon projections into the future which quantify the expected costs and savings of a project. The **discount rate** (i) is the minimum attractive rate of return of a project and is the opportunity cost to the company of the money to be spent; it should be equal to or greater than the cost of capital. Sometimes a risk adjusted discount rate is used, i.e. the discount rate used to evaluate a risky undertaking is inflated to reflect that risk [9, 11].

For measures other than payback period, a **length of study** must be established. The length should ideally be the life of the proposed system; in reality this is often impractical. A mechanized system has an uncertain future — hardware can be reused for different software and software can be ported to new hardware. The analyst may have to select a time frame consistent with other similar projects. For the typical project flow profile with high initial costs followed by increasing or steady benefits (Figure 6), a longer study period and a lower discount rate yields more favorable results.

Internal Rate of Return (IRR) measures the inflows versus the outflows over time to arrive at a rate of return. Some organizations have published *hurdle rates* — the minimum IRR acceptable for any project. A critical assumption of IRR is that cash inflows can be invested at the IRR; this is often not true and has inspired variations of this indicator. These modified internal rates of return often ask the analyst for an interest rate for both cash outflows (cost of money) and cash inflows (investment rate).

Net Present Value (NPV) or **Net Worth** (NW) are different names for the process of figuring the present value of all cash flows at a certain discount rate and summing them. If the study involves comparing two or more options for the expert system with differing lives and the NPV approach is desired, an **Equivalent Annuity** (EA) is often used. This is found by calculating the NPV of a project and dividing by the Present Worth of Annuity factor for the number of years of the life.

Payback period is popular because of concern with risk and short term profitability; it measures the point in time where all cash outflows have been recaptured by inflows and ignores subsequent flows. It can be calculated in either a discounted or non-discounted format.

Benefit to cost ratios or profitability **ratios** measure the

Table 1. Commonly Used Value Indicators.

Indicator	Advantages	Disadvantages
Internal Rate of Return (IRR)	Brings all projects to common footing. Conceptually familiar. No assumed discount rate.	Assumes reinvestment at same rate. Can have multiple roots.
Net Present Value or Net Worth (NPV or NW)	Very common. Maximizes value for unconstrained project selection.	Difficult to compare projects of unequal lives or sizes.
Equivalent Annuity (EA)	Brings all project NPVs to common footing. Convenient annual figure.	Assumes projects repeat to least common multiple of lives. May impute salvage value.
Payback Period	May be discounted or non-discounted. Measure of exposure.	Ignores flows after payback is reached. Assumes standard project cash flow profile.
Benefit to Cost Ratio	Conceptually familiar. Brings all projects to common footing.	May be difficult to classify outlays between expense and investment [11].

sum of the discounted inflows divided by the sum of the discounted outflows, and give consistent results with NPV or EA.

Measures can be calculated by many software packages including all the commonly used spreadsheets (Figure 5) and by calculator. In fact, figuring the indicators is trivial once the dollar flows and timing are established.

Holistic Methods

Many emerging technologies characterized by fuzzy environments do not lend themselves well to traditional engineering economic analysis. Expert system projects may not prove in by the numbers, but still have compelling justification. Holistic (nonclassical) methods focus on ranking projects via multi-dimensional attributes and including both monetary and nonmonetary factors [1, 2, 14].

These methods include **profile charts** (Figure 1) and **symbolic scorecards** [14], both ways of comparing projects by relevant decision criteria. These models are particularly advantageous when several cost or benefit variables are unknown [9].

A **linear additive model** (Figure 2) scores projects by weighting performance and decision criteria; this is similar to the two previous methods with the addition of specific scoring numbers. Summations of the following form are used:

$$V_j = \sum_{i=1}^{n} w_i x_{ij}$$

where

V_j = j^{th} alternative score
w_i = i^{th} decision criteria weight
n = number of decision variables
x_{ij} = rating assigned for i^{th} decision variable of j^{th} alternative.

Nelson [9] uses a model which linearly adds dimensions including technology assessment, equipment evaluation, and cost/budget data. The system value model developed by Troxler and Blank [16] scores prospective systems on suitability, capability, performance, and productivity. Each measure consists of vector valuations of component parts, then the results are bar charted for comparison.

The **analytic hierarchy process** (AHP) developed by Saaty [10] diagrams the identified decision criteria hierarchically with their interactions. Parallel pairwise comparisons are made and matrix eigenvalue scores are calculated for each contributing factor. Varney *et al.* [17] showed that this process is not too sensitive to inconsistencies in judgement. Figure 3 shows the same example expert system analyzed by a mechanized AHP program - *Automan* by the National Institute of Standards and Technology.

A final approach has been to suggest **expert systems** themselves as tools to project justification. This approach synthesizes analytic and judgmental data to arrive at recommendations [2, 14].

There are several drawbacks to nonclassical justification methods. Organizations do not use such methods with regularity and decision makers may be unfamiliar with them. When delineating and ranking attributes, and the project's fulfillment of the criteria, subjectivity occurs. Human judgement tends to be inconsistent from person to person, and even within one person.

These methods are normally project specific so that results cannot be generalized to other problems [16]. Furthermore, comparisons between an expert system justified by multi-attributes and another project analyzed traditionally will be difficult and confusing. If a multi-variate method is used, the analyst should fully explain why and how it is appropriate, and supplement it with traditional analysis when

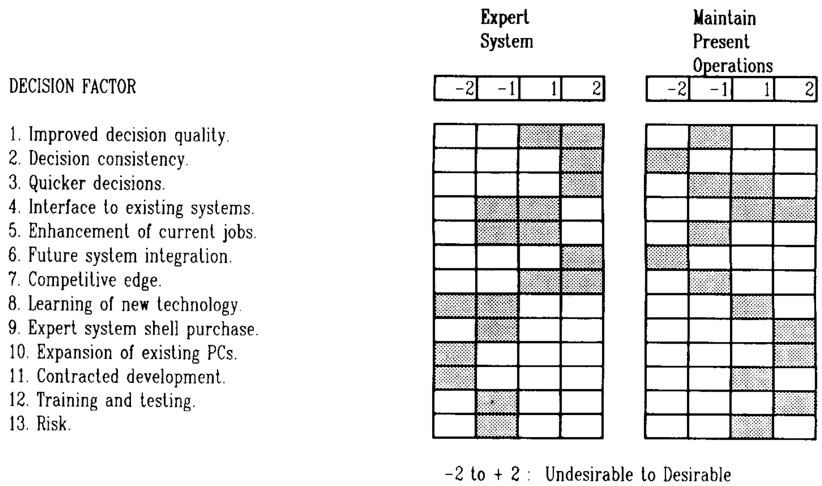

Figure 1. Sample Profile Chart for an Expert System.

DECISION FACTOR	Decision Factor Weight (-1 - +1)	Expert System Rank (0 -1)	Expert System Weighted Value	Present Operations Rank (0 - 1)	Present Operations Weighted Value
1. Decision quality.	1	0.8	0.8	0.7	0.7
2. Decision consistency.	1	0.9	0.9	0.4	0.4
3. Decision speed.	0.9	0.9	0.81	0.6	0.54
4. Interface to existing systems.	0.5	0.5	0.25	0.9	0.45
5. Job satisfaction.	0.3	0.6	0.18	0.2	0.06
6. Future system integration.	0.7	0.9	0.63	0.1	0.07
7. Ability to compete.	0.8	0.9	0.72	0.2	0.16
8. Implementation of new technology.	-0.1	1	-0.1	0	-0
9. Software purchases.	-0.5	0.7	-0.35	0.2	-0.1
10. PC purchases.	-0.8	0.8	-0.64	0.3	-0.24
11. System development/maintenance.	-0.9	1	-0.9	0.4	-0.36
12. Training and testing.	-0.2	0.8	-0.16	0.1	-0.02
13. Risk.	-0.5	0.6	-0.3	0.3	-0.15
TOTAL OF EACH ALTERNATIVE			1.84		1.51
NORMALIZED TOTAL OF EACH ALTERNATIVE			1		0.8206522

Figure 2. Sample Linear Additive Model for an Expert System.

DECISION CRITERIA

Pairwise Comparisons Between Decision Criteria

	A	B
A. Benefits	-	1.5
B. Costs	0.67	-

A. BENEFITS	1	2	3	4	5	6	7	Expert System	PMO
1. Improved decision quality.	-	1	1.2	2	3.3	1.4	1.3	1.2	0.83
2. Decision consistency.	1	-	1.2	2	3.3	1.4	1.3	3	0.33
3. Quicker decisions.	0.83	0.83	-	1.9	3	1.3	1.2	1.5	0.67
4. Interface to existing systems.	0.5	0.5	0.53	-	1.8	0.7	0.6	0.6	1.67
5. Enhancement of current jobs.	0.3	0.3	0.33	0.56	-	0.4	0.3	3	0.33
6. Future system integration.	0.71	0.71	0.77	1.4	2.5	-	0.9	9	0.11
7. Competitive edge.	0.77	0.77	0.83	1.67	3.3	1.1	-	4.5	0.22

B. COSTS	1	2	3	4	5	6	Expert System	PMO
1. Learning of new technology.	-	0.2	0.15	0.11	0.5	0.2	0.1	10
2. Expert system shell purchase.	5	-	0.6	0.55	2.5	1	0.4	2.5
3. Expansion of existing PCs.	6.67	1.67	-	0.9	4	1.7	0.42	2.4
4. Contracted development.	9.1	1.8	1.1	-	4.5	1.9	0.4	2.5
5. Training and testing.	2	0.4	0.25	0.22	-	0.4	0.125	8
6. Risk.	5	1	0.59	0.53	. 2.5	-	0.5	2

Calculated Rankings by Criteria and Overall

	Weight	Share	Expert System	PMO
A. BENEFITS				
1. Improved decision quality.	0.19	0.12	0.55	0.46
2. Decision consistency.	0.19	0.12	0.75	0.25
3. Quicker decisions.	0.17	0.1	0.6	0.4
4. Interface to existing systems.	0.1	0.06	0.38	0.63
5. Enhancement of current jobs.	0.06	0.03	0.75	0.25
6. Future system integration.	0.14	0.08	0.9	0.1
7. Competitive edge.	0.16	0.09	0.82	0.18
B. COSTS				
1. Learning of new technology.	0.03	0.01	0.09	0.91
2. Expert system shell purchase.	0.17	0.07	0.29	0.71
3. Expansion of existing PCs.	0.27	0.11	0.3	0.7
4. Contracted development.	0.3	0.12	0.29	0.71
5. Training and testing.	0.07	0.03	0.11	0.89
6. Risk.	0.16	0.07	0.33	0.67
OVERALL RATING			0.52	0.48

Figure 3. Sample AHP for an Expert System.

and where possible.

COSTS AND BENEFITS OF AN EXPERT SYSTEM

The nuts and bolts of a justification study is identifying and quantifying, if possible, the expected costs and benefits. Normally these are forecasted in dollars by year for the life of the study and categorized (Figure 5).

Problematic for expert systems is that cost estimates become more specific and reliable as the system is developed [2]. The analyst may choose to employ nonclassical methods to handle justification early in the development process, switching to analytical methods as the system takes shape.

When studying a novel mechanized system for Southwestern Bell Telephone Company, the author used traditional methods to justify the system over the present manual operations. A linear additive model was then used to compare various vendor alternatives for the proposed system.

Costs

An expert system may require the purchase of several

software packages such as expert system shells, spreadsheets, data base managers, and language compilers. These can be apportioned among all the projects which will use them.

An expert systems is not totally bought off the shelf; knowledge engineering and programming must customize the application. Because of the human effort involved, this development cost will probably be the largest. Besides **programming time**, the time the domain experts spend defining the knowledge and testing the system should be included.

Hardware costs are fairly straight forward as models and numbers of machines and their costs can be anticipated by in house purchase organizations and/or vendors. If the expert system is planned for reused hardware, the opportunity cost of not selling or using that hardware for another project must be estimated. Leasing of hardware is common; the terms of the lease will indicate whether it is an operating lease or a capital lease and the cash flows can be treated accordingly.

Other equipment which may be needed for an expert system implementation include printers, furniture, office space, communications lines and devices, measuring instruments, etc. Documentation and training costs must be considered as would any permanent or temporary **personnel** increase.

If a Request for Proposal (RFP) has been issued, some figures for the system cost can be drawn from the responses. An RFP is a good tool to record the scope, timetable, architecture, and functions of the proposed system.

Benefits

Benefits are usually steady or increasing over the life of the project, and may significantly lag costs, especially for a innovative technology (Figure 6). For expert systems, areas most benefited are interpretation, prediction, design, and monitoring [8]. Feigenbaum estimates that professional and semi-professional work can be speeded by factors of tens to hundreds [3].

An expert system can **save decision time**, especially for novice employees or for tasks which have numerous possible solutions. Estimating the impact of the system on the targeted labor force can be done by survey, expert opinion, or job study. The number of hours (or people) saved can be translated into dollars per year by using a loaded labor rate. Loading takes into consideration that each employee costs the organization far more than simply salary — there are benefits, taxes, insurance, supervisory costs, and other overhead.

Along with time savings, an expert system can benefit a company by **improving decisions** and making them uniform. One of the advantages of an expert system is the explicit representation and recording of knowledge and procedures [8]; use of a well constructed system means anyone can make a decision as would an expert [7]. Consistent, quality decisions can mean less waste, satisfied customers, faster response times, and improved quality.

An expert system may allow workers to perform **new tasks** previously done by others or not done at all. This can enlarge jobs and increase employee fulfillment.

Finally an expert system may have long term **synergistic and strategic benefits** such as opening new markets, improving competitiveness, advancing technology, and positioning the company for the future. If these benefits cannot be quantified satisfactorily, they can be introduced as intangible benefits into the narrative part of a traditional study or handled through the multi-variate methods described earlier. For a new domain like expert systems, nonmonetary benefits may far outweigh identified savings [1, 14].

PERFORMING AND DOCUMENTING THE STUDY

The study should outline the decision criteria and the justification methodology. It should explain any unusual justification approaches, and discuss why they are appropriate.

Reasons for the proposed expert system and the scope of the development effort must be explained early in the documentation. Decision makers want to know up front why this project is even under consideration. Alternatives explored, including maintaining the *status quo*, should be discussed.

The study should include decision criteria and the system's forecasted benefits, costs, and timing. It needs to identify sunk costs. Assumptions made (e.g. order clerks will perform their jobs 20% faster with 15% fewer errors) and the data sources, such as vendors or the accounting department need to be recorded (Figure 5).

Since expert systems are relatively new and untried, they may meet with corporate skepticism. An analysis can address this by testing the results against various contingencies. This is termed **sensitivity analysis**. Some questions which can be answered are:

1. What if development is delayed by a year?
2. What if labor savings are only half of projections?

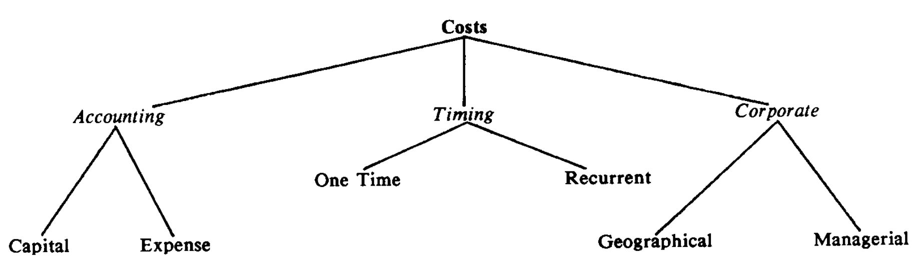

Figure 4. Generic Cost Categories.

Table 2. Typical Expert System Costs and Benefits.

COSTS	BENEFITS
<u>One Time</u>	<u>Quantifiable</u>
Software Shell Purchase Software Development Other Software Purchase Hardware Lease or Purchase Communication Equipment Office Space and Furnishings Training and Documentation	Improved Decision Speed Improved Decision Quality Automation of Tasks Ability to Perform New Tasks Standardization of Decisions Shorter Employee Training Time
<u>Ongoing (Recurrent)</u>	<u>Nonmonetary</u>
Operating Personnel Communication Lines Hardware Maintenance Software Upgrades Office Space and Utilities	Synergy With Other Projects Expanded Long Term Opportunities Strategic Positioning Job Enrichment Recording of Knowledge

3. What if the benefit per improved decision is overestimated?
4. What if hardware costs decrease by 25% over 3 years?
5. What is the organization's loss if the worse happens and the project goes belly up after a year?

Use of a spreadsheet software package or similar to alter various parameters will facilitate sensitivity analysis. Sensitivity analysis can be either determinative (altering variables to other reasonable values) or stochastic (investigating the effects of the probability distribution of variables). Graphing is an ideal method to portray the effects of changes on the consequent economic decision factors.

INTERPRETING AND COMMUNICATING STUDY RESULTS

A good study does not stand alone — it must be supplemented with perceptive interpretation and reasonable recommendations. Those most familiar with the project are in the best position to provide this insight.

An **Executive Summary** is a vital component of any study. This is usually limited to a page and highlights the reasons for the system, the major costs and benefits, the study methods used, and the important results and recommendations. Busy corporate decision makers may not get much further than the Executive Summary so it needs to pack a big punch in a small package.

Another area for interpretation is the sensitivity analysis, especially if it yields some less than encouraging results. The interests of management will be the likelihood of outcomes and minimizing risk. This is the place to describe **contingency plans**, worst case scenarios, and fallback positions.

For an emerging technology, such as expert systems, a discussion of the probable **future of the technology** and its pace of progression is pertinent. There may be a good case for delaying a project if knowledge engineering or software packages anticipate a significant near term improvement. Similarly, the ability to grow the expert system will help allay **obsoletion fears**.

CONCLUDING REMARKS

Expert systems spring from a relatively immature science, and as such, are not readily understood by many organization decision makers [4]. They may hold unreal expectations in artificial intelligence or may be overly cautious about plunging into the unknown. Obtaining funding for an expert system requires the transformation of perceptions into a clear view of the value of the project. A justification study is the vehicle for delineating the project and evaluating it by accepted means.

The study can be simple or elaborate, traditional or multi-variate, but should include a timetable for development and operation, the anticipated costs, benefits, and interactions (including nonmonetary ones), and a summary of conclusions and recommendations. An expert system should be treated, to the extent possible, like any other potential investment under consideration by the organization.

References

[1] A. B. Badiru, "Automation Strategies," *Industrial Engineering*, vol. 22, no. 2, February 1990, pp. 27-30.

[2] L. Blank and H. Carrasco, "The Economics of New Technology: System Design and Development Methodology," *Proceedings of the 1985 Annual International Industrial Engineering Conference*, pp. 161-168.

[3] E. A. Feigenbaum, "Penrose and Feigenbaum on AI: Is Intelligence Manufacturable?" *IEEE Spectrum*, vol. 27, no. 2, February 1990, pp. 49-50.

[4] M. S. Fox, "AI and Expert System Myths, Legends, and Facts," *IEEE Expert*, vol. 5, no. 1, February 1990, pp. 8-20.

[5] E. L. Grant, W. G. Ireson, and R. S. Leavenworth, *Principles of Engineering Economy*, Eighth Edition. New York: John Wiley & Sons, Inc., 1990.

[6] P. Harmon and D. King, *Expert Systems*. New York:

	YEAR										
	0	1	2	3	4	5	6	7	8	9	10
COSTS (000)											
Software Shell	25	1	1	1	1	1	1	1	1	1	0
Development	25	25	5	3	2	1	1	1	1	1	0
Hardware	15	15	0	0	0	0	5	5	0	0	-3
Other Equipment	5	5	2	0	0	0	2	2	0	0	-1
Maintenance	0	2	2	3	3	3	3	4	4	4	5
TOTAL	70	48	10	7	6	5	12	13	6	6	1
PV at 15%	70	41.739	7.5614	4.6026	3.4305	2.4859	5.1879	4.8872	1.9614	1.7056	0.2472
BENEFITS (000)											
Labor Savings	0	15	20	20	30	30	30	30	30	30	30
Improved Quality	0	10	20	30	40	40	50	50	50	50	50
TOTAL	0	25	40	50	70	70	80	80	80	80	80
PV at 15%	0	21.739	30.246	32.876	40.023	34.802	34.586	30.075	26.152	22.741	19.775
CASH FLOWS	-70	-23	30	43	64	65	68	67	74	74	79
CUMULATIVE	-70	-93	-63	-20	44	109	177	244	318	392	471
DISCOUNTED FLOWS	-70	-20	22.684	28.273	36.592	32.316	29.398	25.188	24.191	21.035	19.528
CUMULATIVE	-70	-90	-67.3	-39	-2.45	29.866	59.264	84.452	108.64	129.68	149.21

Present Value - Costs	143.81
Present Value - Benefits	293.01
Net Present Value	149.21
Equivalent Annuity	29.73
Profitability Index	2.0375
Payback Period	3 yrs, 8 mnths
Discounted Payback Period	4 yrs, 2 mnths
Internal Rate of Return (%)	40.003
Modified Internal Rate of Return (%) (Borrow at 15%, Invest at 12%)	25.409

NOTES:

1. Development includes 1 expert for years 0 and 1 for 4 hours a week.
2. Supplemental hardware and equipment is purchased in years 6 and 7.
3. System maintenance costs are assumed to increase slightly over the life of the system.
4. Labor Savings is four people, 1 hour per day in year 1, 1.5 hours per day in years 2 and 3, and 2 hours per day in years 4 through 10.
5. Improved quality assumes 1 less mistake per month in year 1, 2 less mistakes per month in year 2, 3 less mistakes per month in year 3, 4 less mistakes per month in years 4 and 5, and 5 less mistakes in years 6 through 10.
6. Salvage value assumed in year 10 for hardware and equipment.

Figure 5. Spreadsheet of Expert System Costs and Benefits With Traditional Calculations and Documented Assumptions.

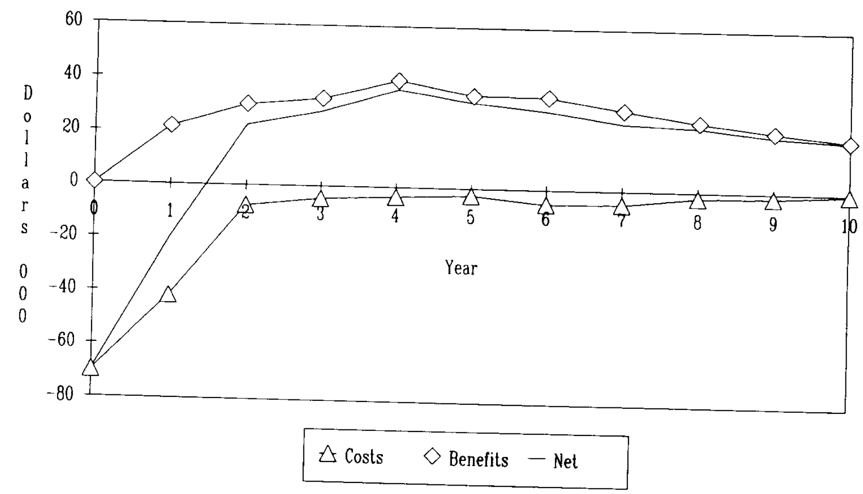

Figure 6. Graph of Discounted Costs and Benefits from Figure 5.

John Wiley & Sons, Inc., 1985.

[7] D. Leonard-Barton and J. J. Sviokla, "Putting Expert Systems to Work," *Harvard Business Review*, vol. 66, no. 2, March-April 1988, pp. 91-98.

[8] A. Martin and R. K. H. Law, "Expert System for Selecting Expert System Shells," *Information and Software Technology*, vol. 30, no. 10, December 1988, pp. 579-586.

[9] C. A. Nelson, "A Scoring Model for Flexible Manufacturing Systems Project Selection," *European Journal of Operational Research*, vol. 24, no. 3, 1986, pp. 346-359.

[10] T. L. Saaty, *The Analytic Hierarchy Process*. New York: McGraw-Hill, 1980.

[11] N. E. Seitz, *Capital Budgeting & Long Term Financing Decisions*. Hinsdale, Il.: Dryden Press, 1989.

[12] N. E. Seitz, *Financial Analysis: A Programmed Approach*. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1984.

[13] B. G. Silverman, Editor, *Expert Systems for Business*. Reading, Ma.: Addison-Wesley Publishing Co., 1987.

[14] W. G. Sullivan, "Models IEs Can Use To Include Strategic, Non-Monetary Factors In Automation Decisions," *Industrial Engineering*, vol. 18, no. 3, March 1986, pp. 42-50.

[15] G. J. Thuesen and W. J. Fabrycky, *Engineering Economy*, Seventh Edition. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1989.

[16] J. W. Troxler and L. Blank, "A Comprehensive Methodology for Manufacturing System Evaluation and Comparison," *Journal of Manufacturing Systems*, vol. 8, no. 3, 1989, pp. 175-183.

[17] M. S. Varney, W. G. Sullivan, and J. K. Cochran, "Justification of Flexible Manufacturing Systems With the Analytical Hierarchy Process," *Proceedings of the 1985 Annual International Industrial Engineering Conference*, pp. 181-190.