Economic Evaluation Techniques For Advanced Manufacturing Technology Investments

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. Good review.
. Discussion needs
further elaboration.
. Little Excel programming

EMGT 535

TERM PROJECT

ECONOMIC EVALUATION TECHNIQUES
FOR
ADVANCED MANUFACTURING TECHNOLOGY
INVESTMENTS

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ABSTRACT

Today's highly competitive and dynamic environment drives the manufacturers to the adoption of the advanced manufacturing technologies, so as to face the global challenge. Thus, the question for the manufacturers becomes; "which AMT investment to make?", which can only be decided after pursuing a careful analysis of the alternatives. The purpose of this paper is to provide a review of the economic analysis and justification techniques, which are gathered from the related literature, for the evaluation of the Advanced Manufacturing Technology (AMT) investments. Also a case study is analyzed as a part of this study, and the results drawn out of this examination are presented in conjunction with the discussions taking place in the other related literature.

1. INTRODUCTION

Global competition has necessitated significant changes in strategy and focus on the part of the manufacturers. Among other requirements, this led to pressures on the manufacturing firms to increase quality and respond quickly to customization, while decreasing costs. On the other hand, reactions of the manufacturers in dealing with this increasing competition has been to "automate, emigrate or evaporate."

One strategy is a greater investment and further development in flexible automation and advanced manufacturing technology (AMT). AMT, when implemented properly, provides the manufacturing firm three major strategic benefits, that are sought by managers [18];

- Improved product quality
- Reduced lead time
- Flexibility in the manufacturing environment

AMT can be defined as computer integrated manufacturing (CIM), flexible manufacturing systems and cells (FMS and FMC), flexible assembly systems (FAS), robotics, etc.

Justification and evaluation of capital allocations for AMT investments are also becoming more and more important for decision makers since these are long-term investments, which do affect the competitiveness and future of the manufacturers significantly, in this both locally and globally competitive environment.

Although the justification techniques that were developed and utilized during early years served their purposes well, the advancement of technology and an ever-increasingly competitive world forced the manufacturing firms to re-evaluate the techniques that have been embraced for so long [11, page:119]. In this project, the evaluation techniques of AMT investments that are being used, and discussions on their applications, are presented in the light of the related literature.

The decision to adopt a new technology depends critically on the feasibility of the decision's, from the engineering point of view, to the particular application. However, the project's financial and economic feasibility determines whether the firm should undertake the investment or not, especially in today's world, where manufacturing is thought not as a tactical tool, to reach the demand that already exists, but as a strategic weapon which enables the company compete in the highly competitive markets.

The outcome of this study is expected to provide the engineering managers with a detailed review of the evaluation techniques of AMT investment decisions which are currently being used, with the comparisons of these techniques presented in the related literature.

2. EVOLUTION OF TECHNOLOGY

In this section, the definition and development of AMT is given briefly in conjunction with the evolution of the justification processes of these technologies.

Early in the evaluation of technology and its use in the manufacturing function, machines were developed and used to replace humans. These machines were special purpose devices created for special repetitive operations. Meredith and Hill [13] trace the more recent development of advanced manufacturing technology by delineating four levels as in Table 1 below.

Level	Advanced Technology	Examples
1	Stand-Alone Systems	NC Machines, Robots
2	Manufacturing Cells	GT, FMS, CAE
3	Linked Islands	MRP-II,AS/RS,CAD/CAM,CAPP
4	Full Automation	CIM

Table 1. Levels of Advanced Manufacturing Technology [11]

"Traditional" economic evaluation techniques are widely used to justify Level 1 category applications. In such cases the benefits and associated cash flows are highly identifiable and quantifiable. As such; rate-of-return, payback, or discounted cash flow analysis are appropriate [13]. As one moves from this first level to higher levels, the evaluation of investments becomes more complex because of many "non-monetary" benefits which has to be taken into consideration during the evaluation processes. For example, at Level 4, the less tangible factors are often at least as important as the more readily quantifiable monetary variables, and if not considered in the decision model they are by default, assigned a value of zero in the analysis [9-15]. As a result, when one moves from Level 1 to Level 4, one is simultaneously moving toward more non-quantifiable costs and benefits. Therefore, more advanced levels of technology complicate the justification of the investments.

Another aspect of higher level manufacturing systems which affects the justification is the difficulty in forecasting the useful life of prospective projects. For Level 1 and 2 advanced manufacturing applications, the useful life of the system is relatively well established. This lends itself more readily to inclusion in a traditional accounting justification analysis in terms of the period of needed service of the machinery, or the period of the useful life of the machinery, for calculating the effects of cash flows, depreciation charges and the like in the economic model. On the other hand, because of the rapid changes in Level 3 and 4 technologies, the useful or economic life of the assets are not as easily estimated, and thus more difficult to consider in the justification process [1].

3. EVALUATION TECHNIQUES FOR AMT

Evaluation techniques for AMT investment decisions are generally discussed in the literature under these three types [14]:

1) Economic approaches

2) Analytical approaches

3) Strategic approaches

The important distinction made between these categories is the theoretical basis upon which they are founded; where the essence of the differentiation is the treatment given to non-monetary factors. Economic approaches strictly give no treatment to non-monetary factors, while analytical approaches and strategic approaches explicitly recognize the importance and inclusion of these influences.

In the remaining of this section, these three evaluation techniques are going to be presented with the comparisons and conclusions of the recent methodologies developed in these fields.

3.1. Economic Approaches:

Economic techniques have been applied in economic analysis for a number of decades [11, page:122]. Their evolution came out of a desire to base a decision upon quantified economic effects over the life cycle of proposed alternatives. These methods are relatively simple to calculate and apply; this is part of the reason for their widespread use. A listing of the economic evaluation techniques is given in Meredith and Suresh [14] as;

- Payback
- Return on investment (ROI)
- Internal rate of return (IRR)
- Net present value (NPV)

According to a 1984 survey by the National Electrical Manufacturers Association presented in a study by Bolland and Goodwin [2], 91% of the responding business executives cited payback method as their major consideration in factory automation. One can see then the importance of economic evaluation methods as perceived by today's decision makers. However, this dependence on traditional economic evaluation is also considered as the source of problems of today's manufacturing firms [2]. Fraser and Posey [8] establish a four step framework which summarizes the traditional tactical engineering economic evaluation approach. This method is similar for most engineering economic models:

1. Describe the alternatives.
2. Forecast the cash flows for each alternative.
3. Compute the NPV of cash flows for each alternative.
4. Select the alternative with the greatest NPV.

Tombari [24] divides economic evaluation techniques into two categories:

- Screening techniques
- Time value techniques

Screening techniques are those that offer an evaluator a "quick and dirty" look at investment potential; payback period and ROI are the two most widely used of these methods. As basic measures of project liquidity and risk [7] a recognized deficiency of these techniques is the manner in which they are interpreted and included in the decision process. Individual decision makers often arbitrarily incorporate their use, setting differing guidelines or project acceptance, and as such, they are often ambiguous in their application. Another shortcoming is the lack of consideration given to the time value of money, and the fact that they seek only to measure cost basis recapture.

Time value techniques are more in-depth and make a more explicit consideration of all cash flow estimates. They do consider the time value of money and therefore are more realistic. These types of methods use hurdle rates or minimum attractive rate of returns (MARR) as the interest rate that prospective projects must at least earn in order to be considered further. In most applications, the MARR is used for discounting purposes in equivalent worth calculations. As it is presented in a study by Carrasco [4], hurdle rates have in the past been artificially inflated to account for project riskiness and to incorporate any relevant tax effects that may come into play in the analysis. As such, they are many times misapplied.

Beside the misapplication of hurdle rates, economic evaluation methods are characterized by their concentration on the displacement of direct labor [4]. Although direct labor constituted a large portion of the total product cost in many industries once, today that cost is relatively small [6]. This shift has been from direct to indirect costs. Increased indirect costs have been due to the increasing costs of traditional overhead items, and the indirect costs associated with design functions, cost of quality, work in process, material tracking, and scheduling. The effect of the reduced role of direct labor in the total product cost has been to shift the burden of justification away from techniques that emphasize direct labor displacement. It is no longer appropriate to consider economic evaluation of a system like CIM or a FMS based only on the amount of direct labor savings that will be realized over the system life. As a conclusion, it can be said that; traditional evaluation methods tend to fail in the justification of AMT because, product content direct labor savings make up only a fraction of the potential overall benefits, in today's manufacturing environment.

On the other hand, for lower level factory automation operating in a specific environment, the cost and benefit cash flows of technology implementation are fairly straightforward to quantify [4]. In these applications, economic evaluation methods serve the purpose of aiding decision maker quite well. The problem arises in justifying the implementation of higher level advanced manufacturing systems because these systems are characterized by a large amount of intangible benefits which are often difficult to quantify. For these applications also, the traditional economic evaluation methods fail.

The allocation of product overhead cost is stated [11, pp.121-124] as another area where inappropriate procedures are being applied in the economic evaluation of AMT. As Lavelle et al. [11] defines, during the time when traditional economic evaluation techniques were developed to evaluate lower level automation technologies, product overhead costs were allocated as a percentage of direct labor content. That is, overhead costs accumulated as product progressed through the manufacturing processes; which worked well when the majority of costs were contained within the manufacturing function. However, in environments where the majority of costs are outside of this sphere, the concept of overhead cost is grossly distorted. Seed [19] delineates five methods for assigning indirect costs to cost centers and production:

- Unit of production
- Investment
- Standard direct conversion cost
- Standard material cost
- Total standard direct costs

Seed [19] states that, these methods make an attempt to amend past misapplication.

To try to rectify the problems associated with the traditional evaluation techniques, and with the realization of the importance of indirect and intangible factors, new formulations have been suggested. Most of these modified traditional methods seek to consider non-monetary and indirect costs and factors by recognizing their existence, and including them in the model. Rygh [16] offers a model and example of its usage in the economic evaluation of an AS/RS system, and includes a list of tangibles and intangibles as in Table 2 below.

Tangibles	Intangibles
* Manpower (direct)	* Profit on Lost Sales
* Manpower (indirect)	* Poor Management Decisions
* Maintenance	* Less Equipment Damage
* Depreciation	* Easier Housekeeping
* Interest	* Improved Working Conditions
* Excess Inventory (cost)	* Better Management Control

Table 2. Tangibles and Intangibles Used in an AS/RS Justification [16]

3.2. Analytical Approaches:

Analytical methods are used where the evaluation of investments have to be made with complex or uncertain information. These methods can be summarized as follows:

- Value Analysis:

This approach is particularly useful where attempts are being made to assess the merits of proposed but previously untried technical innovations or R&D initiatives [22, pp.25-27]. This method involves finding "value first, cost second" in a prospective alternative. The essence of this technique is to calculate the value of an alternative and then ask the question, "Is the extra value in this alternative worth the extra investment?." Keen [10] advocates the application of value analysis in the advancement and evaluation of innovation.

- Risk Analysis:

This approach involves the use of expected value analysis for the discrete and continuous variables in the decision process [3]. Included is a fitting heuristic of variables to distribution functions, and the use of those functions in the calculation of a measure of merit for decision making.

- Portfolio Analysis:

The objective of portfolio analysis is to provide assistance in choosing the optimum investment alternative from the qualified, i.e. unquantified, data [22].

- Non-numeric Models:

These evaluation techniques fall outside the normal cost/benefit trade offs. Meredith and Suresh [14] give two examples: the first is the "sacred cow", i.e. the brainchild project of a particularly influential individual where the decision to go ahead or stop is held by one person. Second example is the "operating necessity" where the project is essential for operational continuity.

- Scoring Models:

These models may either be weighted or unweighted. An unweighted model which is described by Meredith and Suresh [14] is presented to clarify the method. In this unweighted method which is named as "0-1 factor model", a set of relevant factors, or criteria, is selected and the investment is scored by several raters, simply as to whether the investment fulfill the individual criteria.

A practical tool utilized in the decision making process of AMT investments is the "Analytical Hierarchy Process" (AHP) developed by Saaty [17], which uses pairwise comparisons to get the relative importance of the project characteristics.

- Programming Models:

The advancement of the computing power of today's machines has made the programming models more attractive. Sullivan and Orr [20] describe the use of Monte Carlo simulation in an uncertain economic environment. Tayyari and Parsaei [23] propose a linear/dynamic formulation which is called "total cost analysis" (TCA). Park and Son [5] propose an economic evaluation model for AMT investment decisions by giving the key definitions for intangible benefits of AMT and expanding these benefits and costs in a formulation. In their study, they address the measurement issues of quality and flexibility. They state that quality conformance cost definitions can be used to predict the savings coming from the implementation of AMT.

- Expert Systems:

As Lavalle et al. [11] state, artificial intelligence applications are also being utilized as viable tools for economic evaluation of AMT. Although in the past, problems with development and implementation have slowed their application, expert systems have been suggested as a means in aiding decision makers in the economic evaluation process. Sullivan and Reeve [21] describe the use of XVENTURE, an expert system based decision aiding tool, which includes six factors that are important to capital investment decisions. Expert systems are defined as a new and exciting area of research and their application in the decision making and economic evaluation process is seen as a fertile area for the future [11].

3.3. Strategic Approaches:

This section describes a collection of evaluation techniques which can best be categorized as "strategic" in nature [14]. These factors deal with the implementation of technology in a manufacturing environment on the "corporate strategic" level and tend to focus on decisions that affect the entire enterprise. Meredith and Suresh [14] delineate four considerations that are often used by corporations in the economic evaluation of AMT systems as follows:

- Technical Importance:

From a strategic point of view, a desired end can not be reached unless a particular project, which is a prerequisite for an important follow-on activity, is undertaken first. Individually, the project may not be financially justifiable, but when grouped with the follow-on activity, returns may be favorable.

- Business Objectives:

A project might be found justifiable just because it directly achieves the firm's business objectives.

- Competitive Advantage:

This consideration is valid when the company bases the justification of the system on a clear opportunity to gain a significant advantage over the firm's competitors by choosing the AMT system.

- Research and Development:

An AMT investment may be a part of the ongoing R&D project. The possibility of failure is accepted but strategic impact of success justifies the risk.

An important aspect of any large AMT investment justification and implementation is the championing process. Meredith [12] points out the importance of the champion in his studies. According to his findings, a champion is an absolute necessity, regardless of the evaluation techniques being used. Meredith [12] defines the champion as the person who is in the position to assess the strategic potential of an AMT investment and spearhead a "plan top down and implement bottom up" strategy. As a result, the championing process can be looked at as a key strategic method.

4. IMPLEMENTATION

In this section, an example case including; the analysis of an AMT investment decision, chosen from a study from the related literature, and its solution; using the evaluation techniques described above, is presented. The results and comparisons of these techniques are discussed so as to clarify the strengths and weaknesses of the methods examined.

Example problem is taken from a study by Lavelle and Liggett [11, page.128]. A brief definition of the problem is given below. The solutions brought to this case, using various analysis techniques can be observed in Appendix I and II.

4.1. Case:

The Tacoma Tulip Factory is considering investing in a new AGV system to link some "stand alone" automation they currently have operating. Although they were able to reduce their decision to two competing alternatives, they could not decide which alternative to choose. The expected cash flows are as follows:

Alternative A

Investment Cost :	"$2,500,000 "
Annual Direct Labor Savings :	"$800,000 "
Annual Maintenance Cost :	"$45,000 "
Annual Operating Expense :	"$125,000 "
Annual Property Taxes/Insurance :	"$30,000 "
Periodic Rewire Cost (every 5 years) :	"$85,000 "
Annual Administrative Savings :	"$100,000 "
Estimated Useful Life (Years):	30
Estimated Salvage Value :	"$500,000 "

Alternative B

Investment Cost :	"$4,000,000 "
Annual Direct Labor Savings :	"$1,000,000 "
Annual Maintenance Cost :	"$20,000 "
Annual Operating Expense :	"$20,000 "
Annual Property Taxes/Insurance :	"$65,000 "
Periodic Rewire Cost (every 5 years) :	"$70,000 "
Annual Administrative Savings :	"$66,000 "
Estimated Useful Life (Years):	30
Estimated Salvage Value :	"$0"

Analysis of this investment is made using economic analysis methods (NPV, IRR, Benefit-Cost Ratio and Payback) and analytical approach (Analytical Hierarchy Process- Utilizing the Expert Choice Software Package). Solutions (See: Appendix I-II) are compared with the findings of Lavelle and Liggett [11], which also includes an additional solution to the particular problem using a strategic approach.

When the case is analyzed using economic approaches, considering a MARR of 20%, the NPV of alternative A is found to be higher than alternative B, which recommends the decision maker to choose alternative A. The IRR's of both alternatives are calculated to be same (28%). When Benefit-Cost Ratios and Payback Periods of these two alternatives are calculated, alternative A happens to be a better investment than alternative B (See: Appendix I).

When the case is solved by using AHP (Using the Expert Choice Software), which is an analytical approach developed by Saaty [17], alternative A is again recommended as the best alternative since it maximizes the AHP Total Weighted Score (See: Appendix II).

Another solution, which is given in the study of Lavelle and Liggett [11], using the strategic approach, recommends alternative B as the best choice, according to the weighted evaluation technique that it uses.

As a result of these solutions, it has been observed that, the decision among AGV systems for the Tacoma Tulip Factory is effected by [11] :

1) the category of justification/evaluation technique used,

2) the types of attributes considered in evaluating these alternatives.

The final decision is left to the consideration of the decision maker because of the conflicts among three approaches.

5. CONCLUSION

This work represents an investigation into the topic of economic methods for evaluation and justification of investments in AMT. It includes not only the traditional approaches, but also the new techniques and much of the recent discussions taking place in the related literature. Changes in the technology and the need to compete in a world-market are the two factors which escalated the importance of economic evaluation and decision making processes of advanced manufacturing technology investments. In addition to the main purpose of this study, which was to provide an overall review of the AMT investment evaluation techniques, a number of other factors, with respect to the differences in old and new methods, are also discussed. A case study is presented as an example to compare the viewpoints of these techniques. Regarding the findings of the studies in the related literature, the conclusions of this study, including the comparisons of the economic analysis techniques of AMT investments, are drawn out as follows:

Economic approaches, which can be named as NPV, IRR, ROI, Payback Period etc., tend to focus on "short term" goals. These approaches don't allow for "intangible" factors explicitly. Some of these approaches don't recognize the "time value of money." Analytical approaches, which include AHP, value analysis, risk analysis, programming models etc., allow for monetary and non-monetary factors. These methods can be very detailed, based on the size of the problem.

Strategic approaches are considered in the long term AMT investment decisions. In these approaches, attributes tend to be both intangible and subjective. Linear scoring can be given as an example of this type of evaluation approaches.

As a result, regarding the discussion above, it is the engineering manager's competence, to decide which approach to pursue in the evaluation process of advanced manufacturing technology investments. In addition, it seems to be one last important point to mention; in today's highly competitive and dynamic environment, decision making process of AMT investments is more than an economic analysis; in fact it is the successful combination of interdisciplinary management practices.

REFERENCES

[1] Bennett, R.E., Hendricks, J.A.,"Justifying the Acquisition of Automated Equipment," Management Accounting, July, 1987, pp.39-46.

[2] Bolland, E., Goodwin, S.L., "Corporate Accounting Practice is Often a Barrier To Implementation of CIM," Industrial Engineering, July, 1988, pp.24-26.

[3] Buck, J.R., "Risk Analysis Method Can Help Make Firms' Investments Less of a Gamble," Industrial Engineering, November, 1982.

[4] Carrasco, H.R., "Justification of Advanced Manufacturing Systems Using Multi-Attribute Decision Analysis," Proceedings from IIE Integrated Systems Conference & Society for Integrated Manufacturing Conference, November 12-15, 1989, pp.564-568.

[5] Chan, S. Park, Young, K.S., "An Economic Evaluation Model for Advanced Manufacturing Systems," Engineering Economist, Vol.34, No.1, Fall 1988, pp;1-25.

[6] Curtin, F.T, "New Cost Methods Needed For Manufacturing Technology," Management Review, April, 1984, pp.29-34.

[7] Degarmo, E.P., Sullivan, W.G., Bondatelli, J.A., Engineering Economy-8th Edition, Macmillan Publishing Co., 1988.

[8] Fraser, J.M., Posey, J.W., "A Framework for Replacement Analysis," European Journal of Operational Research, 40, pp.43-57.

[9] Hunter, S., "Cost Justification : The Overhead Dilemma," Robots 9 Conference Proceedings, 1982.

✗ [10] Keen, P.G., "Value Analysis: Justifying Decision Systems," MIS Quarterly, March, 1981.

[11] Lavelle, J. P., Liggett, H. R., Economic Methods for Evaluating Investments in AMT, Ed. H.R. Parsaei at al., Elsevier Science Pub., 1992, pp.119-139.

[12] Meredith, J.R., "Strategic Planning for Factory Automation by the Championing Process," IEEE Transactions on Engineering Management, Vol.EM-33, No.3, August, 1986.

[13] Meredith, J.R., Hill, M.M., "Justifying New Manufacturing Systems: A Managerial Approach," Sloan Management Review, Summer, 1987, pp.46-61.

[14] Meredith, J.R., Suresh, N.C., "Justification Techniques for Advanced Manufacturing Technologies," International Journal of Production Research, Sept.-Oct., 24(5):1043-1057.

[15] Meyer, R.J., "A Cookbook Approach to Robotics & Automated Equipment," Robots 9 Conference Proceedings, 1982.

[16] Rygh, O.B., "Justifying an Automated Storage and Retrieval System," Industrial Engineering, July, 1981.

[17] Saaty, T.L., The Analytical Hierarchy Process, New York:McGraw Hill, 1980.

[18] Sarkis, J., "The Evolution to Strategic Justification of Advanced Manufacturing Systems," Economic and Financial Justification of AMT, Ed. H.R. Parsaei at al., Elsevier Science Pub., 1992, pp.141-163.

[19] Seed, A.H., III, "Cost Accounting in the Age of Robotics," Management Accounting, Oct., 1984, pp.39-43.

[20] Sullivan, W.G., Orr, R.G., "Monte Carlo Simulation Analyzes Alternatives in an Uncertain Economy," Industrial Engineering, November, 1982.

[21] Sullivan, W.G., Reeve, J.M., "XVENTURE: Expert Systems to the Rescue," Management Accounting, October, 1988, pp.51-58.

[22] Swann, K., O'Keefe, W.D., "Advanced Manufacturing Technology : The Investment Decision Process. Part 1," Management Decision, Vol.28, No.1, 1990.

[23] Tayyari, F., Parsaei, H.R., "Cost Analysis for Economic Justification for Automated Technologies," Proceedings from IIE Integrated Systems Conference & Society for Integrated Manufacturing Conference, November 12-15, 1989, pp.584-587.

[24] Tombari, H.A., "To Buy Or Not To Buy: Weighing Capital Investments," Production Engineering, March, 1987.