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Cost justification problems for AMT investment and related issues are explored in this paper. Literature on economic evaluation methods for advanced technology are summarized along with their applicability and practicality. As a last point, the engineering manager's role in such a decision is discussed.

COST JUSTIFICATION OF
ADVANCED MANUFACTURING SYSTEMS

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ABSTRACT

Productivity, competition, and satisfaction of customer needs drive the manufacturers to examine the advanced manufacturing techniques such as Flexible Manufacturing Systems, Just-in-Time, CAD/CAM, etc. Technology is available for better production quality and higher degree of flexibility. The question is to make the investment decision for being competitive based on an economic evaluation.

Cost justification problems for AMT investment and related issues will be explored in this paper. Literature on economic evaluation methods for advanced technology will be summarized along with their applicability and practicality. As a last point, engineer manager's role for such a decision will be discussed.

1. INTRODUCTION:

Traditional capital investment decisions performed by engineers dealt with the replacement or retirement of obsolete equipment in manufacturing firms. Today, rapidly changing technology and shortened product life cycles lead to an uncertain economic environment. Moreover, changing characteristics of manufacturing techniques require complex decision analysis [12,page:42]. Traditional cost accounting methods do not help to discover these characteristics. Since, current accounting measures are based on mass production analyst can not get the required data.[9,page:1]

The decision to adopt a new technology depends critically on its engineering feasibility to the particular application. However, the project's financial and economic feasibility determines whether the firm would invest or not. Special characteristics of advanced automation techniques require several modifications of conventional capital budgeting methods.[7,page:949]

There have been some criticisms of the use of Discounted Cash Flow (DCF) techniques, such as Net Present Value (NPV) or Internal Rate of Return (IRR) for evaluating manufacturing system investment decisions on the validity of the conceptual basis. Hodder[5] gives the conceptual weaknesses, bias against long-term projects and an inability to evaluate strategic investments with future growth opportunities as the objections to DCF techniques. In the same paper, it is also stated that the argument of the use of DCF analysis' leading to an underinvestment in long-term projects.

Suresh[14] summarizes the investment justification problems as; "the high capital costs of integrated systems, capital budgeting procedures emphasizing fast payback with the short term oriented reward systems, shrinking product life cycles, high rates of obsolescence in machining technologies, and above all, the problems in the quantification of intangibles like improvements in quality, lead time, and flexibility" [14,page:1658]. These intangible benefits are as important as the use of correct evaluation techniques and cost accounting system and they make more difficult to analyze the project appraisal.

In this paper, first we will explore the available literature looking for the alternatives to solve the problems that were stated briefly above. Conventional cost accounting system deficiencies, quantification solutions for intangible benefits, general approaches to make an investment decisions, and finally the comparison of Japanese investors in manufacturing and

U.S. manufacturers will be presented. In section 3, we will try to emphasize the role of engineering economists in this environment in relation to his/her expanding role through the strategic decisions.

2. ISSUES, METHODS, and APPLICATIONS:

2.1 Evaluation Techniques of Intangible Benefits:

High quality, reliable delivery, shorter lead times, flexible capacity are important considerations for today's manufacturing environment. Economic evaluation of new manufacturing systems should include these points to come up with a more reliable decision basis. After realizing the limitations of traditional economic evaluation models, practitioners developed different modified models.

Kulatilaka [7] have proposed a theoretical model consists of consideration of benefits such as reliability, product quality improvements along with any other expected traditional costs and revenue. She summarized the incremental, when compared to existing plant, expected cash flows of the proposed FMS project as follows:

(A)Initial Costs (incurred at time 0)

1)Purchase of machine and equipment

2)Rearrangement of plant and space savings

3)Redesigning of product

4)Interfacing costs

5)Retraining labor and/or hiring labor with new skills

6)Other installation costs

(B)Operating Costs/Benefits (incurred throughout system life)

1)Labor savings

2)Increased skilled labor

3)Material savings

4)Energy cost increases

5)Heating, lighting cost charge

6)Lower inventory costs

7)Revenue from increased output to faster switching times,etc.

8)Other product and plant specific operation costs

(C)Tax Effects

1)Taxes on net change in operating cash flows

2)Investment tax credits

3)Depreciation tax shields

[7,page:954]

Kulatilaka expands her analysis by adding the risk consideration to the obtained cost/benefits to give a single NPV formula for the project. However, it is difficult to implement this conceptual model in practice.

Park and Son [9] propose an economic evaluation model for advanced manufacturing techniques (AMT) by giving the key definitions for intangible benefits of AMT and expanding these benefits&costs in a formulation. In their paper,they address the measurement issues of quality and flexibility. Quality conformance cost definitions can be used to predict the savings coming from the implementation of AMT. These costs are prevention costs, appraisal costs, internal failure costs, and external failure costs. In general, "quality of conformance refers to the degree with which the final product meets its specifications" [9,page:4]. This categorization gives the desired documentation for quality measurement. There are some indicators and available data in standard accounting system that can be used to reflect product service effort, remedial engineering, and production rework. These are include; direct labor, total scrap, warranty expenses, product liability, maintenance and repair on these equipment [9,page:5]

Primrose[10], and some other literature [1,2,6,15] are agree on the definitions of better quality products measurement indicators. He gives a list of criteria:

1.Reduced cost of scrap

2.Reduced cost of rework

3.Reduced warranty and service costs

4.Reduced cost of lost production carried by scrap and rework

5.Reduced inspection and quality control costs

6.Increased sales of better quality products.

Park and Son paper also defines some flexibility types. Their flexibility types include the equipment flexibility, product flexibility, process flexibility, and demand flexibility. However, Azzore-Bertele give a more complete definitions for flexibility types. Additionally, they relate these definitions to the measurable benefits of an FMS to be used in an economic analysis.

In Park and Son study, the opportunity costs are introduced as the cost of not adopting the new technology. Opportunity costs do not represent actual dollar outlays, rather they represent "those economic benefits that are foregone as a result of pursuing some alternative course of action".[9,page:7]

Robert Kaplan states the importance of the opportunity cost consideration by giving an example from Henry Ford: "If you have to need a new machine and don't buy it, you pay for it without getting it." [6,page:88]

In Park,Son formulation opportunity costs, earned benefits from improved quality, and flexibility are combined along with the traditional investment costs. Their model allows the calculation of multiperiod production performance. Constraints are based on limited resource allocation, budget allocation, and balance of supply and demand. In their mathematical model, objective function is to maximize total revenues, after subtracting inventory and other tangible manufacturing expenses. This study covers all aspects of an advanced manufacturing technique investment analysis and gives a complete insight.

Azzone and Bertele outline a method for the evaluation of flexible manufacturing systems, which considers both economic and strategic aspects. It has been pointed out that the choice of a manufacturing system should not be done just according to economic and financial evaluations, but also checking its coherence with the firm's strategic position as well. Another perspective is that profitability computation gives a better comparison index for the decision of flexible manufacturing system implementation.

Azzone-Bertele study combines these two approaches. In short, they believe the selection of an investment should be done on the basis of its profitability. Since the profitability of a manufacturing system depends not only on the first planning but also on its the firm's strategic position, the correct evaluation of investments in flexible automation requires net cash flows to be expressed as a function of the firm's strategic position.

Their method in detail consists of three steps [1,page:763];

1.The firm's strategic position is expressed by a few numerical values each representing a performance required of the manufacturing system. All system is fulfilling these requirements are equivalent with respect to the firm's strategic position.

2.The general concept of flexibility is subdivided in a few elementary concepts. Each elementary flexibility can be measured either deterministically or stochastically.

3.Connections between the cost of obtaining strategic performances and the manufacturing system's flexibility are defined. These definitions allow to consider the effect of flexibility on investment's expected net cash flows.

There are four levels of variables which are effective with each other levels. Distribution of demands, response time, level of service, technological compatibility, and frequency of introduction of new products are constructing the first level of hierarchy. They are affecting the upper level components; machining capacity, costs (fixed and variable), demand, and prices. These two step factors in combination determine the investments, costs, and revenues. At the top level these three are controlling the profitability of the firm.

On the other hand, each flexibility types (they used as the types of flexibility the followings; routing flexibility, process flexibility, product flexibility, production flexibility, volume flexibility, and expansion flexibility. They have chosen these six elementary flexibility types to characterize their system's performance in economic evaluation.) influences every dimension of the model. Azzone-Bertele model synthesis the four submodels concerning respectively determination of product mix, calculation of machining times, computation of the number of machine tools, and evaluation of cash flows.

In summary, they attempt to connect a firm's strategic position with investment's profitability by coming from operational level.

Other researchers give other aspects of quantification of intangible benefits and costs as well as identification of unusual characteristics of an FMS evaluation. Suresh[14] presents a decision support system (DSS) structure for flexible automation investments. Since the available analytical models continue to grow and the simulation methods become more sophisticated, there is a need to integrate a diverse range of tools and techniques into an effective decision support system for this important application.

Suresh study introduces an important evaluation requirements: Most of the studies have assumed a one-time implementation of an integrated system. But, Suresh says that "a phased or modular implementation is likely to be the norm in most cases". This progressive perspective should be included to all investment analysis.

Dynamic environment of flexible manufacturing system and its effect on the evaluation were discussed by Kulatilaka [8]. The difference of this study's methodology is to identification of benefits of FMS that arise from the ability to cope with uncertainty. A stochastic dynamic programming model used in this paper to capture the value of flexibility along with the dynamic operating schedule of the production process. This study's results can be used to determine the importance of FMS, and it proposes a way to modify existing capital budgeting methods.

2.2 Cost Accounting Issues for AMT Investment:

Management accounting system's roles are to develop appropriate performance measures and to design the company's cost accounting system [2,page:206]. Kaplan [6] discussed the issues related to cost accounting system inadequacies. The nature of competition and the demand for internal information which were provided by cost accounting system were very different today from the days present cost accounting principles have been set. This makes the provided accounting information unreliable to use for an AMT investment decision.

Kaplan and Johnson [2,page:209] have classified the management accounting system's shortcomings into three categories:

(1)Unreliable information; Current management accounting systems do not provide relevant information to help operating managers to reduce costs and improve productivity.

(2)Distorted product costing; These systems do not accurately measure the costs associated with manufacturing, marketing and distributing each of a firm's individual products.

(3)Short-run vision; The emphasis on periodic financial statements forces managers to take a short-run view of profitability, at the expense of long-run viability.

Burden[2] provides a good overview on management accounting systems in an AMT environment. He summarizes the literature from following point of views; performance evaluation,product costing & activity based cost accounting. According to Kaplan & Burden a compatible cost system should capture the measures for quality, inventory performance, productivity, flexibility and innovation. If the firm's accounting system report the required information for critical performance measures and emphasize a long-term vision, the AMT project proposals can be evaluated on a reliable basis.

In this context, we can see the connection between management cost system and Flexible Automation System implementation. Quantification problems of intangible benefits are stated in different ways. Analyst need proper definitions and measures of these benefits to use in the proposed evaluation techniques. Revised management accounting system provides us this information.

Primrose[10] acclaims that every benefit can be identified and they can be redefined. With the help of redefinitions, benefits can be quantified.[10,page:191] He shortly describes the procedure in two stage;

1.Re-define into quantifiable terms

2.Calculate the magnitude of the value.

The other requirement for new management cost system is true product costing. Pricing decisions, new product introductions, the dropping of obsolete products, and response to competitors' products can be done on time just by the correct information. As a result, we can say that the cost accounting system has a strategic importance in concerning with the viability of an implemented advanced manufacturing system.

As an alternative to traditional cost accounting system, Activity- Based Cost (ABC) accounting system has been suggested. ABC fits the needs of FMS. It handles the diverse product mix and volume resulted from FMS. ABC allows to understand the impact of different designs on cost and flexibility and to modify their designs accordingly.

2.3 Review of Methods used to Evaluate Investment Projects:

For a world-class manufacturing firm, the capital investment decision requires different cost justification tools to capture every aspects of decision analysis. We discussed the difficulties of manufacturing investments. In general terms, these difficulties are;

a)Intangible benefits

b)Outdated cost system

c)Crude traditional investment analysis methods

d)Dynamic flexible manufacturing environment

Flexible automation allows the rapid change in product mix, volume and higher quality. As a result of these advantages, it is hard to anticipate the coming years' production schedules. Even after quantification of intangible benefits, we still need some modifications in evaluation models. In the first part of this section some new methods summarized. In general, we can apply more sophisticated models in combination.

Reeve and Sullivan[11] give a good summary of the methods applicable to interrelated investment analysis. These techniques can be classified as follows;[11,page:116-134]

1.Mathematical programming

2.Option value analysis

3.Scoring models

4.Simulation techniques

5.Decision flow networks

6.Artificial intelligence and knowledge based expert systems

Swann and O'Keefe[15] introduced similar techniques under a different scheme. They state Payback, ROI, IRR, and NPV as economic justification methods. Value analysis, portfolio analysis, risk analysis, mathematical programming, and scoring models are grouped as analytic approaches. Finally, technical importance, business objectives, and competitive advantage are underlined as strategic analysis techniques. Since the advanced manufacturing methods are strategic and long term investments, ideally we need a method that combine and evaluate the intangible benefits, strategic implications, and the economics. We will briefly discuss some of these methods.

1.Mathematical Programming:

Linear, Integer, or Dynamic programming techniques can be used. They attempt to maximize (minimize) an objective function subject to a number of constraints. The mathematical models cannot capture the risk. Another disadvantage is that one objective function formulation. Additionally, the model is correct to the extent the input into the model is valid.[11,page:119]

2.Option Value Analysis:

Value analysis involves an incremental approach. This method captures the consideration of value implicit in the active management of projects. Active management is defined as "the prerogative of management to change the course of action of an existing project by either abandoning the project, lengthening or shortening the investment commitment time period, coupling existing projects with new projects to achieve future growth, committing investments to maintain flexibility, or any other type of contingent based planning that represent options to the firm". [11,page:120]

This method captures the value of time phased active management in the project selection decision. On the other hand, the applicable areas for option value analysis are limited.

3.Scoring Models:

Scoring models weight the subjective criteria of an investment decision. In simple unweighted model, a set of relevant factors, or criteria, is selected and the project scored to whether the project fulfills the individual criteria.

This approach has the capability to provide a much more finely tuned results. However, more extensive data collection or intuitive managerial judgments are needed. Additionally, the assumption of linearity and criterion independence becomes more questionable as the model becomes increasingly complex.[15]

A practical approach to solving relatively difficult project ranking problems is the "Analytical Hierarchy Process" (AHP). This methodology uses pairwise comparisons to get the relative importance of project characteristics.

4.Simulation:

Simulation describes a more systematic approach to risk in which a series of investment variables are subject to random variation. It involves the following stages;

1)A series of variables are identified which are to be subject to random variation.

2)Simulation of random variation is assigned to each variable based on managerial perception.

3)A total NPV for the project is calculated by taking random combination of the variables.

4)A distribution of project NPV's is obtained by repeating the process many times over all the variables.

5)Project NPV's can then be compared.

The simulation can be built from known data without understanding all aspects of the problem. The output is easily be interpreted. Sensitivity analysis can be performed.

5.Decision Flow Networks:

This type of analysis especially convenient at modeling investments over a long period. Each time phased decision has outcome probabilities which then lead to the next periods' decision branch [11,page:127]. There exist some complexities in network design of big problems. However,this method incorporates more data then mathematical programming does, and measures risk.

6.Artificial Intelligence/ Expert Systems:

These systems allow a more flexible approach to problem solving. Expert systems use heuristic that enable to suggest a solution to problems which are not easily formulated with any other method. Its applications are increasing everyday. Many software systems are available. But developing an expert System is very time dependent and an expensive method.

3. MANAGEMENT IMPLICATIONS:

3.1 Strategic Decision Making & Advanced Manufacturing Techniques

Considering the impacts and capacities of flexible automation, we can confidently say that advanced manufacturing techniques are powerful alternatives for tomorrow. We discussed the some important system barriers against the implementation of these techniques in the preceding section. Even for these barriers, advanced automation methods are promising for better quality, higher productivity and flexibility, and the other targets of today's manufacturers.

Since the investment decision for AMT is being made in a very uncertain environment (future technology changes, sales forecasting, etc.) and it is required the use of a lot of information, comes from different levels of a firm, effective decision making can be accomplished only by synthesis of operational level technical data with strategic level vision. Fraser, and Leimkuhler[4] define three levels of decision in an organization: strategic, tactical, and operational.[4,page:149] "The three levels are differentiated by time: How often the decisions are made and for how long the decision will affect the firm." Strategic decisions affect the organization for many years and therefore should be made by considering costs and benefits of a project over a long period. Considering the long term benefits of flexible automation systems we can conclude it is a strategic investment. At the same time, the investment decision involves detailed analysis sometimes including the leaving some short term benefits. In other words; "Strategic decisions usually involve trading off losses in near future for large gains far in the future" [4,page:150].

3.2 Strategic Decision Making and Engineering Economy

Converse to traditional engineering economy, today's investment decision makers has evolved into a "bottom-up" set of principles and techniques for evaluating the economic merits of proposed capital investments.[12,page:42-44]

Engineering economy practitioners typically dealt with tactical rather than strategic investment decisions. However, in an AMT environment they deal with multiple objectives, uncertain and continuous dynamic environment, nonmonetary factors rather than classical replacement analysis, comparison of a "defender" and "challenger" machine tools. In this new era, engineering economists role changed through strategic decision making. At the same time, literature indicates that the inadequacies of traditional investment analysis techniques such as payback period,ROI, NPV, were perceived by the management. But, because of the lack of more acceptable and practical approach they continue to use the conventional methods. "If engineering economy practitioners are to assist management in the appraisal of new technologies that are essential to a firm's survival, different models and methodologies must be developed and applied to actual problems."[12,page:45] To come up with a such methodology, the practitioners have to work with operational level engineers and they should combine this technical data with the global issues of organization.

Sullivan[13] discusses the changing role of Engineering Economists with the changing industrial conditions. He introduces a new way thinking for engineering economists. According to this study, formulation and execution of strategy, development of critical factors, monitoring against target have the highest priority for engineering economy. Development of ideas and options; cost management systems; and the correct process are coming next to survival goal respectively. He adds the potential interest areas to engineering economy practitioners. These are:

(1)What financial and non-financial performance measures are actually needed to judge investments in the light of a firm's strategy for remaining competitive and ensuring its survival?

(2)How might the principles and techniques of engineering economy be utilized to assist in the creation of more life-cycle complete but less costly solutions to engineering problems?

(3)Can activity-based cost management systems (CMS) accurately measure costs associated with scale, scope, experience, technology and complexity, and can CMS actually lower product costs through improved allocation of resources during conceptual design activity?

(4)How can investment decision making be redesigned to allow the dynamics of a volatile marketplace to be interpreted across interrelated portfolios of present and planned resource commitments?

3.3 Japanese and U.S. Practices Comparison:

Another consideration comes from the comparison of the Japan practices with the U.S. investors. We do not have extensive literature on Japanese investment decision analysis. Hodder's study gives us an overview about this topic. His study is based mostly on interviews with executives of Japanese manufacturing firms.

This study explained the one year ROI calculation is widely used in Japan. Even there are some varieties in this analysis usage, the basic idea is that estimating the project's accounting income for a "typical" year and dividing by the initial investment.[5,page:19] Most Japanese firms are not formally using DCF techniques, they incorporate the time value of money in their analyses.

In the same study it is explained that Japanese firms compensate this crude analysis with the extensive discussions of underlying assumptions and possible future scenarios. The widespread use and misuse of risk-adjusted discount rates in the U.S.is stated as one difference in practices of two countries. The other is more extensive discussions in Japanese firms of project assumptions, including risks and possible management responses. This approach could be the main concern of U.S. firms.

4. CONCLUSION:

Recognizing the importance and necessity of the advanced manufacturing technologies, firms are giving more attention to justification problems of the new techniques. Engineering economists role is changing as well as the management practices for engineers.

Fundamental problems in cost justification of investment analysis for flexible automation are explained with their other issues. Basic difficulties can be summarized as follows:

1.Incompatible traditional investment techniques.

2.Using traditional cost accounting system.

3.Difficulty of quantification of intangible benefits.

4.The large capital investment.

5.Lack of long term vision.

All of the subjects are potential and critical subjects for engineering & economy disciplines. Today, an advanced technology investment decision is more then an economic analysis. It is the result of a successful interdisciplinary management practices.

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