APPLICATIONS OF SEQUENTIAL ANALYSIS: A TOOL FOR DECISION MAKING IN CAPITAL EXPENDITURES

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Bachelor of Science

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Stillwater, Oklahoma

1964

Submitted to the faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF BUSINESS ADMINISTRATION
August, 1965

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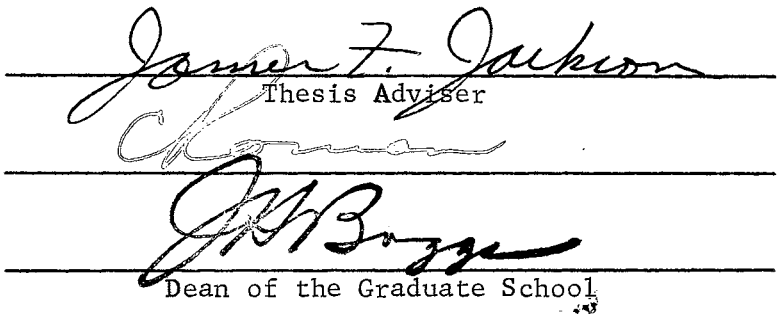
Thesis Approved:



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ACKNOWLEDGEMENT

The writer wishes to thank his adviser, Dr. James F. Jackson, for his useful suggestions and guidances during this study. Also, the writer appreciates Dr. Milton F. Usry and Dr. W. W. Thompson serving on his report committee.

Acknowledgement is also given to the Engineering and Development Department of Continental Pipe Line Company for the assistance that was rendered in preparation for this report.

The writer also wishes to express gratitude to his wife, Ann, for her patience and encouragement throughout the graduate program.

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CHAPTER I

INTRODUCTION

Sequential Analysis is an analytical technique for exposing the anatomy of a business investment decision in order to provide helpful information for identifying the choices, risks, gains, and goals open to an enterprise. This paper presents sequential analysis as a tool which enables management to evaluate in a more direct manner the uncertainty and risk involved in possible future decisions. The organization of analysis illustrates the interaction of decision events, chance happenings, competitors' actions, consumer demands, and possible future decisions and alternatives open to the business.

In order to get an overall view of the capital expenditure decision, the report begins with the phases of application of this technique and continues with the illustration of sequential analysis for three types of capital investments: a long-term asset, an incremental product addition, and for research and development.

Several limitations must necessarily be explained. The newness of this tool of analysis is noted by the fact that recently many firms have instituted some sort of discounted return technique for capital expenditure evaluation. The sequential analysis approach for decision making purposes is studied from a theoretical viewpoint and is relatively untested as a practical tool of evaluation. The technique requires certain assumptions which will be noted in the text. The last limitation noted

involves the application of sequential analysis. Due to the lack of availability of case studies, hypothetical cases are developed for illustrative purposes. In an effort to make these as realistic as possible a certain amount of pertinent information has been acquired from several leading petroleum companies. With the basic purpose, scope, and limitations of this analytical approach in mind, the basis groundwork has been established. This allows the presentation of a complete description of sequential analysis.

The Decision Making Approach

Investment decisions can be made more intelligently and effectively with the implementation of better methods of identifying and estimating risk and uncertainty. Three layers of knowledge can be described as necessary to management in the decision making approach. First, there is knowledge of methods and techniques, useful in devising answers to specific problems. Second, there is the knowledge of important realities, conditions, and trends affecting the nature of a business situation. Third, there is the knowledge of what goals, policies, and procedures are desirable for the organization.[1] The first layer is relevant to sequential analysis as presented here.

Analysts trained in marketing, operations research, engineering, and finance have a real contribution to make. However, these disciplines need to be integrated in the project if management is to get a clear picture of the available alternatives and their consequences. The following

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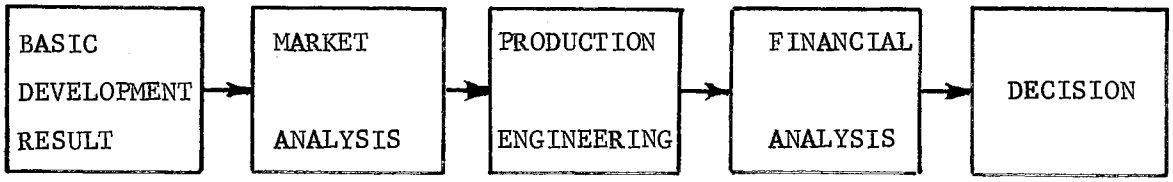
[1]David W. Ewing, "The Knowledge of an Executive," Harvard Business Review, Vol. 42 (March-April, 1964), p. 92.

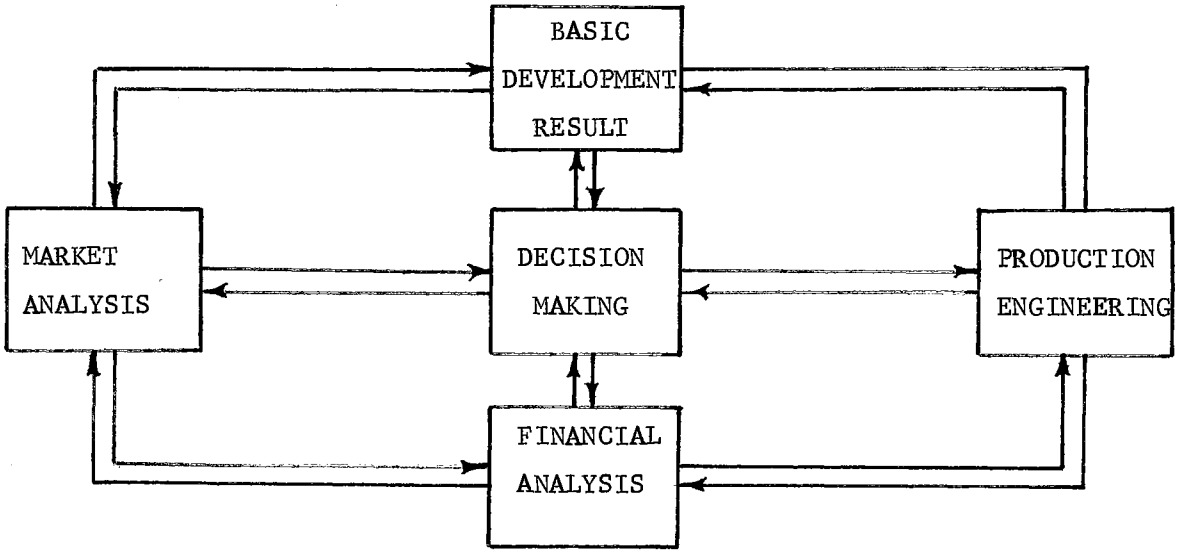
illustrations note the differences in approach to the decision making process.[2]

Too often the analysis and decision process on a new investment opportunity seems to follow this sequence.



There may be some interaction between market analysis and production engineering or between production engineering and financial analysis, but not a great deal.

The type of interaction which management must seek to become more effective looks something like the diagram below.



The decision making nucleus of the preceding diagram is top management, where the final analysis and decision inevitably will take place. As can

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[2]John F. Magee, "How to Use Decision Trees in Capital Investment," Harvard Business Review, Vol. 42 (September-October, 1964), pp. 81-82.

be seen by these two diagrams, decision making is an integrated function of the different operations of a business organization.

To be able to carry out this integrated function, management must have efficient and well-designed tools with which to work. Decision making in the present time has been augmented by such techniques as PERT (Project Evaluation Review Technique), PERT-Cost, CPA (Critical Path Analysis), Game Theory, Simulation by computers, Mathematical Programming and Sequential Analysis. As the title indicates, Sequential Analysis (synonymously known as "Decision Trees,") is one of these tools; in the following pages the application, procedures, and ramifications of its use are presented.[3]

Before the presentation of sequential analysis as such, two questions must be explored to understand the importance and necessity of effective decision analysis. They are stated as follows: (1) What is function of investment capital in the firm?, and (2) Why do we need to assess risk and uncertainty?

In answer to the first question it is seen that management judgment exercised in directing the flow of new funds into the business enterprise has a very significant bearing upon current and future earnings per share and a profound influence on the long-term growth and development of the firm. To an investment banker the function of capital is to earn a return. To management the function of capital is to get inputs changed into outputs in the most efficient manner in order to maximize the capital investment by profits and consumer satisfaction. Bierman and Smidt refer

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[3]John F. Magee, "Decision Trees for Decision Making," Harvard Business Review, Vol. 42 (July-August, 1964), p. 126.

to the term investment as the commitment of resources made in the hope of realizing benefits that are expected to occur over future time periods.[4] The function of capital, then, is to permit management to meet the manufacturing and marketing objects more efficiently.[5]

The second question concerning risk assessment is one which has in the past, now does, and will in the future make decision making a more and more important necessity to organizational operation. Business decisions fall into essentially two different contexts which are conditions approaching certainty and conditions of uncertainty. The quantitative analysis which supports decision making under certainty usually takes the form of maximizing some objective (e.g., profits or production) subject to a set of constraints (e.g., costs).

Decision making under risk and uncertainty requires some modification in the procedure. The constraints and the function to be maximized are not precisely known by the decision maker. This requires management to make estimates of the relevant parameters in such a way that subsequent actions are based on these estimates. Guess estimates, historic data, industry comparison and projected research are all sources of information for the quantifying of effects on profits by risk and uncertainty. The terms risk and uncertainty are used together to describe situations where all the relevant consequences of the alternatives are not known. There are actually two elements of uncertainty to be considered in making the

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[4]Harold Bierman, Jr., and Seymour Smidt, The Capital Budgeting Decision (New York, 1960), p. 2.

[5]James C. Hetrick, "Mathematical Models in Capital Budgeting," New Decision Making Tools for Managers, ed. Edward C. Bursk (Cambridge, 1963), p. 189.

internal investment decisions: (1) What is the likelihood that the estimate of cash flow is correct? and (2) What happens to the profit prediction if the actual events do differ from the predicted events?[6] The need to try to evaluate risk and uncertainty then becomes necessary because the decision maker does not know all relevant consequences of the alternatives under consideration. Since the investment of money involves risk, the object of evaluation is the employment of available funds to obtain the maximum advantage for the business enterprise.

Capital expenditure decisions form the framework for a company's future development and are a major determinant of efficiency and competitive power. Top management needs an objective means of measuring the economic worth of individual investment proposals in order to have a realistic basis for choosing among them and for selecting those which will best achieve the company's long-run goals. Decision trees as presented here provide top management with an objective means of measurement. The next chapter involves the six phases of a capital expenditure decision and the Sequential Analysis technique.

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[6] Bierman and Smidt, p. 123.

CHAPTER II

THE PHASES OF APPLICATION OF SEQUENTIAL ANALYSIS

Chapter II presents a set of broad guidelines which direct the reader toward application of sequential analysis as a tool of evaluation for capital expenditures. This section brings together pertinent information and data which can be placed on the "tree" of decisions and develops an expository device which is used to present the "life history" of an investment proposal. This "life history" is an idealized one in that it presents the stages that a proposal should go through in a decision making process.

The decision making procedure for expenditures is divided into six parts. Before the actual breakdown of the decision process, it is advantageous to examine capital investments in general.

Successful operation of a business requires a continuing series of correct profit-producing decisions. Decision making errors may be serious, but an error in the selection of a purpose to use capital funds is usually costly. Management needs an investment yardstick which can be applied to any proposal and make it comparable with all other investment opportunities. One of the best ways to look at these is by comparing rates of return.[1] In the following sections relevant techniques of data collection

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[1]Charles B. Allen, "Evaluation of Capital Projects--An Application of the Investor's Method," N.A.A. Bulletin, Vol. XLII (January, 1961), p. 45.

and application are examined.

This text deals with the relationship of capital expenditure evaluation processes and the decision tree technique. It is one task to analyze, compile, and apply a series of basic steps in a decision making process. It is quite a different task to strive to relate this information to a specific technique. The current literature and texts have been perused, and the results of this search are contained in the six phases of application. These phases are Consideration, Investigation, Correlation, Implementation, Regulation, and Evaluation. In order to visualize the scope and interrelations of these stages, Figure 1 is used as an illustration.

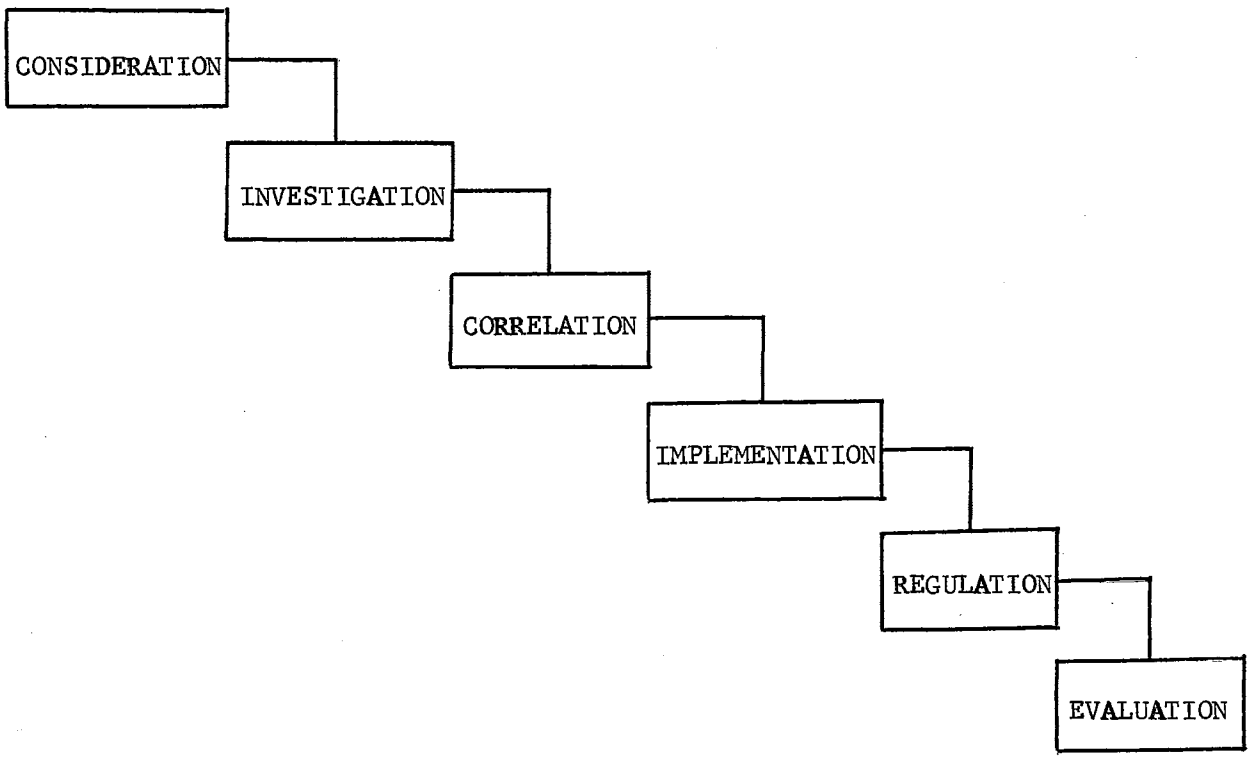

Fig. 1. Six Phases of Application of Sequential Analysis

With the utilization of these six stages, a systematic approach evolves which is important in the decision making process. What management needs is not just a tool of analysis or formula for applied evaluation, but a method of logical reasoning by which the resultant decision for expenditures is derived. Much has appeared in the literature about techniques that answer specific questions for particular situations. This paper presents a technique which reduces the misdirection of management efforts. C. Jackson Grayson, Jr., states that the main advantage of formal processes is that they tend to reduce the chances for error and inconsistent action. This can be shown by recapitulating what the decision maker has to perform in his mind in bringing together all the factors influencing his decisions.[2]

In the discussion of each of these phases, it will be obvious that some overlap is evident and that the sections are not mutually exclusive. This is the result of one decision or problem situation not being exactly like one that has previously been encountered. The technique of sequential analysis illustrates once more its diversity and flexibility. The guidelines and analysis contained in the succeeding explanations prove valuable if an overall view of capital expenditure decisions is realized.

A. The Phases of Application of Sequential Analysis

Consideration

When considering capital outlay decisions, management is held between a demanding group of stockholders and board of directors on the one hand

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[2] C. Jackson Grayson, Jr., Decisions Under Uncertainty (Boston, 1960), p. 174.

and a similarly demanding group of employees and consumers on the other. Faced with the task of pleasing the different objectives of stockholders, consumers, and employees, management executives are recognizing the need for a realistic program for selecting opportunities.

Of prime importance in the consideration part of the decision would be a definition for capital outlay. A capital outlay can be defined as an expenditure of monies today for which the turnover into cash requires a period of years, and any benefits or profits are obtained from future operations.[3] A capital outlay is important to the future prosperity of a corporate enterprise.

A three-fold task is faced by management when considering an investment proposal. First, the problem of satisfying stockholders, employees, and consumers is quite evident. Second, the proposal has to attempt in some way to guarantee the long-range survival of the company. The last job of the proposal should help management use its material and human resources at top efficiency.

In the identification of the problem and the alternative solutions, a number of sources of information may be used. Executive imagination, trend analysis, market analysis, operations research, engineering, exploration, and competitor's maneuvers constitute just a few of these sources. As the first section indicated, an integrated approach to effective and efficient decision making is the needed approach to the identification of the problems or opportunities and the evaluation of alternatives and consequences open to the enterprise.

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[3]G. V. Rohleder, "Evaluating Investments by the Discounted Cash Flow Method," World Oil, Vol. 141 (September, 1955), p. 50.

One author has broken the sources of ideas for discovering capital investment opportunities into six parts. They are as follows:[4]

1. Audit of the economic effectiveness of existing facilities.

2. Industrial engineering studies of the technology of the operation or function.

3. Comparison of known competitive methods and facilities.

4. Maintaining contact with salesmen of alternative resources.

5. Stimulation of the organization at all levels to think creatively.

6. Conducting organized research.

Capital expenditures can be defined according to their purpose. One author divides them as follows:[5]

1. Expansion Items--expenditures which create added facilities and the subsidiary services necessary to increase or launch product and sales of either existing or new products.

2. Product Improvement Expenditures--items to meet or surpass competition in existing lines through better quality, packaging, design, advertising, etc.

3. Cost Reduction Programs--proposals including replacement of equipment, which reduce company expenses by plant redesign, supervisory training, manufacture of parts instead of by purchase or other means.

4. Necessity Tasks--which have to be undertaken by law for the protection of employees or for other reasons which directly and immediately affect the company's ability to stay in business.

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[4]Donald F. Istvan, Capital Expenditure Decisions, How They Are Made in Large Corporations (Bloomington, Indiana, 1961), p. 9.

[5]Harwood T. Merritt, ed., "Building a Sound Capital Investment Program," Management Review, Vol. XLVII (August, 1958), p. 57.

5. Strategic Investments--investments like management training, institutional advertising, and basic research which have a healthy (though gradual) impact on the whole firm.

An inherent managerial responsibility is to thoroughly examine each new investment proposal by asking several questions. Will it properly safeguard the equity of the stockholders? Will it constitute proper utilization of stockholder funds when measured against the principle that the only situations worth consideration are those that will increase shareholder equity over the long run? Since companies have limited capital resources, does the proposed investment constitute a relatively effective use of capital? Will it tend to yield a better return on investment than do other proposals that may be available.[6] Of course, not all of these decisions are applicable to every expenditure decision. Nevertheless, this last comment points up the encompassing view of investment decisions which management should strive to achieve. Capital investments presented here are considered to be of a strategic nature, which would indicate that the outlay is an integral part of the firm's spending and profit planning scheme; but it does not have a specified period of time, such as long or short term, attached to the decision.

The capital budgeting problem as a whole takes into account five elements. It considers the manner in which the company is organized to perform the capital budgeting function, the determination of the availability and cost of capital, the analysis of the investment proposals, the selection of the projects to be undertaken, and the follow-up and evaluation

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[6] J. V. Jones, "Management Planning of Capital Allocations to Business Activities," N.A.A. Bulletin, Vol. 43 (September, 1961), p. 5.

of results.[7]

One reason for studying the considerations and alternatives for investment decisions is to make available more information about how a special group of men make their capital budgeting decisions in the most important areas of corporate administration.[8]

Consideration could be summed up into one phrase, "Search for alternatives and opportunities that maximize the utilization of a business enterprise's resources." This search is performed not by just the board of directors, or the production manager, but by everyone in the firm who is involved with the progress of the enterprise. Consideration (Search) is important no matter what technique of evaluation is used. The source of ideas being determined, the alternatives, plans, or proposals are then ready for the next step or phase in the application process--Investigation.

Investigation

The impetus of this section is to outline the major choices that are necessary for the use of sequential analysis as a tool in the decision making process. Synonyms which can be used in the place of investigation would be breakdown, inquisition, examination, or analysis. The scope of this section is determined by the relationships and tools of analysis which help quantify the data required for computations. Investigation

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[7]Robert Beyer and Donald J. Trawicki, "The Proposed Plant--A Profit Maker or Not?" The Controller, Vol. XXVIII (November, 1960), p. 523.

[8]For a comprehensive study of a classification of factors that help determine the decisions of business management with regard to expenditures and financing, the author recommends perusal of Jacoby and Weston's study of these factors.

Also see Neil H. Jacoby and J. Fred Weston, "Factors Influencing Managerial Decisions in Determining Forms of Business Financing: An Exploratory Study," Conference on Research in Business Finance, pp. 167-172.

provides the basic framework for decision trees which exhibits the alternatives, choices, and decisions for capital expenditures in the best possible manner.

The manager who has to make a decision has two possible alternatives. One approach which will indicate what choice should be made is the computation of projected costs and revenues. These computations may be made by the manager himself or they may be made by a subordinate.

The other approach to a decision is the subjective, judgmental approach. The use of managerial judgment in making economic decisions amounts to weighing the various factors involved without converting them to quantitative terms. A high degree of emphasis is placed on the quantitative aspects of decision making. However, not everything can be assigned as a number or value, so the qualitative aspects of the procedure cannot be eliminated.

The following subsections start a schematic of the decision tree process and continue with tools and techniques for the quantification of relevant variables.

Projection of a Decision Tree

Sequential analysis exposes the anatomy of a business decision. For example, a situation presents itself where an individual has the opportunity to increase his investment portfolio. In this case he has to make the decision as to whether or not he wants common stocks or corporate bonds. The chance events or happenings center on the risk of the company in which he invests either progressing or not progressing. The following decisions tree portrays the investment decision and the consequences of going up one branch or the other.

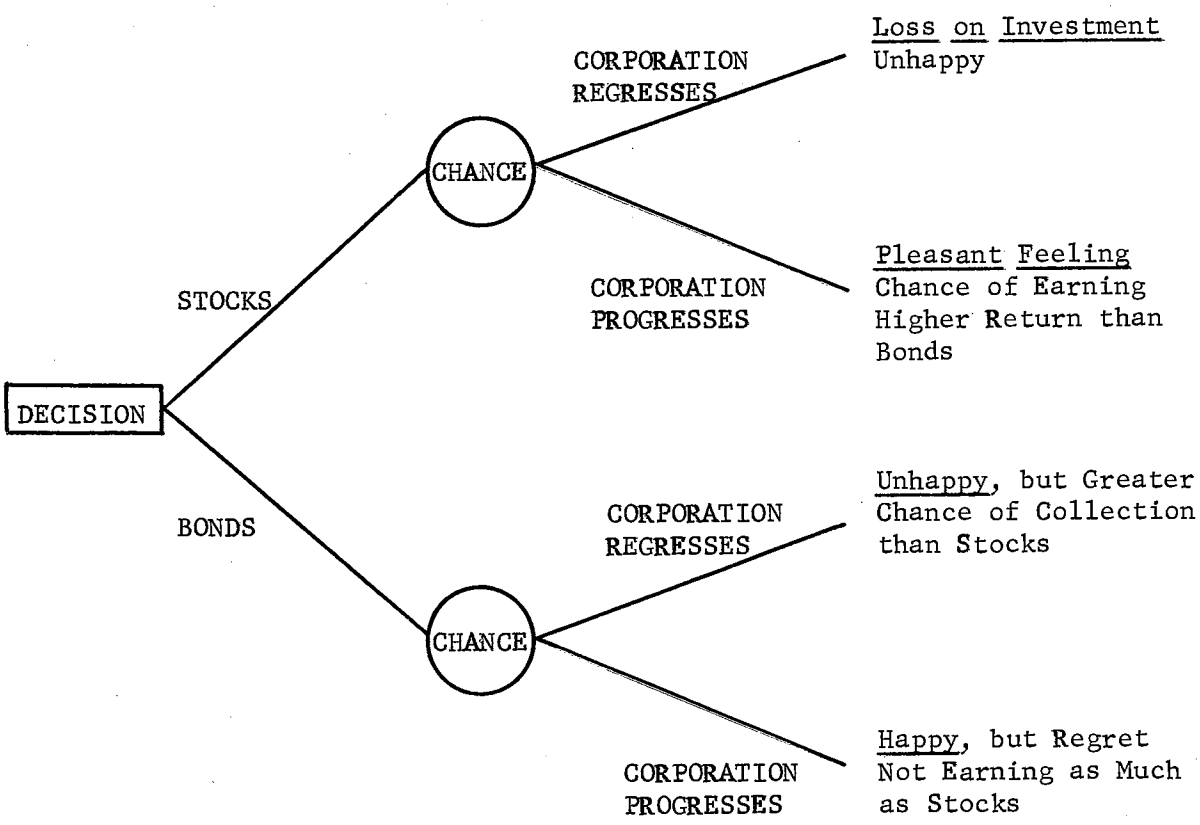

Fig. 2. The Decision Tree for Investment

The example of an investment problem illustrates the uncertainties and issues that the decision maker must resolve in making expenditure judgments. It is evident from the small practical application that the technique is no better than the information that can be placed on its "branches." A decision tree combines the "action" choices with the different "events" or consequences of action which are affected by chance and other exogenous variables. It is best to only place in the tree the decisions and events and consequences that are relevant to the given problem situation.

Time Span

Since time is very important in the use of capital, the length of time used for analysis effects its value. In the technique used here, time influences the number of variables and the complexity of the computations. The span or period of examination can most effectively be broken into several stages and thereby reduce some of the difficulties of analysis. Sequential analysis is not limited by time, and it fits into the strategic planning operations of an enterprise.

Management must conduct a searching analysis of every proposal to determine (1) the forecast of future demands, (2) the economic life of the project, (3) the cost of capital, (4) the risk involved, and (5) the investment required and earnings expected. These estimates require engineering, marketing, and financial analysis. Each of these is presented separately in the following text.

Demand Forecasts

Demand forecasts can range on a continuum from "guesstimates," which are unsophisticated and rely entirely on judgment, to full models of economic indicators, which are theoretically sophisticated in description and application. There will always be a large area of judgment in any business forecast, but the forecaster who starts with pertinent and reliable data has a sound foundation from which to predict the most probable course of future events. Any forecast, therefore, must begin with the gathering of information.[9]

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[9] J. William Blythe, "Business Forecasting," Management Review, Vol. 53 (February, 1964), p. 34.

Long-Range Forecasts

Effective forecasting depends upon setting up plausible assumptions and the use of imaginative techniques to show what these assumptions imply about the future. Growth in the total economy is implicit in all long-range business forecasting. Care must be taken in setting the level from which a long-range forecast starts and in obtaining an appropriate series to represent the industry to be forecast. After the foundation for the prediction is set, the next step is to project industry totals and then to estimate the degree of company penetration in the total market.[10] The market penetration, coupled with internally generated budgets and expenditure programs, form the basis for the long-range strategic plans of a corporate enterprise.

Some firms may start with an analysis of national income and economic trends in appraising their own markets; the prevailing practice appears to be a much narrower outlook. This can be seen in smaller firms where the market is "felt" in the form of orders, etc., which guide the enterprise's actions.

Short-Run Forecasting

There are several tools that are explained in forecasting literature which can be used by a firm for projecting short-run data. They are only mentioned here as techniques. Trend or time series analysis, correlation analysis, and the construction of relatives are the three and are explained thoroughly in any statistics text.

It is necessary in the individual firm to decide how much it should

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[10]Elmer C. Bratt, "Methodology in Long-Range Business Forecasting," The Commercial and Financial Chronicle, Vol. 191 (February, 1960), p. 566.

invest or what kinds of assets it should acquire. A sales forecast aids the firm in this decision by establishing its anticipated level of activity. The firm's sales forecast cannot be made without some estimate of what the industry is going to do. The industry depends in a large measure on the predicted level of activity in the economy as a whole.

The businessman uses economic forecasts to assess the relative advantages of investing in fixed or liquid assets in light of the expected business cycle.[11] Without going into a complete sales forecast, it is necessary to explain that this information is attained from economic indicators and also the sales department in the firm. Preparation of a good forecast is dependent to a large degree upon having an organized system of compiling the forecast.

When considering the forecast of capital expenditures, a schedule of projected fixed asset additions or retirements is prepared with careful consideration of the following factors: (1) equipment required for new or expanded programs, (2) normal replacement items, and (3) the amount of total capital expenditures forecast in relation to past levels and other considerations.[12]

Caution is necessary when dependence is placed entirely on forecasts. Out of centralized corporate marketing research activities can arise one or more of these organizational shortcomings: (1) closed-circuit thinking; (2) proliferation of excessive, oftentimes, unused data; and (3)

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[11] Edward G. Bennion, "Capital Budgeting and Game Theory," Harvard Business Review, Vol. 34 (November-December, 1956), p. 116.

[12] Robert B. Cooke, "Eliminating the Pitfalls in Financial Forecasting," N.A.A. Bulletin, Vol. XLIII (January, 1962), p. 16.

shortsighted directives.[13] The previous article substantiates the warning concerning complete reliance on forecasts and requires an equitable evaluation of all elements of capital expenditure decisions.

Economic Life

The economic life of a project is the period when it produces benefits. It need not be equal to the physical life of the asset, because the length of economic life depends primarily upon the obsolescence of the product involved or the nature of the project itself. Much depends on the period of time over which the investment is justified. In such cases it may be justified to calculate the return on investment over a range of economic lives.

Robert Anthony describes three separate definitions that can be used for the "life" of equipment as the (1) physical life, (2) the technological life, and (3) the product-market life.

The "physical life" is considered to be the number of years the machine will probably be of use to the company in performing the technical job for which it was purchased. "Technological life" refers to the period of time that elapses before a new machine makes the present machine obsolete. The "product market" life of an asset is defined as the termination of economic life that occurs when the company ceases to market or issue the benefits produced by an asset.[14] The evaluation of the economic life of an asset is a very important consideration and should be viewed care-

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[13] J. L. Heskett and Louis W. Stern, "Grass Roots Market Research," Harvard Business Review, Vol. 43 (March-April, 1965), p. 116.

[14] Robert N. Anthony, Management Accounting (Homewood, Illinois, 1964), pp. 625-627.

fully due to the timing and consequences of future replacement.

Cost of Capital

The controversial topic of cost of capital is an area of much controversy due to the fact that it is extraordinarily difficult to estimate. The cost of capital of a firm may be defined as a weighted average of the cost of each type of capital. The weight for each type of capital is the ratio of the market value of the securities representing that source of capital to the market value of all securities issued by the enterprise.[15]

Risk and Uncertainty

Although some consideration of the risk involved in an investment is reflected in the determination of the economic life, a more comprehensive analysis of risk is essential. Risk can be explained as the extent of the probability that the benefits of a project will not be realized.

Of all the decisions that business executives must make, none is more challenging than the determination of assumptions and their impact on investments decisions. The element of risk enters the picture, and the executive does not get much help in making this decision from the conventional tools of analysis.

It must be acknowledged that some attempt is usually made in this type of analysis to allow for the existence of uncertainty. This attempt typically takes the form of superimposing on the results of the available bits of data a "risk discount" to be subtracted from the expected yield

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[15]The term security includes common and preferred stocks and all interest-bearing liabilities, including notes payable.

Also see Harold Bierman, Jr., and Seymour Smidt, The Capital Budgeting Decision (New York, 1960), p. 135.

(or a "risk premium" to be added to the market rate of interest). Investment decisions are then supposed to be based on a comparison of this "risk adjusted" or "certainty equivalent" yield with the cost of capital. No satisfactory explanation has yet been provided, however, as to what determines the size of the risk discount and how it varies in response to changes in other variables.[16]

In 1955 John McDonald in an article concerning businessmen's decisions said:

> The business executive is by profession a decision maker. Uncertainty is his opponent. Overcoming it is his mission. Whether the outcome is a consequence of luck or wisdom, the moment of decision is without doubt the most creative and critical event in the life of the executive.[17]

The lack of knowledge about the future causes a tremendous amount of consternation for the decision maker. It causes management to consider in detail several questions such as: (1) What the risks involved appear to be? (2) Who is bearing the risk? (3) How do we take the risk into consideration? It is evident that judgment has a great deal to do with the quantification of risk and uncertainty in an investment decision.

Cash Outflow and Inflow

The use of tools previously mentioned, such as sales forecasting and economic life determination, are an aid to the determination of the financial fluctuations of capital investments. Risk and uncertainty also play

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[16] Franco Modigliani and Merton H. Miller, "The Cost of Capital Corporation Finance and the Theory of Investment," American Economic Review, Vol. XVIII (June, 1958), p. 261.

[17] John McDonald, "How Businessmen Make Decisions," Fortune, Vol. LXI (August, 1955), p. 8.

a big role in this investigation, especially when concerned with cash income.

To calculate the cash income for existing assets, the net profit after taxes is found by adding back all charges which do not represent actual cash outlays. The tools of forecasting are applied in the analysis of future cash incomes, and the analysis of cash flow is no better than the projection of estimated demand or sales. Forecasting financial requirements lies at the heart of accounting and financial decisions.

On the other hand the net cash outlay that is needed to realize the benefits of a project can generally be considered as the investment required. Cash outlay is computed without regard for the accounting treatment of the funds spent.

In summary, the decision makers are ready to place on a decision tree a project that can be fitted into an adopted form which will state what the project is to accomplish, how much money or other asset value will be spent or financed. It will also tell when these outlays will be made, when the project will become operative, and what economic life may be reasonably expected. Also, what information as to net receipts will be returned during the assets operation, and what ultimate recovery of cash or other asset values will be received at the close of the project's economic life. To see the information from the Consideration and Investigation phases of application brought together, the Correlation phase is now undertaken.

Correlation

The function of correlation is to bring together the information and data contained in the Consideration and Investigation phases of applica-

tion. The function of this "synthesis" section is to fit the total program for expenditure analysis into the form of sequential decision making and to consider the entire time span that is involved during the decision.

In order to visualize what is transpiring during the explanation of the correlation phase, the example problem of a decision tree is utilized. The branches of the decision tree represent alternative courses of action or decision. Starting with a decision point (the decision whether to invest in stocks or bonds) each alternative on the tree represents the result of a chance event (the progressing or not progressing of the example corporation). At the end of each branch is a reward which in the case of the example would be one of four separate outcomes.

The result of the correlation phase then would be to apply information to each branch of the decision tree in order that the actual decision possibilities for the technique can be realized.

Before going further it is time to discuss the criteria which will be the basis for measurement of the economic worth of capital expenditure problems. The appropriate standard for corporate investment decisions in this report is the maximization of expected wealth, or of discounted cash profit, where future cash profit is discounted to present value at a discount rate equivalent to the market "cost of capital" of enterprises of similarly uncertain future.[18]

The values needed then at each "node" of decision under the standard of maximum expected cash profit are: (1) The assessment or probability of each alternative uncertain outcome, (2) the cash inflow associated

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[18]John F. Magee, "How to Use Decision Trees in Capital Investment," Harvard Business Review, Vol. 42 (September-October, 1964), p. 84.

with each combination of decision result and chance happening, and (3) an estimate of the discount factor to be attached to the deferred cash flows in the stage or to the future possible value of the outcome. With the data added to the skeleton of the tree, the important relationships among factors, objectives, and means of control are illustrated and identified.

To sum up the requirements of making a decision tree, management must do the following:[19]

1. Identify the points of decision and alternatives available at each point.

2. Identify the points of uncertainty and the type or range of alternative outcomes at each point.

3. Estimate the values needed to make the analysis, especially the probabilities of different events or results of action and the costs and gains of various events and actions.

4. Analyze the alternative values to choose a course.

The synthesis of data needed for analysis has now been completed, and this information placed on the tree.

Implementation

In this section the findings of the synthesis or correlation stage of analysis are put into action. At this point the decision tree layout has been determined, the chance and decision nodes identified, and the appropriate relevant data added. The next logical step is the action or

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[19] John F. Magee, "Decision Trees for Decision Making," Harvard Business Review, Vol. 42 (July-August, 1964), p. 130.

implementation phase.

In order to analyze all of this, it is necessary to set up mechanical sequence for the evaluation of the different alternative branches. To evaluate the data in the application of sequential analysis, the following procedure is required:

1. Step 1. Each of the branches is analyzed at the end or final stage decisions points. Using the criteria of maximizing discounted cash profit, select the branch with the largest net present value. This value is then designated the "prime position value," meaning that this branch would be chosen if the final stage decision were made at the present time.

2. Step 2. Each decision alternative is evaluated at the next preceding stage. This evaluation is achieved by computing the expected discounted cash profit (cash flow) including the value of the succeeding stage as if it were a total sum received at the end of the period.

3. Step 3. Repeat this process (Step 2) at each stage until the value of each branch is determined at the first stage. This is called a "carry back" process.

Time is a significant factor and is accounted for in the establishment of the criteria for evaluation as a discount rate. When the time span of a stage or branch is significant, the discount rate to be applied to the cash flows must be estimated. The consideration of the time span does not alter the steps of evaluation; however, care must be taken to use the discount factor properly when determining the value of each respective branch of the tree. The next phase of Sequential Analysis deals with the control of the process and its results.

Regulation

No system or process for the analysis of capital expenditures is complete unless there is some means of measuring how well it is functioning. The question to be answered then is "How is performance measured?"

Charles Allen describes certain parts of a control program in the N.A.A. Bulletin. He stated that by general acceptance a control program over capital expenditure projects usually has four parts: (1) preliminary consideration and appraisal of projects, (2) formal requests for appropriation of funds, (3) measurement of expenditures against appropriations, and (4) the post-completion audit of results.[20]

The regulation of a program of capital outlay analysis aids in the determination of the feasibility of the system. The results and the decisions made using the prescribed tool should be compared with the actual situation as it develops in order that the usefulness of the technique can be checked. When the criteria of measurement and the answers from analysis are satisfactorily compatible, the method of sequential analysis becomes a useful technique.

The decision tree approach is no better than the quality of information used for its operation. The control for this technique is not primarily related to its mechanical technique, but is the valid information that is required for any decision making process.

Evaluation

The application phases of sequential analysis are completed with dis-

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[20]Charles B. Allen, "Evaluation of Capital Projects--An Application of the Investor's Method," N.A.A. Bulletin, Vol. XLII (January, 1961), p. 46.

cussion related to evaluation, follow-up, or appraisal. Frequently, a term such as "post-completion audit" is used as a substitute for the term evaluation.

Evaluation serves several purposes. The decision making team is able to appraise the operation and performance of the expenditure. Another purpose is that during the process of appraisal, the decision maker(s) can delete or add certain parts of the analysis which will improve the technique for future investments.

Many volumes have been written concerning the topic of return on investment. This is a major portion of evaluation and is the result of a comparison of the benefits derived from an investment with the outlay for a capital project. Much work is necessary to determine the proper return, and several guidelines have been proposed. In establishing the return factor at the corporate level, the following bench marks will be generally applicable:

1. For a total company return, 20 to 35 percent before tax is a satisfactory range (but this is dependent on the industry).

2. Within protected product lives, 30 to 40 percent should result over the long run. (Again, this is a function of the project, industry, and the time period).

3. ROI should be better than the industry average.

4. Compare ROI ratio with the best companies within the industry.

5. The more competitive the industry, the narrower the ROI ranges are.[21]

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[21]Harvey O. Edson, "Setting a Standard for Your Company's Return on Investment," The Controller, Vol. 51 (September, 1958), p. 412.

Gilbert Rohleder sets forth six criteria for a good yardstick to accept or reject the economic worth of investment opportunities in this way:

1. A good yardstick is objective; that is, it measures both earning power and group satisfactions.

2. It pinpoints the relative position of various projects.

3. It considers all aspects of cash flow.

4. It summarizes in a single figure all the relevant data.

5. It is sensitive enough to allow for uncertainties.

6. It indicates whether or not the project earnings are below the minimum accepted level.[22]

The central requirement of a good yardstick is that it should measure what the proposed outlay will do to net earnings. This permits a realistic comparison of one investment proposal with another. The evaluation process or criteria of measurement should be applicable to all types of proposals and permit appraisal in terms of a single set of standards.[23] Such purposes as expansion of company size, market share, working capital position, and degree of separation of management from ownership and directorship of a company make evaluation or appraisal an important aspect of the analysis of capital expenditures.

B. Summary

The purpose of Chapter II has been to present from a study of current

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[22] G. V. Rohleder, "Evaluating Investments by the Discounted Cash Flow Method," World Oil, Vol. 141 (September, 1955), p. 51.

[23] Joel Dean, "Measuring the Productivity of Capital," Harvard Business Review, Vol. 32 (January-February, 1954), p. 120.

material a set of broad guidelines which direct the reader toward the technique of applying sequential analysis as a tool of analysis for capital expenditures. The six phases of application have been discussed separately.

Consideration is the conceptualization or source of proposals for capital expenditures. Capital outlays can be for expansion, product improvement, cost reduction, necessity, or strategic operation. Numerous sources of these projects can be utilized by the decision makers.

After the ideas are considered, investigation of the major alternatives and their consequences develops the data required for the operation and application of the decision tree.

The function of correlation is to bring together the information and data that is contained in the first two stages of application.

Implementation is the action phase of sequential analysis. The layout of the decision tree is projected, information is placed on the "branches," and operation of the technique is underway.

The last two steps or phases of application--Regulation and Evaluation, provide the control and follow-up on the answers and indications given to the decision maker by the Implementation of sequential analysis.

To this point a descriptive process has been utilized to describe the technique of this decision making tool. In Chapter III Sequential Analysis is applied to three different situations, wherein the format of analysis follows the six steps of application as presented in Chapter II.

CHAPTER III

EXAMPLES DISPLAYING SEQUENTIAL ANALYSIS

The sequential analysis tool of evaluation is presented in three case illustrations in this chapter. Chapter II emphasizes the six steps of applying sequential analysis, and Chapter III utilizes the results of these phases.

The three examples contained in the following pages are described by the following classifications: (1) Capital Investment for Long-Term Asset, (2) Capital Investment for Incremental Product Development, and (3) Capital Investment for Research and Development.

For the purposes of illustration, several assumptions for clarity and simplicity have been made. The format for each of these cases is such that the six phases of application as discussed in Chapter II are utilized. The first four phases of application--consideration, investigation, correlation, and implementation--have been emphasized. The decision tree concept presented here clarifies for management the alternatives, goals, uncertainties, monetary gains, and data needs involved in an investment problem.

A. Key Steps in Building and Using a Decision Tree for Investment Project Analysis

Step 1. The identification of the problem and its alternatives (consideration)--executive imagination, trend analysis, market analysis,

operation research, engineering exploitation, and competitor's maneuvers constitute a number of sources from which information about investment opportunities may come. As the first section indicated, an integrated approach to effective and efficient decision making is a much needed approach to the identification of the problems or opportunities and the evaluation of alternatives and consequences open to the enterprise.

Step 2. The projection of the structure of the decision tree (investigation)--the investment decision's underlying structure of alternatives are formulated.

Step 3. Obtaining the data needed (correlation)--various sorts of analyses are utilized to estimate the cash flows and probabilities of certain events.

Step 4. Evaluation of alternative courses or branches (implementation)-- a good evaluation will test which alternatives appear desirable in the light of the standards used.

To expedite the explanation and illustration of sequential analysis the hypothetical examples of three capital investment decisions follow.

B. Capital Investment for Long-Term Asset

The first case illustrates the sequential analysis approach to the decision for an investment for a long-term asset. The technique does not make the decision, but it does serve management as a tool of exposition.

Consideration

Planter's Pipeline Company is faced with an immediate decision as to the size of pump station to put on their petroleum product line coming

out of the Planter's Refinery to the delivery (demand) point 100 miles away. A decision tree characterizing their investment problem is illustrated if Figure 3.

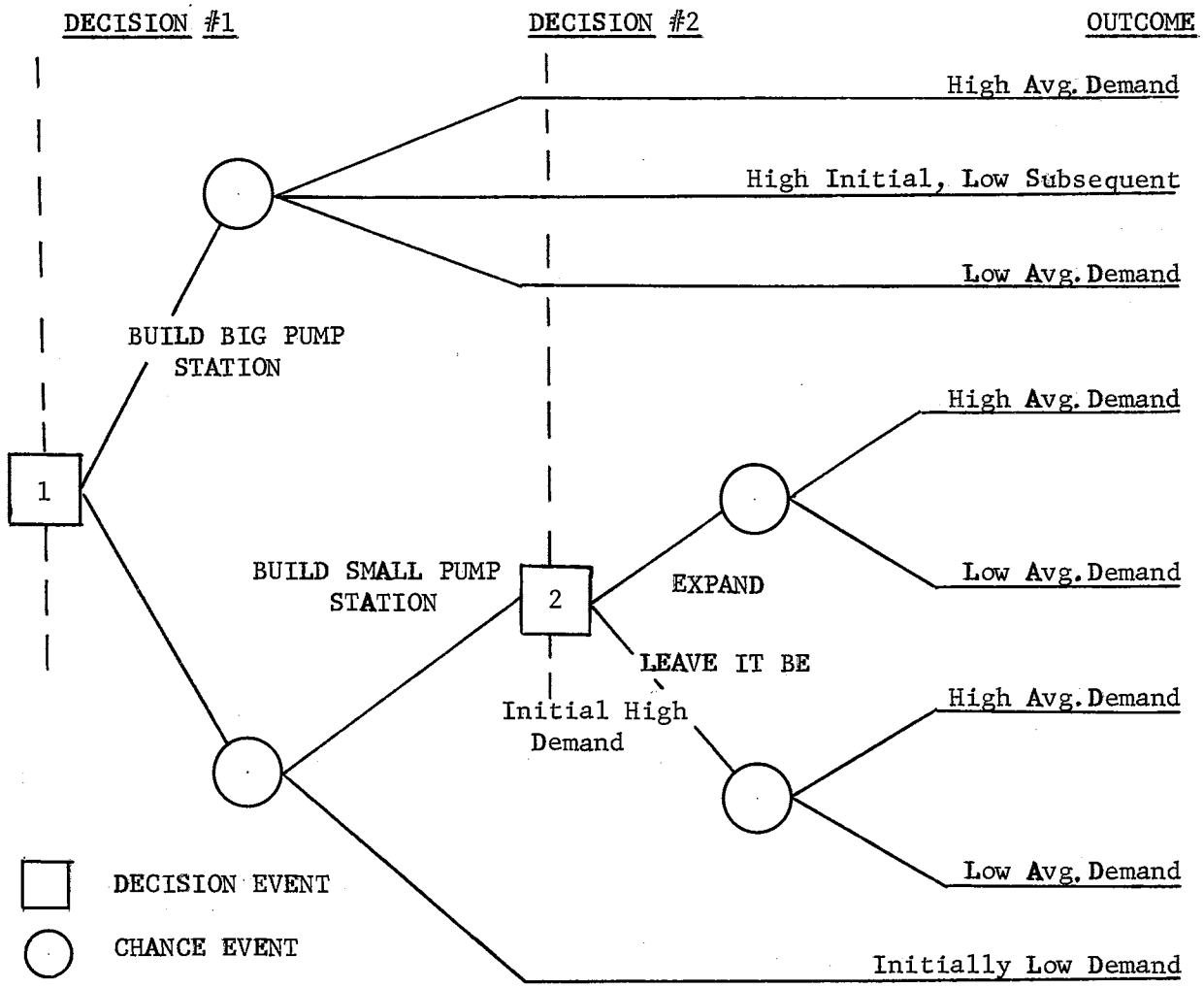

Fig. 3. Planter's Pipeline Decision Tree

As shown by the diagram, the only decision that must be decided now is whether or not to build a small or large pump station. But if a small

one is built and the demand for petroleum products is high, then after two years the company can decide whether or not to expand its pump station or maintain the small facility.

Investigation

In making these decisions the management of Planter's must take into account costs, returns, and probabilities which appear likely. From the functionally integrated decision making team comes the following information.

The estimates by marketing research show a 65 percent chance of a large market in the long run and a 35 percent chance of a low demand, forecasted similarly to the following:

Demand--high initially, sustained high	65%	
Demand--high initially, long run low	5%	Low 35%
Demand--low and continued low	30%	
Demand--low and long term high	0%	

The chance that demand will initially be high is 70 percent (65 + 5). If the company experiences high initial demand, the probability that it will continue high is 93 percent (65 ÷ 70). The comparison of 93 percent to 65 percent shows that high initial demand increases the chance of high continued demand in subsequent periods. If demand is low, the chances are 100 percent (30 ÷ 30) that it will remain low. The conclusion is that demand in the initial period of decision is a rather good indicator of demand in the succeeding periods.

Annual income estimates for each demand condition by the financial analysis section of the decision making team follows:

1. A big pump station with initial high demand would yield

$1,100,000 annually in cash flow.

2. A big pump station with initial high demand but with low subsequent demand would earn only $110,000 annually because of inefficiencies and high fixed asset cost.

3. A small pump station with low demand would yield annually a cash flow of $425,000.

4. A small pump station during an initial period of high demand would yield $475,000 per year, but would not be able to meet competition in a larger market; so yearly income in the long run would be $325,000.

5. If small pump station were expanded to meet high demand, it would yield $725,000 cash flow annually. (It would not be as efficient as large pump station built initially).

6. If small pump station were expanded, but high demand was not maintained, the annual cash flow would be $75,000.

The cost estimated for a large pump station put in operation would be 3 million dollars and a small station about 1.35 million dollars. The additional expansion of the small plant would cost 2.2 million.

Correlation

With this additional information with which to work, the decision tree of Figure 4 would appear as the following on the succeeding page. With all the pertinent data placed on the appropriate branches of the tree, the consequences of the different courses of action are compared.

Implementation and Evaluation

The evaluation of the alternatives on the decision tree follows the "carry-back" concept which was presented in Chapter II. At the time of

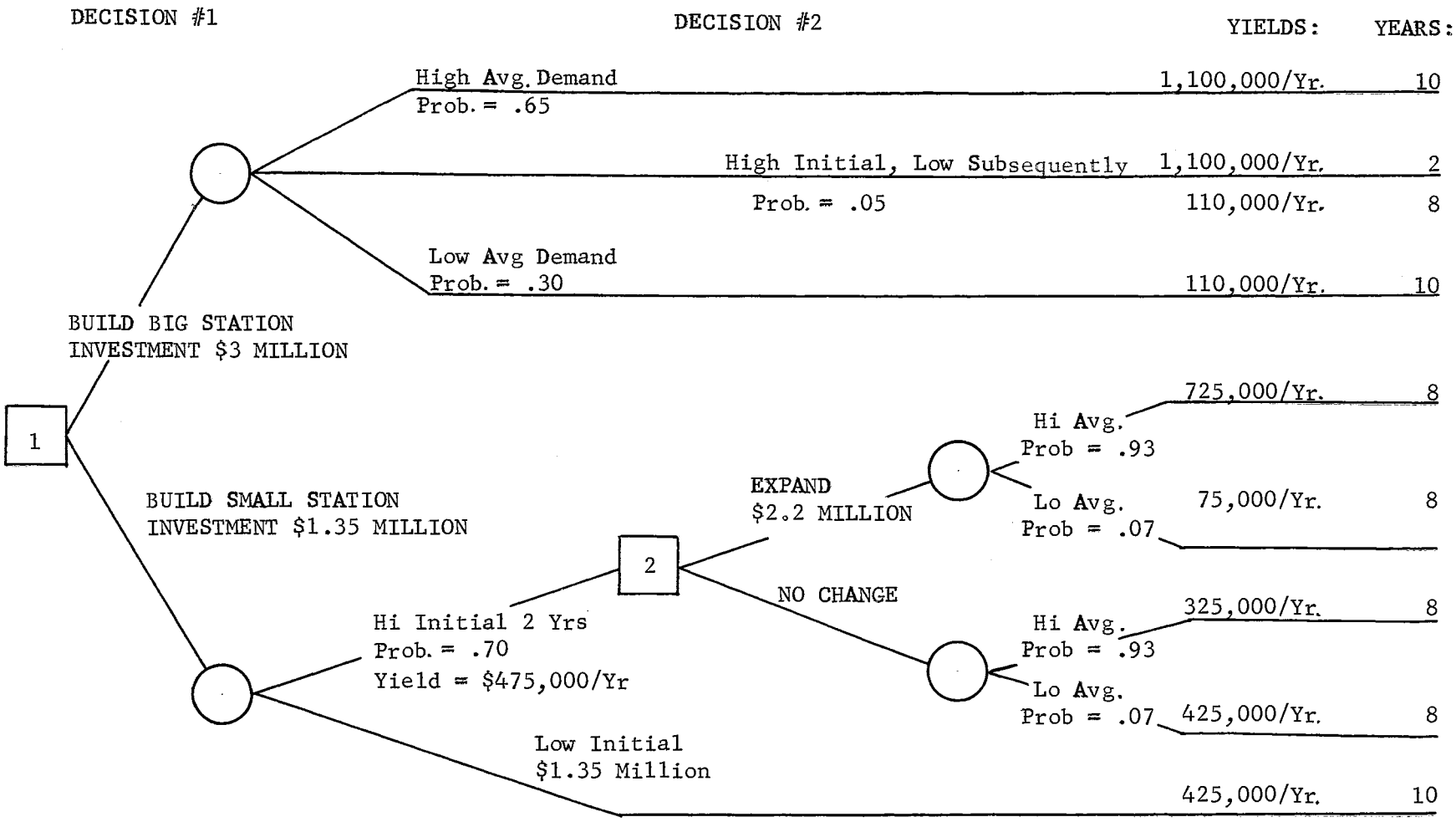

Fig. 4. Complete Decision Tree for Planter's Expansion

making Decision #1 in Figure 3 Planter's Pipeline management disregards the Decision #2 due to the fact that it does not have to make it or does not know if it will have the opportunity to do so. However, if the option was apparent at Decision #2 the company would make a decision with the following type of analysis.

Choice	Chance Event	Probability (1)	Total Yield 8 Yrs ($000's)		Expected Value ($000's) (1) x (2)
Expand Pump Station	High Avg. Demand	.93	5,800		5,394
	Low Avg. Demand	.07	600		42
				Total	5,436
				Less Investment	2,200
				Net	3,236
No Expansion	High Avg. Demand	.93	2,600		2,418
	Low Avg. Demand	.07	3,400		238
				Total	2,656
				Less Investment	0,000
				Net	2,656

Fig. 5. Analysis of Decision #2
(Maximum Expected Total Cash Flow)

This exhibit shows that the expected value of the expansion on the small pump station after eight years is $580,000 greater than the no-

expansion decision. The reason that Decision #2 had to be evaluated was that a monetary value is needed to "carry-back" to Decision #1 and compare the gain from taking the lower branch (the small pump station) with the gain from building a large station initially. The monetary value at Decision #2 is called the "prime position value" or the expected value of the preferred branch.

Stated differently, it is worth $3,236,000 to the management of Planter's Pipeline to get to a position where Decision #2 can be made. With this in mind the best action for Decision #1 can now be determined.

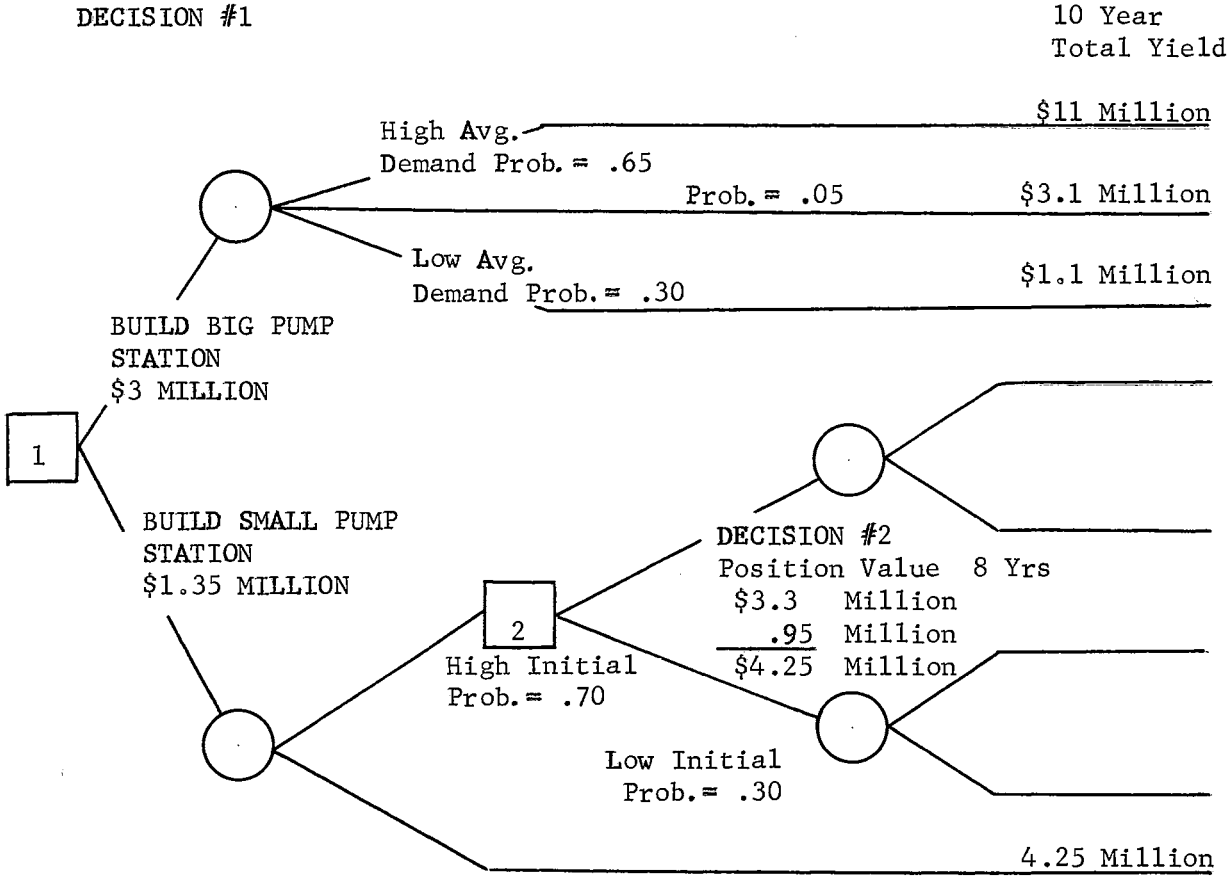

Fig. 6. Analysis of Decision #1

With the information contained in Figure 6 the decision as to whether or not Planter's Pipeline Company should build a large or small pump station can be easily made. The yields are reduced by their probabilities in order to achieve expected values.

TABLE I

ANALYSIS OF DECISION #1

Build Big Pump Station	($11 x .65) + (3.1 x .05)
	($1.1 x .30) - ($3 Million) =
	$4.64 Million
Build Small Pump Station	($4.25 x .70) + ($4.25 x .30) -
	($1.35 Million) =
	$2.9 Million

The choice which maximizes expected total cash yield at Decision #1 is to build a large pump station initially.

Effect of Time on Future Earnings

The decision used by the Planter Pipeline Company was made without considering the time value of the profits or costs involved. The presentation was planned without this consideration for the purposes of explanation of the technique. With sequential analysis the use of a discount rate is, in effect, an allowance for the cost of capital (lending rate and cost of borrowing). This technique is similar to the use of a discount rate in the present value or discounted cash flow techniques.

To illustrate the use of discounting the cash flows, 10 percent arbitrarily is taken as the discount rate, and the analysis is repeated again

starting with present values at Decision #2. The next exhibit displays this added evaluation.

A Cash Flow Present Value

Choice-Outcome	Yield	Present Value* (ooo's)
Expand - High demand	725/yr, 8 yrs.	$4,250
Expand - Low demand	75/yr, 8 yrs.	440
No Change - High demand	325/yr, 8 yrs.	1,914
No Change - Low demand	425/yr, 8 yrs.	2,490

* The first year is not discounted, second year is one year, etc.

Choice	Chance Event	Probability (1)	Total Yield 8 Yrs ($000's)		Discounted Expected Value ($000's)
Expand Pump Station	High Avg. Demand	.93	4,250		3,950
	Low Avg. Demand	.07	440		31
					3,981
				Less Investment	2,200
					1,781
No Expansion	High Avg. Demand	.93	1,914		1,780
	Low Avg. Demand	.07	2,490		168
					1,948
				Less Investment	0,000
					1,948

Fig. 7. Analysis of Decision #2 with Discounting

On the following page Figure 8 further "enhances" the preceding exhibit.

Choice	Chance Event	Probability	Yield	Discounted Yield	Discounted Expected
	High Avg.	.65	1,100/yr.	7,370	4,790
Build Big Plant	High Initial		1,100/yr, 2		
	Low Avg.	.05	110/yr, 8	2,640	132
	Low Avg. Demand	.30	110/yr, 10	670	205
				Total	5,127
				Less Investment	3,000
					2,127
	High Initial Demand	.70	475/yr, 2	908	635
		Decision #2	1,948	1,590	1,111
Build Small Station					
	Low Initial Demand		425/yr.	2,860	850
				Total	2,596
				Less Investment	1,350
					1,246

Fig. 8. Analysis of Decision # 1 with Discounting

The large pump station is again preferred.

C. Capital Investment for Incremental Product Development

In this section sequential analysis is applied to a situation where a capital expenditure is required for the development of an incremental product facility. The example is set up using some relevant data from a leading petroleum company's engineering seminar material. The information has been disguised for this example, but it represents an actual situation.

Consideration

The first step in this example is to define the situation facing the hypothetical Conart Pipeline Company. The basic condition is that Conart's existing pipeline from El Paso, Texas, to Tucson and Phoenix, Arizona, is operated at full capacity; and Conart is faced with an expansion for incremental product demand. The addition is called a loop line. The alternative to not building the additional pipeline is to maintain the status quo with the uncertainty of the demand for the transportation facility either remaining at capacity or decreasing due to the competition's better facilities. Management must make a decision, and Figure 9 displays a decision tree with the alternative decisions and chance events.

Investigation

The prime objective of the Conart Pipeline Study is to reduce Conart's transportation costs from El Paso to Tucson and Phoenix. Basically, this could be accomplished by constructing a new pipeline independently or constructing a new pipeline cooperatively with Conart owning a portion.

Some of the most important sources available for applicable information are other departments and districts of the parent company and other companies. In the case of Conart, the Product Supply and Distribution Department furnished an estimate of the industry volume of petroleum consumed in the area. The growth rate of the area was estimated as 6 percent per annum for five years, and 5 percent per annum for the next five years.

In order to prepare an accurate cost estimate, reliable sources of information are needed. These sources may be grouped into four general categories: (1) other departments, (2) past projects, (3) contractors,

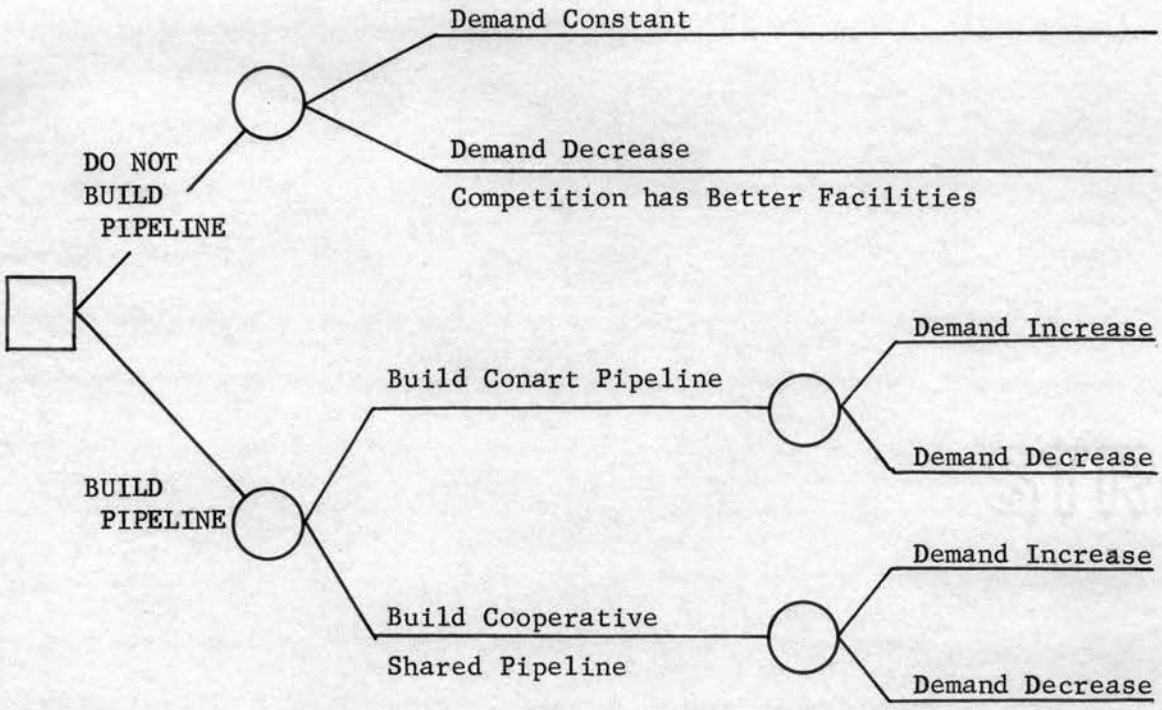

Fig. 9. Conart Pipeline Decision Tree

and (4) suppliers.

The next step is estimating the operating expenses. Past expense records and data for overhead expenses are used to prepare and estimate the variable expenses. In order to calculate the revenue, an 8 percent financial return on the investment will govern the decision.

The information for the decision which is gathered from these separate sources is summarized as follows:

Forecasted Demand Probabilities

Condition	Probability
Demand--Constant and sustained	85%
Demand--Decrease if line not built	15%
Demand--Increase if built	90%
Demand--Decrease	10%

The annual income estimates for each outcome, as reported by the

cost accounting section, are as follows:

1. If the loop line expansion is not built and demand is constant, the yield would continue to average $246,000 annually in cash flow for 10 years.

2. If the loop line expansion is not built and demand decreases, the yield would average $75,000 annually in cash flow for 10 years.

3. If the loop line is built by Conart independently and demand increases, the yield is estimated to be $385,000/year for 5 years and $415,000/year for the next 5 years in cash flow.

4. If the loop line is built by Conart independently and demand decreases, the yield will average $246,000 annually in cash flow.

5. If the pipeline is built by Conart cooperatively and demand increases, the yield will average $508,000 per year in cash flow for 10 years.

6. If the pipeline is built and Conart owns a portion, with a decrease in demand, the average yield would be $430,000 per year for 10 years.

The estimates for the cost of the loop line if built independently is 2.5 million dollars; however, if the 50 percent ownership option is chosen, the investment would cost 1.2 million dollars.

Correlation

By placing all of the relevant data on the branches, the decision tree for Conart's proposed expansion is now ready for the action phase of analysis. Figure 10 is the result of correlation. Table II shows the discounted yields of the six outcomes.

TABLE II

CASH FLOW PRESENT VALUE AT 8 PERCENT

Choice-Outcome	Yield ($000's)	Factor[1]	Total Yield Present Value ($000's)
Not Build-Constant Demand	$246/10 yrs.	6.710	$1,650
Not Build-Decrease Demand	75/10 yrs.	6.710	504
Build Independent Inc. Demand	400/10 yrs.	6.710	2,690
Build Independent Dec. Demand	260/10 yrs.	6.710	1,750
Build Cooperative Inc. Demand	508/10 yrs.	6.710	3,420
Build Cooperative Dec. Demand	430/10 yrs.	6.710	2,890

[1]Factor for the Present Value of $1 received annually for N years.

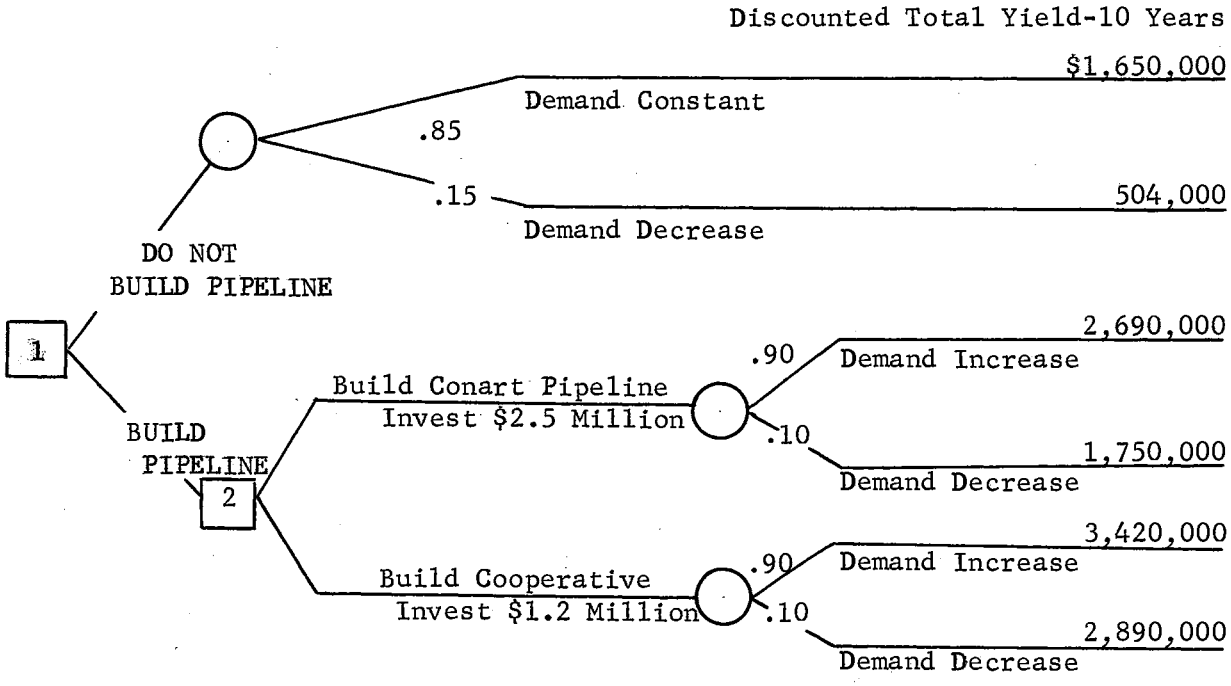

Fig. 10. Completed Decision Tree for Conart

Figure 11 shows an analysis of Decision #2.

Choice	Chance Event	Probability	Total Yield		Discounted Expected Value ($000's)
Build Independent	Demand Inc.	.90	$2,690		$2,420
	Demand Dec.	.10	1,750		175
				Less Investment	(2,500)
					95
Build Cooperative	Demand Inc.	.90	3,420		$3,080
	Demand Dec.	.10	2,890		289
				Less Investment	(1,000)
					$2,169

Fig. 11. Analysis of Decision #2

This exhibit shows that the expected value of the pipeline when built as a cooperative effort is worth $2,070,000 more after 10 years than to build the pipeline independently. The "Prime Position Value" of Decision #2 is now $2,169,000, which means that it is worth this amount to Conart if the decision is made at the present time.

The decision which maximizes expected total cash yield at Decision #1 is to build a cooperative loop line expansion. This decision is worth

Choice	Calculated Expected Value	
Do Not Build Pipeline	.85 x $1,650,000	$1,400,000
	plus .15 x $504,000	75,500
		$1,475,500
Build Pipeline	Prime Position Value - $2,169,000	2,169,000
	Difference	$ 693,000

Fig. 12. Analysis of Decision #1

$693,000 in discounted cash flow over the 10-year decision period to the Conart Pipeline Company.

D. Capital Investment for Research and Development

The last example of this chapter involves a situation in which research and development expenditures behave in much the same manner as capital expenditures. This example is drawn from an article published in the Journal of Industrial Engineering.[1] The problem is to determine the minimum cost of a feasibility study for a control instrument to be put into production.

Consideration

By the use of a decision tree a simplified development program for a control on a high temperature system can be analyzed. The problem is theoretical and hypothetical and is used only for illustrative purposes.

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[1] Graham Pearson, "Profit Probability Analysis of Research and Development Expenditures," Journal of Industrial Engineering, Vol. XVI (March-April, 1965), pp. 186-191.

The problem that confronts the decision makers is to conduct a feasibility study to determine whether or not an electrical or pneumatical control system for high temperature measurement should be produced.

Investigation

The illustration for the evaluation of this process by sequential analysis is contained in the next exhibit. Provided that the experimental research is performed on the models (pneumatic and electrical), the information that is needed for the tree would be the costs for each decision and alternative and the probabilities of the chance events. Cost figures are applied to the lines representing activities, rather than to the decision boxes because the activities require the expenditure of time and money.

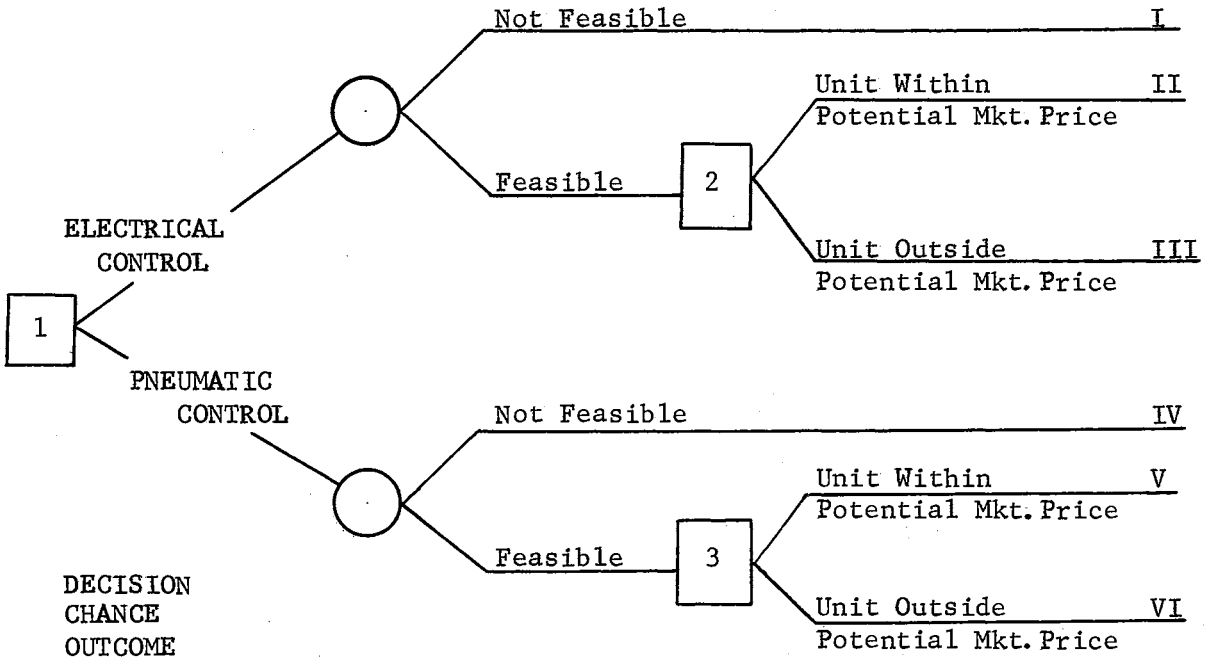


Fig. 13. Sequential Analysis for Feasibility Study

The cost of the study and its results are summarized as follows:

1. The cost for the feasibility investigation of the pneumatic system is $40,000.

2. The cost for the feasibility investigation of the electrical system is $20,000.

3. The cost of the electrical system not proving feasible and the project dropped, but a report is written, is $1,500. This is Outcome I.

4. Outcome II, the electrical is accepted for production because unit price is within the potential market price. Cost of investigation and reporting is $1,500.

5. Outcome III, the project is dropped after the unit price for the electrical system is found to be outside the potential market price. Cost is $1,500.

6. Outcome IV, the project is dropped because the pneumatic control system is found to be unsuitable. The cost of investigation and report writing is $1,500.

7. The result of Outcomes V and VI are similar to items four and five discussed above. Outcome V the project is dropped, and Outcome VI the project is found suitable for production.

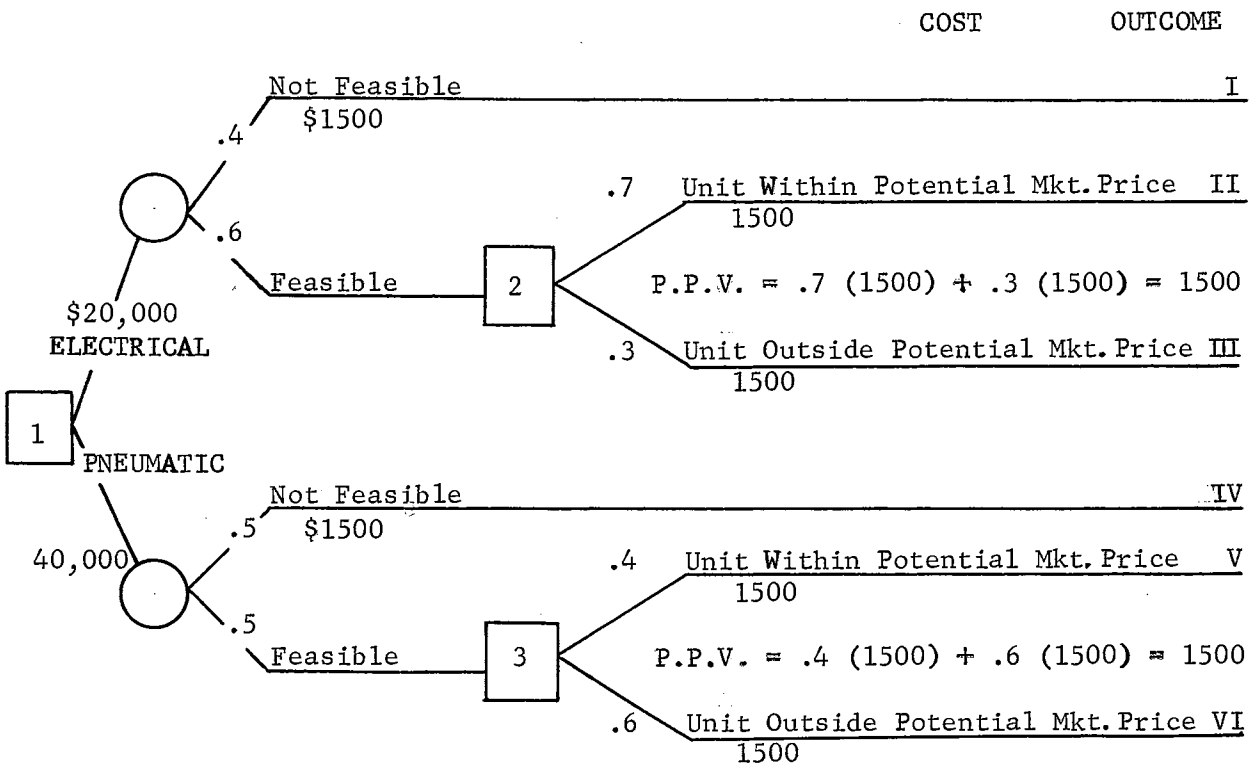
The next step is the application of probabilities to the network. The probabilities are assigned to each alternative at a given decision box, with the total of all probabilities at each decision box equal to one. For this analysis the assignment is:

Outcome	Probability
I--Project Dropped	.40
II--Project Suitable for Production	.70
III--Project Dropped	.30
IV--Project Dropped	.50
V--Project Suitable for Production	.40
VI--Project Dropped	.60

Correlation

Figure 14 contains the portrayal by sequential analysis of this situation. The criteria for this problem will be minimum expected cost. The time period involved is of short duration and a discounted analysis is unnecessary.

The decision at the time #1 would be to pursue the development of an electrical control system for high temperature measurement. The decision to do so is worth a saving at time #1 of $20,000 of expected cost.



P.P.V. = Prime Position Value

Fig. 14. Completed Sequential Analysis for Feasibility Study

Choice	Chance Event	Probability	Total Cost	Expected Value
Electrical	Feasible	.6	$1500	$ 800
	Not Feasible	.4	1500	700
			Plus Cost of Investigation	20,000
				$21,500
Pneumatic	Feasible	.5	$1500	750
	Not Feasible	.5	1500	750
			Plus Cost of Investigation	40,000
				$41,500

Fig. 15. Analysis of Decision #1

This decision does not count out the pneumatic control system; the sequential analysis just indicates that with a criteria of lowest expected cost for research and development the electrical control system is the most feasible.

CHAPTER IV

SPECIAL CONSIDERATIONS AND SUBSEQUENT APPLICATIONS OF SEQUENTIAL ANALYSIS

The purpose of Chapter IV is to briefly discuss several concepts of evaluation that would enhance the technique of sequential analysis. Starting with a synopsis of other methods of capital expenditure evaluation, the section moves into the characteristics of Bayesian Statistics and then to Sensitivity Analysis.

Other Approaches to Capital Investment

The approach presented here can be compared with the more conventional discounted cash flow techniques. One method would be to evaluate the investment decision in terms similar to those used in PERT analysis. That is, to evaluate the alternatives under the "most likely," the "optimistic," and the "pessimistic" cash flows using the present value techniques.

A different approach is to calculate the net expected present value with the cash flows weighted by the estimated likelihood of their occurrence. For the strict capital budgeting techniques four evaluation methods are used. They are (1) Payback, (2) Average Return on Investment, (3) Present Value, and (4) Discounted Cash Flow.

It should be noted that these are tools that can be used. Like a wrench, they are of greatest utility when used consistently for the jobs

they are intended.[1] There is no one of these tools that is good for every purpose. The most appropriate tools are determined by the circumstances and the needs of the situation. The decision tree analysis brings out the impact of both uncertainty and possible future decisions conditioned on future developments.

Bayesian Statistics

The function of Bayesian Statistics is to give a means for building in subsequent information to modify estimates of probabilities. It is also to assist the decision maker in making up a decision and, in particular, to show how the evidence from the sample inquiry should influence the decision. The pertinent problem is the requirement to make estimates of the relevant parameters of a business decision in order to base subsequent action of these estimates. This means that if, to the decision maker, uncertainty about the value of a parameter exists, he can consider the set of possible values the parameter may take on; he can also assign a subjective probability weight to each value of the parameter, and calculate its expected value and use this as the expectation of his estimate. This makes possible a logically consistent course for the decision maker as to whether or not to act just on the prior probability assessments or gather information, revise the prior probabilities, and then decide to act or gather more information.[2]

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[1] Milton F. Usry, The Evaluation of Capital Expenditure Proposals (Paper read before joint session of the Accounting Section of the Southwestern Social Science Association and the Southwestern Section of the American Accounting Association, San Antonio, Texas, April 12, 1963), p. 6.

[2] Harold Bierman, Jr., Lawrence E. Fouraker, and Robert K. Jaedicke, Quantitative Analysis for Business Decisions (Illinois, 1961), p. 6.

The Bayesian approach requires that for rational action the decision maker must have a personal state of belief attaching a fractional probability to each possible value of the unknown parameter prior to the acting--and this is the prior distribution. The state of belief or knowledge might, of course, not be immediate and explicit in numerical form; but it could in principle be elicited by a suitable controlled experiment testing the individual's choices among various combinations of outcomes and rewards.

The posterior probability distribution summarizes the state of knowledge or belief of the individual after making use of the new information gained by sample evidence at the stage of the investigation under discussion. The approach as a whole is called Bayesian, because of the crucial role played by Bayes' Theorem in indicating how a specified prior probability distribution when combined with sample evidence leads to a unique posterior distribution for the unknown parameter.[3]

With the presentation of the characteristics of the approach, it is easy to see that the decision tree approach is of greater utility when the estimation of the probabilities of chance events are improved. A basic reference for work in Bayesian Statistics is Schlaifer's statistic text.[4]

Sensitivity Analysis and Simulation

The examples and problems considered in this report have involved

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[3]Jack Hirshleifer, "The Bayesian Approach to Statistical Decision," Journal of Business, Vol. 34 (October, 1961), p. 471.

[4]Robert Schlaifer, Statistics for Business Decisions (New York, 1961).

choosing among alternatives with a single set of forecasts given. There is always uncertainty about the future, and a decision among alternatives often can be made more efficiently if the result of the evaluation is sensitive to moderate changes in certain forecasts.

Sensitivity refers to the relative magnitude of the change in one or more elements of a capital investment problem that will reverse a decision among alternatives. Thus, if one particular element can be varied over a wide range of values without affecting the decision, the decision under consideration is said not to be sensitive to uncertainties regarding that particular element. On the other hand, if a small change in the estimate of one element will alter the decision, the decision is said to be very sensitive to changes in the estimate of that element.[5]

In the presentation of the Planter's Pipeline problem only one chance variable was considered--that being petroleum product demand. Contrary to this example most problems have many chance variables which would constitute the conscription of a range of probabilities for use in this analysis. Added to demand for products in the example could be such variables as costs, market fluctuations, cyclical trends, research and development results, and share of the market. Each of these conditions is so uncertain and dependent on so many things that different techniques should be used in determining the range of probabilities.

A form of simulation known as the Monte Carlo Method of handling several uncertain variables could be used. The principle of the Monte Carlo Method is to find some cheap way of making artificial trials, the

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[5]Eugene L. Grant and W. G. Ireson, Principles of Engineering Economy (New York, 1960), p. 240.

possible events of which have the same long-run frequencies as the events in which we are really interested. After a large number of trials are made, the required probabilities are assessed on the basis of the relative frequencies with which the various artificial events occur.

Another form of simulation in which the objective is to give a clear picture of the relative risk and probable odds of coming out ahead or behind in the light of uncertain knowledge is proposed by David B. Hertz in the Harvard Business Review.[6] To carry out this method, three general steps are:

1. Estimate the range of values for each of the factors (e.g., range of selling price, demand, economic life, etc.) and, within that range, the likeliness of occurrence of each value.

2. Select at random from the distribution of values for each factor one particular value. Then combine the values for all of the factors and compute the rate of return (or present value) from that combination.

3. Repeat over and over again to define and evaluate the odds of the occurrence of each possible rate of return. For each of these rates the chances that it may occur are determined. The average expectation is the average of the values of all outcomes weighted by the chances of each occurring.

Actually, Hertz's technique is the simulation of an investment problem that generates randomly the combination of the many variables which contribute to the rate of return on an expenditure. The resultant is a distribution which displays the relative chances that a certain rate of

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[6]David B. Hertz, "Risk Analysis in Capital Investment," Harvard Business Review, Vol. 42 (January-February, 1964), p. 95.

return will be achieved.

The value of the computer in developing clear representations of the uncertainty and risk surrounding alternative investments has been proved. Simulations can produce valuable information about the sensitivity of the possible outcomes to the variability of input factors and to the likelihood of achieving various rates of return.

Another area of exploration would be the use of discrete or continuous chance variables in the application of the sequential analysis approach presented. In the example for Planter's Pipeline discrete chance variables were used. A discrete chance variable is one in which there is a clear-cut chance or probability of an event happening, while continuous chance variables can take on a whole range of answers or probabilities.[7]

Continuous chance variables can be manipulated in two ways. One way is to "chop" the continuous variable into the form of discrete variables, such as using high, low, or medium estimates of the event occurrence. The second method is to take the continuous event by stages in such a way as to fix a part of the range of possible outcomes for which any alternative is best.

Such subjects or considerations as tax advantages, opportunity costs, structure and characteristics of the firm, and types of capital to be invested are left to the integrated functions of the decision making team and are not covered as such in this presentation of sequential analysis as a tool for capital investment decisions.

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[7]Ernest Kurnow, Gerald J. Glasser, and Frederick R. Ottman, Statistics for Business Decisions (Illinois, 1959), p. 32.

CHAPTER V

SUMMARY

The sequential analysis or decision tree approach to decision making in capital investment pushes into the spotlight three special aspects to be considered. These aspects are:

1. Consideration of alternatives and consequences open to the decision makers.

2. Examination of special problem areas pertinent to the decision making process.

3. Clarification of the uncertainties involved in the allocation of the capital resources.

This paper began by discussing the need of management for an integrated approach to the analysis of capital expenditures. Along with this integration an efficient, usable, flexible, and adaptible tool is necessary. Sequential analysis is that tool. Management always requires an objective means of evaluating the economic worth of individual investment proposals in order to have a realistic basis for choosing among them and picking those which will mean the most to the company's long-run prosperity.

Chapter II dealt with the phases of application of sequential analysis. They are (1) Consideration, (2) Investigation, (3) Correlation, (4) Implementation, (5) Evaluation, and (6) Regulation. Capital expenditure programs operate best in an enlightened environment where all the

personnel understand the economics of capital investments and of the measurements and controls which a sound program entails.

Also in the second chapter the basic requirements for the utilization of sequential analysis were presented. They are as follows:

1. Identify the points of decision and alternatives available at each point.

2. Identify the points of uncertainty and the type or range of alternative outcomes at each point.

3. Estimate the values needed to make the analysis, especially the probabilities of different events or results of action and the costs and gains of various events and action.

4. Analyze the alternative values to choose a course using the "carry-back" technique.

Chapter III contains three examples of the application of sequential analysis. The criterion for the evaluation of the investment situations is the maximum discounted cash flow using the assumed risk or discount rate that is applicable in each case.

Special applications and improvement of the application of sequential analysis concentrate on the improvement of the important data that is placed on the decision tree for analysis. Bayesian Statistics, Sensitivity Analysis, and Simulation provide three avenues of approach for the improvement of the probabilities and subsequent results of the alternatives in a decision that are governed by risk and uncertainty.

What this analysis technique provides is a clearer picture of the odds against or for a particular move, so it can be made or not made with eyes open to what is involved in the form of rewards and of consequences.

The time will never be reached when management finds that making

capital expenditure decisions is an automated process requiring no exercise of their judgment. It will always be the management's task to consider investment opportunities and utilize their judgment to investigate their cost, the benefits to be gained, and the risks involved. The sequential analysis technique is merely a device for analyzing investment proposals in a consistent manner after management has exercised its judgment. This technique cannot suggest a proposal nor can it estimate costs or savings, risks, or economic life. However, the team of good management judgment and sequential analysis can achieve success in capital expenditure decision making.

A decision is essentially a choice from alternatives. Decision trees are a tool for the evaluation of uncertainties and risks involved with the different alternatives and opportunities open to the enterprise. Realizing the limitations of use and applicability for sequential analysis, the decision tree provides management with a tool that indicates profitability, recognizes all pertinent factors of a decision, permits simple and easy application, and at the same time permits an overall view of the investment decision at hand.

Sequential analysis will aid management in its important role of decision making, but management must still exercise judgment and make the final decisions.

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Report: APPLICATIONS OF SEQUENTIAL ANALYSIS: A TOOL FOR DECISION MAKING IN CAPITAL EXPENDITURES

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Scope and Method of Study: This report has been undertaken as an examination of the applications of sequential analysis as a tool for decision making in capital expenditures. In order to get an overall view of the capital expenditure decision, the report begins with the phases of application of this technique. It continues with the illustration of sequential analysis for three types of capital investments. They are a long-term asset, an incremental product addition, and for research and development.

Findings and Summary: The term decision tree is used as a synonym for the name of this technique. The branches of the decision tree represent alternative courses of action or decision. At the end of each branch is a reward which is the consequence of an alternative branch. By the use of the "carry back" technique and the "prime position value," alternatives can be analyzed. The criteria used in the decision process is the maximum discounted cash profit. Sequential analysis is a tool for the evaluation of uncertainties and risks involved with the different alternatives and opportunities open to the enterprise.

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