San Fernando Valley State College

RESOURCE ALLOCATION TO SUPPORT CORPORATE GROWTH OBJECTIVES

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Science in Business Administration

by

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ABSTRACT

RESOURCE ALLOCATION TO SUPPORT CORPORATE GROWTH OBJECTIVES

by

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The present paper is concerned with the influence of growth objectives upon the allocation of limited resources. The study is limited to objectives definable in terms of product growth, market growth, or a combined goal involving each. More general goals such as sales growth or facilities growth may be expressed in terms of factors implicit in the relations linking available resources and corporate objectives.

Methodology is developed to represent resource allocation to support attainment of established growth goals assuming that unlimited resources are available in the market; the corporation is restrained only by its ability to purchase needed commodities. Feedback from sales replaces resources utilized with the increased sales available only through allocation of profits to satisfy this need.

Simulation is employed to establish relations influencing allocation of resources with feedback by means of a profit function supplying the additional resources needed to satisfy the demands of an expanding market. The influence of the environment within which the firm operates also affects assignment of resources and is considered in the simulation. The results of such a process disclose the degree to which desired goals may be realized and provide guidance in directing efforts to achieve these goals.
Chapter 1
INTRODUCTION

Role of Objectives

Survival under the governmental, economic and social environment within which the modern corporation must function has become increasingly dependent upon the ability of the firm to properly utilize its limited resources so as to best achieve its desired objectives. As a corollary to this assertion it is emphasized that the selection of goals must be compatible with resources available to the firm if suitably dispersed during appropriate activities of the firm. Proper adjustment of corporate activities to support company goals and of company aims to reflect capabilities is a continuous process that requires constant reassessment to account for the changing environment within which these activities function. All activities of the firm must be directed toward accomplishing the objectives of the enterprise. Otherwise the organizational structure is unlikely to ever attain the unanimity and objectivity that are most essential if corporate goals are to be realized.

Simulation of corporate activities under appropriate restraints as imposed by available resources, and within the environment in which it must perform, will disclose the degree to which desired goals are realized. Such a representation will provide guidance in directing these efforts. Necessary adjustments in operations to realize desired goals may be determined by means of a mathematical model expressing relations between resources of the firm and objectives, with appropriate feedback mechanisms to indicate degree to which stated goals are attained under a given allocation schedule.

Definition of corporate objectives is a requisite before any business enterprise can initiate activities. Objectives may indicate action to be taken, areas to be emphasized, or goals to be accomplished. Malcolm, Rowe, and McConnell emphasize that "before initiating any course of action the objectives
Selection of objectives is of prime importance in providing guidance to the modern corporation although Drucker discards traditional profit maximization objectives on the grounds that they are inadequate to explain current business phenomena or analyze modern business experience. 2

LeBreton and Henning 3 reject this deemphasis of profit based goals on the grounds that profit maximization is necessary to determine the economic cost of accepting non-profit objectives, thus viewing all company programs on the basis of their ability to contribute to profits. In the case of objectives relating to product development or a desire for increased market penetration such a criterion would provide indication of foregone profits but not necessarily the degree of realization.

Drucker defines five areas in which tangible objectives for performance may be established. 4 These are market standing, innovation, productivity, physical and financial resources, and profitability. Objectives in these foregoing areas are somewhat difficult to distinguish in actual practice since such goals are rarely independent of each other. Koontz and O'Donnell stress the lack of universality in Drucker's generalizations, arguing that "different kinds of enterprises have different objectives and purposes generally applicable to business enterprises may not be to others." 5


4 Drucker, loc cit, page 63.

There is universal agreement on the necessity for establishing objectives to provide a goal for operations. Opinion is more divided concerning the nature of such goals and their relations to each other and to their supporting subsidiary activities. Gross defines objectives as serving a specific category of purpose such as "satisfaction of interests, output, input-output relations, efficiency, mobilization of resources, investment in viability, observance of codes, and rationality." ⁶ The goals suggested are expressible either quantitatively or qualitatively. Difficulties inherent in attempting to relate attainment of stated goals to these criteria have been reviewed by a number of authors. ⁷ ⁸ ⁹ Some application of utility theory is generally applied to qualitative goals to achieve common unit of measurement; however, the impossibility of establishing values of utility for a corporation makes this application relatively useless as a measure of achievement.

Quantitative goals may be specified in terms of a measurable factor. Such relations are usually expressible in terms of some common measure such that the relative merits of each objective are established. Profit maximization is the objective specified most often to provide a measure of achievement. This


goal is stated in terms of dollars which provides a convenient reference for relation of subsidiary or attendant goals.

**Purpose**

The present thesis is concerned with the influence of growth objectives upon the allocation of limited resources. Since resources must be distributed in a manner to best support the goals of the organization, it is postulated that the relationships linking available resources and stated objectives are definable and may be utilized to simulate operations of the firm over a number of periods of time to establish that scheme of resource allocation best suited to corporate growth desires. It is assumed that stated goals are attainable with available resources. Where necessary, goals are adjusted to support this premise. Consideration is given to supplementing available resources using feedback from sales to support attainment of growth goals.

Unfortunately, substantiation of any methodology attempting representation of corporate response to an indicated control function requires that "real world" data be available for comparison. Correlation between input and output in terms of allocation of available resources and desired production for such a representation is seldom available. However, the interrelationships employed are sufficiently straightforward that their validity should hold. Far too many complex factors are involved in an actual situation; as a result, any conclusions arrived at from an attempted comparison with model data would be somewhat questionable. A simulation using an idealized model to illustrate the influence upon operations of trade-offs involving resource allocation and growth goals under a controlled environment provides data that would be more significant in indicating relative influences as discussed in the following section.

**Approach**

The general approach to the problem of expressing necessary allocation of corporate resources to stated objectives is by definition of the relations linking these factors and identification of the factors implicit in these relations. The study is limited to objectives of product growth, market growth, or a combined goal of both expressed in terms of dollar sales. Any number of products
entered in one or more markets may be considered. More general goals such as sales growth or facilities growth may be expressed in terms of the aforementioned factors. Sales growth is defined as the change in sales from sales in the preceding time period. Facilities growth is measured in terms of resource growth necessary to support increased sales, achieved by feedback of proceeds from sales. A flow diagram depicting relations involved in translating corporate objectives into resource requirements is presented on Figure 1 – 1. The effectiveness of the system illustrated is highly dependent upon accurate definition of the factors which make up the intermediate links.

Simulation will be employed to establish both short- and long-term relations that may influence resource allocation. The requirement that resources of the firm and objectives be compatible will be applied only to the end results on the basis that short-term goals may be manipulated by the firm (management) in order to better achieve the long-range goals. Feedback of a profit function to supply additional resources needed to satisfy the demands of an expanding market will be included. The influence of the environment within which the firm must function also is studied relative to its effect upon assignment of resources. Project selection as affected by corporate objectives under the restraints imposed by available resources and the market environment is considered and the feasibility of adapting the concept introduced is indicated.

Effectiveness

The effectiveness of a corporation's objectives in establishing realistic operating goals is not always apparent from published statements of accomplishments. Goals actually intended by statements of objectives can only be determined by inference from actual accomplishments by the company. To assure some degree of consistency between stated goals and accomplishments, it becomes necessary to regularly review organizational goals and the means devoted to their attainment. The activities of the firm may require redirection or differing emphasis if stated goals are not compatible with capabilities or with one another.

The cost-effectiveness criterion is cited by Daniels and Lathrop as "a measure designed to present in succinct terms the measure of the planner's
Figure 1.1. Flow Diagram of Objective/Resource Requirement Interrelationships.
real goal: the economic use of limited resources to attain clearly-stated objectives. The concept represents a rational approach to the central task of decision-making: the optimal allocation of limited resources. Application of this general notion at present seems to be largely limited due to communication difficulties such as the inability to define measurable goals and to establish a basis for measurement of achievement. Although quantitative analysis does provide much necessary information to the decision-maker, these remain only guides to the decision. Unmeasurable aspects of the environment and system effectiveness also are concerned in ultimate determination of the decision.

Measurement of utility provides the most all inclusive (although unmeasurable) tool for weighing outcomes. "Utility is designed to explain and depict the results of highly subjective conclusions and evaluations concerning diverse and incommensurate factors--'outcomes' of a decision." The utility function for an individual may be readily developed qualitatively in terms of wealth, profit, units of specific items, etc., using a technique described by Marschak (who is primarily concerned with monetary measurements). However, it is generally considered inadequate as a guide to corporate decision-making since the biases and indecisions of the individual decision maker are directly reflected in the model and no one individual has the same tastes and beliefs as a corporation. A board of directors utility function is necessary; however, no one has yet developed a theoretical technique for deriving a

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10 Daniels and Lathrop, loc cit, p. 1.
11 Ibid, p. 4.
12 Jacob Marschak, "Actual Versus Consistent Decision Behavior," Behavioral Science, Volume 9, Number 2, April 1964, pp. 103-110.
multi-person utility function. Here, a more positive approach relieving the manager from establishing criteria for a risk situation is needed.

Churchman, Ackoff, and Arnoff propose the use of weighted effectiveness as a basis for selection of a course of action.\textsuperscript{14} They emphasize the need for a measure of the importance of objectives in order to measure effectiveness. If all objectives are expressed in quantifiable terms, a measure of efficiency relative to each goal is developed. The efficiency functions for each course of action are added to obtain a combined efficiency relative to all objectives (effectiveness function). Objectives expressed in quantifiable terms are related to common units. A similar model for system effectiveness using estimated measures of performance for alternate systems is used by Bain.\textsuperscript{15}

\textsuperscript{14}Churchman, Ackoff, and Arnoff, loc cit, p. 122.

Chapter 2

CORPORATE GROWTH OBJECTIVES

Overview

Factors relevant to representation of the activities of the firm in achieving compatibility between growth objectives and allocation of available resources to best support these goals may be represented in a multiplicity of manners.

The literature reviewed in the present chapter defines parameters relevant to quantification of objectives, resource allocation, environment, and project selection. Much of the available methodology either requires information in a format not usually available to the firm or demands a degree of processing inconsistent with the output to be derived. Little attention is given to the continual competition for the limited resources available among various activities, all of which are presumably striving for a common goal or to the interrelationships among these activities. The role of corporate growth as an objective in its own right is generally subverted to profit making activities of the firm.

The model developed in the following chapter considers growth, defined in terms of improvement of sales of a particular product, sales within a particular market, or total sales, as a primary goal to which a corporation may direct its efforts. Provisions for consideration of multiple goals involving several products and/or markets and introduction of new or improved products which may replace existing lines is included. Information necessary for implementation of the process is generally available to each firm although cost information must be provided for each product/market situation. The model is particularly adaptable to simulation of the activities of the firm over several periods of time to indicate the influence of resource allocation among production and sales activities upon desired growth goals under the changing environment within which the firm must operate.
Careful planning is necessary to adjust to changing environmental conditions in supporting goals of continuous growth (and profitability) under competition. Reilly\(^\text{16}\) stresses the need for corporate objectives to recognize that new business resulting from technical innovation must exist side-by-side with maintenance of any competitive advantage present in the changing environment.

Types of objectives needed by a company desiring growth are described by James Quinn.\(^\text{17}\) These are the kinds of business in which the company desires to operate (expressed in terms of a desired market), method of growth (acquisition, merger, internal development), direction of growth (horizontal or vertical), rate of growth (limited by resources).

A number of analytical approaches to the problem of relating available resources to feasible projects have been developed. The majority of these studies allocate resources to achieve a profit maximization objective. Lesser consideration has been given to the relation of resource allocation to growth-oriented goals.

David Packer derives a model to provide insight into the regenerative processes creating growth, the role of managerial policies in these processes, and ways for designing policies that promote desirable performance.\(^\text{18}\) This study probes the nature of the corporate growth process through the impact of managerial action on growth performance. Packer emphasizes that "growth does not depend on either the market or the firm alone. It results from interactions between them."\(^\text{19}\)


\(^{19}\) Ibid, p.2.
Daniels\textsuperscript{20} provides a methodology by which the relation between investment and sales in steady state operation may be applied where introduction of a new product or change in the scale of operations is considered. He establishes an initial tabulation describing each program in terms of the sequences of anticipated investments and sales for each time period. The probabilities that each step in the sequence will be achieved are applied and the program distributed over the desired time periods using assumed shapes of investment and sales curves. A multiplying factor (defined in terms of the expected rate of market growth) is employed to generate the sequence of probable investments and sales past the time period in which the initial decision was made. If the scale factor matches the growth rate of the market, the sales growth should match market growth after the start-up transient with market share ultimately becoming constant.

Hulburt and Scalera derive a model for the annual fractional gain in corporate sales due to new product research.\textsuperscript{21} They express the feedback effect on growth from investment of a fixed annual fraction of profits in new product research and development and define a growth parameter in terms of total future sales generated per dollar of current sales. Model parameters may represent returns averaged over any income-producing actions such as acquisitions, investment, plant expansion from current income as well as research expenditures.

**Objective Function**

Resources of the firm, such as manpower, production capacity, and financial, all contribute to a sequence of operations which is directed toward


attainment of one or more, independent or dependent, overall objectives.

Churchman, Ackoff, and Arnoff suggest that the proper course of action to be selected from among available alternatives cannot be chosen without information concerning the relative importance of the desired objectives. They assign a relative importance to each goal using an arbitrary scale and utilize this value to weight the efficiency of each course of action for each objective. The relative effectiveness of any course of action is obtained from the sum of its weighted efficiencies. Some means of expressing the efficiency of each course of action for each weighted function is necessary to account for possible variations in expected results over a period of time.

When corporate objectives are quantifiable, the foregoing procedure is implemented by expressing overall aims generally, in terms of some criteria relating to profit and/or stockholders equity. Secondary objectives are seen as primarily supporting the foregoing goals and are therefore considered quantifiable in terms of the above aims.

Profit maximization objectives can be somewhat incompatible with other goals of the corporation which are established to guide corporate efforts toward attainment of desired long-range plans. Long-range objectives are generally selected so as to "expand the organization's profitable mastery over both its external environment and its internal behavior." Progress toward achievement of these aims may be evaluated by progressively measuring both competitive strength and efficiency. The former factor is indicative of the changing status of the firm in its external environment.

Competitive strength is usually measured in terms of growth and stability which represent an evaluation of the firm's manufacturing and marketing
activities. Long-range growth objectives are established in a variety of forms:

- Rate of sales growth represents a standard against which the conformance of current operations to long-range objectives may be measured.
- Expansion of product lines may also provide a goal toward which corporate activities may be directed.
- Increase in share of a specific market segment provides an indication of increased competitive strength.
- Enlargement in scope of market served is another goal toward which corporate operations may be oriented.

It should be noted that the foregoing growth aims may be independent of one another (except for sales growth which may include any of the others) or may assist each other to achieve whatever goal has been established for each factor.

With corporate objectives specified, a strategy of manufacturing must be established to specify the means by which resources to secure each objective are to be acquired, allocated, and employed. This activity requires analysis of the transformations involved to determine the combination of available resources best suited toward achievement of the desired objectives.

The selection of growth goals are suggested primarily by the corporation's marketing research activities. These actions relative to selection of aims for product/market interactions include survey of current activities in the market and competitive fields. Aguilar lists the following activities relevant to the external information that is required under the general heading of "market tidings."

- Market potential - supply and demand considerations for market areas of current or potential interest.
- Structural change - mergers, acquisitions, and joint ventures involving competitors; new entries into the industry.
- Competitors and industry - general information about a competitor, industry policy, concerted actions in the industry, etc.
Pricing - effective and proposed prices for products of current and potential interest.
Sales negotiations - information relating to a specific current or potential sale or contract for the firm.
Customers - general information about current or near potential customers, their markets, their problems.  

These data are assumed available and the firm's product and market goal defined and feasible. Cost information including processing, operations, etc., is also established as are the resources available such as personnel, raw materials, facilities, and cash.

Stimulation of corporate growth is seen as a "bedrock objective" of strategic long-range planning by Brian Scott.  

Internal growth may be attained in two manners: expansion by internal development of resource capabilities and/or acquisition of other companies or products. Both methods have the same effect - increase of resource capabilities. This gain must be supported by an increase in sales. The effectivity of any corporate growth is ultimately reflected in terms of total sales. This is the criteria selected as a measure of degree of attainment of the growth objective.

Packer's study of the relations linking resource acquisition with corporate growth assumes an unlimited market relative to the firm's output so that an increase in potential demand will always be produced by activities directed

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26 Ibid., p. 99.
toward this purpose. 27 The market is considered as responding to only the firm's expenditure of professional effort and its delivery delay while composed of sources that could obtain substitutable products from competitors. Professional effort and production capacity are treated in the aggregate. Increases in the aggregate professional effort are considered to generate commensurate increases in potential demand; increases in new capacity units increase the production capability. The study concentrates on over-all performance; product considerations are considered implicit in the gross effect of professional activities on potential demand.

Ansoff establishes a "growth vector" to indicate the direction in which the firm is moving with respect to its reference product-market posture as shown in Figure 2-1. 28 Market penetration represents an attempt to increase sales without departing from the original product-market strategy. Performance is improved by either increasing sales to present customers or by finding new customers having the same requirements. Market development finds the company attempting to adapt a present product line to a new market. Product development introduces new products to replace existing ones. These three strategies all represent expansion of present firm activities. They may be followed employing the same technical, financial, and merchandising resources used for present product lines. Survival under the usual economic competition requires that all three of these courses of action be implemented. 29


The diversification strategy represents growth by means of both new products and markets. These usually require new skills, new techniques, and new facilities leading to physical and organizational changes in the business structure, representing a distinct change from previous experience. Diversification then, as seen by Ansoff, represents a change in course for a firm, but not necessarily growth.\(^3\) The discussion of factors contributing to the growth objectives herein is limited to expansion strategies with product and market development representing the growth contribution of diversification objectives.

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![Figure 2-1 - Growth Vector](image)

The objective function representing each of the forms of growth described in the foregoing paragraphs are defined as follows:

**Market Penetration** –

Allowing \(M_i(t)\) to represent the projected value of product market \(i\) in period \(t\), and \(S_i(t)\) total dollars sales in market \(i\) in period \(t\); then \(S_i(t)/M_i(t)\) represents the fraction of market \(i\) anticipated for period \(t\).

Similarly, \(S_i(t-1)/M_i(t-1)\) is the fraction of market \(i\) captured in the preceding (reference) period. Market growth is attained when \(S_i(t)/M_i(t) > S_i(t-1)/M_i(t-1)\) or

\[
\left( \frac{S_i(t)}{M_i(t)} \right) - \left( \frac{S_i(t-1)}{M_i(t-1)} \right) > 0
\]

Market Development -

If $S_{ij}(t)$ is total sales of product $i$ in market $j$ in period $t$, then the share of total market represented is $S_{ij}(t)/M_{i}(t)$ and successful introduction would be attained if the desired penetration (preselected fraction of estimated market) were achieved.

Product Development - Successful introduction of a new product would be reflected as part of the market penetration objective. Where the particular product under consideration was not offered in the preceding period, no fractional sales increase relative to the product itself can be defined. Accordingly, this growth objective is expressed with respect to the preselected market size as a market development goal, $S_{ij}(t)/M_{i}(t) > 0$.

Other growth objectives may be expressed in terms of the foregoing definitions. Facilities growth may be achieved only if the need for additional plant and/or machinery may be substantiated by the need to support increased sales and service. The feasibility of this aim will be dependent upon available resources and those necessary to support market and product goals.

Sales growth is readily expressible in terms of total sales and is thus a function of previously defined factors. However, a desire to achieve some increase in total sales may not be compatible with individual product or market goals due to interactions between the latter factors.

In any case, growth objectives may be expressed in terms of dollar sales in each period. The resources of the firm may be allocated in a number of ways to produce these sales. Relations between product and resource allotment will define the manner in which the allocation must be made to support the desired growth goal.

Compatibility of resource allocation with any combination of the foregoing objective functions for the short-range with fixed resource availability can be readily established using the model of equation (3 - 9). Compatibility with longer-range objectives may be established using average values of the expectation of sales and market value as in the model for sales growth due to
research expenditures by Hulburt and Scalera. 31 An improved model of long-range growth including facilities growth may be attempted using a simulation technique with the profit function applied to provide an increase in available resources to support the growth objective with the latter function providing the basis for resource allocation.

Environment

The importance of environmental factors in determination of actions selected in marketing products is emphasized by Daniels in stating that product development emphasizes "programs which will meet such risk criteria as may be imposed, particularly with regard to survivability of the firm under existence of . . . environments (which) have been considered . . . in the analysis." 32

Both environmental factors and corporate objectives will significantly influence the way in which resources are allocated. Miller and Starr suggest that although assignment of resources will be changed depending upon desired objectives, environmental factors considered should include geographical factors, political considerations, local economic factors, backlog or work, reputation, and tie-in with other projects (synergism). 33 Affected inputs may include product prices and volumes, raw material costs, economic conditions (import restrictions, tax rates, regulated production output), subsidiary income, and discretionary expenses (research and development, sales of securities, write-offs, advertising).


In their exploration of the anatomy of the planning process Gilmore and Brandenburg employ the master plan of the enterprise to express the relationship between the company and its competitive environment. The master plan includes formulation of performance objectives for the firm and finding the proper product-market-sales approach combination for effective accomplishment of these goals. The purpose of the former (economic mission) phase in the planning process is to select the external competitive environment for the firm, and to establish overall goals for company performance in that environment. The second (competitive strategy) phase specifies the manner in which objectives in the competitive environment should be pursued and establishes the proper relationship between capabilities of the firm and problems and opportunities in its environment.

Schnier discusses the advantages to a centralized production planning system, and specifies organizational objectives and a measure of the state of the organization and its environment as among the essential elements of such a system. Subgoals of the various functions are defined in terms of the market and of production. Where such subgoals conflict, corporate objectives must provide the basis for resolution. The state of the organization includes inventories, production capabilities, and other internal factors.

Different demands may be placed upon corporate resources depending upon the particular sector of the external environment within which the firm chooses to operate. Similar products may be developed with two entirely different target markets:

- a low-priced moderate quality line for broad distribution with wide advertising; or

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a high-priced, high-quality line for limited distribution.

These two diverse market objectives would place considerably different demands upon factors contributing to the corporation's goals. If the manufacturers involved had different objectives (maximization of return, market reputation, growth), different operating strategies would be employed as necessary to attain the desired goal.

The company may respond to its environment with two types of strategies: product strategy (specific product areas sought, types of projects) and product-backing strategy (allocation of resources to attain corporate objectives within environmental constraints). Although these strategies are interdependent to some degree, Daniels considers the former to be dominant with the latter assumed compatible. 36 Environmental factors involved in the determination of product strategy that are beyond control of the company are often difficult to quantify; however, their effect upon the total environment must be taken into account in defining the constraints within which limited resources must be allocated to maximize expected returns to the company.

O'Brien emphasizes the need for consideration of the changing environment within which the product is offered in developing new product strategy and the attendant resource commitment. 37 Potential profits and risk are large during the rapid growth phase of product growth. Risks may be minimized by entering the market during the consolidation phase during which competition is


reduced. New product research and development becomes mandatory during the maturity (market saturation) phase to evolve a replacement model for continuation of corporate growth trends.

"The means usually available to a marketing executive in his task of creatively adjusting to a dynamic environment are product variation, marketing channels, price and promotion (advertising and personal selling)." 38 Continuous adjustments to a changing environment require constant review of decisions, procedures, and objectives by the firm to assure coordination of efforts and aims.

The effect of environment is inherent in the model of the firm's product interactions with its market and the market response to economic conditions. Environmental effects are inclusive in prediction of market size, demand, costs, sales price, and time-influenced variations of these factors.

Resource Allocation

A number of models for allocation of resources under various conditions of project dependence and certainty have been developed. In general, allocations are based on a profit maximization criterion. E. W. Davis reviews various solutions that have been proposed for the resource allocation problem and notes that although a variety of analytical solutions are available for time/cost trade-off problems, available solution techniques for the problem of resource allocation under constraints are limited to heuristic procedures. 39

In the past 18 years, a number of solutions to the problem of allocation of capital resources have been developed. In 1951, Joel Dean presented a basic procedure for capital budgeting that called on the firm to compute the internal rate of return for each project and to rank these projects in decreasing order under this criterion. 40 This process requires that the decision be made


40 J. Dean, Capital Budgeting, Columbia University Press, 1951, N.Y.
in perfect certainty, the firm operate in perfect capital markets, investment functions be continuous, and all projects be independent of each other. Loric and Savage extended this theory to include cases wherein the projects are not independent and returns on any project may contain alternations in sign. Weingartner uses linear and integer programming to show that optimization is possible for many capital budgeting problems assuming that "future interest rates and future flows associated with investments are known with certainty." 

Reisman, Rosenstein, and Buffa present a methodology for allocation of a fixed amount of resources among competing sectors of an enterprise under conditions of uncertainty. Three criteria are specified: the project contributes to achievement of the aim of the enterprise, the project serves other projects, the project uses as inputs the outputs of other projects or functions. The method provides a formalism which allows all projects to compete for available resources on the basis of relevance to general objectives.

Clarke utilizes simulation to evaluate capital investments under uncertainty. The system under surveillance is reproduced in quantitative terms and Monte Carlo methods employed to synthetically generate data to simulate "real world" data. Simulation permits thorough appraisal of an investment by determining the sensitivity of the profitability criterion to minor changes in system parameters.

A dynamic programming approach to project selection is proposed by Hess\(^\text{45}\) to include consideration of the many reappraisals and budgeting decisions that occur following proposal of the project and prior to its commercialization. Hess structures the budgeting problem to include consideration of these sequential decisions. Optimal project budgets are determined for either constrained or unconstrained aggregate budgets utilizing dynamic programming techniques. The decision to initiate, or continue, the project; and how much to allocate for the coming period is determined from estimates of such parameters as life, cost, pay-off (if successful), and probability of success. The models developed take maximization of total expected net profit as the corporate objective. The decision model takes the sequential decision process relating allocation to project reevaluation at the start of subsequent periods into consideration thus including the effect upon the system, and upon subsequent decisions, of an earlier decision in the model.

Hess' approach is also utilized by Atkinson and Bobis\(^\text{46}\) to develop a dynamic model for use in determining money to be spent on product oriented research programs. They assume that decisions are made intuitively on the basis of usually inadequate data and emphasize the need for quantification of these bases with consideration to the logical consequences of such assumptions. The results from their optimizations indicate significantly increased expected returns for the programs studied. However, these effects are achieved by concentrating available resources upon those projects anticipated to produce the

\begin{flushleft}

\begin{flushleft}
highest profits. The authors emphasize that the optimal allocation of funds is not necessarily compatible with maximization of expected profits. Allocation under the constraint of anticipated losses, for example, is not considered.

A statistical model for use in forecasting manpower requirements for a project-oriented organization, including consideration of subjective probability of starting and/or the conditional probability of the starting date is presented by Lejk and Wortham.\(^47\) The authors utilize expected values and variances in consolidating the requirements of all projects into a long-range plan. The method, as presented, is somewhat restricted in that the projects under consideration are assumed independent of each other. Extension of the approach to the prediction of corporate resources necessary to support overall objectives must include consideration not only to the demands each project will place upon available resources, but also, to any means by which the same resources may be used to support several projects simultaneously with the attendant cost reductions and efficiencies.

Daniels and Shane\(^48\) see resources as a limiting factor upon the attainment of desired objectives. Included under available resources are money, people, facilities, and time. These factors impose restraints upon any total system. Some means of logical selection must be employed in establishing allocations of such resources so as to best support desired corporate goals.

Assignment of available resources is represented by a product allocation matrix, \(p_{ij}(t)\), in which each row, \(i\), pertains to a single product and each column, \(j\), represents allocation of a single resource of the firm in period \(t\).

---


It is this assignment of resources on the basis of project selection that must be correlated with organizational desires. Available resources represent an input into a system, which transforms them by means of activities provided by the firm into outputs of goods and/or services. It is these outputs that must relate to corporate objectives.

Available resources will depend to a large extent upon corporate forecasting of requirements in view of current and anticipated products. If utilization of available resources can be matched to project requirements, the desired maximization of utility is attained. If insufficient resources are available to support expected sales, several courses of action may be considered:

- Surplus resources may be traded for resources in short supply (e.g. money may be utilized to purchase additional materials or to rent additional production facilities).
- Reevaluation of short-term goals to establish objectives more in keeping with company capabilities as limited by resource availability.
- In a longer-term simulation to establish resource allocations to support growth objectives, short-term objectives may be adjusted to permit realization of the longer-term goals.
- Additional resources may be obtained on a loan arrangement, such as borrowing money, obtaining material on credit, etc. The costs of such action will affect other goals of the firm and unduly complicate the model developed herein. Accordingly, the firm's borrowing capability will be considered in the present development as included in available resources such that the latter represent a restraint upon the firm's ability to exceed some defined growth objective.

Resource requirements as defined by desired growth goals may represent a restraint upon such aims. Environmental factors such as market growth, competition, and economic factors will impose other restraints under which the system representing corporate operations must function if maximum use of company capabilities is to be made in furthering the desire for growth. Simulation
of the activities of the firm using the model developed in Chapter 3 will permit trade-off studies to determine which functions should be actively pursued to best approach the desired growth objectives. Facilities growth is included to reflect the need to support increased sales by using available capital resources and increased borrowing power where available.

**Project Selection**

Selection of product lines for replacement of products in the maturity phase of their growth cycle requires a preparatory period, usually several years, prior to actual introduction in the market. During this preparatory period other potential programs will appear. Selection of the programs appropriate to the company's objectives and capabilities, and efficient allocation of available resources become an essential part of corporate planning. The selection process must include allowance for uncertainties in the environment assumed in making the project choice.

Evaluation of the consequences of various courses of action may be effected using simulation to estimate the results of program funding, timing delays, expenses, competitive factors, and the overall environment within which operations are carried out, upon objectives. Results of the simulation are utilized in prediction of those projects most likely to succeed under the assigned environment, maximization of the likelihood of success as a function of resources expended, and evaluation of the influence of environment upon success. Quantification of many of the factors involved in such a simulation is impractical due to lack of either adequate information or past experience. Value judgments usually are applied in the form of scaling factors to provide a basis for project selection.

Daniels and Shane⁴⁹ see project selection as a function of the relation between expenditures and sales with in-house effort proportional to the product

---

of potential sales volume times a confidence factor. The decision as to project selection must be made on the basis of the kind of risk--technological, financial, and environmental--management is willing to accept. Some quantitative measure must be applied in incorporating these risks within an operating model. Too often potential risks are either optimistically ignored or conservatively considered as certainties.

Project selection must be coordinated with corporate goals. The first step in evaluating requirements to support present product lines is prediction of the potential market for each product. This includes assessing requirements to maintain product appeal under competition and changing market requirements. Present products will not support growth goals under a dynamic environment. New products must be developed or additional market applications for existing products devised. The situation is illustrated on Figure 2-2 which shows a typical long-term sales chart necessary to support a sales growth objective. As sales of present products fall off, new products (or entry into new markets) must be available if growth is to continue. Research and development of new products must be initiated well in advance of introduction. Allowance for product development is necessary in determination of allocation of resources to support growth goals.

Considerable literature is available relative to both growth as a legitimate corporate goal and allocation of resources to support desired objectives. However, little of this methodology specifically attempts correlation of available resources of various types with growth goals for several products in the same and/or competing markets. A technique is developed in the following chapter to define this relationship using the types of data that would normally be available to a company considering whether growth is to be achieved by expansion of present products or by diversification. The method requires that some knowledge be available regarding market growth and varying costs and resource availability with time

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Quinn, loc cit, p. 194.
Figure 2-2  Long-Range Sales Variation Showing Product Mix Necessary to Support Growth  
(Source: Quinn, pg. 194)
Chapter 3

CRITERIA

Premises

No all-purpose model representative of actual operational history under the constantly changing environment under which the firm must survive and prosper is readily available although a process attempting correlation of current partial models is being developed at the Wisconsin Simulation Laboratory. The necessity that such a model accurately forecast the consequences of actions taken precludes that such a tool be readily available except, perhaps, for an extremely limited firm/market relation. Accordingly, it becomes necessary that any model attempting to depict operations of the firm under a changing market situation include sufficient restrictions to limit the model to an area in which pertinent factors may be defined with some possibility of success.

The methodology developed requires that a feasible solution to the problem posed exist, i.e., that sufficient resources are available to permit realization of desired growth goals. It is presumed that sales are sufficiently high that total costs are covered; however, the profit function is not considered as an objective in its own right but only to provide a source of funds to supply additional resources to support increased sales. Competition for market domination may determine the magnitude of resources (money for advertising, promotional material) necessary to realize the desired share. This latter allocation is essentially a separate factor relative to the product/market mix. However, if the growth objective is established, it follows that resources will be allocated in the manner that will best support realization of the established goals.

Unlimited resources are assumed available in the market place. Here the corporation is restrained only by its ability to purchase the needed commodities. Feedback from sales will replace resources used. Increased capability to support a higher sales goal can only come through allocation of profits to this function.
These premises are inherent in the general model to represent resource allocation to support growth objectives.

Definitions

Variables employed in the process to be developed are of two types - exogenous factors which result from causes external to the firm, and endogenous factors which are produced from within the company. Exogenous variables are used to arbitrarily establish the external conditions under which the response of the system will be observed. As such, they permit examination of the reaction of the internal system to stimuli originating within the external environment.

The assumption is implicit, when using an independent variable to provide a test input, that the function itself is unaffected by the response of variables within the model (endogenous). If the system affects these variables and is, in turn, sensitive to them, the feedback linkages between the variables and the model itself may prove sufficiently significant to display a perceptible influence on the response of the model.

Under the foregoing definition, the only truly exogenous variable in the present paper is $M_j(t)$, the dollar value of the $j$th market in period $t$ expressed in value of expected total sales of all products sold within this market. Market value is used as the independent variable in the simulation models presented in Chapter 5.

Several of the other factors considered in this section are also largely influenced by factors external to the firm but are also affected by internal elements. These terms are largely exogenous in nature but can conceivably affect and/or be affected by the firm itself.

Included are:

$$c_k(t)$$

cost per unit of resource $k$ in period $t$.

Since the assignment of resources to production is in terms of number of units (expressed as man-hours, items, machine hours, etc.) the cost to purchase these resources will depend on the firm's market standing (desirability on part of
suppliers to maintain accounts) and competitive pressures (supply-demand relationship) for available resources.

\[ C_i(t) = \begin{bmatrix} \sum_{k} P_{ik}(t) a_{ik} \end{bmatrix} \begin{bmatrix} C_k(t) \end{bmatrix} \begin{bmatrix} 1 \\ 1 \end{bmatrix} \]

Total costs will depend on market standing, competitive pressures in bidding for resources, and internal efficiencies.

\( G_i(t) \) Profit from total sales of product \( i \) in all markets in which offered in period \( t \). Sales price will depend on economic conditions and competitive pressures.

\( P_{ik}(t) \) dollar amount of resource \( k \) to produce required units of product \( i \).

\[ \sum_{k=1}^{1} P_{ik}(t) = C_i(t) \]

\( P_i(t) \) units of product \( i \) to be produced in period \( t \). This factor will be influenced by anticipated market size and the estimate of the portion of this market the firm expects to capture due to product price and/or utility under the expected conditions, both economic and competitive.

\( s_i(t) \) unit sales price of product \( i \) in period \( t \). The market price will be largely determined by the influence of competition and market demand.

\( S_i(t) \) Total sales (in dollars) of product \( i \) in all markets in period \( t \).

\( S_j(t) \) Total sales (in dollars) of all products sold in market \( j \) in period \( t \). Expected sales will
depend on market characteristics and the capability of the firm to survive and grow under this economic and competitive environment.

Largely endogenous factors, which may be influenced to a secondary extent by the external environment include:

- $a_{ik}$: Units of resource $k$ needed to produce one unit of product $i$. This factor is largely defined by production and quality assurance controls which are intended to improve operating efficiencies.

- $R_{k}(t)$: Total dollar amount of resource $k$ required in period $t$.

$$R_{k}(t) = \sum_{i} p_{ik}(t)$$

Since resources may have been purchased in different periods at different costs, total resources are expressed in terms of units of resource. The total on hand of any resource in a given period will depend largely upon the firm's buying and inventory policies.

**General Model**

An objective function may be developed from the corporation's stated objectives to provide criteria toward which the allocation of available resources may be directed. Growth goals are expressed for a specific period of time: a week, a month, quarter, or year, in terms of the fractional increase in share of a specific market, $j = 1, \ldots, n$; fractional increase in sales of a specific product, $i = 1, \ldots, m$; fractional increase in total sales; and/or fractional increases in individual or total resources. For convenience, these goals are related to dollar sales through definition of appropriate transformation relations. The model developed may be used only with a finite planning horizon consisting of a given number of time periods denoted by $T$. Each individual time interval
Figure 3-1. Matrix Notation

- square matrix
- diagonal matrix
- column matrix
- scalar quantity
within the span is denoted by t.

Examples of typical organizational goals representing several types of growth aims are presented in the following paragraphs. The decision variable, \( x_b(t) \), \( b = i, j \), is employed to represent the fractional growth to be attained in the \( t^{th} \) period.

Where the desired objective is an increase in the share of a given market, \( j \), by a fraction \( x_j(t) \) over the preceding period, the sales requirement, in dollars, is

\[
S_j(t) = M_j(t) \left( \frac{S_j(t-1)}{M_j(t-1)} + x_j(t) \right) \quad (3-1a)
\]

If several products are entered in the same market, total sales are considered

\[
S_i'(t) = S_i(t) = M_i(t) \left( \frac{S_i(t-1)}{M_i(t-1)} + x_i(t) \right) \quad (3-1b)
\]

In the foregoing relations, the term \( S_i(t) \) represents sales to be achieved by the individual firm in market \( i \) during the present period \( t \). \( M_i(t) \) is the projected value of the total market, \( j \), for the present period, \( t \), to be divided among all firms competing within it. \( S_i(t-1) \) and \( M_i(t-1) \) are the firm's sales and total market value in the preceding period, \( t-1 \), with the ratio indicating the market fraction of the individual firm in that time interval.

An objective to increase sales of a given product, \( i \), by a fraction \( x_i(t) \) over total sales for this product in the preceding period, \( S_i(t-1) \), may be expressed in terms of anticipated sales for the present period, \( S_i(t) \), in dollars.

\[
S_i(t) = S_i(t-1) \cdot \left( 1 + x_i(t) \right) \quad (3-2)
\]

A required increase in total sales of \( X(t) \) is defined in terms of total sales in the preceding period.
\[ TS(t) = (1 + x(t)) \sum_{i=1}^{n} S_i(t-1) \]  \hspace{1cm} (3-3a)

\[ = (1 + x(t)) \sum_{i=1}^{n} S_i(t-1) \]  \hspace{1cm} (3-3b)

Compatibility between product growth and sales growth must be present in a gross sense. A similar agreement must be present where several products are offered for sale in the same market. This requirement may be illustrated by considering a two product market environment with a market growth goal for period \( t \) of \( x_i(t) = x_1 \) and a gain in product \( i = 1 \) sales of \( x_1(t) = x_2 \). The necessary sales gain for product \( i = 2 \), \( x_2(t) = x_3 \), may then be determined. Increased dollar sales for each product are defined using equation (3-2).

\[ S_1(t) = S_1(t-1) \cdot (1 + x_2) \]  \hspace{1cm} (3-4)

\[ S_2(t) = S_2(t-1) \cdot (1 + x_3) \]

The increased market share is obtained using equation (3-1b) to establish the total anticipated sales in period \( t \).

\[ S_1(t) + S_2(t) = S_1(t-1) = M(t) \left( \frac{S_1(t-1) + S_2(t-1)}{M(t-1)} + x_1 \right) \]  \hspace{1cm} (3-5)

The necessary goal for sales of product as required by the previously established sales goals is obtained by substituting equation (3-4) into equation (3-5).

\[ x_3 = \left( \frac{M(t)}{M(t-1)} - (1 + x_2) \right) \left( \frac{S_1(t-1)}{S_2(t-1)} \right) \]

\[ + \left( \frac{M(t)}{M(t-1)} - 1 \right) + \left( \frac{M(t)}{S_2(t-1)} \right) x_1 \]  \hspace{1cm} (3-6)

Data required to obtain this factor are dollar sales of each product in the previous time period, total value of the market in the previous time period, and
the projected total value of the market for the present period.

Resource growth goals are established in a similar manner. Total resources are referenced to available resources in the preceding period. Although like resources may be compared in like terms, e.g. manhours, units of resource, etc., relation of all terms to dollar values will produce the most convenient reference. The fractional increase in resource \( k = 1, \ldots, l \) is expressed as

\[
\frac{R_k(t)}{R_k(t-1)} - 1
\]

while the increase in total resources is

\[
\sum_{k=1}^{l} \frac{R_k(t)}{R_k(t-1)} - 1.
\]

This goal is related to the profit function \( G(t) \) since replacement and purchase of resources will come from gains on sales.

The foregoing examples indicate the means employed in definition of an objective function for model definition. The function is expressed using matrix notation in terms of dollar sales of each product for a specific time period,

\[
\begin{bmatrix}
S_i(t)
\end{bmatrix}
\]

Expected product sales in terms of the number of units of each product, \( P_i(t) \), are obtained knowing the unit sales price of each, \( s_i(t) \), in dollars per unit. The latter function will depend on total cost to produce each unit of product which includes both costs assignable directly to product and fixed costs which do not change in total over large volumes of product. In addition environmental conditions such as competition, consumer acceptance of the product at the asked sales price, and the desire to stimulate demand will influence this factor. Expected sales in period \( t \) in units of product \( i \) sold are
The units of products that may be produced are limited by available resources of the firm. A transformation matrix, \( a_{ik} \), which relates resource input to product output may be defined for determination of units of resource required for production of the needed production. \( a_{ik} \) is the units of resource \( k = 1, \ldots, l \) required for production of each product \( i = 1, \ldots, m \); such that net resources required for production of the total products to be fabricated

\[
\sum_{i} R_k(t) = \sum_{i} \sum_{i} p_{ii}(t)
\]

may be obtained. The input-output relation is expressed in units required per unit produced to develop a function that is invariant with time. The required allocation of resources is

\[
\begin{bmatrix}
    p_{ik}(t)
\end{bmatrix} = \begin{bmatrix}
    P_i(t)
\end{bmatrix} \begin{bmatrix}
    a_{ik}
\end{bmatrix}
\]

where the prime denotes units of resource. As previously noted, needed resources are more conveniently expressed in terms of dollar cost. The transformation matrix for this expression may be written

\[
\begin{bmatrix}
    a_{ik}
\end{bmatrix} \begin{bmatrix}
    c_k(t)
\end{bmatrix}
\]

where \( c_k(t) \) is the cost per unit of resource \( k \) in period \( t \). Net resources required for production of the total products to be fabricated in period \( t \) are obtained in dollars from equations (3-7) and (3-8)

\[
\begin{bmatrix}
    P_{ik}(t)
\end{bmatrix} = \begin{bmatrix}
    \frac{1}{s_i(t)}
\end{bmatrix} \begin{bmatrix}
    S_i(t)
\end{bmatrix} \begin{bmatrix}
    a_{ik}
\end{bmatrix} \begin{bmatrix}
    c_k(t)
\end{bmatrix}
\]

Where development and introduction of a new product is under consideration resource allocation is defined using the general expression proposed by Wadel
and Bush for forecasting of engineering manpower requirements. In terms of the probability of occurrence of the assignment function

$$E(p_{ik}(t)) = \sum p_{ik}(t) \Pr(p_{ik})$$

where $E(p_{ik}(t))$ is the expected resource requirement as a function of time, $t$.

$p_{ik}(t)$ is the dollar value of resource $k$ allocated to product $i$.

$\Pr(p_{ik})$ is the probability of occurrence of $p_{ik}$ if project $i$ is initiated in period $t = 1, \ldots, T$.

A somewhat more rigorous estimate of resource requirements may be obtained taking into account the overall probability of project initiation at all. The relation for expected resource requirement is then

$$E(p_{ik}(t)) = \Pr_i \sum p_{ik}(t) \Pr(p_{ik})$$

where $\Pr_i$ is the overall probability of going ahead with the product development so that $0 \leq p \leq 1$.

The influence of environment upon the factors comprising the foregoing model is difficult to depict analytically; however, the effect is inherent in definition of such considerations as market size, product cost, and anticipated demand. Life cycles of current products and new product development are also determined by factors not completely controlled by the firm.

The foregoing model may be augmented to produce a profit function for use in determining the potential increase in available resources to support increased sales.

---

The total cost of product $i$ in period $t$ is

$$C_i(t) = \sum_{i=1}^{n} p_{ii}(t)$$ (3-11)

Profit from sales of product $i$ in the period is the difference between sales and costs

$$G_i(t) = S_i(t) - C_i(t)$$ (3-12)

Some simple applications of the foregoing relations to both a single product firm and a multi-product firm are illustrated in Chapter 4. A simulation based on the process is presented in Chapter 5 to introduce time-dependent variants into the system. A situation in which the firm's growth aims are consistent with available resources is established to provide a basis for evaluation of the influence of a changing market environment upon the allocation of resources to support several growth-oriented objectives. Feedback from profit is employed to increase available resources to support increased sales.
Chapter 4

APPLICATIONS

Single-Product Firm

The trivial case of a firm desiring to increase sales of a single product in a single market by a fraction $x$ serves to introduce the more general applications. Marketing surveys, sales forecasts, and predictions of economic growth indicate the desired growth to be feasible.

Desired sales, $S(t) = S(t-1) (1 + x)$ where

$S(t-1) = \text{sales in previous period.}$

Costs are:

- Labor = $c_1 \$/unit
- Machine = $c_2 \$/unit
- Material = $c_3 \$/unit

The resources to support the assigned objective are then (in dollars)

- Labor = $c_1 S(t)$
- Machine = $c_2 S(t)$
- Material = $c_3 S(t)$

Where available resources are not sufficient to permit the required level of production the growth goal must be adjusted to reflect this limitation. Assuming available labor is restricted to $R_1$ dollar value, an increase in sales of

$$x(t) = \frac{R_1}{S(t-1)p_1}$$

is all that can be supported.

If the company has sufficient cash available to permit an increase in the supply of labor (assuming the necessary labor can be purchased), the original goal may yet be attained. The required amount of available resource, in dollars, is
Foregone gains due to alternate usage of the money must be considered in relation to the value assigned to achieving the desired goal. A more complete illustration of the applicability of resource allocation/growth objective compatibility may be achieved by considering the problem from the standpoint of a multi-product business.

**Multi-Product Firm**

A better example of the relationships between established goals and available resources may be set forth by considering the case of a two-product firm in two markets. The G and W Company manufactures two items: gidgets and widgets. The former product is offered for sale only in market 1; however, widgets are sold in both markets 1 and 2. Sales objectives specify the market penetration shown in Table 4-1.

<table>
<thead>
<tr>
<th>Product</th>
<th>Market 1</th>
<th>Market 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>25,000</td>
<td>0</td>
</tr>
<tr>
<td>W</td>
<td>2,000</td>
<td>10,000</td>
</tr>
</tbody>
</table>

Resource requirements and total resources available are listed in Table 4-2. Total resource requirements and total resources available are determined by applying equation (3-9).

\[
\begin{bmatrix}
  R_1 \\
  R_2 \\
\end{bmatrix} = \begin{bmatrix}
  1 & 1 \\
\end{bmatrix} \begin{bmatrix}
  P \\
\end{bmatrix} \begin{bmatrix}
  a \\
\end{bmatrix} \\
= \begin{bmatrix}
  1 & 1 \\
\end{bmatrix} \begin{bmatrix}
  25,000 & 2,000 \\
  0 & 10,000 \\
\end{bmatrix} \begin{bmatrix}
  4 & 2 & 1 \\
\end{bmatrix} = \begin{bmatrix}
  148,000 & 86,000 & 61,000 \\
\end{bmatrix}
\]
Table 4-2

Resource Requirement and Availability
for G & W Company

\[
\begin{bmatrix}
    a_{ij} \\
    \downarrow
\end{bmatrix} = \begin{bmatrix}
    4 & 2 & 1 \\
    4 & 3 & 3 \\
\end{bmatrix}
\quad i = G, W
\quad j = 1, 2, 3
\]

\[
\begin{bmatrix}
    R_i \\
    \downarrow
\end{bmatrix} = \begin{bmatrix}
    150,000 & 80,000 & 61,000 \\
\end{bmatrix}
\]

Comparison with available resources in Table 4-2 indicates that sufficient quantities of resources A and C are present; however, realization of the established objectives is limited by resource B. Assuming resources are not interchangeable on a dollar-for-dollar basis, sales goals will have to be modified to a level that the company can support. Feasible goals are listed in Table 4-3.

Selection of the alternate goals will relate to the company's long-range objectives. Considerations will include profit maximization which may support a desire to increase resources, increased market penetration which may dictate that sales of widgets in market 1 be maintained regardless of the effect upon performance in other markets, or a combination of these goals to substantiate continuation of a product line until the projected market develops.

Extension of the G and W case to a longer term simulation which allows consideration of environmental factors and development of new or improved products to replace a product in the saturation stage requires that the probability that available resources will be employed for feasible undertakings be considered. This required broader application of the foregoing model is discussed in the following chapter.
Table 4-3
Modified Sales Objectives for G & W Company
(1,000 units of products sold in each market)

<table>
<thead>
<tr>
<th>Alternate</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product</td>
<td>Market</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>G</td>
<td>25</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>W</td>
<td>0</td>
<td>10</td>
<td>2</td>
</tr>
</tbody>
</table>
Chapter 5

SIMULATION

Basis for Analysis

A more thorough examination of the relations linking corporate growth aims with available resources may be accomplished using simulation. A mathematical model of a corporate market/objectives system was established in Chapter 4 using the relationships set forth in Chapter 3. The resultant system details a description of the process relating conditions at one point in time to subsequent conditions at later points in time. Observation of the behavior of the model in response to applied stimuli will indicate the influence of changes in resource allocation, market environment, and growth objectives upon product selection.

The G. and W Company example advanced in the preceding chapter is expanded to provide a basis for simulation. The two products manufactured are both offered in market 1. However, only product W is entered in market 2. The situation may relate to an automotive accessory item offered both as an accessory on the vehicle (market 1) or as a replacement item for use in competition with similar products manufactured by other companies in market 2. The total market projection for the next 10 periods is as shown in Table 5-1.

Both markets are clearly growth markets. G and W Company may normally expect sales of their products to maintain their share of the total projected demand. However, product G is still in the early stages of development and is expected to continue to increase its share of market 1. Product W is closer to its maturity stage. It will maintain its sales in market 2 for a time but new or improved competitive products are anticipated to decrease its share in this market. Product W enjoys some tie-in sales in market 1 as a result of its association with product G. Combined sales of product W in both markets may be sufficient to justify continuing production of the product. It is assumed that product G sales are independent of availability of product W.

Goals for ten periods of operation are established as follows:
Product G - 90% gain in share of market
Product W - Maintain constant share of market 1; Maintain constant total dollar sales in market 2.

Sales objectives for both products in their appropriate market environment are also listed in Table 5-1. In establishing a basis for analysis of resource/goals relations, it is assumed that these goals are met. Variations of both environmental conditions (market size) and sales goals (increased market share, increased product sales, increased total sales, etc.) may be applied to the model as desired to establish outcomes.

Resource requirements to produce products G and W are listed in Table 5-2 for the three resources which are utilized. These data are expressed in units of each resource to provide a basis for allocation that is invariant with time. Costs of these factors are expected to increase with time according to the schedule contained in Table 5-3. Total direct costs, assignable to each product are

\[ c_G(t) \cdot P_G(t) + c_W(t) \cdot P_W(t). \]

Fixed costs, which are not expected to change within any single interval of time, regardless of the volume of activity, must be added to obtain the total operating cost within each period

\[ C(t) = c_G(t) \cdot P_G(t) + c_W(t) \cdot P_W(t) + FC(t). \]

Product sales price must then be established by the need to replenish resources utilized in production during the preceding period and the need to remain competitive in the market. Secondary factors such as the economic environment, a desire to increase sales, decrease competition, or reduce inventories will also contribute to designation of product sales price.

Sales must be sufficient to at least replenish resources utilized at the anticipated replacement cost. If growth is to be achieved, additional units of resources must be provided. Market conditions must be conducive to support the necessary conditions of price and sales volume. Otherwise alternate methods to attain the required growth objectives must be formulated. Alternate goals
may be established if it is determined that established growth aims are not attainable.

Total sales in period n-1 are then

\[ S(t-1) = s_G(t-1) \cdot P_G(t-1) + s_W(t-1) \cdot P_W(t-1) \]

where

\[ S(t-1) \geq C(t) \]

These relations are employed with the product cost and sales price variations listed on Table 5-4 to develop the total sales and costs figures on Table 5-5. The requirements established in Tables 5-2 and 5-6 define several growth objectives for the G and W Company. Growth goals projected for the end of ten periods of operation are identified (using the definitions in Chapter 3) as follows:

Product G - Market growth:

\[
\frac{15.31}{4.00} = \frac{80.6}{40.0} = 0.39 = 1.9 \text{ or } 90\% \text{ gain}
\]

Sales growth

\[
\frac{15.31}{4.00} = 3.82 \text{ or } 282\% \text{ gain}
\]

Product W - Sales growth

\[
\frac{1.10}{.70} = 1.57 \text{ or } 57\% \text{ gain overall}
\]

\[
\frac{.80}{.40} = 2.00 \text{ or } 100\% \text{ gain in market 1}
\]

Total sales growth

\[
\frac{16.41}{4.70} = 3.49 \text{ or } 249\% \text{ gain}
\]

Resources growth

\[
\frac{10.57}{2.84} = 3.72 \text{ or } 272\% \text{ gain}
\]

Once a model of the firm's operations is available, attention may be directed to determination of the influence of various external stimuli upon resource requirements. During normal operations under the model developed, the firm will require that specific quantities of each resource utilized be available.
to support growth objectives as required. The requirement for the model of Table 5-5 are listed in Table 5-6. Data represented in this tabulation are obtained by application of equation (3-9) using information developed in Tables 5-1 through 5-5.

**New Product Development**

The basic model for operation of the G & W Company, Table 5-2, discloses that although product W is presently contributing 15 percent of total sales, this portion will decrease to 6.7 percent by the end of the tenth period. This projection indicates that allocation of limited resources to production of product W tends to impede rather than support corporate objectives based upon sales and/or resources gain; growth goals may be better supported by introduction of a new product, X, to eventually replace W in both markets.

The conditions established in the previous section continue to apply. However, now, the timing for development of product X and the attendant deemphasis of product W must be included. Product X resource requirements and costs are listed in Table 5-7. Projected sales are shown in Table 5-8. Since it is not certain in which period development of this item is to be initiated, probabilities of go-ahead are assigned for the most likely periods and an expectation of sales determined. There is no requirement that sales follow the same month by month trend regardless of the start time as considered herein. Environmental influences can cause completely different variation of sales with time of go-ahead. The constant variation considered is employed as a convenience.

Resource requirements to support the anticipated volume of sales are shown on Table 5-9 for two levels of project initiation – a 0.7 probability that product development will be commenced at all, and certainty that the product will be developed. Production does not begin until the third period following go-ahead. Resource units utilized prior to this time are expended in product development and are not recovered in sales. Product development is continued through introduction to the market until the sixth period following, at which time all resources are directed to production.
Development costs are obtained by phasing out production of product W and diverting these resource units to development and production of product X. Some decrease in net profits are, of course, to be expected; the prime purpose toward which the resources of the firm are directed being successful introduction of product X into markets 1 and 2 at the projected level of sales.

As in the basic model of the firm's operations (Table 5-5) all resources are considered to be committed to realization of the established goals. Total sales data are combined with product cost variations from Tables 5-4 and 5-7 to develop total sales and costs information contained in Table 5-10. In period 9 sufficient resources are not available to permit realization of planned goals for both products G and X. Profits are not sufficient due to loss of income from product W and product X sales not yet covering costs to obtain the needed resources. The corporation has two actions available at this point in attempting continuation of its objectives of growth. Sales goals for product G may be maintained with an attendant slowdown in market penetration of product X. This action will keep the company's prime product dominant in its market and will keep sales that might go to competitors if insufficient units of product are available. Planned introduction of product X can be stretched out as necessary considering resource units available from sales of G. This will most likely require appreciable reconsideration of the potential market for product X due to changing environmental conditions.

The problem at period 9 may be illustrated using equation (3-9). Total sales in period 8 were $12,555,000.00 which provide a restraint upon total resources available for the ninth period. It is recognized that product W will no longer be produced and that available resources will be allocated to products G and X -- product X goals are primary, with product G sales limited by units produced.
Unit sales prices:

\[ s_G(9) = $20.00 \quad s_X(9) = $16.34 \]

\[
\begin{bmatrix}
\frac{1}{s_{i}(9)}
\end{bmatrix}
= \begin{bmatrix}
.050 & 0 \\
0 & .061
\end{bmatrix}
\]

Total sales in period:

\[ S_G(9) = $13,202,000.00 \quad S_X(9) = $420,000.00 \]

\[
\begin{bmatrix}
S_{i}(9)
\end{bmatrix}
= \begin{bmatrix}
13202000 & 0 \\
0 & 420000
\end{bmatrix}
\]

where \( S_G(9) \) is from Table 5-1 modified during the simulation process to match available resources;

\( S_X(9) \) is from Table 5-8.

Transformation:

\[
\begin{bmatrix}
a_{ik}(9)
\end{bmatrix}
= \begin{bmatrix}
4.32 & 4.16 & 4.20 \\
3.24 & 5.20 & 4.20
\end{bmatrix}
\]

(Tables 5-2 and 5-7)

Resource Requirements:

\[
\begin{bmatrix}
p_{ik}(9)
\end{bmatrix}
= \begin{bmatrix}
.050 & 0 \\
0 & .061
\end{bmatrix}
\begin{bmatrix}
13202000 & 0 \\
0 & 420000
\end{bmatrix}
\]

\[
= \begin{bmatrix}
4.32 & 4.16 & 4.20 \\
3.24 & 5.20 & 4.20 \\
2.851 & 2.746 & 2.772 \\
.083 & .133 & .109
\end{bmatrix}
\times 10^6 \text{dollars}
\]

where \( p_{ik}(9) \) indicates dollars of each resource.

The total dollar requirement \( \Sigma p_{ik}(9) = $12,555,000 \) coincides with the total available, which indicates the feasibility of the derived allocation.
for the assigned goals. Total sales from this assignment are used in establishing available resources for allocation to the following period in a similar manner.

The situation considered herein maintains the original planned sales schedule for product X and accepts a temporary reduction of sales growth of product G. As sales of product X continue to develop, additional resources can be allocated to production of product G to permit achievement of planned goals at a later period. Resource requirements based upon achievement of product X sales goals at two levels of probability of introduction are shown in Tables 5-11 and 5-12. Both models are consistent with the desired objective of development and introduction of product X to replace product W. Previously noted growth goals are redefined in view of results from the simulation based upon resource availability as follows:

**Product G - Market Growth**

\[
\begin{align*}
Pr_X &= 1.0 & 13.802/80.6 & = 1.71 \\
Pr_X &= 0.7 & 14.856/80.6 & = 1.84
\end{align*}
\]

Total Sales Growth

\[
\begin{align*}
Pr_X &= 1.0 & 14.432/4.00 & = 3.071 \\
Pr_X &= 0.7 & 15.297/4.00 & = 3.255
\end{align*}
\]

Resources Growth

\[
\begin{align*}
Pr_X &= 1.0 & 9.300/2.84 & = 3.275 \\
Pr_X &= 0.7 & 9.845/2.84 & = 3.467
\end{align*}
\]

Certainty that new product development will be initiated requires that more resources be allocated to this goal, thus reducing the potential growth
for the near term although placing the company in a much stronger position to resume the long-term growth objectives.

It is noted that assignment of two levels of probability of start of new product development has a relatively insignificant influence upon the growth goals attained at the end of ten time periods in the case developed.

**Influence of Environment**

Thus far, a somewhat idealized model of the firm’s operations in its environment has been taken into consideration. Growth goals and available resources have been consistently related so that objectives may be realized with complete utilization of resource capabilities. Unfortunately, the firm does not usually operate within an environment that is ideally matched to its resource capabilities and growth goals.

When the anticipated market fails to develop, the company must adjust to the new environment by adjusting the allocation of limited resources within appropriate restraints. The most immediate of these is imposed by the reduced sales which restrict the amount of resources that may be replaced. Some consideration can be included in the market model to represent the possibility of realization of the projected market using a relation similar to that employed in equation (3-10) to account for the probability of use of available resources. The adjusted market model is shown in Table 5-13. In view of the deteriorating market outlook for product G which contributes the majority of resource replacement costs, a decision to carry through the planned introduction of a new product is considered. Other considerations discussed in the preceding section are unchanged although available resources and their allocation will be influenced by the capability of the company to purchase needed resources.

**Utilization of surplus resources.** The inability of the market to absorb the full capacity of the G and W Company production in the second period introduces a surplus for the first time in the series of simulations being developed. The prime intent of the process under development is support of objectives to introduce product X at a predetermined time while maintaining some
sales growth for product G under the imposed market restraints. This surplus is accordingly utilized to produce inventory of product G at the prevailing costs. This inventory is stockpiled against the point at which feedback from sales is insufficient to provide enough units of product to satisfy market demands, thus producing the surplus unit at lowest cost (in the present example). Referring again to equation (3-9), the resource requirement in the second period is

\[
p(2) = \begin{bmatrix} .050 & 0 \\ 0 & .029 \end{bmatrix} \begin{bmatrix} 4588000 & 0 \\ 0 & 74000 \end{bmatrix} \begin{bmatrix} 4.04 & 4.02 & 4.00 \\ 4.04 & 6.03 & 12.00 \end{bmatrix} \\
= \begin{bmatrix} 229400 & 0 \\ 0 & 21140 \end{bmatrix} \begin{bmatrix} 4.04 & 4.02 & 4.00 \\ 4.04 & 6.03 & 12.00 \end{bmatrix} \\
= \begin{bmatrix} .927 & .922 & .918 \\ .081 & .121 & .242 \end{bmatrix} \times 10^6 \text{ dollars}
\]

or \[\sum_{k=1}^{3} R(2) = 3,232,000\] at a total cost

\[
C(2) = p(2) + FC(2) = (3.232 \times 1.310) \times 10^6 \\
= 4.542 \times 10^6
\]

The funds available from period 1 operations for purchase of resources,

\[S(1) = 4,700,000\] permit a surplus

\[S(1) - C(2) = 158,000\]

which is applied to production of product G to be stockpiled until needed to fill market demands.

In the seventh period, the feedback function (period 6 sales) is insufficient to permit the desired production of products G and X (production of product W has been discontinued).
where the second term includes resources allocated to product development but not directly contributing to production. Total resource allocation is

\[
\begin{bmatrix}
0.050 & 0 \\
0 & 0.071
\end{bmatrix}
\begin{bmatrix}
8034000 \\
0
\end{bmatrix}
+ \begin{bmatrix}
0 \\
.029
\end{bmatrix}
\begin{bmatrix}
000 \\
.033 .027
\end{bmatrix}
\] 10^6 dollars.

or a total variable cost \( VC(7) = 5,199,000 \). However, 19,450 units of product G have been stockpiled using the surpluses available from periods 2 and 3. These are now offered for sale to provide additional funds for purchases of needed resources for continued production of products G and X. Total resources utilized in this period are obtained using cost functions for the periods in which the additional units of resources were purchased.

\[
\begin{bmatrix}
0.050 & 0 \\
0 & 0.071
\end{bmatrix}
\begin{bmatrix}
8034000 \\
0
\end{bmatrix}
+ \begin{bmatrix}
0.050 & 0 \\
0 & 0.071
\end{bmatrix}
\begin{bmatrix}
2620000 \\
0
\end{bmatrix}
+ \begin{bmatrix}
0.050 & 0 \\
0 & 0.071
\end{bmatrix}
\begin{bmatrix}
127000 \\
0
\end{bmatrix}
= \begin{bmatrix}
2.258 & 2.207 & 2.236 \\
.021 & .033 & .027
\end{bmatrix}
\] 10^6 dollars

Resource allocation may be obtained in terms of units of resource by expressing the transformation matrix \( a_{ij} \) in units of resource per unit of product.
Reallocation of insufficient resources. The model summarized on Table 5-13 satisfies the basic desire to introduce product X and attain a pre-selected level of sales in the 10th period. However, the failure of the market to support product G sales growth creates a serious financial problem resulting in the company being unable to maintain its position in the product G market beyond period 7. This situation causes the sales from product G to deteriorate at a faster rate than sales from product X can develop. The results of the simulation depicted, indicate the need for the G and W Company to reexamine its planned operations in the light of a reevaluation of sales goals. Several alternative plans of action may be considered. Product W can be discontinued immediately and the available resources assigned to production of additional units of product G starting in the seventh period. Development and introduction of product X can be delayed until a more advantageous period. This action would permit product G sales to more closely approach the anticipated level until continuation of the desired sales growth can be achieved by introduction of product X. Consideration may also be given to development and introduction of product X at a slower rate. This would require assignment of resources at a
reduced rate although a greater total amount of resources may be utilized over the longer period of time in product development.

Role of Objectives

The inability of the firm to support its basic product line in a declining market environment while simultaneously utilizing limited resources for development and introduction of an improved product suggests that reexamination of established objectives is in order. The results of this reevaluation will indicate whether selection of alternate courses of action might more effectively support similar purposes. Growth may be defined in a number of manners as discussed in Chapter 3. Simulation of the firm's use of resources to achieve other growth goals may indicate the possibility of sustaining a higher degree of growth using a different strategy.

Capability for consideration of possible combinations of feasible actions is inherent in the general model presented in Chapter 3. The objective matrix permits representation of any combination of quantitative goals which may be translated into sales growth functions as previously discussed. Establishment of sales goals for each individual product or collectively, to represent desired objectives produces the input function toward which the distribution of available resources is to be directed. Such an application indicates whether sufficient quantities of necessary resources are available (or may be obtained) to support the objective functions under consideration.

Although a wide range of combinations of product G sales, product W sales, and schedules for introduction of product X are available to the G and W Company, two extremes of action are feasible other than the model considered in Figure 5-13. One decision would suspend production of product W and divert any additional available resources to production of product G. Loss of revenues from product W sales would limit income available for purchase of additional resource units, although this factor would be offset to some extent by the reduced requirements due to deletion of the W product line. It is emphasized that the important factor to operation of the firm in addition to introduction of
product X in the sixth period, is total sales of product G in period ten.

An alternate strategy would delay introduction of product X until a firmer base of product G sales is established -- possibly beyond the time span considered herein. This decision would preclude allocation of resources to development of product X pending indication of an overall market environment more conducive to realization of desired goals expressed in terms of growth in areas other than as presently indicated.

Analysis of the first course of action -- terminating production of product W and utilizing released resources for production of additional units of product G discloses that insufficient income is generated to support market requirements. Fixed costs are not covered in the seventh time period. As a result, growth objectives are not supported by the action considered due to the loss of revenues from sales of product W during the first six periods.

Concentration upon maintenance of available sales of products G and W, thus delaying introduction of product X until a more advantageous market outlook prevails produces the results contained in Table 5-15. The market deterioration noted in the preceding section continues to adversely affect sales growth of product G. Product W sales are continued in this simulation while sufficient resources are available to produce required units of product. This action generates additional profits that permit a greater amount of resource units to be obtained than in the former case where product W sales were discontinued.

Comparison of the model of Table 5-15 with the basic operation (Table 5-13) indicates that setting aside introduction of product X will increase total sales in the tenth period by 0.8 percent although sales of product G will be increased by 29.2 percent. If the available market for G is to be maximized in terms of product sales, production of product W may not be extended beyond the seventh period in either case.

The growth objectives of the operations discussed in these final two sections are not the same. Various combinations of growth may be attained, even under an adverse market environment, depending upon resource availability
and allocation. Selection of objectives provides the basis upon which resource allocation must be effected. The ability to allocate resources to satisfy assigned objectives indicates the feasibility of potential goals and provides a guide to operations directed toward the attainment of these goals. Simulation of the operation of the entire system is effective in indicating the effectivity and outcomes of various courses of action, thus providing a guide to action. However, it is the decision of the corporate manager, based upon the results obtained from the simulation process, as to which course of action is best suited to the long-range goals toward which the firm is striving.
Table 5.1
Market Projection and Sales
Objectives (10^6 Dollars)

<table>
<thead>
<tr>
<th>Period</th>
<th>Market 1</th>
<th>Market 2</th>
<th>Total Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M_1$</td>
<td>$S_G$</td>
<td>$S_W$</td>
</tr>
<tr>
<td>1</td>
<td>40.0</td>
<td>4.00</td>
<td>10.0</td>
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<td>44.0</td>
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</tr>
<tr>
<td>3</td>
<td>48.4</td>
<td>5.81</td>
<td>11.0</td>
</tr>
<tr>
<td>4</td>
<td>53.0</td>
<td>6.89</td>
<td>11.5</td>
</tr>
<tr>
<td>5</td>
<td>57.8</td>
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<td>6</td>
<td>62.7</td>
<td>9.40</td>
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<td>67.7</td>
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<td>72.4</td>
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<td>9</td>
<td>76.8</td>
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<tr>
<td>10</td>
<td>80.6</td>
<td>15.31</td>
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Table 5.2
Resource Requirements (Units)

<table>
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<tr>
<th>Product</th>
<th>A</th>
<th>B</th>
<th>C</th>
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</thead>
<tbody>
<tr>
<td>G</td>
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<td>2</td>
<td>1</td>
</tr>
<tr>
<td>W</td>
<td>4</td>
<td>3</td>
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</table>

Table 5.3
Resource Costs ($/Unit)

<table>
<thead>
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<th>A</th>
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Table 5.4
Product Cost and Sales Price ($/Unit)

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Table 5.8
Product X Sales
(10^6 Dollars)
### Table 5.9
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Table 5.11
Resource Requirements to Support Introduction of New Product (P(X) = 1.0) (10^6 Units)
Table 5-12
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Total: \(.880 \quad .460 \quad .160\)

\((10^6 \text{ Units})\)
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* Adjusted market model based on realization of 70% of expected increase in Product G sales.
Table 5.14
Resource Requirements with Introduction of New Product in Reduced Product G Market Environment (10^6 Units)

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* Includes units of surplus available in period  ( ) Surplus units assigned to G production
Table 5.15
Total Sales and Costs *
(10^6 Dollars)

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<th>Period</th>
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* Reduced Product G demand with decision to delay development of Product X.
Chapter 6

CONCLUSIONS

Methodology for expressing the relations between allocation of corporate resources and expressed growth goals of the firm has been developed. Relations presented comprise a guide for dispersal of limited units of production in a manner that will best support attainment of previously established growth-oriented objectives.

As with any attempted approach to developing an operational model, the validity of the output data cannot be improved over that of the information input to the model. The types of growth considered in the present paper are all basically related to a common factor -- market demand. Prediction of the requirements of the market in which the company either operates or plans to operate, and estimation of resource costs over the period of concern are of prime importance in establishing the reliability of the developed relations.

It is realized that growth is rarely employed as a sole objective for the firm. The typical corporate entity is far more likely to have diverse associated goals relating to maximization of profit, return on investment, increase of stockholders' equity, retention of family control, or contribute to the solution of social problems. Where such aims may be quantified and related to sales, market domination or such a quantifiably expressible goal, the model advanced may still be utilized. However, it is noted that specification of numerous interrelated objectives is likely to necessitate that the problem be formulated using a high speed digital computer to define the numerous interdependencies in the resulting system.

The last two objectives noted are qualitative in nature and are not readily expressed in quantitative terms. Some preliminary attempts have been made to provide approaches to effect such an expression. However, the

results attainable are far too nebulous to justify the effort required for their
determination. It is felt that application of utility theory might provide a
means of establishing the relationships between objectives expressible only in a
qualitative sense and some measurable operational factor. For example, where
an objective might be stabilization of employment of skilled personnel, the
relations to product improvement or diversification may be used to identify and
evaluate relevant factors.

The method advanced in the present paper is limited to representation
of the course of action to be followed in allocation of limited resources by
indicating the following:

- what resources become available if a decision is
  made to terminate production of a product;
- how best to allocate insufficient resources to
  support growth goals;
- how best to utilize surplus resources, if available,
  in support of growth goals.

No method or simulation will advise the manager as to the proper
course of action to be taken. Only potential results of various actions are
indicated. The selection of the strategy to be employed is an individual respon-
sibility with analytical results serving as a guide to action which may be
employed to support the desired goals.
BIBLIOGRAPHY


APPENDIX

Derivation of Models Used in Simulations

The model employed to simulate operations of the firm under the combinations of resource availability, corporate objectives, and environmental influences is based on full utilization of proceeds from sales to support purchase of required resources in the forthcoming period. Total costs in period \( t \) are thus set equal to total sales in the preceding period, \( t-1 \).

\[
TC(t) = TS(t-1) \quad (A-1)
\]

Variable costs are then equal to the total costs less fixed costs.

\[
VC(t) = TC(t) - FC(t) \quad (A-2)
\]

Units of resource allocated to product \( X \) are known from the established goals. In all cases, maximization of sales of product \( G \) is considered subject to the foregoing requirement. Units of product \( W \) that may be produced are determined from costs available for production.

\[
CW(t) = VC(t) - \left( C_G(t) + C_X(t) \right) \quad (A-3)
\]

Units of product obtained are

\[
P_W(t) = \frac{CW(t)}{a_W} \quad (A-4)
\]

and sales of product are

\[
S_W(t) = P_W(t) s_W(t) \quad (A-5)
\]

Total sales in the period

\[
S(t) = S_G(t) + S_W(t) + S_X(t) \quad (A-6)
\]

are applied to purchases of resources for the following period and the process repeated.

The complete model used in the simulation of introduction of Product \( X \) (Tables 5.10 and 5.11) is presented in Table A.1. Units of resources allocated to each product are determined using the relationships developed in Chapter 3.
Table A-1
Model for Introduction of Product X

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Note: Units are expressed in thousands; costs and sales in 10^6 dollars.