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DISSER TATION

Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
In the Graduate School of
The Ohio State University

by

Lawrence C. Phillips, B.B.A., M.B.A.

* * * * * *

The Ohio State University

1966

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Three companies participated in the case study investigations. Contributions of valuable time by numerous corporate officials made the dissertation possible.
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CHAPTER I

INTRODUCTION

The overall management task is concerned with decision making, organization, and communication. The decision process, organization structure, and information transmitting function are interdependent. An information system modification may disturb the decision process through its effect upon the degrees of participation of functional management groups. Management organizational changes likewise create a need for information system readjustments.

Social scientists suggest that the information transmitting function is crucial to decision-making. Communication involves the act of selection or "filtering" by informational sources. Decision criteria are influenced as selective information is communicated upward.\(^1\) The communication process is evidenced by the development of a formal information reporting system. An information system is defined as an

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interconnecting network of verbal and written communications which facilitate group participation in decision-making activity.

The primary objective of an information system should be to maximize the effectiveness of the decision process. Information must be effectively transmitted to the various management groups who share the decision-making responsibilities.

Accounting should be vitally concerned with corporate information systems. Its role may encompass the collection and transmission of all types of economic data. Accounting reports might include the results of engineering feasibility studies and/or market research reports. The traditional role of accounting appears to have confined itself to a rather insignificant element within the overall information system. It has focused upon historical record-keeping activities which were designed to facilitate financial statement preparation and to enable management to fulfill its stewardship responsibilities. The significance of this and future research in accounting may assume the difficult task of re-defining and redirecting the role of accounting.

The rudiments of decision theory, developed principally by sociologists and social psychologists, have evolved from the study of group behavior. Much of the literature focuses upon group interaction, the decision, or the
process by which the decision evolves. The decision process
is typically viewed as a frame of reference for the study of
organizations.²

This dissertation considers the following decisions:
(1) the initial project acceptance, (2) continuing project
review, (3) technical decisions, and (4) the total R & D budg­
et determination. Common characteristics are evident. All
require the accumulation and evaluation of extensive amounts
of information. A search for available alternative actions
becomes significant. The combined effect of the decision
process may change the basic nature of a corporate organiza­
tion. Successful R & D produces changes in the existing
product mix which necessitate modifications to marketing
strategy, production methods, and financial policy.

The Research and Development Problem

Research management problems result from existing
information system inadequacies. A system should provide suf­
fficient and relevant information for the primary R & D deci­
sions. Business evaluation techniques should be applied in
a manner which will enable management to evaluate decision
criteria.

²Albert H. Rubenstein and Chadwick J. Haberstroh,
Some Theories of Organization (Homewood, Illinois: The Dor­
The research management problem is compounded by (1) attitude and goal conflicts among group participants, (2) the difficulty of measuring the results of research, (3) rapid growth in the R & D function, and (4) the need for group participation in the decision process.

Recent growth in research and development expenditures has accentuated the importance of its management function. Table 1 represents expenditures by the various institutional segments.

TABLE 1

Funds Applied to Basic Research, Applied Research, and Development 1961-62
(In Millions of Dollars)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total</th>
<th>Basic</th>
<th>Applied</th>
<th>Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal government</td>
<td>$2,090</td>
<td>$238</td>
<td>$606</td>
<td>$1,246</td>
</tr>
<tr>
<td>Industry</td>
<td>10,870</td>
<td>403</td>
<td>1,955</td>
<td>8,512</td>
</tr>
<tr>
<td>Colleges and universities</td>
<td>1,400</td>
<td>695</td>
<td>457</td>
<td>248</td>
</tr>
<tr>
<td>Other nonprofit institutions</td>
<td>380</td>
<td>152</td>
<td>160</td>
<td>68</td>
</tr>
<tr>
<td>Total</td>
<td>$14,740</td>
<td>$1,488</td>
<td>$3,178</td>
<td>$10,074</td>
</tr>
</tbody>
</table>


*Within the industrial sector approximately 60% of the expenditures are financed by the federal government.
Privately supported research and development outlays have increased from $116 million in 1930 to $5 billion in 1963. These statistics correspond to the "Industry" caption appearing in Table 1 if one adjusts the expenditures for the percentage of federal government support. Economic projections of the magnitude of future R & D outlays indicate an increasing growth rate of expenditures as a percentage of the gross national product. Thus research management problems do appear to be of significant magnitude and certainly suggest a need for further study by accountants.

Scope of the Study

R & D capitalization and amortization policy influences the timing of corporate profits which in turn may affect the decision as to the amount budgeted for R & D since reported profitability is often a criteria in this decision. This relationship is analyzed in this study. Since other R & D decisions are not directly influenced by financial accounting policy, no attempt has been made to develop directly a general financial accounting theory for research and development.


The research scope has been limited to the study of privately supported research expenditures which are incurred by profit-seeking firms. Activity which is conducted or sponsored by non-profit institutions including Federal government agencies, universities and foundations is excluded.

Research Methodology

The conduct of three case studies was selected as the primary research method. A general information system model was formulated. Case study observations were compared with the model system.

The study findings should enable corporate managers to assess the quality of an R & D program. A study of the decision process and an assessment of information needs and systems utilization should result in improved decision-making. The findings are particularly relevant for firms which are primarily engaged in applied research and development activity. It should be noted from an analysis of Table 1 that the bulk of privately supported industrial activity is applied and development rather than fundamental.

Previously conducted questionnaires and case studies were drawn upon to test the reliability of the case study findings. The writer attended a two week research management seminar sponsored by Battelle Institute and Ohio University in
order to gain insight into the management problems of research. A review of the relevant literature also was undertaken.

The detailed case study approach appeared to be the most desirable method of constructing and testing the systems model. However, due to a limited number of case study observations, a generalization of the findings was not possible. A questionnaire might be developed as a future supplement to the existing study.

Organization of the Study

Chapter II depicts the general problem of organizing the research function and formulating research policy, as found in the literature and the case studies. It includes an evaluation of environmental and organizational influences upon R & D policy. Continuing to draw largely on the case studies, Chapter III identifies the primary R & D management decisions as (1) the preliminary idea evaluation, (2) the initial project acceptance, (3) continuing project review, (4) technical decisions, (5) the total R & D budget determination, and (6) the post audit appraisal. In addition, information reports are related to these six primary decisions, and the utilization of decision criteria and the role of the corporate information system are evaluated. An information systems model is formulated and is compared with the case study
investigations. Chapter IV summarizes the findings of the study. The Appendix contains a descriptive case analysis for each of the three companies studied.
CHAPTER II

MAJOR POLICY DETERMINATION

Major corporate policy may be viewed as a composite of ideas or attitudes concerning the operational activities of the firm. Policy may be explicitly formalized. A recent questionnaire reported that approximately 79 per cent of participating firms had established written R & D objectives. This investigation revealed, however, that objectives were too general to be of specific usefulness to the conduct of the firm's activities. Case study investigations by this writer largely substantiate these findings. Only one firm, however, had expressly formulated R & D objectives. Objectives appeared to be inadequately communicated to the participating management groups.

Policy may be implicitly stated through a series of major decisions which are made over an extended time period. Policy evolves as a corporate management observes and reacts to its changing environmental forces. The total R & D budget decision represents the primary method of executing or modifying research and development policy. Funds are

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5 Seiler, p. 52.
committed to projects and an overall research scope is established.

Overall research policy is concerned with (1) determining the overall scope or importance of the R & D function, (2) establishing a desirable ranking of types of research, and (3) assigning task and decision responsibilities. A top management task must necessarily involve the determination of the overall scope of the research function. Determination of research scope and types of research to be conducted is heavily influenced by environmental forces such as market concentration, firm size, technological opportunities, and industry conditions.

Research policy determination is affected by the firm's major decision criteria. Commonly adopted criteria, which overlap to some extent, include profitability, growth, maintenance of market share in existing product areas, and survival. If R & D effort is to complement overall firm objectives, research decisions should employ similar criteria. Nevertheless, these criteria were of varying degrees of importance to the three firms studied. Only one of three firms employed profitability as a primary criterion for the initial project acceptance decision. Two firms considered maintenance of market share significant to the initial project acceptance. Profitability, although imperfectly measured by one firm, was
considered by two participants prior to the continuing evaluation and implementation decisions. Growth objectives were not explicitly considered by the decision criteria. Survival criteria were expressed through established financing policies and attitudes toward the acceptance of risk levels.

Expectations predicated upon these criteria should become a basis for determining the types of R & D activity to be conducted. Research policy decision makers should be guided by (1) long-range planning reports and (2) studies of market potentials and product technological changes. Case study investigations revealed that these reports were not being supplied to top management in an adequate manner. Only one firm prepared summaries of R & D costs by product areas and type of research.

Broad corporate policy may include statements or attitudes concerning capital investment, product line diversification, and methods of financing. Thus, in one firm studied, a total research budget was constrained due to a policy of financing solely from internal growth. A restrictive product-line diversification policy may limit research exploration to a relatively narrow product range. Financial solvency attitudes may dictate the pursuit of short-range project types.

Management attitudes toward risk will be reflected in research policy. Cost-saving, new process projects frequently
involve minimal uncertainty and rapid pay-off. During initial stages new product projects may involve high risk and long pay-off expectations. The decision process should reflect risk assessments through the employment of proper economic evaluation techniques.

Management Assessment of Research Productivity

A determination of the overall research scope requires an evaluation of R & D productivity. Once determined, R & D productivity should be compared with expected returns from other types of capital investment. As with most capital investments, R & D is characterized by the incurrence of an initial investment outlay in expectation of the receipt of future cash flow benefits and a time lag between the two events.

Some index or measure of research productivity such as the project analysis report found in Table 2 is necessary to solve the problem of determining the scope of research activity. The three firms studied did not prepare this type of evaluation report. Thus, policy was set upon the basis of insufficient information.

Since research and development expenditures should compete with other types of capital projects, the R & D budget should not be determined independently. The anticipated returns on a research project should be compared with other
### TABLE 2
PRODUCTIVITY EVALUATION
AND TOTAL BUDGET DETERMINATION

<table>
<thead>
<tr>
<th>Project Number</th>
<th>Area</th>
<th>Classification</th>
<th>Revised Project R.O.I. Stage of Completion</th>
<th>Revised Project R.O.I. Sunk Costs</th>
<th>Revised Project R.O.I. Full Costs</th>
<th>Original Estimated Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>New product</td>
<td>Devl.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Product improve­ment</td>
<td>Applied</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Cost saving-new process</td>
<td>Proposed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>New product</td>
<td>Proposed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Revised Estimated Costs</th>
<th>Actual Costs Completed</th>
<th>Expected Costs Completed</th>
<th>Estimated Costs During Budget Period</th>
<th>Projected Date of Completion and Implementation</th>
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</table>
capital investment expectations and accepted if the expected cash flows, discounted to present value by the firm's cost of capital rate, exceed the investment outlay by the greatest amount. In the three companies studied, R & D projects were generally considered independent of the capital investment decision process.

A recent attempt, through an application of regression analysis, to determine a marginal rate of return of R & D expenditures for a firm suggests that substantial underinvestment in R & D is evident among many firms.\textsuperscript{6} The case studies largely support this claim. Firms X and Y were investing in projects that had return expectations greatly in excess of their average capital costs. Management personnel freely expressed the conviction that their firms had a back-log of projects which could be undertaken if funds were available. It was found that dollar limits which have no relation to productivity were placed upon the research and development budget.

In commenting upon the possibility that a law of diminishing returns may apply to research and development activity, Bichowsky stated that unlimited research can produce exploitable technology which exceeds the effective

\textsuperscript{6}Edwin Mansfield, "Rates of Return from Industrial Research and Development," \textit{American Economic Review} (May, 1965), 320.
capacity of a firm. If immediate exploitation of research project results is not feasible, management should adjust the anticipated economic results for the diminished advantages due to time delays in the preliminary stages.

Organizing the R & D Function

Policy must provide a basis for making the administrative decisions about allocating existing research resources and how responsibilities are assigned to organizational sub-units. Top management must also formulate a structure of decision authority. Two questions were asked: (1) To what extent should primary R & D decisions be shared by research and non-research personnel, and (2) what degree of non-research management control over the decision process is desirable?

Orton found that approximately two out of three firms maintain relatively centralized R & D organizations; of the thirty-eight companies which he interviewed, twenty-three maintain centralized type research organizations. However, to counteract possible diseconomies of large scale research


units as evidenced by Cooper, functional decentralization has been employed by some firms. Thus, research management segments are formed causing problems of identification and possible conflict of group interests. Decentralization of the R & D function undoubtedly influences the decision process and the information system. Coordination, planning, and control become more complex as task responsibilities become further removed from the centralized management group. Decentralized decision-making becomes necessary. Resource allocation policy makers should consider (1) possible areas of duplication of facilities and research results by divisional effort, (2) ability of individual sub-units to achieve a desired task, and (3) possible conflicts with overall corporate policy.

Traditionally, decentralization commences with the establishment of divisional research laboratories to handle technical problems of quality control and production process flaws. Fundamental research has generally been retained under the auspices of central research management direction.

Resolving the problem of decentralizing research facilities and task assignments simplifies the resource allocation problem since funds may be allocated on the basis of

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individual project needs. Need may be estimated through the employment of rational evaluation techniques. However, corporate activity is not static; shifts in the nature of research activities are to be expected and imply that a continual reassessment of management policy is necessary.

If research operations are decentralized, should the research decisions related to divisional operations be made by divisional top management or retained by research personnel? Generally, technical decisions related to manpower assignments, program scheduling and employee performance measurement are retained by the research personnel. If, however, the division top management is assigned profit-center responsibility, its authority should extend to the economic evaluation of divisional research projects. This is true if one defines a profit-center as Dean does as a semi-autonomous group of facilities and functions chosen so that profit performance becomes the main guide to the evaluation of divisional performance and the main guide by which the manager makes his critical decisions. Nevertheless, in one case study the headquarter's research management was jointly participating in the total R & D budget determination for an autonomously operated division. Headquarters issued supplemental lump-sum budget appropriations to the division.

10Rubenstein and Haberstroh, p. 339.
Top management should establish its intent regarding group participation in the decision process. Management groups including research management, top management, marketing, finance, and production may jointly participate in the decision process for the R & D effort. Research decision authority may be delegated to a management committee. Lorsch and Lawrence report that research committee management improves interdepartmental communication and reduces sources of conflict.11 Two of the firms studied employed management committees to participate in the project acceptance and continuing evaluation decisions, but top management retained its authority over the total budget decision, and technical decisions were made by research management for all three.

Maintenance of control over the functioning of the decision process is necessary. Anthony reports that over sixty per cent of the firms studied received all their budgeted funds in a lump sum rather than by projects, and almost one-third of the firms did not revise budgets during the fiscal period.12 Almost ninety per cent of the respondents


12 Robert N. Anthony, Management Controls in Industrial Research Organizations (Boston: Division of Research Graduate School of Business Administration, Harvard University, 1952), p. 105.
to Anthony's questionnaire reported that the vast majority of research proposals were not rejected by top management.\(^\text{13}\) Similar findings were revealed in the three case studies conducted fifteen years later. Top management interest in procedural and organizational checks including post-audit appraisals appeared to be negligible in the three companies studied. Inadequate information and the absence of active top management involvement with individual projects appeared to have caused the apparent apathy. These results indicate that project acceptance decisions are often made by lower management prior to approval by top management. Despite top management's intent to participate in the initial project acceptance decision, its actual participation often may be negligible.

Management Attitude Toward Innovation

The success of a firm's R & D program is dependent upon its top management's overall attitude toward the innovation function. The responsibility for research produced innovation may be delegated to research staff personnel even though primary decision responsibility should be retained by top management. Since innovation affects virtually the

entire firm's activities and purpose, it should not be treated as a specialized functional responsibility.

The Effect of Primary Group Attitudes Upon Management Policy

Conflicting management attitudes and goals may exert a profound influence upon the type and amount of research conducted and upon the outcome of individual research decisions. It is erroneous to characterize the management of a firm as a unified whole possessing common objectives and attitudes. Of several management components usually present, group orientations frequently are in conflict. Consequently, corporate top management groups have frequently followed a "hands off" policy toward the R & D function. Anthony describes the primary problem facing research management as the existence of group conflict. Two principles—(1) research workers require freedom, and (2) management must manage—are described as mutually inconsistent.\(^\text{14}\) Clearly, conflict may be minimized if the research director views his primary role as administrative rather than scientific. The employment of decision-making committees represented by a balance of functional representatives may also reduce management group attitude conflicts. The case study investigations clearly revealed

\(^{14}\text{Anthony, p. 15.}\)
the presence of these attitudes. Group conflict and research dominance contributed to a breakdown of communication among the participating functions.

Attitude conflicts and power phenomena, such as "empire building," may greatly reduce top management's ability to establish goals for the research departments. Such manifestations are evidenced within research organizations by their reluctance to abandon economically undesirable projects and their overconcern with the absolute number of projects and personnel which they control.

Effective stimulation of employee motivation seems possible only when individuals are permitted to satisfy personal goals. According to McFadden, industrial researchers possess the following attitude traits: (1) intellectual attainment and freedom requisites, (2) professional recognition aims, (3) financial reward expectations, and (4) management status consciousness. The extent to which these goals are satisfied, including the higher order wants such as self-esteem, reputation and self-fulfillment, is dependent upon the employee's cultural and social background and intellectual level. Since it may be assumed that the majority

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15 J. A. McFadden, Jr., "Industrial Research Must Be Planned and Controlled," Controller, XXIX (November, 1961), 531.

of R & D personnel possess considerable desire to satisfy these higher order wants, the degree to which these needs are met is usually presumed to affect the productivity of research and development output. If the concept of control is viewed as an authoritarian measure and is employed as a method of enforcing unilaterral authority or punishing non-conformists, thus failing to satisfy these higher order wants, it could reduce productivity. However, another concept of managerial control is as follows: control is (1) redirecting and supplementing the information flow to enable non-research personnel to become knowledgeable concerning research problems, (2) the use of management committees to encourage intergroup participation in the decision process, and (3) the initiation of reliability checks to improve management's reliance upon information sources. Under this concept, control is increased management participation in the decision process through greater knowledgeable involvement and should not deter employees from achieving personal satisfactions.

Market Concentration Influences

Management policy is necessarily influenced by the firm's market conditions. A monopolistic or quasi-monopolistic market position may result from prior innovating activity. The duration of this advantage is dependent upon the existing
market and competitive structure. The overall research objective should be to produce exploitable technology which creates a preferred market position.

A firm must simultaneously operate within numerous markets. It should assess its position within both existing and future markets. Integration with research policy and planning is necessary because an innovation may become valueless due to the reaction of competing firms.

Primary research decisions are predicated upon time advantages which are directly related to anticipated competitive reactions, market setting, and the rate of technology. Case study findings indicate that firms recognize the importance of analyzing market positions and competitor strengths. All firms devoted major sections of their project proposal study to short-run analysis of rivals' existing products, technology, distribution facilities and market share. These analyses were, however, short-run and did not facilitate the determination of long-range planning.

Influences of Firm Size

Markham, reporting upon the findings of recent statistical studies of the effects of market size upon innovation, concluded that economies of scale may be operative. "Up to a certain size, innovational effort increases more than
proportional to size; at that size, which varies from industry to industry, the fitted curve has an inflection point and among the largest few firms innovational effort generally does not increase and may decline with size." 17 Evidence is, however, inconclusive regarding the aggregate effects of size upon innovation policy. Although fewer numbers of small firms engage in research activity, the ones which do spend proportionately similar amounts as larger firms. 18

A small firm which is not firmly established in a particular market and does not possess sufficient marketing and financial resources to exploit an aggressive move may decide upon a role of imitator rather than innovator. Defensive research may be emphasized including a heavy reliance upon applied and development rather than fundamental research. Firms do not usually sell technical ideas per se although occasional evidence of marketability of research is revealed through merger negotiations and the sale of patents. Schmookler reports that large firms use only 50.6 per cent of the patents which they hold while the corresponding figure for small firms is 75.5 per cent. 19 Thus, large firms may spend considerable

17 Markham, American Economic Review, IV, No. 2, 329.
research effort to protect an established market position through patent protection.

Industry Conditions

The majority of research and development expenditures are incurred by a few industries. More than one-half of the total R & D expenditures in the United States are incurred in the aircraft, electrical machinery, and chemical industries.\(^\text{20}\)

The aircraft industry is undoubtedly influenced by government support. Electronics and chemicals appear stimulated by the existing state of technical knowledge relative to its potential development. Unutilized potential favors innovation and such industries are characterized by a high rate of growth and rapid product obsolescence. Long-run new product and product improvement research may be stressed.

Historical Background of the Firm

A firm's original purpose for incorporation and its subsequent growth may have been due to the exploitation of an invention by its founders. The innovating character of the firm is not only established but becomes so deeply rooted that such firms will tend to favor investment in R & D over other forms of capital investment.

\(^{20}\)Jewkes, Sawers, and Stillerman, p. 152.
Indirect Exogenous Influences

The total research budgeted appropriation may be affected by factors such as stockholder relations, employee morale, the procurement of a government contract, and the availability of trade or bank credit. These considerations, while undoubtedly important to the management, may be singled out as reasons for the curtailment of a research project or the restriction of an overall research budget allocation. Thus, short-term profitable operations for the purpose of placating stockholder demands for dividends may result in a restriction of long-run research output. Obtaining credit or a government contract may be predicated upon the existence of immediate earnings.

These indirect pressures may emerge as a research appropriation constraint which is based upon a fixed percentage of profits or sales. Substantial underinvestment in research and development resulted from an overemphasis upon these criteria in the three companies studied.

These indirect pressures may also influence the overall management attitude toward the research and development program. A conservative attitude toward risk taking may result from a defensive reaction to exogenous pressures. Pressures for the maintenance of position and self security may permeate the management group. The results may appear in a
relative deemphasis upon high risk and highly profitable projects as typified by fundamental and new product research. The research function may subrogated to the conduct of defensive type research including process improvement, minor product improvement, and patent protection activity.

Highlights of Chapter II

Chapter II was concerned with the problem of organization of the R & D function and the formulation of research policy. The effects of environmental and organizational influences upon policy formulation were considered.

R & D policy decisions include (1) the determination of an overall scope, (2) the establishment of a desirable ranking of types of research, and (3) the assignment of task and decision responsibilities. Overall scope should consider the primary policy objectives of the firm including profitability, growth, maintenance of market share and survival. Information reports which are needed to aid in the determination of an R & D scope are (1) long-range planning reports, (2) technological forecasts, and (3) productivity indexes or assessments.

R & D organizational problems relate to the allocation of research facilities, resources, task responsibilities and the establishment of a decision structure. The relative
decentralization of R & D activities and decision authority may be dependent upon the nature of a firm's operations and its management philosophy.

Environmental and organizational factors influence a firm's policy regarding R & D scope, types of R & D to be conducted, and the assignment of task and decision responsibilities. These influences include (1) firm size and historical background, (2) industry and market conditions, (3) management attitudes toward innovation, (4) primary group conflicts, and (5) indirect exogenous factors such as management reactions to stockholder or creditor demands.
CHAPTER III

THE RESEARCH AND DEVELOPMENT
DECISION PROCESS

This chapter considers the primary R & D decisions made by firms which are engaged in research activity. The components of the information system model which are applied to the case study investigations and are summarized in Table 5 are introduced and discussed in relation to these primary R & D decisions.

The preliminary project evaluation phase consisting of idea generation, screening and the initial project acceptance is considered first. Preliminary evaluation procedures should include the establishment of a screening committee which is directly concerned with improving the process of generating and selecting new ideas. Project acceptance proposals should include project descriptions, market analysis, evaluation of project compatibility with research policy, time-adjusted R.O.I. estimates, and a proposed activity schedule. Case study findings and the literature search both revealed that fundamental research project decisions must rely extensively upon the subjective discretion of research management due to the general inability of measuring
the economic progress of such projects. Applied and development project analysis, however, should be highly comprehensive. Qualitative and quantitative factors should be properly weighted, and investment return standards should be established for the various project types.

The information system model includes a third set of criteria related to the continuing project decision. Decision-makers should be provided with revised estimates of R.O.I., project completion times and market analysis, and current summaries of actual costs. "Sunk cost" techniques should be systematically applied, and frequently revised project budget reports are needed.

A fourth set of criteria which are discussed relate to technical decisions. Technical reports include work progress evaluations, feasibility assessments and time and cost estimates. These reports should be revised frequently and integrated with the project analysis so that continuing review may properly consider the effects of the technical changes.

A fifth set of criteria relate to the total R & D budget decision. The R & D budget determination should include evaluation of the following: (1) estimates of individual project budget needs, (2) revised research project plans, (3) a summary of R & D costs by product areas and type of research, and (4) an estimate of overall research
productivity. The total R & D budget determining process should rely extensively upon an evaluation of individual project needs, and special reports should be provided to facilitate the determination.

Finally, the chapter considers the desirability of conducting post-audit appraisals. Such reports are considered necessary to reduce estimating bias and to improve the reliability of the overall R & D reporting process.

The Initial Project Acceptance Decision

**Information system model.**—The initial two items included in the information system model relate to project acceptance and screening. These items are presented below.

1. The preliminary idea evaluation phase—An autonomous initial project screening committee is needed to properly evaluate and generate research and development ideas. Non-research participation is desirable to facilitate inter-departmental communication.

2. Project proposals-initial acceptance—Proposals should include project description, market analysis, compatibility with the firm's research policies, time-adjusted R.O.I. estimates, and a proposed activity schedule.

   a. Failure to describe a project results in an improper definition of the problem.
b. Market analysis permits a rational assessment of exogenous environmental influences.

c. Return on investment estimates permit a rational decision through a comparison of minimum return to the firm's capital costs.

d. The activity schedule informs the decision-maker that the technical phases of the project have been adequately planned.

The generation of new ideas—New ideas for R & D projects may originate from external and internal sources. The results of a survey of 121 industrial research laboratories list some frequently used sources. These are summarized in Table 3.

### Table 3

<table>
<thead>
<tr>
<th>Idea Source</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>44.7%</td>
</tr>
<tr>
<td>Operating</td>
<td>15.9%</td>
</tr>
<tr>
<td>Sales</td>
<td>15.8%</td>
</tr>
<tr>
<td>Executive</td>
<td>11.4%</td>
</tr>
<tr>
<td>Commercial Research</td>
<td>4.9%</td>
</tr>
<tr>
<td>Persons outside the organization</td>
<td>2.5%</td>
</tr>
<tr>
<td>Other</td>
<td>4.8%</td>
</tr>
</tbody>
</table>

100.0%

New ideas may be internally generated by fundamental research effort. Chart 1 describes the contribution of such activity toward the production of project ideas. The collection of idea sources from fundamental effort is costly in relation to other sources. Firms should evaluate the productivity and the cost of new idea sources. An assessment of the ability of the firm to exploit the volume of new ideas may be necessary.

CHART 1

FUNDAMENTAL RESEARCH CONTRIBUTION TO THE APPLIED RESEARCH EFFORT

<table>
<thead>
<tr>
<th>Primary Classification</th>
<th>Applied Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td></td>
</tr>
<tr>
<td>Fundamental</td>
<td>Technological</td>
</tr>
<tr>
<td>Probe by</td>
<td>Ideas</td>
</tr>
<tr>
<td>Areas of Inquiry</td>
<td>Conceived</td>
</tr>
</tbody>
</table>

1. New Products
   - A
   - B
   - C

2. Cost Saving Projects
   - D
   - E

3. Product Improvements
   - F
   - G
   - H

Management must consider what procedures are necessary to improve the idea generation process. Many firms have established a management review committee which performs the preliminary screening process and attempts to improve the quality of ideas which are formally proposed. Such committees are
often staffed by a judicious mix of research and non-research middle managers in order to improve interdepartmental coordination.

Booz, Allen and Hamilton report that only one-third of all new product research projects in 120 large companies ever produce marketable products. An improved quality of project proposals should result in fewer project abandonments and a greater number of successful new product or process implementations. The screening committee should be responsible for the preparation of a proposal evaluation. The evaluation should include a tentative project description, market analysis, evidence of compatibility with research objectives, profitability projections, a proposed activity schedule, and a summary of the merits of the proposal. The report becomes the basis for the preparation of the initial project acceptance proposal.

The three case studies indicated little concern among firms for a formalized idea generating process. Firms did not evaluate the cost or productivity of the various idea sources. Two companies bypassed the screening committee phase and combined it with the preparation of the project proposal. All firms reported that research and marketing were the primary sources of new ideas.

Company X formed an initial screening committee composed of research and non-research managers. Tentative evaluations were prepared and submitted to top management for approval. Much of the control over the screening process was retained by the research function. The committee chairman was responsible to the research director. Major elements of the evaluation were prepared by research personnel.

Evidence of inadequate communication among non-research and research personnel was revealed by the Company Y study. No project screening or acceptance committee had been established. Preparation of project specifications without the joint coordination of research and marketing was creating problems. Project proposal information estimates were not freely communicated to the participants.

Company Z bypassed the initial screening phase. However, close communication between marketing and research was evident. Active marketing department participation in the initial project acceptance decision reduced the dominance of the research function.

**Project acceptance--fundamental research projects.**

Fundamental research may be defined as an exploratory probe of scientific facts in which neither program methods nor the results to be obtained is determinable. Its final products are ideas which may be employed by the applied and development
activity. Fundamental research is not, however, directed toward the achievement of specified technological ideas but may result in the establishment or the disproving of scientific principles which were based upon unknown relationships at the project's inception.

Case studies disclosed that little privately supported fundamental research was being conducted. One research director expressed a conviction that the majority of fundamental activity is being directed by non-profit research foundations, universities, and federally supported industrial projects. Accounting and research officials also expressed the opinion that fundamental research activity is more difficult to control and evaluate than the applied and development types. Its non-programmatic nature makes it difficult if not impossible to measure output objectively.

All firms reported that research directors were given "blanket authorizations" to provide for fundamental projects. These amounted to a fixed percentage of the total R & D budget. Thus, evaluation techniques were modified for fundamental projects. Research directors retained sole authority over initial project acceptance in this area. The decision to engage in fundamental research cannot be documented by profitability projections. An activity schedule may be stated only in general terms due to its non-programmable nature.
The findings of a research study reveal that all firms rely heavily upon subjective qualitative judgments of research personnel to make fundamental research project decisions.\textsuperscript{22} Once the overall decision is made concerning the general direction into areas of inquiry and the relative emphasis to be given to fundamental research, individual project decisions rely upon technical progress evaluations. Technical evaluation relates to an assessment of creativity, accomplishment, and application of skills of the research project groups. Project authorization authority is delegated to the research director within the limitations of an overall fundamental research budget constraint.

The study is primarily concerned with applied and development projects. Table 1 indicates that the vast majority of privately supported activity is included within these classifications.

An inability to measure satisfactorily the progress of fundamental projects limits the potential usefulness of a firm's information system. Since active participation by non-research groups is not required in this phase, intergroup coordination is not crucial.

Project acceptance—applied and development projects.—

Information requirements for new product proposals can and should be highly comprehensive concerning market conditions and competition, technical feasibilities, financing requirements, and profitability projections. A market analysis should include estimates (1) of customer demand, (2) of the effect of the new product introduction upon existing products, and (3) of the capabilities of the firm's distribution system. Other analyses should evaluate the number and strength of sellers, the availability of product substitutes, and the project's compatibility with the firm's overall and research objectives.

Cost saving—new process and minor product improvement proposals may require a less extensive analysis since these projects relate to existing processes which produce an established product line. Thus, market and competitive analysis and the compatibility evaluation may be cursory. Cost-savings are predicated upon continued future demand for the product being manufactured. If drastic product mix shifts are anticipated, the effects should be included in the project acceptance evaluation.

Top management participation in the initial project selection is highly desirable since the initial project acceptance is crucial to the entire R & D decision process.
Substantial funds are expended subsequent to the initial acceptance, and other R & D decisions including the total budget determination are heavily dependent upon individual project analysis. If top management involvement is low, irrational total budget criteria may be employed since usually top management is particularly qualified to evaluate a project's compatibility with the firm's objectives.

The top management of firms X and Y intended to actively participate in the initial project acceptance decision. However, the top management of firm Y was not given sufficient information to properly evaluate the relevant criteria. Company Z's top management delegated its initial project acceptance decision authority to research and marketing management personnel. In all situations the total budget determination was made independently of individual project needs.

Weighing decision criteria.—Management should establish appropriate weights upon the various decision elements. What emphasis should be placed upon qualitative versus quantitative information? Some of the qualitative information such as market and competitive analysis may be properly quantified. If technical work is relatively routine as in the majority of applied and development projects, research
costs and project completion can be projected with reasonable accuracy.

Qualitative analysis concerning the project's compatibility with firm objectives is difficult to weigh. Suppose one project adequately meets profitability objectives but will not further the firm's product diversification or product line objectives. It is apparent that much is dependent upon available alternatives. If compatible and equally profitable alternatives exist, the qualitative information will determine the project choice. Profitability objectives are usually complementary to other objectives of the firm.

The decision-maker should be provided with investment return standards. Minimum rates of return may be established for primary R & D project types. Thus, cost-saving or process improvement projects requiring little risk and a relatively short payoff period may be assigned a return standard which approximates the firm's weighted average cost of capital. A corresponding "structure of required yields" may then be built upon the least-risk project type. Product improvement projects should normally fall somewhat between the minimum return and that required for new product research. The firm's existing presence in the market reduces the uncertainty of market potential estimates for product improvement research. Product improvement benefits arise from additional sales which
are generated by the innovation. Although difficulties of its determination are evident, Company X reported that such calculations were being made and relied upon.

Williams, in studying 13 British firms, found (1) evidence of delay of highly profitable projects, (2) substantial acceptance of unprofitable projects, (3) little use of time-adjusted rate of return or profitability techniques. Possible explanations for this phenomena include: (1) influences of project sponsors, (2) inadequate knowledge of capital budgeting techniques, and (3) weak competitive market conditions which leave ample room for non-profit goals. Under the assumption that decision-makers should rationally attempt to maximize the present worth of the firm's financial resources through investment in the most profitable projects, profitability criteria should be employed as the primary basis for project acceptance decisions, and profitability methods, which are time-adjusted, should be utilized due to the long time interval between the incurrence of research cost and the receipt of benefits from the project's implementation.

The project sponsor may impose his non-profit or status objectives upon the decision process. Substantial removal of such sponsor bias may be accomplished through

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the establishment of proper evaluation and control techniques including integrated committee assignments.

Only one of the three firms employed profitability evaluation techniques in the initial project acceptance decision. Qualitative information including estimates of technical feasibility and market and competitive evaluations were considered by all firms. Only one firm attempted to inject risk into project selection through the use of probability techniques. Companies made no attempt to develop a "structure of yields" from which to rank R & D projects. Few projects were initially rejected, indicating an absence of choice among alternatives, a gross underinvestment in research and development, and/or an excessive influence upon project selection by sponsors.

Approximately fifty per cent of Y Company's R & D projects were customer supported. No attempt was made to estimate the benefits which accrue from their acceptance. Customer supported projects may complement privately supported effort or may result in the generation of future sales volume. Rough estimates of project benefits should be made. Customer supported projects of uncertain benefit should be accepted only if the absorption of idle research capacity is needed.
Information system model.--The information system model should contain a third set of criteria which relate to the execution of continuing project decisions. Such decisions require the communication of control reports to decision-makers. These reports should include revised estimates of R.O.I., project completion times and market analysis, and current summaries of actual costs. "Sunk cost" techniques should be systematically applied. Revised project budget reports should be provided and these reports should include estimated costs to complete a project and comparisons of actual and estimated costs. Control over continuing project evaluation should be implemented by establishing a functional committee responsible for the collection of data supporting the report revisions. Infrequent review, imperfect review techniques, and research dominance of the continuing phase result in the continuation of projects which should be abandoned, improper allocation of funds to continuing and proposed projects and a lack of interdepartmental communication.

Project planning.--One firm which was studied separated the overall plan into various sub-sections including (1) business evaluation, (2) product plan, (3) technical project plan, (4) marketing plan, (5) manufacturing plan,
and (6) a financial plan. Responsibility for coordinating and evaluating the overall activity is generally delegated to the research function. Replacing the R & D personnel responsibility with a management committee appears to be a desirable method of improving intergroup communication and achieving balanced decision making. The responsibility for the accumulation of revised data should also be assigned to the committee. Members should be selected from the participating functions which are directly involved with the conduct of the activity. Continual plan revision is imperative.

An overall program plan should be prepared for each continuing project. It may supersede the project proposal as the primary information report. Relevant data contained in the proposal including profitability projections and qualitative analysis may be incorporated within the plan. The report should serve as a planning and decision evaluation guide and as a control over subsequent project activity.

Reporting.—Top management review of individual continuing projects is desirable. Fixed decision or review points should be established. The reviews should correspond with the established budget periods since the reviews provide a basis for the total budget determination. If the budget period is extended to an annual basis, top management should be informed directly of the projects whose status
has changed significantly during the year.

Quinn estimates that over 70 per cent of all research laboratories employ a formal budgeting process. The National Association of Accountants reported in a similar study, that about the same percentage of companies budgeted research costs by projects as well as by object. The case study investigations revealed that all three firms maintained a formal R & D annual budget and reporting system, but only one firm revised its budget during the year.

As a result of extensive interviewing, Orton indicated that the process of identifying R & D costs with projects was being adequately performed. Cost identification and allocation was not considered to be a major obstacle to financial analysis. The management of firms X and Y expressed similar convictions. Z Company had recently installed a project budget system and was concerned with a lack of information reliability. Numerous studies including those appearing in the appendix indicate that the bulk of expenditures may be classified as directly identifiable labor. The importance


26 Orton, p. 49.
of accurate overhead allocation methods is minimized due to its relative insignificance. Firms generally applied overhead costs to projects on the basis of a predetermined overhead rate. Thus, reasonably accurate and timely project budget reports may be prepared as a guide for continuing evaluation.

Most firms prepare operating budgets and accompanying reports. Costs are accumulated by object of expenditure within the various research departments. The operating budget reports may serve as a control and performance evaluation measure for service functions or departments which are not directly responsible for the direction of individual research projects. Primary continuing evaluation, however, focuses upon individual project analysis. If operating budgets are prepared, reports should be communicated to officials who are responsible for technical evaluation.

Project budget reports are prepared by accounting or by an R & D administrative group. These reports should be distributed to research and top management to be employed as a continuing evaluation guide. Project budget information was prepared by research administration groups for firms X and Y. In all instances project budget reports were prepared. Reports were distributed to research and top management by firms X and Y. Company Z project budget reports were not available to top management.
Project budget reports should include comparisons of actual and estimated expenses for the review period and the total accumulated project costs. Estimated costs to complete along with original total project cost estimates should be included in the report.

The budget report possesses limited usefulness as a decision guide unless it is integrated with the project activity schedule. Project activity schedules provide the primary basis for budget preparation and measurement of technical accomplishment. If revised estimated costs to complete are not encompassed by the budget report, no reliable measure of accomplished output is ascertainable. During a budget period considerable effort may be expended without accomplishing the intended results. Firm Z's project budget report did not include revised estimated costs to complete. Continuing decisions were based upon incomplete information.

Establishing decision criteria.—Since short-run project continuation-abandonment decisions should be based upon profitability expectations, return on investment estimates should be reported to the decision making groups and should encompass "sunk cost" evaluation techniques. Consequently, fundamental and applied research and development costs, which are incurred earlier, should be excluded. If the expected discounted net benefits exceed the anticipated future research
and development and capital investment outlays, projects should be continued. "Sunk cost" techniques are appropriate for short-run continuation-abandonment decisions throughout the continuing and implementation phases. Employment of these techniques, as illustrated in Chart 2, accentuates the importance of the initial project acceptance decision.

CHART 2
CONTINUING R & D PROJECT EVALUATION--
NET PRESENT VALUE APPROACH

<table>
<thead>
<tr>
<th>Actual R &amp; D Costs Incurred To Date</th>
<th>Estimated Future R &amp; D Costs</th>
<th>Future Fixed Capital Required Relevant Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net investment</td>
<td>$80</td>
<td>$140</td>
</tr>
<tr>
<td>Expected annual revenues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected annual costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(excluding amortization)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected annual net cash flows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present value of an annuity of $1.00 for 10 years discounted at 10%</td>
<td>$245.80</td>
<td>$245.80 - $200.00 = $45.80</td>
</tr>
<tr>
<td>Present value of the project</td>
<td></td>
<td>$245.80</td>
</tr>
<tr>
<td>Net present value using</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sunk cost technique:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net present value using full costs:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
profitability is predicated upon future costs only, a project, once accepted, becomes increasingly more difficult to reject.

Firms X and Y applied "sunk cost" techniques to continuing projects in situations where abandonment was being seriously considered. Firm Y, however, did not employ time-adjusted return on investment projections. A three year pay-back standard was applied. Both firms did not systematically revise all project financial evaluations. Few projects were abandoned. Firm Z did not employ profitability projections or "sunk cost" techniques or make plan revisions.

The timing of project activity and its implementation may affect a project's future benefits and the total R & D costs which are incurred. Normally, project acceleration increases research costs and project benefits. Time-cost-benefit relationships should be incorporated into the information which is supplied to management. The activity schedule should result in an optimal adaptation which considers the effects of these three variables. Management should approve time estimates and be informed as to substantial time deviations from the original plan.

**Project implementation.**—Research activity creates potentially exploitable technology. The importance of the implementation decision to the overall R & D activity necessitates a reassessment of commercial feasibility. The
decision should consider only future costs and benefits. Previously incurred R & D effort is irrelevant to the decision. Management information needs are dependent upon the type of research which is conducted. Primary classifications might include new products, product improvements, new processes, cost savings on existing processes, patent development and raw material research.

New product research generally requires additional investments in capital equipment and working capital. The implementation decision should employ "sunk cost" applications. Working and fixed capital requirements become the relevant net investment outlay to be compared with the projected net benefits. The financial evaluation section of the project proposal or research plan should be revised in accordance with these concepts. Thus, implementation becomes a capital budgeting decision and should be treated as such.

A marketing director of a large corporation lists as the primary cause of new product failures the following: (1) Lack of a well-thought-out marketing plan. (2) Lack of pre-testing of the product with customers. (3) Lack of market test. (4) Insufficient product research. (5) Lack of pre-testing of the packaging. This insight describes the

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apparent importance of the marketing effort and the need for adequate functional communication and coordination. One of the research executives of a firm which was studied stated that the primary difficulty of the firm to date was the coordination of functional responsibilities during the implementation stage. Frequently, new products were introduced prior to sufficient development or testing. A research program can not be conducted based upon technological considerations but must be integrated into the firm's overall management plan.

Product improvements should be evaluated similarly to new product projects. However, fixed capital requirements may not be extensive if the improvement utilizes the basic manufacturing process employed by the superseded product. Profitability evaluation measurement techniques may be crude due to the problem of determining the revenue contribution. One researcher commented that there are situations where marketing research could not accurately assess the value of product improvements regardless of its extensive application. Firm X in the study calculated the revenue contribution as the estimated sales revenue of the new improved product less its effect upon the superseded product. New product and product improvement research must utilize extensive market

28 Quinn, Yardsticks for Industrial Research, p. 197.
and competitive analysis. Prior to implementation, revisions are imperative.

Cost-saving process modification research types require relative emphasis to be placed upon the manufacturing section of the research plan. The smooth transition from development activity to production requires planning and coordination. Profitability calculations are readily determinable.

Economic evaluations of cost-reducing new and improved processes are fairly widely accepted. In this area the profitability of the improvement can be rather accurately predicted before its installation and measured after operations begin.\textsuperscript{29}

Other final product research types include raw material research and patent development. Development of substitute materials for production processes may be classified with cost-saving new process types. Valuation problems may arise if its nature is exploratory and defensively oriented. A threatened loss of supply or increased price of important raw materials may lead firms to experimentation with substitute material sources through development or acquisition and testing. Patent research is primarily a by-product of fundamental and new product applied effort. Whenever possible, patent costs and royalty income should be identified with the particular projects.

\textsuperscript{29}Ibid., p. 133.
All three firms studied reported that the project implementation decision authority was retained by top management, and that their predominating types of research activity were new product and product improvement. None of the firm revised profitability projections prior to the implementation decision. Firm Z reported that fixed capital requirements were normally insignificant, and that the majority of projects were automatically transferred from research to production.

Technical Decisions

**Information system model.**—The information system model should include the following fourth set of criteria for technical progress decisions. Technical reports should include (1) revised time and research cost estimates and (2) an evaluation of technical problems. Technical report communications are necessary to effectively execute project scheduling revisions. Technical reports should be integrated with economic analysis and should utilize "scientific" scheduling techniques.

**Integration of technical information with economic planning.**—Research management should be assigned the responsibility for evaluating technical problems. If technical feasibility assessments are changed between established management project review points, the information should be
immediately communicated to the decision making group because changed technical expectations are necessary for the revision of economic phases of project planning and evaluation. Revised time and research cost estimates should also be included. Since economic evaluation criteria become paramount to programmable applied and development projects, technical feasibility becomes a quantifiable variable which is included in the profitability estimates.

Technical and economic decisions, although interrelated, require different types of analytical information. Technical decisions include project feasibility evaluations, personnel performance assessments, and scheduling and organizing problems.

Technical feasibility appraisals and project activity schedules should be included in the initial project proposal and the revised research plan. Project feasibility is normally considered to be a relative rather than an absolute concept. A project may be considered technically feasible providing time delays and research costs do not negate its economic attributes. Such assessments should be continuous. As a project progresses, changed expectations may invalidate initial assumptions concerning the effect of technology upon cost and time. These revisions should be incorporated into the research plan and be made available to the primary decision making groups.
Technical progress summaries are employed by research personnel as an interdepartmental communications guide. The report should comment upon proposed scheduling changes, project feasibility or technical problems, R & D group performance evaluations, and deviations from the activity schedule. Project budget reports, technical progress summaries and activity schedules are integrally related and dependent. Project budget reports require continual revised estimates of the cost to complete a project since activity schedules are continually altered. Progress summaries trigger the revision of activity schedules. If activity schedules contain comparisons of actual and estimated R & D costs by research phase, budget summaries are required to update activity schedules.

**Evaluating R & D personnel.**--Research management is assigned the responsibility for evaluating the performance of research personnel, but adequate measures of accomplishment have not been developed. Evaluations of the skill, creativity, and efficiency of project groups are largely based upon subjective judgment because a project may prove to be unprofitable due to many causes other than inefficient research effort. The discovery of additional technical knowledge may invalidate initial assumptions regarding anticipated costs and accomplishments. Since some effort should be made to systematically evaluate employee or group performance
through the information reporting system, incorporation of employee performance evaluations into the technical progress report might be employed as a systematic method of recording the subjective judgments of project directors.

"Scientific" scheduling techniques.--Since effective project scheduling permits an accurate assessment of the ensuing technical feasibility problems together with a more efficient selection and assignment of manpower, events and activities may be programmed with Gantt charts, Pert-cost, and critical path systems. However, none of the firms studied employed Pert evaluation techniques. Only firm Y employed a modified Gantt chart for its project scheduling. R & D costs and times were estimated for each research phase, and variances from planned accomplishment were explained to the firm's research director in monthly technical progress summary reports.

The Total R & D Budget Decision

Information system model.--The fifth set of criteria which relates to reports for the total budget decision includes (1) estimates of individual project budget needs, (2) revised research project plans including "sunk cost" profitability estimates, (3) a summary of current R & D costs by product areas and type of research, and (4) estimates of overall research productivity. In attempting a maximization of
research productivity, the total budget determination should be predicated upon a profitability evaluation of individual projects based upon an index. Otherwise, irrational total budget criteria will be employed, and long-range objectives will be ignored.

**Budget determination for applied and development projects.**—Lump-sum budgeting should be discouraged. Top management requires the following information sources: (1) individual project budget requests from research management and (2) revised research plans which include profitability evaluation. If the total R & D budget is independently determined, a firm's top management develops arbitrary and irrational decision criteria. Budget appropriations may be determined by applying a fixed percentage of sales or profits standard which is irrational since existing profits have no relationship to the firm's present R & D effort. With availability of funds operating as a dominant criterion, all three firms studied deviated from these arbitrary fixed percentage standards only during unusual circumstances.

Notwithstanding that a firm's limited ability to obtain funds may operate as a legitimate constraint upon the R & D budget, investment decision criteria should be divorced from financing decisions since a management should independently ascertain its investment needs and secondly arrange for fund
sources. If a financial constraint is imposed, the problem is recognized as a financial management failure and not as a normal consequence of the budget process.

The total R & D budget decision becomes an ineffective defensive control measure for top management groups who are not actively involved in the overall research decision process. Such groups may implicitly relinquish their decision authority to research personnel. Individual project information is not communicated to top management. It may "rubber stamp" initial project proposals. Information reliability checks are absent from the information system. The total budget decision should be predicated upon an understanding of the economic and technical aspects of continuing and proposed R & D projects.

Budget determination for fundamental research.—The three companies in the study first determined the total budget and secondly permitted the research director to select fundamental projects providing they did not exceed a fixed percentage of the total budget. Overall productivity measures were not contemplated.

Productivity evaluation requires the valuation of fundamental research activity. The final product of such endeavor is the creation of technology which is adaptable to further applied and development activity. Valuation of the output might be expressed as the sum of money the firm would
be willing to pay for the technology which was created during a given period. An alternative expression of value might be the loss from not exploiting the fundamental technology.

Quinn suggests a quantitative evaluation technique for post-analysis of fundamental research.

The evaluator, therefore, must first trace the applications of fundamental knowledge made in the more applied phases of research and development. Where values may be assigned to these applications, the evaluator may extrapolate the present value of the applications back to the period of fundamental inquiry without which the application would not have been possible. Where knowledge can be identified as to the inquiry which produced it and the time it was produced, a return on investment may be computed; and the then-present value of the cash flows that exploiting the knowledge created may be compared with the cost of obtaining the knowledge itself.30

These valuation techniques possess limited applicability. The extensive time interval required by the present value technique negates its use as a decision making tool. The entire technological and commercial nature of a company may radically shift during a "research to commercial application cycle." Budget decisions should be based upon future expectations rather than past accomplishments. Opportunity cost valuation approaches are predicated upon hypothetical costs which are not readily measurable.

Other quantifyable measures have been employed as

30 Quinn, Yardsticks for Industrial Research, p. 198.
decision guides. Such measures include (1) the absolute number of new ideas transmitted to the applied phase, (2) the number of new patents produced, and (3) the number of new products introduced during a review period. Reliance upon absolute numbers necessarily implies that all numbers possess equal value. Absolute numerical comparisons do not serve as an adequate performance indicator due to the absence of any defined standard.

**Special reports.**—Information reports, which describe the relative emphasis and progress being made within broadly defined areas, should be provided to top management. Special reports might include cost accumulations by research type, product line, and research classification as illustrated in Table 4.* In the three companies studied, no reports of this type were made.

A return standard may be employed as a supplemental guide for determining a total research budget. An overall net present value for research can be calculated by combining the total profit and investment expectation of individual projects and including a minimum desired rate of return in the following formula:

\[
P - R \& D \text{ costs} = R \times I
\]

*See Table 2 for an illustration of an individual project analysis which would complement Table 4.
### TABLE 4
RESEARCH ACTIVITY DEVOTED TO PRODUCT LINES AND PRIMARY CLASSIFICATION TYPES (Expressed in Percentages)

<table>
<thead>
<tr>
<th>Product Improvement</th>
<th>Cost Saving</th>
<th>Total by Product Line</th>
<th>Total Research</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PRODUCTS</strong></td>
<td>X</td>
<td>Y</td>
<td>Z</td>
</tr>
<tr>
<td>Research Classification:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fundamental</td>
<td>1%</td>
<td>4%</td>
<td>-%</td>
</tr>
<tr>
<td>Applied Programmatic</td>
<td>10 30</td>
<td>10 15 20 15 50</td>
<td></td>
</tr>
<tr>
<td>Applied Non-programmatic</td>
<td>2 8</td>
<td>- - 10 - 10</td>
<td></td>
</tr>
<tr>
<td>Development</td>
<td>10 20 5 15 8 12 35</td>
<td>23% 62% 15% 30% 42% 28% 100%</td>
<td></td>
</tr>
</tbody>
</table>

where:  
- \( P \) = expected profit before R & D costs  
- \( Y \) = total investment in the projects  
- \( R \) = desired rate of return on investment

and:  
R & D costs become the unknown.  

The formula's solution thus arrives at the optimum total research budget for the ensuing period. Projects which are not amenable to R.O.I. estimates of course may be excluded from the calculation.

---

31 Seiler, p. 91.
Post-audit Evaluation

**Information system model.**—A sixth set of criteria relates to post-audit evaluation. These appraisals are necessary to improve information reliability and estimating procedures. Audits should appraise the effectiveness of initial acceptance, continuing review and project implementation decisions.

**Information reliability.**—Reliable information is essential to effective decision-making. If information reports contain biased assessments of a project's desirability, management may discount the value of the reporting and exclusively rely upon intuition or subjective judgment. Management action which is based upon unreliable information may result in an implicit transfer of decision authority to the function which accumulates data and prepares the financial analysis. None of the three companies studied conducted post-audit reviews, and little interest was evidenced for the establishment of reliability checks.

**Appraisal techniques.**—Reports should include (1) an analysis of expected versus actual competitive conditions, (2) comparisons of estimated R & D costs with time and actual data, and (3) actual versus estimated R.O.I. Reports should be sent to the primary decision-makers and to the functions
which were responsible for the original estimates. The audit reports should focus upon the propriety of individual decisions which were made during the project life. Thus, initial acceptance, continuing review, and technical decisions should be separately reviewed.

Summary of the Case Study Analysis

Table 5 contains a summary of the results of applying the information system model to the case study investigations. The techniques being employed by these three firms are compared to each other and to the model.

TABLE 5
SCHEDULE OF CASE STUDY FINDINGS--DEVIA TIONS FROM THE INFORMATION SYSTEM MODEL

<table>
<thead>
<tr>
<th>Items</th>
<th>X</th>
<th>Company Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The preliminary idea evaluation phase.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Has a formal screening committee been established?</td>
<td>(A) Yes</td>
<td>(A) No</td>
<td>(A) No</td>
</tr>
<tr>
<td>B. Do non-research personnel participate in the initial screening?</td>
<td>(B) Yes</td>
<td>(B) Yes</td>
<td>(B) Yes</td>
</tr>
<tr>
<td>1. Which functions are represented?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Research</td>
<td>(a) Yes</td>
<td>(a) Yes</td>
<td>(a) Yes</td>
</tr>
<tr>
<td>Items</td>
<td>Company X</td>
<td>Company Y</td>
<td>Company Z</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>b. Marketing</td>
<td>(b) Yes</td>
<td>(b) No</td>
<td>(b) Yes</td>
</tr>
<tr>
<td>c. Finance</td>
<td>(c) No</td>
<td>(c) No</td>
<td>(c) No</td>
</tr>
<tr>
<td>d. Top management</td>
<td>(d) Yes</td>
<td>(d) Yes</td>
<td>(d) No</td>
</tr>
<tr>
<td>C. Does the idea collecting agency function in an advisory capacity?</td>
<td>(C) Yes</td>
<td>(C) No</td>
<td>(C) No</td>
</tr>
<tr>
<td>D. Where do the majority of new ideas originate?</td>
<td>(D) Marketing and research.</td>
<td>(D) Marketing and research.</td>
<td>(D) Research--primary; marketing--secondary.</td>
</tr>
<tr>
<td>E. Do some projects bypass the initial screening?</td>
<td>(E-1) Yes</td>
<td>(E-1) Yes</td>
<td>(E-1) Yes</td>
</tr>
<tr>
<td>1. Discretionary projects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Minor product improvements?</td>
<td>(E-2) Yes</td>
<td>(E-2) No</td>
<td>(E-2) No</td>
</tr>
<tr>
<td>3. Are discretionary and product improvement projects significant?</td>
<td>(E-3) No--Each discretionary project is limited to $10,000 without top management approval. Less than ten per cent of the projects are discretionary.</td>
<td>(E-3) No--Discretionary projects may not exceed a $10,000 individual project limit.</td>
<td></td>
</tr>
</tbody>
</table>
2. Project proposals—initial acceptance.

A. Do proposals include:

1. Project description?
   a. Information supplied by:
      (a) Research
         (a) Project sponsor—(Research or marketing.)
         (a) Project sponsor—(Research or marketing.)

2. Market analysis?
   a. Information supplied by:
      (a) Marketing
         (a) Marketing
         (a) Project sponsor—(Research or marketing.)

3. Evaluation of compatibility with the firm's research policies?

(E-3) No—
Approximately 15 per cent of research center expenditures relate to discretionary projects.

<table>
<thead>
<tr>
<th>Items</th>
<th>Company</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Approximately 15 per cent of research center expenditures relate to discretionary projects.
TABLE 5—Continued

<table>
<thead>
<tr>
<th>Items</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

a. Information supplied by:

4. Time-adjusted R.O.I. estimates?
   a. Information supplied by:  
   (a) Research

5. Estimates of future expenditures?
   a. R & D
   (a) Yes
   (a) Yes
   (a) Yes—Man-hour estimates only.
   1. Information supplied by:
      (a-1) Research
      (a-1) Research
      (a-1) Research
   b. Production
      (b) Yes
      (b) No*
      (b) Yes—except for research center projects.
      1. Information supplied by:
         (b-1) Production
         (b-1) Not determined.

*Estimates are supplied by production subsequent to the initial project acceptance. These estimates are employed in the continuing review.
### TABLE 5—Continued

<table>
<thead>
<tr>
<th>Items</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>c. Distribution</td>
<td>(c) Yes</td>
<td>(c) No</td>
<td>(c) No</td>
</tr>
<tr>
<td>1. Information supplied by:</td>
<td>(c-1) Marketing</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>d. Fixed capital</td>
<td>(d) Yes</td>
<td>(d) No**</td>
<td>(d) No**</td>
</tr>
<tr>
<td>1. Information supplied by:</td>
<td>(d-1) Accounting</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>6. A proposed activity (A-6)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

schedule?

a. Includes time estimates of individual research phases?

b. Includes cost estimates of individual research phases?

**B. Basis for estimating project benefits—forecasting tools employed:

**Estimates are supplied by the Research Administration department subsequent to project acceptance.

***Incremental capital costs associated with R & D are normally insignificant. Significant capital expenditure proposals are included in the capital budget.
TABLE 5—Continued

<table>
<thead>
<tr>
<th>Items</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sales projections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(volume)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Customer feedback?</td>
<td>(1-a) Yes</td>
<td>(1-a) Yes</td>
<td>(1-a) Yes</td>
</tr>
<tr>
<td>b. Formal market research surveys, etc.</td>
<td>(1-b) No</td>
<td>(1-b) Yes</td>
<td>(1-b) Not determined.</td>
</tr>
<tr>
<td>c. Forecasting aggregate product demand through index correlation?</td>
<td>(1-c) No</td>
<td>(1-c) Yes</td>
<td>(1-c) Not determined.</td>
</tr>
<tr>
<td>2. Sales projections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(price)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Use of existing substitute product prices?</td>
<td>(2-a) Yes</td>
<td>(2-a) Yes</td>
<td>(2-a) Yes</td>
</tr>
<tr>
<td>b. Value analysis?*</td>
<td>(2-b) Not determined.</td>
<td>(2-b) Yes</td>
<td>(2-b) No</td>
</tr>
<tr>
<td>c. Customer inquiry?</td>
<td>(2-c) Yes</td>
<td>(2-c) Yes</td>
<td>(2-c) Yes</td>
</tr>
<tr>
<td>d. Demand elasticity studies?</td>
<td>(2-d) Yes</td>
<td>(2-d) No</td>
<td>(2-d) No</td>
</tr>
</tbody>
</table>

*This term refers to an estimate of savings which will accrue to prospective customers through the purchase of a new product. The seller establishes a selling price which is based upon the amount of customer savings.
<table>
<thead>
<tr>
<th>Items</th>
<th>Company X</th>
<th>Company Y</th>
<th>Company Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Use of variable sales estimates (optimistic, pessimistic and likely)</td>
<td>(3) Yes</td>
<td>(3) No</td>
<td>(3) No</td>
</tr>
<tr>
<td>4. Number of years sales are projected.</td>
<td>(4) Ten</td>
<td>(4) Three</td>
<td>(4) One year for development projects.</td>
</tr>
<tr>
<td>5. Basis for cost projections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. R &amp; D and production costs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Use of standards?</td>
<td>(a-1) Yes</td>
<td>(a-1) Yes</td>
<td>(a-1) No</td>
</tr>
<tr>
<td>2. Comparison with prior projects?</td>
<td>(a-2) Yes</td>
<td>(a-2) Yes</td>
<td>(a-2) Yes</td>
</tr>
<tr>
<td>3. Use of project schedule?</td>
<td>(a-3) Yes</td>
<td>(a-3) Yes</td>
<td>(a-3) Yes</td>
</tr>
<tr>
<td>b. Distribution costs</td>
<td>(b) Basis not determined.</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>c. Fixed capital</td>
<td>(c) Basis not determined.</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>C. Are expected R &amp; D returns compared with returns from other types of capital investment?</td>
<td>(C) Indirectly through the cost of capital return standard.</td>
<td>(C) No</td>
<td>(C) No</td>
</tr>
</tbody>
</table>
### TABLE 5—Continued

<table>
<thead>
<tr>
<th>Items</th>
<th>Company</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>D. Is top management intent to actively participate in the initial project selection?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(D) Yes</td>
<td>(D) Yes</td>
<td>(D) No--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Responsibility is delegated to research and marketing.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>E. Does top management formally approve new projects?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(E) Yes</td>
<td>(E) Yes</td>
<td>(E) No</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>F. Are individual project proposal reports evaluated by top management?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(F) Yes</td>
<td>(F) Yes</td>
<td>(F) No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Execution of continuing project decisions.

**A. Has the intended responsibility for continuing review decisions been delegated by top management?**

| (A) No                                                               | (A) Yes | (A) No |

1. If yes, is the responsibility delegated to the research director?

**B. Has a management committee been established which collects and evaluates revised data?**

| (B) No                                                               | (B) No  | (B) Yes |

1. If not, is this a research department function?

<p>| (B-1) Yes                                                            | (B-1) Yes | ---    |</p>
<table>
<thead>
<tr>
<th>Items</th>
<th>Company X</th>
<th>Company Y</th>
<th>Company Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. Is top management actively involved with individual projects?</td>
<td>(C) Yes</td>
<td>(C) No</td>
<td>(C) No</td>
</tr>
<tr>
<td>1. Is a quarterly review of major projects conducted by top management?</td>
<td>(C-1) No</td>
<td>(C-1) No</td>
<td>(C-1) Yes</td>
</tr>
<tr>
<td>D. Do non-research functions participate in continuing project review decisions?</td>
<td>(D) Yes</td>
<td>(D) No</td>
<td>(D) Yes</td>
</tr>
<tr>
<td>1. If yes, which functions are represented?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Marketing?</td>
<td>(1-a) No</td>
<td>---</td>
<td>(1-a) Yes</td>
</tr>
<tr>
<td>b. Finance?</td>
<td>(1-b) No</td>
<td>---</td>
<td>(1-b) No</td>
</tr>
<tr>
<td>c. Other?</td>
<td>(1-c) Top management.</td>
<td>---</td>
<td>(1-c) Top management.</td>
</tr>
<tr>
<td>E. Is revised project analysis available to the following groups:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Top management?</td>
<td>(E-1) Yes</td>
<td>(E-1) No</td>
<td>(E-1) No</td>
</tr>
<tr>
<td>2. Marketing?</td>
<td>(E-2) No</td>
<td>(E-2) No</td>
<td>(E-2) Yes</td>
</tr>
<tr>
<td>3. Finance?</td>
<td>(E-3) No</td>
<td>(E-3) No</td>
<td>(E-3) No</td>
</tr>
<tr>
<td>4. Research?</td>
<td>(E-4) Yes</td>
<td>(E-4) Yes</td>
<td>(E-4) Yes</td>
</tr>
</tbody>
</table>
TABLE 5—Continued

| Items                                                                 | Company | | | |
|---|---|---|---|---|---|
| F. Are the following types of revised information available to decision-makers? | X | Y | Z |
| 1. Revised market and competitive analysis? | (F-1) Yes | (F-1) No | (F-1) No |
| 2. Project completion time estimates? | (F-2) Yes | (F-2) Yes | (F-2) No |
| 3. R.O.I. analysis? | (F-3) Yes | (F-3) No | (F-3) No |
| 4. Systematic application of "sunk cost" techniques? | (F-4) No | (F-4) No | (F-4) No |
| 5. Frequently revised project budget reports including estimated costs to complete and comparisons of actual and projected costs? | (F-5) Yes | (F-5) Yes | (F-5) No |
| 6. Frequently revised operating budget reports? | (F-6) Yes | (F-6) Yes | (F-6) Yes |
| 7. Revised project schedules? | (F-7) Yes | (F-7) Yes | (F-7) Yes |

4. Technical progress decisions.

A. Are frequently revised time and cost estimates included in technical reports? | (A) Yes | (A) Yes | (A) No |
<table>
<thead>
<tr>
<th>Items</th>
<th>Company X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Are technical reports submitted to the research director?</td>
<td>(B) Yes</td>
<td>(B) Yes</td>
<td>(B) Yes</td>
</tr>
<tr>
<td>C. Is technical planning accompanied by the following:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Gantt Charts?</td>
<td>(C-1) No</td>
<td>(C-1) Yes</td>
<td>(C-1) No</td>
</tr>
<tr>
<td>2. Pert-cost and/or critical path systems?</td>
<td>(C-2) No</td>
<td>(C-2) No</td>
<td>(C-2) No</td>
</tr>
<tr>
<td>D. Are technical reports integrated with economic analysis?</td>
<td>(D) Yes</td>
<td>(D) No</td>
<td>(D) No</td>
</tr>
<tr>
<td>1. Are modifications in the technical plan communicated to economic planners so that the following are promptly revised:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Budget reports?</td>
<td>(l-a) Yes</td>
<td>(l-a) Yes</td>
<td>(l-a) No</td>
</tr>
<tr>
<td>b. Project analysis?</td>
<td>(l-b) Yes</td>
<td>(l-b) No</td>
<td>(l-b) No</td>
</tr>
<tr>
<td>c. Project schedules?</td>
<td>(l-c) Yes</td>
<td>(l-c) Yes</td>
<td>(l-c) No</td>
</tr>
<tr>
<td>2. Are technical feasibility evaluations considered by decision making groups for the project acceptance and continuing review?</td>
<td>(D-2) Yes</td>
<td>(D-2) Yes</td>
<td>(D-2) Yes</td>
</tr>
</tbody>
</table>
5. The total R & D budget decision.

A. Is the total R & D budget determined by top management?

B. Which of the following items are submitted to top management prior to the total R & D budget determination:

1. Estimates of individual project needs?

2. Revised project analysis including "sunk cost" profitability estimates?
   a. Are the revised "sunk cost" estimates systematically applied?

3. A summary of current R & D costs by product area and type of research?

4. Estimates of overall R & D Productivity?

<table>
<thead>
<tr>
<th>Items</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Is the total R &amp; D budget determined by top management?</td>
<td>(A) Yes</td>
<td>(A) Yes</td>
<td>(A) Yes</td>
</tr>
<tr>
<td>B. Which of the following items are submitted to top management prior to the total R &amp; D budget determination:</td>
<td>(B-1) No</td>
<td>(B-1) No</td>
<td>(B-1) No</td>
</tr>
<tr>
<td>1. Estimates of individual project needs?</td>
<td>(B-2) Yes</td>
<td>(B-2) No</td>
<td>(B-2) No</td>
</tr>
<tr>
<td>2. Revised project analysis including &quot;sunk cost&quot; profitability estimates?</td>
<td>(2-â) No</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>a. Are the revised &quot;sunk cost&quot; estimates systematically applied?</td>
<td>(B-3) No</td>
<td>(B-3) No</td>
<td>(B-3) Yes</td>
</tr>
<tr>
<td>3. A summary of current R &amp; D costs by product area and type of research?</td>
<td>(B-4) No</td>
<td>(B-4) No</td>
<td>(B-4) No</td>
</tr>
<tr>
<td>Items</td>
<td>Company</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>----------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>Y</td>
<td>Z</td>
</tr>
<tr>
<td>C. Are &quot;rule of thumb&quot; standards, ie. percent of sales or profits,</td>
<td>(C) Yes</td>
<td>(C)</td>
<td>(C)</td>
</tr>
<tr>
<td>employed as a primary total budget determinant?</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>D. Are budgets appropriated on a &quot;lump sum&quot; basis?</td>
<td>(D) Yes</td>
<td>(D)</td>
<td>(D)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1. Are individual projects subsequently approved?</td>
<td>(D-l) Yes</td>
<td>(D-l)</td>
<td>(D-l)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6. Post-audit appraisals.</td>
<td>(A) No</td>
<td>(A)</td>
<td>(A)</td>
</tr>
<tr>
<td>A. Are post-audit appraisals conducted?</td>
<td></td>
<td>No</td>
<td>No</td>
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CHAPTER IV

CONCLUSIONS

Requirements of the R & D Information System Model

I. The preliminary idea evaluation

A. A formal screening committee should be established.
   1. Non-research personnel should participate.
   2. Idea collecting agencies should function in an advisory capacity.
   3. All significant projects should be channeled through the screening committee.

II. The initial project acceptance

A. Proposals should include:
   1. A project description.
   2. A market analysis.
   3. An evaluation of project compatibility with R & D policy.
   4. Time-adjusted R.O.I. estimates. (Expected R & D returns should be compared with alternative types of capital investment proposals.)
   6. A proposed activity schedule encompassing time and cost estimates by research phase.

B. Estimating project revenues and expenditures
1. Sales volume projections should utilize the following methods.
   a. Customer feedback.
   b. Formal market research surveys, etc.
   c. Forecasting through index correlation.

2. Selling price projections should include:
   a. Use of existing substitute product prices.
   b. Value analysis.
   c. Customer inquiry.
   d. Demand elasticity studies.

3. Sales estimates should also include:
   a. Useful product life assessments.
   b. Use of variable sales estimates (optimistic, pessimistic, and likely).

4. Project cost estimates.
   a. R & D and production cost estimates should rely upon the following:
      1. Standard costs.
      2. Comparisons with prior projects.
      3. Use of project schedules.
   b. Distribution and fixed capital expenditures should be projected.

III. Continuing project decisions

A. Non-research functions including top management should participate in continuing project review decisions.

B. Frequently revised information should be available to decision making groups. These data include:
1. Project analysis including (1) revisions of market and competitive assessments, (2) project completion time estimates, and (3) R.O.I. analysis predicated upon a systematic application of "sunk cost" techniques.

2. Revised project budget reports including estimated costs to complete and comparisons of actual and projected costs.

3. Operating budget reports.

4. Project activity scheduling revisions.

IV. Technical decisions

A. Revised time and R & D cost estimates should be included in technical reports.

B. Technical reports should be communicated to the technical director.

C. R & D planning should include Gantt Charts and Pert cost and/or critical path techniques.

D. Technical reports should be integrated with economic analysis.

V. The total R & D budget decision

A. The following information types should be available for the total budget decision:

1. Estimates of individual project needs.

2. Revised project analysis including "sunk cost" profitability estimates.

3. A summary of R & D costs.

4. Estimates of overall R & D productivity.

B. R & D budgets should not be appropriated on a lump-sum basis.

C. "Rule of thumb" standards, i.e. per cent of sales or profits, should not be employed as a primary total R & D budget determinant.
VI. Post-audit appraisals

A. Post-audit appraisals are necessary to improve information reliability and estimating procedures.

B. Audits should appraise the effectiveness of initial acceptance, continuing review and project implementation decisions.

Implications for Future Study

The information systems of the three firms exhibited varying degrees of effectiveness as guides to the R & D decision process. Various deviations from the information system model were present in each study. Relevant information was not communicated to decision making groups. Cost and revenue estimates were incomplete. Project evaluations were not revised. In some situations relevant criteria were not considered in the decision process. Quantitative evaluation techniques, applicable to project selection, continuing review, technical decisions, and the total R & D budget determination, were not utilized.

This study indicates a need for the future development, refinement, and/or the application of quantitative evaluation techniques to R & D decisions. A quantitative project selection model should consider facets which are unique to the R & D management problem. These include (1) the problem of selecting an emphasis upon types of R & D—fundamental, applied and development; (2) selection
among end products--new products, improvements, new process, and cost saving process R & D; and (3) selection of privately supported versus customer supported R & D. Future research may develop and apply such quantitative techniques to the R & D project selection decision. The studies indicated a need for the development and application of R & D productivity measures. Additional research might investigate the possibility of developing industry-wide productivity indexes or measures which might be uniformly applied.

Empirical testing of information system models and quantitative evaluation techniques is needed. If an information system model or a quantitative evaluation technique were actually applied to an existing firm, what effect would the change have upon the decision process, R & D scope and ultimate profitability? If committee management decision making were substituted for an existing decision structure, what effects would be elicited? If the degree of top management involvement in the decision process were modified, would a shift in the method of determining an R & D budget occur? A model simulation approach may prove to be a practical alternative to laboratory experimentation.

The thesis was primarily concerned with internal R & D management problems. The study revealed, however, the importance of case study investigation to financial accounting
policy determination. Implementation of R & D capitalization and amortization methods appears to be dependent upon the utilization of managerial techniques. R & D capitalization predicated upon present value expectations must rely upon project selection, continuing review and post-audit project managerial evaluation techniques. R & D capitalization approaches, which are based upon R & D historical costs, must rely upon cost accumulation and allocation techniques. Amortization methods should reflect estimates of project life and expectations regarding rates of technological and market change. Thus, future financial accounting research should test procedural applications.

The limited number of case studies which was conducted does not permit a generalization of the findings. Future research might encompass the application of the information system model to a large number of firms. A questionnaire might be developed to facilitate the testing process. Attempts may be made to improve measurement techniques. A deviation from the model system should ideally be expressed in terms of its effect upon R & D activities, scope, productivity and other key variables.

Other Findings

The accounting profession should consider the relative
importance of its functional role within the R & D information system. Accounting involvement may be defined in relation to the following: (1) responsibility for data collection, preparation of project estimates and analysis and the transmission of information, (2) report preparation, and (3) participation in the R & D decision process.

The importance of the accounting function is directly attributable to its primary custodial responsibility for the administration of the corporate information system. The ability to quantitatively express the results of business activity in monetary terms has been the accountant's main forte.

The accountant's assumed responsibility for the installation and maintenance of managerial controls is generally accepted among management groups. R & D control should be viewed as a total systems concept. Control is manifested and made possible through (1) adequate transfers of information among management groups, (2) the development of quantitative project evaluation or measurement techniques, and (3) the initiation of procedural reliability checks including post-audit appraisals. Effective participation in the control process requires an active accounting functional involvement with the total R & D system. Involvement is evidenced by (1) R & D management committee representation, (2) responsibility for management audits, and (3) active participation
in the preparation of R & D reports.

The case studies revealed that accounting participation in the R & D management process was generally insignificant. In two situations research administration departments had been created. These service departments assisted in the preparation of budgets and assumed primary responsibility for R & D report preparation. Data gathering and financial analysis were frequently assumed by non-accounting personnel. Accounting did not participate in the R & D decision process via management committee assignments.

Post-audit controls were neither desired by top and research management nor operative. Resistance to non-research departmental controls was evident. If post-audits were initiated in these situations, non-accounting responsibility for their execution is probable.
APPENDIX

X COMPANY
CASE STUDY ANALYSIS

Background Information

The X Company was incorporated fifteen years ago and remains a privately owned and managed firm. The company and the instrument control industry have been characterized by rapid growth and technological change.

The company develops, manufactures, and distributes a full line of industrial scanning gauges. Product applications improve the quality control of manufacturing processes through the utilization of electronic components, principles of nuclear radiation, and electronic computer equipment.

Scanning devices of the type manufactured by the firm are a relatively recent phenomena. Company X has been a leader in the field of nucleonic instrument controls. Presently, no competitor offers a full line of products which rival the company's product. A few firms compete for specific market segments. Technological requirements, the infancy of the industry, and patent protection appear to be the important factors which have limited competitive entry. Relative size
and financial resources, typical restraining barriers in established markets, have not yet appeared as influential competitive restraints. The market is characterized by original investment demand rather than the satisfaction of a replacement demand. New uses for existing products and new products which complement existing lines have been continually developed.

The firm's research activity is primarily of an applied and development nature. Research activity is undertaken with a given product objective in mind. Project activity is normally programmatic.

The research process is primarily directed toward new product introductions and product improvements or modifications. Insignificant effort is directed toward manufacturing process types of research such as the development of new or improved production processes or technical assistance to production activities. The firm's main forte is the technological development of industrial control systems.

The research and development organization was recently subdivided into four divisions including nucleonics systems, electronics systems, federal systems, and a new product planning and administrative division. Research projects are readily identified with a particular research operating division. The creation of subdivisions within the research
function was intended to clarify reporting responsibilities and simplify task assignment.

Research budget expenditures approximate fifteen to twenty per cent of total company sales volume. $200,000 of the $1,700,000 research budget is supported by the government and customers. The magnitude of privately supported new product research relative to the firm's sales volume supports the premise that an aggressive research policy is being pursued.

Technological rather than productive superiority has been the firm's main forte. The firm's image is endowed with a research and marketing orientation rather than an emphasis upon production activity. The company's existence, profitability, growth, and industry position are chiefly predicated upon its technological, distribution, and service maintenance organizations. Its original conception was fostered upon a technological base. Top management and primary policy objectives were scientifically oriented. Major management attention and large expenditures are related to these functions. Although production jobs are principally custom-order, standard interchangeable components are common. Manufacturing activity is chiefly an assembly operation.

Expansion has been financed solely from internally generated funds. The firm's attitude toward accepting financial risk through its capital structure via leverage has been
conservative when compared to its willingness to accept research capital investment risk. The firm presently employs a ten per cent rate of return standard for all proposed research investments. The investment policy, although dominated by profitability considerations, is influenced by anticipated competitor reactions. Thus, a projected capital expenditure which does not meet minimum profitability criteria may be accepted if the firm's future market and/or technological position is in jeopardy.
CHART 3
RESEARCH ORGANIZATION

MANAGER

PRODUCT APPLICATIONS MANAGER

PROGRAM MANAGER

RESEARCH AND DEVELOPMENT MANAGER

ELECTRONICS SYSTEMS DIVISION MANAGER

NUCLEONIC SYSTEMS DIVISION MANAGER

MANAGER

MOISTURE CONTROLS MANAGER

MANAGER R & D ELECTRONIC SYSTEMS

MARKETING MANAGER

ARMY/NAVY PROGRAMS

TECHNICAL PROGRAMS MANAGER

RESEARCH AND DEVELOPMENT MANAGER

MANAGER

PLANNING MANAGER

ADMINISTRATION MANAGER

TEST MANAGER

DIRECTOR PATENTS

NEW PRODUCT DEVELOPMENT V.P.

NEW PRODUCT DEVELOPMENT & ADMINISTRATION

EXECUTIVE V.P. RESEARCH
Evaluation of new idea sources for research project application.—The company maintains a screening process which collects, investigates and evaluates new ideas. New products represent the primary form of new idea sources. Product improvements or modifications may pass through the initial screening process if significant amounts of capital are required for implementation. Otherwise, product improvements are channeled directly to the respective research division which is given the responsibility for evaluation and implementation.

New ideas may originate from internal and external sources. External sources include existing customers, potential customers, trade associations, research foundations, consultants, government agencies, other instrument companies, and companies with related technology. Internal sources include the research management, the board of directors, a corporate planning department, and other functional departments. The primary external source of new ideas has come from customers and from companies with related technology.

The screening committee consists of research and non-research personnel. The research group includes the (1) manager—advanced product development, (2) program managers from
the nucleonic, electronics, and federal systems divisions, (3) research and development managers from the three research divisions, (4) federal systems division program manager, and (5) the patent director. Non-research personnel are represented by (1) the corporate planning department manager, (2) marketing department manager—administration and planning, and (3) marketing department manager—industrial systems and applications. This committee acts primarily as an advisory "hearing board" where the soundness of new ideas is discussed during the initial phase. The initial stages of the research and development process are devoted exclusively to a preliminary economic evaluation of new ideas. Acceptance by a majority of the screening committee members results in the passage of a proposal into the second evaluation phase. During this latter phase a product proposal evaluation is prepared by the manager of the new product development department with the assistance of the new product evaluation committee. Table 6 describes its composition and the pooling of information sources.

The screening guide consists of a rather detailed check list of the pertinent factors affecting the project. The projected operations summary contains a ten year return on investment calculation. Working capital, fixed capital equipment and start-up costs are estimated along with estimates
TABLE 6

PRODUCT PROPOSAL

<table>
<thead>
<tr>
<th>Composition</th>
<th>Information Supplied By</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Product description</td>
<td>Committee chairman</td>
</tr>
<tr>
<td>2. Screening guide</td>
<td></td>
</tr>
<tr>
<td>1. General information</td>
<td>Committee chairman</td>
</tr>
<tr>
<td>2. Financial information</td>
<td>New product development, planning and administration department</td>
</tr>
<tr>
<td>3. Description of market</td>
<td>Marketing department</td>
</tr>
<tr>
<td>4. Functional requirements</td>
<td>New product development, planning and administration department</td>
</tr>
<tr>
<td>5. Competition</td>
<td>New product development, planning and administration department</td>
</tr>
<tr>
<td>6. Technical feasibility</td>
<td>New product development, planning and administration department</td>
</tr>
<tr>
<td>3. Project operations summary</td>
<td></td>
</tr>
<tr>
<td>Sales</td>
<td>Marketing department</td>
</tr>
<tr>
<td>Cost of sales</td>
<td>New product development, planning and administration department</td>
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<tr>
<td>Operating expenses</td>
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</tr>
<tr>
<td>Administrative</td>
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</tr>
<tr>
<td>Marketing</td>
<td>New product development, planning and administration department</td>
</tr>
<tr>
<td>Research and development</td>
<td>New product development, planning and administration department</td>
</tr>
<tr>
<td>Manufacturing engineering</td>
<td>New product development, planning and administration department</td>
</tr>
</tbody>
</table>
of the project cash flows. A time adjusted rate of return is then computed.

The product proposal becomes the basis for review by an upper echelon management committee during the second phase. Its members consist of (1) the executive vice president—new product development department, (2) the manager—new product development department, (3) the manager—planning and administration—new product development department, (4) the program manager—new product development department, (5) the marketing director, and (6) the manager—corporation planning department. If committee approval is obtained, the proposal is forwarded to top management represented by the president and the vice president of operations.

Research Procedures, Organization and Decisions—Intensive Study Phase

The intensive study phase evaluates in depth the economic and technical facets of acceptable ideas. The evaluation culminates in the preparation of a Program Plan which becomes the basis for the subsequent applied, development and product introduction phases. The Program Plan is subdivided into the following sections: (1) Business Evaluation, (2) Product Plan, (3) Project Plan, (4) Marketing Plan, (5) Manufacturing Plan, and (6) Financial Plan.

The Business Evaluation section is prepared by the
research division manager and follows the same format of the phase two projected operations summary. A Product Plan, prepared by the research division program manager, includes (1) an analysis of product applications, (2) timing and cost requirements related to installation and training of customer's employees, (3) product specifications, (4) compatibility with the product line, sales force, research and development and manufacturing capabilities, and (5) an analysis of patent position, competitive influences and regulatory constraints.

The intensive study phase becomes the direct responsibility of the appropriate research division. The manager of the research and development division assumes the responsibility for the preparations of the Project Plan. Encompassed by the Project Plan are estimates of time and research cost including manpower, materials, and equipment. Product specifications are described in depth along with the technical scheduling procedural applications.

Sales volume estimates are incorporated into the Program Plan. Customer demand is projected through an examination of existing customer needs. Market research is largely an informal process of personal sales contact with the market. No formalized market research function has been established. Sixty large industrial users represent approximately eighty-five per cent of the firm's relevant market
for new product introductions. Most new products are sold to existing customers. Sales volume projections are reviewed by marketing personnel who specialize in the particular application area being investigated.

New product pricing is based upon (1) an analysis of the customer savings derived from the new product; (2) distribution, production, and development cost estimates; (3) estimated demand elasticity of existing product lines; (4) effect upon existing obsoleted equipment under rental agreements; and (5) competitor and firm's pricing structure for close product substitutes. The primary pricing method employed for products which possess no close substitutes is to establish a price which the customer can repay in two years through savings on its purchase. Such estimates require extensive familiarity with the customer's industrial processes and cost structure. Cost estimates of project costs and cost of production are indirectly employed as a secondary reliability check upon the original pricing estimates.

Periodic studies are conducted by the corporate planning department which estimates the demand elasticity for the firm's existing product lines. These studies are employed as a guide toward an attempted establishment of profit maximizing prices for new products. Unit quantity, price, and cost relationships are graphically related to obtain a profit maximizing
The firm employs a range of estimates from the most optimistic, pessimistic, and likely. The ranges are influenced by projections of capital goods spending for the domestic economy, estimates of the effects of technology and competitor response. Thus, optimistic projections may be predicated upon the anticipation of favorable economic conditions and an absence of competitor moves to counter the new product introduction.

The marketing department—manager of administration and planning prepares the Marketing Plan. Estimates are made of the ten-year market potential, sales volume and selling price, effect upon sales of the present product line, and the anticipated marketing strategy. Promotion and selling expenses are likewise projected.

The Manufacturing Plan is prepared by the vice president of manufacturing. Material, labor, production and engineering overhead are estimated.

The Financial Plan, prepared by finance, estimates the research and development budget requirements. Additional fixed and working capital requirements are also projected. The analysis is incorporated into a return on investment calculation in the business evaluation report.

Immediately following the completion of the Program
Plan report, a management committee reviews the project. Based upon the Project Plan, an acceptance or abandonment decision is made. Acceptance necessitates a budgeted appropriation prior to entering into the applied and development research activity phase. The management committee consists of the president, vice president—operations, executive vice president and managers of corporate planning, marketing, finance, manufacturing, and the new product development department.

Continuing Project Evaluation

Technical evaluation of research project progress is reported monthly by project directors via detailed evaluation reports. Following a review by the appropriate research division manager, the technical progress reports are summarized and sent to top management. Management may compare estimates of the technical progress of individual projects with biweekly budget reports which accumulate actual, budgeted and estimated completion costs for individual projects.

A project may remain in the applied and development stages for one to five years. Thus, a periodic revision of the Program Plan is imperative. Market estimates, technical feasibility studies, estimated costs and other relevant criteria are reviewed during the transition. Top management
is given a full revision of the Program Plan for individual projects prior to each semi-annual budget period and at the completion of a project phase. Top management approval is necessary to advance a project to the development stage. Approval is also required prior to its market introduction. Through the budget approval process, top management retains control over continuing projects which remain in one phase for an extended period.

Top management sources of information for the applied, development and implementation decisions include (1) the revised Program Plan, (2) project budget reports, and (3) technical progress summaries. The composite includes financial, marketing, technical, and general corporate environmental information. Information encompasses both estimates of future costs, benefits, and environmental conditions as well as an analysis of prior period actual and budgeted costs and technical progress.

Profitability decision criteria relative to a continuing project require modification. Research and development costs incurred during prior periods are "sunk" and irrelevant to the continuation-abandonment decision. Revised profitability evaluations are formulated in the Program Plan only when an abandonment is being considered. Research and development costs, which are incurred prior to a given decision
point in the research program, are deleted from the net investment outlay in the return on investment calculation. A project will normally be continued providing it is technologically feasible if the discounted future net benefits exceed the expected future cash outlays. The projections are based upon a ten-year forecast. Future cash flows are discounted at a ten per cent cost of capital. Profitability projections are based upon three estimates which include optimistic, pessimistic, and most-likely possibilities.

Budgeting Procedures and the Total R & D Budget Determination

Formal operating budgets are prepared annually. Minor revisions are made on a quarterly basis while major revisions are implemented semi-annually. Tentative intermediate range budgets are prepared for a two year period.

Budget preparation commences with research department managers and project directors who estimate operating needs for the ensuing period. Research budgets are prepared by projects and by research divisions so that the summation of a research division's project cost is reconciled to the total division expenses. The accounting department aids the research divisions in the preparation of cost estimates. The determination of overhead rate allocations to projects and divisions represents the primary area of assistance. The accounting
department also reviews project estimates through a comparison of the estimates with similar completed actual project costs.

Research costs largely consist of labor and material which are directly identifiable with projects and divisions. Administrative overhead costs are allocated to research divisions. Reallocations are then made to projects based upon estimated project labor hours.

Management approval of the research operating budget is heavily dependent upon research project approvals. Management review of scheduled new projects and evaluation of continuing projects are required. Top management information sources include (1) the Program Plan evaluation report prepared by research management during phase three, (2) technical progress summaries prepared by project directors, and (3) project budget reports which are prepared by the accounting department. This latter report summarizes budgeted and actual costs of prior periods. Top management budget approvals are dependent upon economic and technical evaluation of existing and new projects and upon the firm's profitability and ability to finance the research program. Top management first determines the total research budget appropriation. The budgeting process, operating within the total budget constraint, involves an allocation of the total appropriation to projects on the basis of technological scheduling considerations and
relative project desirability.

Budgeted research costs are accumulated by projects and by research divisions. A monthly operating budget report is prepared by accounting. Expenses are classified by object of expenditure. The operating budget report includes a summary of budgeted versus actual expenses for the month and estimated and actual expenses for the budget period. The operating budget is prepared in detail for submission to research division managers. Top management officials including the vice president of new product development, the executive vice president—operations and the president receive monthly summaries of research expenses of individual division performance.

A project budget report is also prepared by the accounting department. It consists of a bi-weekly tab run of project expenditures. Actual versus budgeted expenses are summarized for the bi-weekly period and accumulated for the budget period. Encompassed by the report are original estimates of total project costs along with revised estimates of total cost and cost to complete. Research project budget reports are summarized in detail for project directors. Research division managers and top management officials receive similar information in summary form. Project budget reports are used by research management officials to evaluate the technical performance of project groups and divisional research
effort. Top management officials evaluate the performance of continuing research projects. Budgets are employed as a basis for quarterly management review of budgets and appropriations. Decisions are made concerning the approval of new projects, and the abandonment versus the continuation or acceleration of existing projects.

Comments Upon the Preliminary Screening and Evaluation Phase

Management has established specific responsibility for the coordination and direction of the preliminary screening and evaluation phase. An advanced product development manager has been delegated the sole responsibility for the coordination of the program during the initial two phases. The manager may overrule the established screening committee and forward a rejected proposal into phase two for the higher echelon committee evaluation.

Establishment of management control is needed to assure a proper flow and utilization of new ideas. The organization reporting procedures facilitate control. Rejected ideas are periodically reported to an upper management committee which reviews tentatively accepted phase three projects.

The new idea acceptance-rejection decision represents the primary concurrent managerial action during the initial research phase. The initial product proposal form encompasses
the quantitative and qualitative criteria which are significant to the decision process. The firm utilizes sufficiently comprehensive and relevant economic information as a basis for the initial acceptance-rejection decision. The evaluation includes an analysis of the corporate environment, technical feasibility, functional requirements, and profitability analysis. The decision criteria appear to be reasonably comprehensive.

The decision to explore a new idea proposal in depth by forwarding it to phase three, an intensive study phase conducted by an appropriate research division, is segmented through the use of three separate management committees. Top management is granted its right to review proposals prior to the commitment of substantial funds to be expended for applied and development activity. The use of a relatively large number of corporate officials from research and non-research functional areas should improve the quality and quantity of new idea proposals. However, the use of committees appears excessive during phases one and two. Benefits might be derived through a combination of the top management review with the committee which approves or rejects the product proposal during phase two. Another alternative would be to remove the top management review from this phase. These officials are already members of the committee which reviews projects during phase three. Substantial research funds are required
only upon commencement of the fourth phase.

Comments Upon the Intensive Study Phase

During the intensive study phase the Project Proposal report is superseded by the Program Plan. Direct responsibility for project evaluation is transferred to the research division manager who is to be responsible for the project development. The Program Plan represents an expanded version of the Project Proposal. A merging of the two reports appears to be desirable to eliminate duplication and provide for continuity of project control. Direct responsibility for the project should be assigned to a committee composed of those individuals who are responsible for the functional plans, i.e., the research Project Plan, Marketing Plan, Financial Plan, and Manufacturing Plan. This modification would avoid the existing research divisional control over the continuing project evaluation.

Comments Upon the Continuing Project Evaluation

Continuing project evaluation requires a systematic procedure for revising the Program Plan. The financial section should include periodic revisions of profitability estimates predicated upon the "sunk cost" concept. Project schedules require periodic revision. The combined sum of revised
estimates becomes the basis for the budget decision, and the project abandonment, delay, continuation, or acceleration decision. The two decisions are obviously interrelated. Project rescheduling and individual budget determination should consider revised profitability estimates and optimum time-cost relationships. Thus, emphasis should be placed upon the completion of the more profitable projects.

Comments Upon the Total R & D Budget Determination

The total research budget appropriation appears to be unduly influenced by considerations of present firm profits and the availability of funds. A highly profitable, established, and growing company should have little difficulty financing an expansion of productive research activity. Existing profits and sales revenues are related to the efforts of prior period's research activity. If the firm's information sources are reasonably reliable, the total budget appropriation should reflect the summation of project needs. Project needs for a budget period are a product of timing influences. Estimates of the time required to complete the activity should be based upon optimal time-cost relationships which include an allowance for the timing effect upon project revenues. Research divisions should submit their project needs to management prior to any determination of the total research budget.
Research division requests may be reviewed through a management assessment of project budget reports, revised Programs Plans, and technical progress summaries.

Comments Upon Post-Audit Appraisals

An installation of reliability checks into the system is necessary. A post-audit review of completed projects should include an evaluation of completed actual costs and benefits with the original estimates contained in the project proposal and the Program Plan. Substantial deviations among research project types should be noted and reported regularly to management. Overly optimistic original estimates contained in project proposals and in the pre-revised Program Plan would be apparent. Post-audit evaluation should tend to improve future estimates as long as the past has some continuity with the future.

Comparison of X Company Procedures With An Information Systems Model

The X Company procedures are compared with the model system which is presented below.

(1) The preliminary idea evaluation phase

An autonomous initial project screening committee is needed to properly evaluate and generate research and development ideas. Non-research participation is desirable to
facilitate interdepartmental communication.

Comments: A management screening committee chairman is independent of research departments but reports directly to the chief research official. Non-research personnel are included on the committee. All information estimates except sales are prepared by the research planning and administration department. Thus, the research function retains some control over the screening process.

(2) Project proposals--initial acceptance

Proposals should include project description, market analysis, compatibility with the firm's research policies, time-adjusted R.O.I. estimates, and a proposed activity schedule. Proposals should be communicated to the decision making group.

a. Failure to describe a project results in an improper definition of the problem.

b. Market analysis permits a rational assessment of exogenous environmental influences.

c. Return on investment estimates permit a rational decision through a comparison of minimum return to the firm's capital costs.

d. The activity schedule informs the decision-maker that the technical phases of the project have been adequately planned.
Comments: Proposal content is highly comprehensive and includes all of the above facets. Proposals are communicated to the primary decision making group.

(3) Execution of continuing project decisions

Control reports should be communicated to decision-makers. These reports should include revised estimates of R.O.I., project completion times and market analysis, and current summaries of actual costs. "Sunk cost" techniques should be systematically applied. Revised project budget reports should be provided. These reports should include estimated costs to complete a project and comparisons of actual and estimated costs. Control over continuing project evaluation should be implemented by establishing a functional committee responsible for the collection of data supporting the report revisions. Infrequent review, imperfect review techniques, and research dominance of the continuing phase results in the continuation of projects which should be abandoned, improper allocation of funds to continuing and proposed projects and a lack of interdepartmental communication.

Comments: Revised estimates of R.O.I. based upon "sunk costs" are only included for projects where abandonment is being seriously considered. Current summaries of actual R & D costs by research type and product areas are not prepared for top management review. The research division
(department) manager, instead of a functional committee, assumes the responsibility for the collection of data supporting the report revisions. Project budget reports are frequently revised. They include estimated costs to complete the project and comparisons of actual and estimated costs. Revised market analysis and completion time estimates are provided.

(4) Technical progress decisions

Technical progress evaluation reports should include revised time and research cost estimates and an evaluation of technical problems. Technical report communications are necessary to effectively execute project scheduling revisions. Technical reports should be integrated with economic analysis. Technical planning should utilize scientific scheduling techniques.

Comments: Technical reports become the basis for revised estimates of cost and time which are encompassed by the budget reports and the Program Plan. Scientific scheduling techniques are not utilized.

(5) The total R & D budget decision

Reports should include (1) estimates of individual project budget needs, (2) revised research project plans including "sunk cost" profitability estimates, (3) a summary of current R & D costs by product area and research type, and (4) estimates of overall research productivity.
a. To attempt a maximization of research productivity, the total budget determination must be predicated upon a profitability evaluation of individual projects. Otherwise, irrational total budget criteria will be employed, and long-range objectives will be ignored.

b. An index of R & D productivity permits a top management assessment of the firm's R & D policy.

Comments: Estimates of individual project needs are submitted to top management subsequent to the total budget determination. R & D cost summaries and overall measures of R & D productivity are not prepared. Thus, influences including (1) a determination of the budget on the basis of a fixed percentage of sales and (2) financial constraints become dominant considerations.

(6) Post-audit appraisal

Post-audit of completed projects is necessary to assess the reliability of the information reports.

Comments: Post-audit reports of completed projects are not prepared. Information estimates contained in proposals and in the revised Program Plans are extensively relied upon for management decisions.
Y COMPANY
CASE STUDY ANALYSIS

Background Information

The Y Company was organized in 1931. The firm originally engaged in the manufacture of rudimentary types of hydraulic equipment for the ceramics industry. During the 1930's the firm manufactured small high-speed hydraulic presses. World War II provided the stimulus for an expansion of product lines into related hydraulic applications.

In 1955 Y Company was acquired by a larger firm which was engaged primarily in the manufacture of automotive and railroad friction products, castings, and forgings. The acquiring firm's primary acquisition objective was diversification of its operations into growth markets. Y Company possessed the established technical knowhow and was operating within the rapidly growing hydraulics market. Y Company's former owner and president became a member of the parent firm's board of directors until his retirement. Other management officials were retained within the succeeding organization structure. Thus, a relatively autonomous hydraulics division was formed.
Y Company lacked the financial capability to tap capital markets for its rapid expansion. Since its acquisition, the parent company has invested $19 million in the Y Division. Problems of eventual corporate continuity became a secondary motivation for the merger. Y Company's original founder was approaching retirement.

The Y Division presently manufactures and distributes hydraulically powered equipment including presses, pumps, fluid motors, valves, and controls. The product line includes over 17,000 components. Products are produced for stock and special order. Customer special orders frequently become part of the regular product line as its market expands. Competitors of the original customer adopt similar hydraulic systems. Components are employed in various types of machine tools, mobile equipment, mining equipment, conveyors, and construction machinery. Marine and aerospace applications have recently been developed. Although broad policy objectives have not been explicitly formalized, the firm's intent is to diversify within markets which complement its proprietary interests. Maintaining or increasing its market share within established product areas represents a corollary firm objective.

Prior to its acquisition, the Y Company operated two manufacturing plants with 100,000 square feet of floor space.
The division's manufacturing operations have expanded to seven plants with over 300,000 square feet of floor space. Four manufacturing plants are located in Europe. The division also maintains six separate stock-carrying sales branches in major cities of the United States.

A two million dollar hydraulics research laboratory was recently constructed. Its operation commenced during 1960. The research facilities are physically and organizationally detached from the Y Division. Research performs services for the Y Division and two other autonomously operated divisional groups. Approximately 85% of its activities relate to the Y Division. The hydraulics laboratory research director reports directly to the headquarters research director of the parent company.

The hydraulics industry has expanded 65 per cent from 1957 to 1964 while Y Company's volume has grown by 124 per cent during the corresponding period. An order back log of five and one half months existed in 1965. An expansion of the parent company's total volume of business has resulted from its post 1955 corporate acquisitions. The parent company sales have expanded from $186 million in 1957 to $241 million in 1964. The firm's total hydraulic business was approximately 51 million in 1964. Consequently, the hydraulic operation is expanding rapidly while the overall corporate
Research activity is principally of an applied and development nature. Less than ten per cent of the research and development budget is expended upon exploratory or fundamental research projects. Company procedures provide some encouragement for the initiation of exploratory and non-programmable applied research projects. Project approval criteria are less stringent for exploratory projects which require less than a ten thousand dollar budget appropriation. Preliminary economic, technical and market analyses are not required. Approval may be authorized by the research director without the sanction of higher authority. Nevertheless, the significant majority of funds are committed to programmable development type projects.

New product and product improvement research are predominant. Technical assistance to production activity and other engineering functions are performed by a separate engineering department within the Y Division. Cost-saving process research projects are insignificant. Recently, the headquarters research laboratory has assumed the responsibility for conducting process-type research projects. Formerly, this function was delegated to the various divisional research facilities.

An increasing percentage of the total research budget
is being financed by the government and customers. Table 7 describes these support relationships for the 1960-65 period. Of the total R & D expenditures in 1965, 15 per cent is government financed. Customer supported research is considered desirable because it complements existing company supported research projects and contributes to the coverage of research overhead costs.

TABLE 7
RESEARCH AND DEVELOPMENT EXPENDITURES

<table>
<thead>
<tr>
<th>Year</th>
<th>R &amp; D Costs Company Supported</th>
<th>Total R &amp; D Costs Company and Customer Supported</th>
<th>Per Cent of Total Research Supported by Non Company Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>$1,093,000</td>
<td>$1,100,000</td>
<td>0.6%</td>
</tr>
<tr>
<td>1961</td>
<td>1,028,000</td>
<td>1,090,000</td>
<td>5.7</td>
</tr>
<tr>
<td>1962</td>
<td>1,006,000</td>
<td>1,100,000</td>
<td>8.5</td>
</tr>
<tr>
<td>1963</td>
<td>835,000</td>
<td>1,050,000</td>
<td>20.5</td>
</tr>
<tr>
<td>1964</td>
<td>730,000</td>
<td>1,350,000</td>
<td>45.9</td>
</tr>
<tr>
<td>1965</td>
<td>790,000 estimated</td>
<td>1,700,000 estimated</td>
<td>53.9</td>
</tr>
</tbody>
</table>

\(^{a}\)Includes government-supported research projects.

The research budget is supported by the Y Division and by supplemental appropriations from the parent company. Appropriations from the parent company have declined from $400,000
in 1960 to $100,000 in 1965. Division supported research appropriations are charged against its earnings.

CHART 4

Y COMPANY
ORGANIZATION CHART

The research laboratory is organized by broad product groupings. Organization focuses upon project groups although specialists are periodically rotated according to the individual project requirements.
CHART 5

RESEARCH ORGANIZATION

Research Director
Parent Headquarters Group

Research Director
Y Division

Chief Engineer

Chief Engineer

Chief Engineer

Administration

Piston Pump
Vane Pumps
Valves
Transmissions
Electronics
Although the director of the division research laboratory is directly responsible to the headquarters research group, its operations are primarily concerned with support of the Y Division. The division research laboratory and the Y Division may be viewed as an autonomous economic unit due to their mutual concern for a common activity. The parent company's research laboratory is not engaged in similar or complementary types of research.

Research Procedures, Organization, and Decisions

Initial project selection.—Research project ideas originate from the marketing and research functions. Marketing contact with customers continually reveals competitor's new product introductions, customer suggestions for product modifications and new applications. No formalized screening process has been initiated whereby all new idea suggestions are pooled and collectively evaluated. The feedback of ideas is tentatively screened and evaluated by marketing and research management prior to the preparation of a formal proposal. The selection process is formalized through the preparation of the research project proposal. Table 8 describes its content and the functions which contribute data.
<table>
<thead>
<tr>
<th>Composition</th>
<th>Information Supplied By</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. General project description and product specifications</td>
<td>1. The function which originates the proposal—marketing or research</td>
</tr>
<tr>
<td>2. Sales and market analysis</td>
<td>2. Marketing director and product marketing manager</td>
</tr>
<tr>
<td>3. Project estimate—R &amp; D cost estimates</td>
<td>3. Research project engineer</td>
</tr>
<tr>
<td>4. Project schedule—modified Gantt chart—plotting of estimated R &amp; D costs</td>
<td>4. Research project engineer</td>
</tr>
<tr>
<td>and time schedule by research phases</td>
<td></td>
</tr>
<tr>
<td>5. Project authority—authorization for the commencement of the project</td>
<td>5. Approved by the division research director, division general manager, and the</td>
</tr>
<tr>
<td></td>
<td>headquarters research director</td>
</tr>
</tbody>
</table>

The sales and market analysis section of the project proposal is jointly prepared by the product marketing manager and the director of marketing. Included in the sales and market analysis is a description of the relevant industrial market for the product, competitive products, and product substitutes. Also included is an analysis of competitive prices, general product specifications, and customer uses.
The sales analysis includes a three year projection of sales quantities and tentatively established prices for the proposed research project. Sales price estimates are heavily dependent upon the particular market situation. Approximately 25 per cent of the project proposals involve catching up with competition. Similar products are already being marketed. Consequently, the firm uses the prevailing market price as a basis for the estimate. Where product substitutes are available, pricing estimates consider substitute product prices and product quality differentials. If no close substitutes exist, an analysis of the value of the product to the customer determines the pricing structure. In all cases the price is determined independently of its anticipated cost of production. Production costs are not estimated during the initial project proposal stage. These cost estimates become a limiting factor which is considered during the later continuation-abandonment decision.

Sales volume projections utilize customer feedback, informed judgment of sales management personnel, and market research studies as information sources. Table 9 illustrates the importance of customer feedback. Rational industrial buyers, relatively high sales concentration, and direct sales contact appear to increase the reliability of the feedback process as a basis for sales volume projections.
The marketing research department provides estimates of market potential. Formal market surveys are conducted and statistics are gathered from S.I.C. classification numbers and trade association data. Outside consultants are frequently relied upon to assist during certain phases of the formal survey process. The personal interviewing phase may be delegated to such consulting organizations. Market surveys typically encompass broad product groupings where market potential is largely untapped.

Demand-elasticity studies have not been employed. Thus, the integration of price-volume projections has not been formalized. Reliability checks have been introduced into the sales projections. The marketing director compares actual sales results from completed projects with the original
estimates. According to this individual, the projections have proved highly reliable.

The project estimate section of the project proposal is a detailed calculation of the various components of R & D cost including design engineering and technician hours, special laboratory equipment costs and other required material costs. R & D costs are estimated by research phases. Included among the phases are design study and layouts, manufacture of experimental units, testing, redesign, and installation. The project engineer who is to be assigned the project prepares the project estimate. Files are maintained of actual and estimated performance data for completed projects. Completed projects which are similar to the proposed projects form the primary basis for estimating R & D costs. Major estimating problems occur where major unanticipated changes in design specifications or layout are required. If major modifications are needed, a review committee composed of department heads from research, marketing, manufacturing, and the patent department review the design. Recommendations for change must be approved by the division research director.

The project schedule, which is prepared by the project engineer, graphically compares estimated research costs and time by individual research phases with the actual performance. This schedule is maintained and updated by the
appropriate project engineer during the research phase. Monthly project budget reports, which are submitted to the project engineers, form the basis for recording the actual performance upon the project schedule. Variances in dollar cost and time are explained to the research director through monthly technical progress reports.

Project selection criteria.—Table 10 describes the quantifiable economic variables which affect the project selection decision.

<table>
<thead>
<tr>
<th>Estimates</th>
<th>Description of Estimating Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales revenue</td>
<td>Three year sales projection at the project's inception.</td>
</tr>
<tr>
<td>Production costs</td>
<td>Estimates are prepared following the research design phase by the plant manager where the product is scheduled for production. Estimates are based upon the design drawings which are compared with existing production costs for similar completed projects.</td>
</tr>
<tr>
<td>Distribution costs</td>
<td>Only freight and warehousing costs are estimated by marketing. The information is not incorporated into the project proposal.</td>
</tr>
<tr>
<td>R &amp; D costs</td>
<td>Estimates by the project engineer based upon past projects and project specifications.</td>
</tr>
<tr>
<td>Capital costs</td>
<td>Tooling and incremental equipment costs are estimated by the appropriate manufacturing plant manager. No estimates are made of working capital requirements. Capital costs are estimated following the research design phase.</td>
</tr>
</tbody>
</table>
Production and capital cost estimates are made after the initial project proposal has been approved. Consequently, economic profitability projections are not formulated at this point. Standard "rule of thumb" projections include a comparison of the sales revenue with the estimated R & D costs. If the three-year sales volume is equal to or exceeds the estimated R & D costs, the project is judged acceptable. For most projects sales volume projections are approximately three times the R & D costs. Thus, few initial project proposals are rejected by the approval authority. During the research process, production and capital cost estimates are transmitted to the research director who projects the payback on individual projects. Distribution and working capital projections are not, however, encompassed by the payback evaluation. A three year payback is desired.

Estimated profitability projections were derived through the use of hindsight. Total yearly R & D and capital investments were compared with the original anticipated results. Table 11 indicates that the company is selecting highly profitable investment opportunities. Table 12 compares the actual profits generated by research projects which were implemented since 1960 with the original estimates. A lag is apparent between the short-run versus long-run benefits. The chart indicates an overly optimistic estimate of the short-run
### TABLE 11

**ESTIMATED RETURN ON INVESTMENT OF RESEARCH AND DEVELOPMENT PROJECTS—1960-1965**

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Investment Including Capital Costs&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Present Worth of an Annuity of $1.00 Received 2 Years in Arrears for 8 Years Discounted at Ten Per Cent&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Expected Profits&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Expected Net Present Worth</th>
<th>Expected Internal Rate of Return</th>
</tr>
</thead>
<tbody>
<tr>
<td>1960</td>
<td>$1,639,500</td>
<td>4.409 x</td>
<td>$850,000</td>
<td>$2,108,150</td>
<td>28%</td>
</tr>
<tr>
<td>1961</td>
<td>1,542,000</td>
<td>4.409 x</td>
<td>775,000</td>
<td>1,874,974</td>
<td>26</td>
</tr>
<tr>
<td>1962</td>
<td>1,509,000</td>
<td>4.409 x</td>
<td>416,674</td>
<td>328,114</td>
<td>14</td>
</tr>
<tr>
<td>1963</td>
<td>1,252,500</td>
<td>4.409 x</td>
<td>568,332</td>
<td>1,253,274</td>
<td>24</td>
</tr>
<tr>
<td>1964</td>
<td>1,095,000</td>
<td>4.409 x</td>
<td>683,334</td>
<td>1,917,818</td>
<td>32</td>
</tr>
<tr>
<td>1965</td>
<td>1,185,000</td>
<td>4.409 x</td>
<td>666,666</td>
<td>1,754,330</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>$8,223,000</td>
<td></td>
<td>$3,960,006</td>
<td>$9,236,660</td>
<td>26%</td>
</tr>
</tbody>
</table>

---

<sup>a</sup>Total investment includes actual R & D yearly expenditures which are company supported and capital costs which were estimated at 50 per cent of R & D costs.

<sup>b</sup>An average lag of two years exists between the incurrence of R & D costs and the generation of sales revenue. An eight year average product life was assumed.

<sup>c</sup>Represents the summation of yearly sales estimates of R & D projects multiplied by a 25 per cent average profit margin. Thus, 1960 projects were expected to generate yearly sales volume of $3,400,000 and profits of $850,000.
TABLE 12

ESTIMATED VERSUS ACTUAL SALES GENERATED BY R & D PROJECTS INTRODUCED FROM 1960-1965

<table>
<thead>
<tr>
<th>Year</th>
<th>Estimated Sales from All Research Projects</th>
<th>Actual Sales from New Products Introduced from 1960-65</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961</td>
<td>---</td>
<td>$307,000</td>
</tr>
<tr>
<td>1962</td>
<td>$3,400,000</td>
<td>1,214,858</td>
</tr>
<tr>
<td>1963</td>
<td>6,500,000</td>
<td>2,895,024</td>
</tr>
<tr>
<td>1964</td>
<td>8,166,700</td>
<td>5,816,820</td>
</tr>
<tr>
<td>1965</td>
<td>10,440,034</td>
<td>9,000,000 (estimated)</td>
</tr>
<tr>
<td>1966</td>
<td>13,173,368</td>
<td>---</td>
</tr>
<tr>
<td>1967</td>
<td>15,840,034</td>
<td>---</td>
</tr>
</tbody>
</table>

aApproximately 50% of those projects included were abandoned prior to implementation.

bCustomer supported research may benefit actual results either by increasing sales or by reducing company supported research costs. No attempt was made to isolate the complementary effects of this type of research activity.

Research benefits and an overly pessimistic estimate of long-run benefits. Qualifying assumptions, which were imputed into the profitability analysis, should be noted.

Evaluation of continuing research projects.—The project schedule section of the project proposal represents the primary
controlling information report for the continuous review. The project schedule graphically compares the estimated research costs of the numerous research phases with the corresponding actual costs. Scheduled completion times of research phases are also compared with the actual time schedule. The project engineer receives a monthly project budget report prepared by the research administration department. Actual project costs are transferred to the project schedule.

The project engineer prepares a monthly technical progress summary. A copy of the project schedule and the technical progress summary are submitted monthly to the research director for evaluation and review. The technical progress summary must include an explanation of cause for significant time and cost deviations which are revealed by the project schedule. Major problems concerned with technical feasibility, time and cost are generally supplemented by verbal communication between these two participants.

Project budgets are budgeted annually. However, the research director revises project budgets as the monthly operating results are made known. A project may be continued on schedule, abandoned or delayed, or accelerated by the research director during any one of nine research phases described in Chart 6. Following the submission of estimates of production, equipment and tooling costs, the research
director computes a project "payback." Three years is normally considered as a minimum cutoff standard. No absolute ranking of continuing project's payback is made. If production cost estimates are found to be excessive, the project may be abandoned. An application of the "sunk cost" concept is employed for all abandonment or project delay decisions. Production cost estimates are made subsequent to the completion of the research design phase. Consequently, "sunk costs" may be significant.

Project termination may be initiated by the action of any individual who signs the project authority including the Y Division research director, the parent company's director of research, the division president and general manager. The Y Division research director presents quarterly and annual reviews of the research program to these individuals. The reviews are intended to keep the remaining top management personnel informed. The reviews broadly describe overall research problems, objectives, needs, and accomplishments.

The total R & D budget determination.—A determination of the annual research budget is made by the division's top management and the parent company's research director. The Y Division's contribution is determined by its general manager and president. A supplemental appropriation is made by the parent company. Its contribution has declined from
Research Phases

1. Design Study and Layouts
2. Detail and Check
3. Manufacture Experimental Unit
4. Test Unit

1. Drawings sent to production for estimate of cost to manufacture, tooling and equipment costs.

2. Research director computes project payback following production and capital cost estimates.

5. Redesign and Detail
6. Manufacture or Rebuild Experimental Unit
7. Test Rebuilt Experimental Unit
8. Redesign & Detail for Production
9. Prepare Performance and Installation Data

1. If major redesign is necessary, a review committee composed of department heads from research, marketing, and manufacturing must approve the change. The research director, however, retains final authority over project termination.

1. Project is transferred to product bank.
$400,000 in 1960 to $100,000 in 1965 while the Y Division share has remained relatively stable. An overall increase in total research expenditures has been made possible by a significant expansion of customer supported research. Table 7 lists the breakdown of customer and company research expenditures from 1960-1965. The total budget determination is influenced by several considerations: (1) the availability of division and parent company funds, (2) division profits, (3) the existing utilization of research facilities, (4) political considerations, and (5) attitudes of the division top management and the headquarter's research director regarding the productivity and needs of the research facilities.

Thus, the research director must select projects within a total budget constraint. The total research operating budget, which contains budgeted costs by object of expenditure, is projected by the division research director. Funds are then budgeted to continuing projects on the basis of project needs. Project schedules are reviewed by the project directors and the research director. The remaining funds are allocated to acceptable new projects which have been scheduled for the ensuing period.

Comparison of the Y Division Procedures With an Information Systems Model

Y Division procedures are compared with the model
CHART 7

INFORMATION FLOW TO DECISION-MAKERS

Top Management Personnel

<table>
<thead>
<tr>
<th>Information Reports</th>
<th>Research Director--Division</th>
<th>Top Management Y Division</th>
<th>Parent Company--Headquarter's Research Director</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Initial project proposal</td>
<td>Approval Required</td>
<td>Approval Required</td>
<td>Approval Required</td>
</tr>
<tr>
<td>2. Project schedule</td>
<td>Review &amp; Evaluation of Continuing Projects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Technical progress summary</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Production &amp; capital estimates</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Monthly operating budget summaries</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Monthly project budget summaries</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Verbal communication from &quot;bench&quot;</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Quarterly &amp; Annual Progress reviews</td>
<td>&quot;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Basis for Annual Same Budget Determination & Project Termination
which is presented below.

(1) The preliminary idea evaluation phase

An autonomous initial project screening committee is needed to properly evaluate and generate research and development ideas. Non-research participation is desirable to facilitate interdepartmental communication.

Comments: A project screening committee has not been established. New project ideas are submitted by marketing and research. Ideas which are initially approved by marketing are forwarded to research for the initial acceptance decision.

(2) Project proposals—initial acceptance

Proposals should include project description, market analysis, compatibility with the firm's research policies, time-adjusted R.O.I. estimates, and a proposed activity schedule. Proposals should be communicated to the decision making group.

a. Failure to describe a project results in an improper definition of the problem.

b. Market analysis permits a rational assessment of exogenous environmental influences.

c. Return on investment estimates permit a rational decision through a comparison of minimum return to the firm's capital costs.

d. The activity schedule informs the decision-maker
that the technical phases of the project have been adequately planned.

Comments: Project descriptions, market analysis and project schedules are adequate. However, information estimates contained in the proposal are limited. Sales volume estimates are projected for three years only. Estimates of production, capital, and distribution costs are not included in the original proposal. Thus, R.O.I. projections are not made. A rational basis for the initial project acceptance decision is impaired.

(3) Execution of continuing project decisions

Control reports should be communicated to decision-makers. These reports should include revised estimates of R.O.I., project completion times and market analysis, and current summaries of actual costs. "Sunk cost" techniques should be systematically applied. Revised project budget reports should be provided. These reports should include estimated costs to complete a project and comparisons of actual and estimated costs. Control over continuing project evaluation should be implemented by establishing a functional committee responsible for the collection of data supporting the report revisions. Infrequent review, imperfect review techniques and research dominance of the continuing phase results in the continuation of projects which should be abandoned, improper allocation of funds to continuing and proposed projects and
a lack of interdepartmental communication.

Comments: Top management intent is to delegate primary responsibility for continuing review decisions to the Y Division research director. Thus, control reports should be communicated to this individual. The project schedule is employed as the primary control report. Project completion times and cost estimates are revised monthly and are incorporated into the budget reports. Other information supplements including market analysis, sales volume projections and estimates of production, distribution, and capital costs are infrequently revised, incomplete, or received only during the latter stages of the project life. "Sunk cost" techniques are not systematically applied. Production, tooling, and equipment estimates are received following the design stage while distribution and working capital costs are not projected. A three-year project payback method is employed as a supplement for R.O.I. estimates. Responsibility for the collection of revised data is assumed by the research director. The employment of imperfect review techniques and research dominance over continuing review decisions is evident.

(4) Technical progress decisions

Technical progress evaluation reports should include (1) revised time and research cost estimates and (2) an evaluation of technical problems. Technical report communications
are necessary to effectively execute project scheduling revisions. Technical reports should be integrated with economic analysis. Technical planning should utilize scientific scheduling techniques.

Comments: The responsibility for technical performance measurement and technical feasibility judgments is delegated to the Y Division research director. Progress evaluation reports including the technical progress summaries and revised project schedules provide an adequate basis of communication between project directors and the research director. Project schedules include budgeted time and costs by research phase compared to actual data. Technical progress summaries explain deviations from the project plan. Technical reports form a basis for project budget report revisions. However, project analysis is infrequently revised. Project scheduling utilizes a Gantt Chart technique.

(5) The total R & D budget decision

Reports should include (1) estimates of individual project budget needs, (2) revised research project plans including "sunk cost" profitability estimates, (3) a summary of current R & D costs by product areas and type of research, and (4) estimates of overall research productivity.

a. To attempt a maximization of research productivity, the total budget determination must be predicated
upon a profitability evaluation of individual projects. Otherwise, irrational total budget criteria will be employed, and long-range objectives will be ignored.

b. An index of R & D productivity permits a top management assessment of the firm's R & D policy.

Comments: The total R & D budget determination is heavily influenced by considerations including (1) standard "rule of thumb" measures such as a percentage of existing Y Division profits, (2) political considerations, (3) availability of funds, and (4) top management subjective attitudes toward the productivity of research facilities. Individual project needs are established after the total R & D budget has been determined. Top management information sources are limited. Cost summaries accumulated by product areas and research types and indexes of overall research productivity are not prepared.

(6) Post-audit-appraisal

Post-audit of completed projects is necessary to assess the reliability of the information reports.

Comments: The firm's marketing department regularly reviews three year sales estimates of completed projects through a comparison with actual data. The results of such investigations are not communicated to other management personnel. Other information estimates and the propriety of the decision process are not reviewed.
Z COMPANY
CASE STUDY ANALYSIS

Background Information

The Z Company is organized into four autonomous operating groups including coatings and resins, foods, chemicals, and international. The coatings and resins product line consists of house paints, floor paints, enamels, lacquers, varnishes, industrial coatings and resins, and various types of related industrial applications. The foods group produce and distribute seasonings, sauces, oils, margarine and shortening products. Chemical products include pigments, powders, perfumery and aromatic chemicals, cooper oxides and inorganic colors. A group operating vice president directs each of the operations. Separate headquarters management, manufacturing, marketing, research and financial personnel are maintained.

The size of the firm's operations is depicted by Tables 13, 14, and 15. Sales, profits, and capital equipment expenditures have exhibited patterns of stability while research and development expenditures have grown rapidly. The firm's profits have increased from $8,147,000 in 1956 to $9,065,000 in 1964.
### TABLE 13

Z COMPANY -- NET SALES
(In Millions of Dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Company</th>
<th>Coatings &amp; Resins</th>
<th>Foods</th>
<th>Chemical</th>
<th>International</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>226.3</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1961</td>
<td>206.7</td>
<td>91.4</td>
<td>88.0</td>
<td>27.3</td>
<td>--</td>
</tr>
<tr>
<td>1962</td>
<td>237.9</td>
<td>95.2</td>
<td>98.5</td>
<td>40.1</td>
<td>4.0</td>
</tr>
<tr>
<td>1963</td>
<td>241.0</td>
<td>96.3</td>
<td>95.6</td>
<td>43.2</td>
<td>5.9</td>
</tr>
<tr>
<td>1964</td>
<td>257.7</td>
<td>105.7</td>
<td>99.3</td>
<td>46.0</td>
<td>6.7</td>
</tr>
</tbody>
</table>

### TABLE 14

Z COMPANY -- EXPENDITURES FOR PROPERTY, PLANT AND EQUIPMENT
(In Millions of Dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Spent</th>
<th>Total %</th>
<th>Coatings &amp; Resins</th>
<th>Foods</th>
<th>Chemical</th>
<th>International</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956</td>
<td>$16.3</td>
<td>100.0</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>1961</td>
<td>7.8</td>
<td>100.0</td>
<td>35.7</td>
<td>30.3</td>
<td>34.0</td>
<td>--</td>
</tr>
<tr>
<td>1962</td>
<td>11.8</td>
<td>100.0</td>
<td>24.0</td>
<td>39.0</td>
<td>37.0</td>
<td>--</td>
</tr>
<tr>
<td>1963</td>
<td>4.0</td>
<td>100.0</td>
<td>15.0</td>
<td>26.0</td>
<td>40.0</td>
<td>19.0</td>
</tr>
<tr>
<td>1964</td>
<td>6.9</td>
<td>100.0</td>
<td>25.0</td>
<td>29.0</td>
<td>28.0</td>
<td>18.0</td>
</tr>
</tbody>
</table>
TABLE 15

RESEARCH AND DEVELOPMENT EXPENDITURES
(In Millions of Dollars)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Firm</th>
<th>Coatings and Resins</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958</td>
<td>2.6</td>
<td>.6</td>
</tr>
<tr>
<td>1960</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>1962</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>1963</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>1964</td>
<td>6.5</td>
<td></td>
</tr>
<tr>
<td>1965</td>
<td>7.0 est.</td>
<td>4.0</td>
</tr>
</tbody>
</table>

The coatings and resins group was selected as the primary source of information for the study. This group is composed of fifteen manufacturing plants in the United States, thirteen product development laboratories, and a headquarters research center. Development laboratories support one or more plant operations. Their reporting responsibilities are attached to the various plant organizations. The research center reports directly to the coatings and resins headquarters management.

The research center budget was $1.75 million in 1965 whereas the summation of development laboratory expenditures approximated $2.25 million. Research center projects are
primarily of an applied and programmable research type. A given final product objective is being sought and research phases are programmed. Applied projects are normally in process from one to three years and are subsequently transferred to the development laboratories. Insignificant amounts of customer or government supported research is being undertaken.

Development projects are principally oriented toward solving application problems for specific customer requirements. Minor product improvements or product specification modifications are included by this type of development activity. New products, which are transferred from the applied research center, are further modified to suit specific customer needs. Such development projects are frequently completed within a one year period.

Research Procedures, Organization and Decisions

Initial project selection.--Project selection procedures for the coatings and resins group are dependent upon the type of laboratory being evaluated. A differentiation is made between development and research center laboratories. Within the development laboratories new ideas originate from sales personnel who are attempting to meet the "tailor-made"
requirements of existing or potential customers. In these situations a detailed laboratory request is prepared by the sales personnel and transmitted to the appropriate laboratory and to the technical service (marketing) department. Other sources of new development projects may originate from the transfer of applied research projects from the headquarters research center. Laboratory requests are routed from development laboratory research personnel to the sales personnel where individual customer needs are explored.

Applied research projects, originating within the headquarters coatings and resins research center, are sponsored by research and marketing personnel. Transmittal forms are sent from project sponsors to the headquarters group research director for approval or rejection. The transmittal is also sent to the technical service products manager for approval.

No formal preliminary screening committee exists for the group’s initial review procedures. Initial project acceptance within development laboratories is the joint responsibility of the technical service manager and the laboratory technical director. The group research director and the headquarters technical service manager act in a similar capacity for the research center.

Research center project proposals (transmittal forms) include a brief description of the project, technical feasibility
estimates, and suggested project priority. No projections of sales volume, costs, and market analysis are made for the project acceptance decision.

The development laboratory project proposals (detailed laboratory requests) include the project description, a brief analysis of competitive products, an estimate of development man-hours by development phase (project schedule), and an estimate of annual sales volume. Estimates of production, working and fixed capital, distribution and total development costs are not included. Thus, profitability forecasts are not available during the initial selection stage.

Project selection criteria are substantially based upon subjective judgment and informal evaluation techniques. Within the research center, fifteen per cent of the budget is allocated to discretionary projects. The technical director of the research center authorizes the initiation and continuance of projects within the established constraint. No formal analysis or approval from the group research director and the technical service manager is required. Acceptance of the remaining research center projects is dependent upon the joint decision-maker's judgments regarding technical feasibility, market competition and a project's compatibility with overall R & D objectives. Estimates of project man-hours are informally compared to previous projects. The
decision process culminates with a judgment which is predicated upon intuition and prior experience.

Development laboratory project acceptance criteria are likewise largely based upon qualitative evidence. The type of project being considered and the quality of the customer are considered. A project will be accepted if fulfilling the customer's need is deemed necessary to maintain the account. Minor product improvements are considered defensive R & D and are considered necessary to defend the firm's market position. For all development projects the estimated annual sales volume for particular projects is compared to the development man-hour estimates. Technical feasibility estimates are considered. Projects will normally be accepted by the laboratory technical director and the technical service manager providing the above estimates and qualitative considerations i.e. maintaining market share, satisfying a major customer's need, and compatibility with other R & D objectives, are acceptable. Few projects are rejected initially.

Top management intent is to delegate the initial project acceptance decision authority to the research and marketing personnel in the research center and in the development laboratories. The opinion was expressed that these decisions are best executed by individuals who are most familiar with the problems at the lower levels.
Evaluation of continuing research projects.—At the research center a management committee evaluates continuing projects. The committee includes the group research director, vice president of operations, industrial sales—technical service manager, technical director of the research center, and the market research director. The group collectively decides upon project rescheduling, including the acceleration, continuation, delay, or abandonment of research projects. Technical service and market research committee members are responsible for the preparation of sales estimates and extension of market analysis during the continuing phase. However, no information estimates are supplied for production, distribution, capital and R & D costs.

The top management including the group and operating vice president and the group research director conduct a quarterly review of significant individual research center projects. Project directors and sales product managers must orally defend their projects before this group.

Research center projects may be rescheduled during the quarter if requested by any committee member. Project budget reports, project schedules and technical progress summaries become the primary basis for the initiation of action during the interlude.

At the development laboratories continuing project
review is the primary responsibility of the lower management laboratory personnel including the technical service manager and the technical director. Quarterly reviews of major development projects are made by the top management of the coatings and resins group. Projects are defended by laboratory project directors and product managers. Top management may decide to terminate a project during this review. During the quarter, however, laboratory personnel may unilaterally reschedule projects. Primary information sources for the continuing review include individual project and operating budget reports, project schedules and technical progress evaluations.

Project budget reports and operating budget reports become the primary information sources for top management. The coatings and resins group initiated budgeting by individual research projects during 1965. Monthly project budget reports for the research center and the development laboratories are distributed to the operating vice president, group research director, industrial sales—technical service manager and the trade sales products manager. The budget reports encompass only accumulations of actual costs by projects and are not compared with the budgeted amounts. Estimated costs to complete are not included or revised during the budget period.
Operating budget reports include comparisons of estimated and actual costs by nature of expenditure. Individual development laboratories and the research center operations are reported separately. Reports are submitted to the operating vice president, group vice president and the group research director. If variances are substantial within a given laboratory, the corresponding individual project budget reports may be closely scrutinized by top management.

Technical progress summaries and project schedules become the primary source of information for the technical evaluation by research personnel. The technical director of the research center evaluates problems of technical feasibility and reports his findings to the management committee. Based upon his recommendation, the project may be terminated. At the development laboratories the technical director may unilaterally reschedule development projects on the basis of the technical progress evaluation.

Project rescheduling criteria including acceleration, continuation, delay, and abandonment are primarily based upon subjective judgment. Profitability and cost estimates are not made and "sunk costs" are not considered. Project plan revisions are made annually for the total budget preparation.

During the continuing review phase for the research center, a management committee considers sales volume
projections, technical feasibility evaluations and project priorities. The quarterly top management review of major projects becomes largely a "selling" of project technical feasibility and economic desirability to top management. Project directors explain the technical relationships and probable outcomes while the sales product managers describe future product uses, market potential and competitive conditions.

Top management intent is to assume a primary role in the continuing project evaluation decision. Its intent is exemplified by (1) its representation on the research center management committee, (2) its interest in quarterly reviews of important research projects, and (3) by its receipt of information reports which form a basis for continuing project evaluation. Chart 8 describes the flow of information reports to the management participants.

**Project implementation.**—Project proposals are not revised prior to the project's implementation. Proposal estimates are revised annually for the budget preparation. Completed research center projects are automatically transferred to development laboratories during the period. Unless a development project requires an extensive amount of capital equipment, transfer to production is routed into production through the preparation of production orders predicated upon the customer order. Pilot plant operations and the purchase
# Chart 8

**Information Flow to Decision-Makers**

<table>
<thead>
<tr>
<th>Information Reports</th>
<th>Lower Management</th>
<th>Top Management</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Research</td>
<td>Research</td>
</tr>
<tr>
<td></td>
<td>Marketing</td>
<td>Operating</td>
</tr>
<tr>
<td></td>
<td>Technical</td>
<td>Group</td>
</tr>
<tr>
<td></td>
<td>Director—</td>
<td>Operating &amp; Group</td>
</tr>
<tr>
<td></td>
<td>Laboratories</td>
<td>Vice Presidents</td>
</tr>
<tr>
<td>1. Initial Project Proposal—Development Labs</td>
<td>Approval Required</td>
<td>Approval Required</td>
</tr>
<tr>
<td>2. Initial Project Proposal—Research Center</td>
<td>Approval required for non-discretionary projects</td>
<td>Approval required for non-discretionary projects</td>
</tr>
<tr>
<td>3. Project Schedule—Research Center</td>
<td>Approval</td>
<td>Approval</td>
</tr>
<tr>
<td>4. Project Schedule—Development Projects</td>
<td>Approval</td>
<td>Approval</td>
</tr>
<tr>
<td>5. Monthly Project Budget Summaries</td>
<td>Approval</td>
<td>Approval</td>
</tr>
<tr>
<td>6. Monthly Operating Budget Summaries</td>
<td>Approval</td>
<td>Approval</td>
</tr>
<tr>
<td>7. Quarterly and Annual Progress Evaluation</td>
<td>Approval</td>
<td>Approval</td>
</tr>
<tr>
<td>8. Annual Summary of Research Costs by Product Area and Research Type</td>
<td>Basis for project rescheduling &amp; the annual budget determination</td>
<td></td>
</tr>
<tr>
<td>9. Post-audit Appraisals</td>
<td>Not Included</td>
<td></td>
</tr>
<tr>
<td>10. Overall R &amp; D Productivity Evaluation Reports</td>
<td>Not Included</td>
<td></td>
</tr>
</tbody>
</table>
of new equipment are generally not required to implement a development project. In situations where extensive new manufacturing facilities are necessary, financing approval is required from the firm's board of directors. Top management actively participates in the implementation and supervision of the proceedings.

**Total R & D budget determination.**—A top management review of continuing projects is made prior to the preparation of the annual budget. The operating and group vice presidents visit individual laboratories with the purpose of ascertaining their needs and reviewing their accomplishments. Decisions are made upon desirable product area concentration, research emphasis and scope. The laboratories are given a lump-sum appropriation. Subsequently, each laboratory submits budgets by projects and departments to the group research director. The individual budgets must operate within the lump-sum constraint which is imposed by top management.

Laboratory total budgets are limited to a fixed percentage of existing sales which are being generated by the supporting plant facilities. Each development laboratory supports one or more manufacturing plants. The research center is related to the sales being generated by the entire coatings and resins group. The individual budgets are based upon project man-hour estimates for continuing and proposed
Laboratory budgets are summarized by type of research and development activity and by major product areas. This summary becomes the basis for an annual budget presentation to management officials including the operating vice president, group vice president, industrial sales manager and the group controller. The group research director conducts the presentation. Overall explanations are rendered concerning spending within major product areas and major research types. The presentation serves to reaffirm or modify the previous total budget decision. An attempt is made to relate R & D objectives which include statements concerning new areas of market penetration, product development and emphasis upon research types to the budget determination. Objectives are general and do not specifically refer to stated growth percentages or research scope. During the presentation, the committee suggestions may be incorporated into the budget.

Operating budget and project budget reports are also relied upon by management for the determination of the total budget. Both budgets and reports are not revised during the budgetary period. Overall productivity evaluation reports which might be employed as a guide to the total budget decision have not been developed.
Comparison of Z Company Procedures
With an Information Systems Model

The coatings and resins group procedures are compared to the model which is presented below.

(1) The preliminary idea evaluation phase

An autonomous initial project screening committee is needed to properly evaluate and generate research and development ideas. Non-research participation is desirable to facilitate interdepartmental communication.

Comments: An initial project screening committee has not been formed for both the research center and the development laboratories. Marketing (technical service) and research jointly participate in the initial project acceptance decision. Screening commences at this point.

(2) Project proposals--initial acceptance

Proposals should include project description, market analysis, compatibility with the firm's research policies, time-adjusted R.O.I. estimates, and a proposed activity schedule. Proposals should be communicated to the decision making group.

(a) Failure to describe a project results in an improper definition of the problem.

(b) Market analysis permits a rational assessment of exogenous environmental influences.
(c) Return on investment estimates permit a rational decision through a comparison of minimum return to the firm's capital costs.

(d) The activity schedule informs the decision-maker that the technical phases of the project have been adequately planned.

Comments: Information estimates contained in the project proposals are inadequate. Estimates of R & D, production, distribution, and capital costs are not included. Sales projections are included only for the development laboratory proposals. Consequently, attempted project ranking based upon return on investment calculations is not possible. Rational R & D investment decision making, based upon a comparison of research investment return with alternative forms of capital investment and with the firm's capital costs, is not quantitatively expressed.

Proposals are not communicated to top management. In accordance with top management intent, research and marketing are sharing the initial project acceptance decision. Thus, proposals are actually communicated to the decision making group.

(3) Execution of continuing project decisions

Control reports should be communicated to decision-makers. These reports should include revised estimates of
R.O.I., project completion times and market analysis, and current summaries of actual costs. "Sunk cost" techniques should be systematically applied. Revised project budget reports should be provided. These reports should include estimated costs to complete a project and comparisons of actual and estimated costs. Control over continuing project evaluation should be implemented by establishing a functional committee responsible for the collection of data supporting the report revisions. Infrequent review, imperfect review techniques, and research dominance of the continuing phase results in the continuation of projects which should be abandoned, improper allocation of funds to continuing and proposed projects and a lack of interdepartmental communication.

Comments: Continuing project evaluation reports to top management include project and operating budget reports. Revised estimates of R.O.I. including revised project schedules and market analysis are not made or communicated to top management. "Sunk cost" techniques are not applied. Individual project budget reports do not include comparisons of budgeted costs with actual or estimated costs to complete. Consequently, top management presently lacks adequate information to continuously review existing projects. Operating budget reports merely describe laboratory compliance with the total budget and are not helpful tools for individual project
decisions.

The research center has established a functional committee which is responsible for the collection of revised data. However, the information estimates which are collected, are inadequate.

(4) Technical progress decisions

Technical progress evaluation reports should include revised time and research cost estimates and an evaluation of technical problems. Technical report communications are necessary to effectively execute project scheduling revisions. Providing managerial intent is to delegate decision responsibility for technical performance measurement to the research function, the reports should be communicated to the research director. Technical reports should be integrated with economic analysis. Technical planning should utilize scientific scheduling techniques.

Comments: Technical progress evaluation reports are communicated to the technical directors of the development and research center laboratories and to the group research center. Responsibility for technical performance measurement and evaluation has been assigned to these individuals. Project schedules are incomplete and infrequently revised. Research costs are not accumulated by research phase. Thus, modifications in technical plans may not be incorporated into
economic analysis. Scientific scheduling techniques are not employed.

(5) The total R & D budget decision

Reports should include (1) estimates of individual project budget needs, (2) revised research project plans including "sunk cost" profitability estimates, (3) a summary of current R & D costs by product areas and type of research, and (4) estimates of overall research productivity.

(a) To attempt a maximization of research productivity, the total budget determination must be predicated upon a profitability evaluation of individual projects. Otherwise, irrational total budget criteria will be employed, and long-range objectives will be ignored.

(b) An index of R & D productivity permits a top management assessment of the firm's R & D policy.

Comments: Information reports required for the total budget determination include budget reports and summaries of current R & D costs by product areas and research types. Quarterly top management reviews of major R & D projects and the annual budget presentation by the group research director also serve the communication process. Budget report limitations were previously described. Estimates of individual project needs, revised project plans including "sunk cost"
profitability estimates, and estimates of overall research productivity are not prepared. The fulfillment of long-range objectives through rational choice procedures cannot be accomplished with rational or objective decision criteria. Primary budget criteria include "rule of thumb" standards.

(6) Post-audit appraisal

Post-audit of completed projects is necessary to assess the reliability of the information reports.

Comments: Post-audit reports of completed projects are not prepared. Evidence indicates a general lack of confidence among participating groups for the reliability of project budgets and information estimates. Due to a general inadequacy of the estimating process, however, the importance of information reliability is lessened.
BIBLIOGRAPHY

Books and Monographs


Anthony, Robert N. *Management Controls in Industrial Research Organizations*. Boston: Division of Research—Graduate School of Business Administration, Harvard University, 1952.


**Articles and Periodicals**


Unpublished Material


