AN INTEGRATED RESEARCH AND DEVELOPMENT PLANNING MODEL FOR A COMPANY SUBJECT TO HIGH RATES OF TECHNOLOGICAL CHANGE

By

WARREN L. EDMUNDSON

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

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Head, Department of Administrative Sciences

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CHAPTER I

INTRODUCTION TO THE RESEARCH AND DEVELOPMENT PLANNING MODEL

Technology and Business

There is probably no segment of society which has been left ɔuched by the rapid growth of the world's technologies. Their growt revolutionalized industry. The consumer sector of the economy has t the tremors from the explosion in technology, and their indirect ects have become evident in the social sector where we see unrest ng groups protesting events which are engulfing us, or movements ard dropping out of the complex society which we have created. The st is for a more peaceful and manageable existence.

Scientific advances are increasingly threatening the technological e of whole industries, as well as individual companies. On the othe d, new opportunities for the profitable exploitation of technology constantly presenting themselves. For some companies and industrie threat will be of such urgency that the choice is between major ersification or disaster, and the actual outcome will depend very h on the ability to foresee the threat and select sound diversifica- ns. Furthermore, the increasing tempo with which new technology anc pletely new technologies are being created is continuously shortenir duct lives. Consequently, companies are faced with the problems of nning for more frequent product changes. This problem is compoundec

the need for longer production runs to recover the heavy developmen
sts and facility costs associated with advanced technology [65].

The Importance of a Planning Model

Annual research and development (R & D) expenditures now exceed tal capital spending in many industrial sectors which are technology tensive, and consequently, among the most important decisions facing e management of high-technology firms are those related to resource location for R & D. Currently, most decisions related to R & D source allocation problems are primarily intuitive, but intuition is reliable when applied to complex problems (such as R & D resource location) which involve high-order, multiloop feedback systems, a rge number of variables, and non-linearities [11].

Planning a relevant R & D program involves anticipating future eds. It is essential that R & D programs initiated today be relevan needs at the time the programs reach completion. These needs, of ırse, may be totally different from the needs existing today. Hence e R & D planner is inevitably involved in forecasting the needs of t ture. Particularly in the research and exploratory development area e R & D planner finds himself involved in forecasting the technology ich will or could be available at some time in the future. This is ıe whether he is interested in being able to counter the technology ich may be developed by a potential competitor, or whether he is terested in making the technology feasible so that it will be available as an option for his own use [11].

Purpose of the Research Study

Since the R & D planner is involved in the forecasting of chnology, whether implicitly or explicitly, it would be helpful to

›vide him better tools and techniques for carrying out this activity. : purpose of this research paper is to develop an integrated planning lel for the research and development function of a company subject to ;h rates of technological change. The model integrates technological :ecasting into the planning of R & D projects with the intent of con- :ting as much of the existing uncertainty as possible into risk. Thu : planner will have a better idea of the odds facing him in any decision.

The model is intended to forecast potential areas for long-term 'porate growth and long-term investments with variable time horizons to twenty years. By utilizing the planning model, the company is :ced to periodically evaluate its strengths and weaknesses, and its ›rt- and long-term objectives, while simultaneously monitoring the 'ironment for technological and social change. After identifying the :ket opportunities by way of the various technological forecasting :hniques, the company can utilize the model for project selection wi ›ital budgeting techniques subject to investment criteria.

The R & D planning model is segmented into four general stages: a policy stage in which the overall company and the R & D departme :ermine the various policies, objectives, goals, and strategies that : company will pursue--also included in this stage is a discussion of : uncertainties in R & D planning and in the use of the proposed R & ınning model; (2) a forecasting stage in which the R & D department ıitors the environment for technological and social change, assesses : environmental impact created by these changes, and identifies marke ›ortunities by way of technological forecasting techniques; (3) a .ection stage in which various projects are screened and accepted :ording to company investment criteria; and (4) an application stage which the completed R & D planning model is implemented and used as company's long range planning system for research and development. application stage includes discussions on organizational structure, ìership, communication, and management of personnel within the R & D artment.

In summary, the model will represent an attempt to provide the R & ager a system of logical analysis for predicting future technical elopments and the impact of these developments on future economic, logical, social, and political environments, while maintaining a rse consistent with long-term company objectives and goals. The nological forecasting methods employed in the model will aid the ger in making assumptions about the future and thereby improve his ction and allocation of expenditures for research and development.

Defining Technological Forecasting

Technological forecasting has been defined as "a quantified predic- of timing and degree of change in technological parameters, attri- s, forms, capabilities, relative desirability, or needs." The ous methodologies which relate to technological forecasting may be dly classified as exploratory, normative, or dynamic. Exploratory capability-oriented) techniques are based on extrapolations of orical technological trends in order to forecast future technolo- l capabilities. In contrast, normative (needs-oriented) forecasting niques are based on the future. Their application requires compila- of a description of the future and extraction of the most probable itions. From these conditions the technological advances that will eeded are identified, technical targets established, and research rams undertaken to achieve them. In essence, an analysis of future ls, priorities, and funding becomes a technological forecast. mic forecasting attempts to join exploratory and normative component a feedback cycle. By building dynamic computer models which repli- real systems, forecasts may be obtained through simulation [11].

While technological forecasting cannot peer into the future to give ystal clear picture concerning the progress that various technologie technological fields will achieve in the next ten or so years, it give a picture of what may transpire and attaches to that forecast rtain level of confidence. It must be noted that the future is fined and that a description of future technological events can only be in terms of probabilities or confidence levels.

Technological forecasting contains the tenet that individual events susceptible to influence, that the time at which they occur can be lated considerably by the application of scheduled and directed rt. This being true, the future can be influenced or modulated as a equence. A second tenet of technological forecasting is that many res are possible and that the paths toward those futures can be ed. Technological forecasting does not offer a crystal picture of future; it presents a choice of futures [19].

The Present Status of Technological Forecasting

Technological forecasting is in its "formative years." It has been mated that technological forecasting is about 50 years behind econo- forecasting. In large measure, the sustenance needed to mature nological forecasting into a science has been lacking. There must n acceptance of the fact that technological forecasting can provide werful tool for planning that is, even in its infancy, several ers more logical than what now exist, and that it therefore warrants ng put to the test on a serious scale. When new methods of managing ence and technology arrive, the refinements and sophistication of nological forecasting will then become accepted [20].

The Relevance of Technological Forecasting

Presently, many companies maintain an on-going program of technolo- l forecasting. These companies realize that no matter how expe- nced individuals or committees may be, they cannot make decisions at rporate or divisional level merely on the basis of intuition. Tech- gy is changing so rapidly that it is necessary to be aware of what oing on not only in a specific field of interest, but also in lementary and competitive fields, in the market place, and in the e social-political-economic environment. Without some formalized od of sifting and weighing all this information, it cannot be used ctively.

If a decision has been made on an intuitive basis, the rationale or ification for it is lost and cannot be repeated or explained. A alized method provides visibility (projects can be evaluated on the basis), and a dialog can be opened up between the decision makers the engineers and scientists. In effect, the techniques provide the s whereby the technical knowledge and judgment of the forecaster can pplied to logical, systematic thinking about the pattern of develop- of a particular technology. This should aid the company in achievi -range goals subject to profit objectives and risk criteria [51].

The main reasons for utilizing technological forecasting are long- corporate growth and long-term investment. Since the first of thes bvious, let us consider long-term investment. The investment may n terms of resources, such as personnel, equipment, and facilities, n terms of research and development. It is just not cost-effective uild a plant, with a life of 30 years, to produce a particular uct if a new technology may render the product obsolete in five s' time, or if needs may change, so that there will no longer be a et for it [20].

Similarly, if the time taken for research is five to eight years, for development three to five years, the earliest possible produc- time is eight years and the actual time could be as long as 13 s. It is therefore essential to know whether some other technology d offer severe competition, or whether needs might change, before urces are allocated to a research program. This can be better eved by utilizing the proposed R & D planning model, whereby the ning is guided by organizational strategies and goals that are odically reviewed and updated when necessary. This will enable the to remain more flexible and plan for resource requirements more ctively [20].

In summary, it can be said that the importance of technological casting is reflected primarily at two levels in the planning proces level involves forecasting future needs for products and services the assignment of priorities to the overall R & D effort. The othe l utilizes capital budgeting techniques in determining which partic projects to undertake in connection with a specific system develop program [20].

The Role of Technological Forecasting in Research and Development

The role of technological forecasting in R & D planning is the sam in other types of planning--to convert as much of the existing uncer nty as possible into risk. Thus, the planner will have a better ide the odds facing him in any decision. Technological forecasting fills this role by helping set goals for R & D projects, and by indi ing opportunities for exploitation.

In the private sector, technological forecasting has been more ily applied in R & D planning than it has in other areas. This ation has arisen from the fact that R & D is more heavily involved future technology than are most other areas demanding planning, an the fact that until recently the only sources of technological for s were the technologists involved in the work. Hence, they were er to obtain for R & D than for other areas. Even though the exis- e of better forecasting methods makes technological forecasts lable for other areas, the need for them in R & D planning will not nish, but will probably increase as the growth rate of R & D slows . It will become even more important to obtain the needed progress limited resources [51].

nological Forecasting and the Research Planner

The research planner can look to technological forecasts for help dentifying what appear to be the most fruitful areas for the invest- of funds. He can rely on technological forecasts to provide a s for decisions to initiate, increase, cut back, or terminate

:icular research projects. He can use technological forecasts to ;ern where and when he will be in jeopardy if no action is mounted ›ffect a timely response to the hazards foreseen [20].

ınological Forecasting and the Development ıner

Technological forecasts can provide guidance concerning the abilit) he technological community to meet future system requirements, whict a principal concern of the development planner. The timing of futur nology can be established by careful forecasting. Forecasts need provide perfectly precise information about the future (which would mpossible to achieve) in order to be useful. Research and develop- planning decisions can be improved by clearer delineation of future nological opportunities, and threats than would otherwise be avail- without a formal forecast derived through a formal process [20].

Planning for Research and Development

Research and development is an inherently uncertain activity. In :al, it deals with the doing of things which have never been done :e, or the investigation of phenomena which are not understood. , the results which will be achieved by an R & D project are never ıin at the outset. There is high likelihood that some surprises be encountered.

Because of the high degree of uncertainty involved in R & D, ıing in this area is even more necessary than in some others. It ;sential that the decision maker take the right risks. The stakes :oo high to permit a haphazard approach to the selection of projects

: pursued, and the level of effort at which they are to be pursued. is perhaps where technological forecasting makes its greatest :ibution to the total R & D planning system [20].

CHAPTER II

ASSESSING COMPANY STRENGTHS AND WEAKNESSES

Establishing the Corporate Identity

The initial development of an R & D planning model begins with the ss of establishing the corporate identity through an objective sis of a company's strengths and weaknesses, and with decisions on ction that should be taken to correct those factors which inhibit ompany's long term profitability. Only by fully defining the rs that make up the company can the planner assist in setting it e best path.

The identification of company strengths and weaknesses is as diffi- as the objective assessment of personal strengths and weaknesses. there is often a level of corporate or personal experience which nied awareness because it is inconsistent with our corporate or nal fantasies. The problem of assessing strengths and weaknesses tively is made particularly difficult, because in so many cases re arises out of previous success. Thus, once success has come, rganization adopts those policies, practices, procedures, strate- and techniques which brought about that success. Meanwhile, tions go on changing and the rigid practices of the past may no r meet the challenges that arise [69].

In contrast, immediate benefits can come from profit improvement nes that will be suggested by a study of company strengths and nesses, and it is well known that improvements frequently yield a er return on investment than the best capital projects. Identifi- on of weaknesses, which may be serious limiting factors to the any's long range plans, is the first step towards their removal. ously, not all weaknesses are correctable, and there are some that y company has to live with, but knowledge of these means that the any can avoid decisions which put strain on areas that cannot with- d it. Some weaknesses can only be removed over a period of time, ways of doing this should be built into the long range plan.

A corollary from this study is that the company will also identify strong areas. The object of this is to show some of the areas on ch the company should concentrate its future efforts. As a by- duct of the study, opportunities may be identified for future expan- n and development that would otherwise not have become apparent. basic aim of long range planning must be to increase profits. The pany that begins its planning with this sort of study is likely to ieve greater success than a competitor who develops its plans in a uum [40].

The Internal Evaluation

The strength-weakness evaluation can be considered under two majo dings: internal and external. In reality the two areas combine to vide a single answer; for instance there may be little purpose in ing production changes to a product unless it has market acceptance 'ollowing discussion considers various criteria which combine to up the internal evaluation.

.t Contribution

The evalution begins with the identification of the profit contri- ›n of each area. The study should be made first by profit centers :hen broken down by product. Having identified the profit strength ıch product, it may be wise to study past trends and internal .ons about the future prospects of each product. If, for example, ıajor contributors show signs of slipping, this should be known. ıis stage the company should have an opinion of its present and :e "breadwinners" [40].

:ation of Resources

The next step is to examine the allocation of resources between ıcts; not only resources of money and plant, but also the scarcer ırces of management talent and technical skills. It so often əns that a declining product area is given to the best people to ȝe "to put it on its feet," when potentially more rewarding areas ıot fully exploited because they are left to the second and third əs of management talent. This sort of analysis may show that R & D rt is misplaced. One so often sees in a company a prestige division ı gets all the plums of personnel and finance because of its past ies, while other divisions with far gerater potential have to take nd place. The sort of decision that should come out of this ysis is where to change the emphasis [40].

s Involved

The investigator will also wish to examine the risks associated market and resource uncertainties, scientific and technical risks, the risks of defining objectives. When dealing with market uncer- ties, an assessment should be made of the long term markets that products or services will satisfy. Resource uncertainties can be mized by discerning from past records the most similar previous vity, and basing the estimates of the costs of a new task on this arison. Scientific and technical risks occur due to the uncertainty o which approach to an objective is most likely to succeed. These s can be dealt with by undertaking preliminary research before the sion to go ahead with the whole project is taken. Finally, the iculty in defining objectives is defining too rigidly at the outset objectives of the work and the criteria of success. All of the e mentioned risks will be discussed in greater detail in the chapter ing with uncertainties in R & D planning [9].

ety Reduction

Many companies take pride in their wide product range. Since every tional product brings increases to inventories, clerical costs, and uently to production costs, it is well worthwhile considering the ngs that can take place from a reduction in the range. Expressing e potential savings in money terms gives an incentive to take on. The aim should be to remove all products with inadequate contri- on to profits, and to reduce the other products offered by making lo the work of several [40].

.stic Allocation of Costs

In all the steps outlined so far, the cost added to the product by ›usiness is of vital importance. In many cases the apportionment of ; between products is on some form of allocation basis. Now it is ıwhile studying the basis of allocation, since although suitable ıany purposes, it may be inadequate for this study. Many allocations ıe that costs fall in a normal distribution, for example that .cing costs are a fixed percentage for all products. Inventories ›e treated on the same basis. If costs are re-allocated on the basis ·tual transactions, two things may become apparent: a skewed dis- .tion between products, and a skewed distribution between different ›mers. In other words, costs do not fall in a normal distribution. ew companies organize their cost data so that they can make any .ions on this basis. The sort of decisions that have been made by .nies applying this sort of analysis are: (1) removal of service many very small customers by a national distribution concern-- ting in a 20 percent cut in fleet size, no loss of turnover because .e ability to concentrate efforts on a smaller area, and a sub- .ial increase in profits; (2) the charging of a minimum price per forcing small customers to wholesalers; and (3) charging small s at a higher rate [40].

sment of Company Resources

So far most of the discussion has been about the company's product. attention should be given to resources. First, an assessment d be made of the company's production facilities. Are they ient? Is there surplus capacity? Is there room for expansion? vo plants be rationalized under one roof? The list of questions e increased.

One thing every company is likely to know is its cash flow position :s ability to raise money. At this stage a rough forecast of cash rces should be made, to give the company some guideline along which velop future strategies. If money is going to be a problem, the ny's freedom of choice may be restricted. In such circumstances y be important for the company to examine its credit policies, and for it to find ways of reducing capital tied up in inventories.

But money and plant are not the only ingredients of a successful ess. Every company depends on people, and no company can afford nore this. Therefore, the question of recruitment and development ople should be studied. If a company has difficulty attracting ight people, there must be a reason, and there is little hope of vement until this reason is identified. A careful stock should be of the ability of each key man; after all there is little point in ning new products if you know your marketing manager is not capable king them profitable. As in all other points dicussed, clear egies should emerge to correct the position. The planner should be aware of the management techniques used within the company, the : of their utilization, and the available techniques not at present applied, accepting the fact that present methods are not neces- y the best ones [40].

The External Evaluation

The consideration of internal evidence is only half of the picture, will not yield the best results unless attention is given to the ld outside the company. Because no company can make profits without tomers, the evaluation should begin with the market place.

ket Standing

First, the company should find out what position each of its major lucts holds in the market, or more important, in each segment of the ket. Great precision is rarely needed, but what is essential is a r idea of the standing of each product in the market, compared with standing of competitive products, together with an appreciation of potential for growth within the market. The company should define its products hold the position they do; what is special about them t makes people give them preference?

Much may be learned from the sales force, although there is fre-ntly a bias in data obtained from this source. A complete apprecia-n may call for marketing research, which may investigate the image the company, as well as market for its products. The channels of tribution should be included in the study for it should be remembere t the channels used by the company will in many cases not be the onl s possible. The company should be sure that it understands its kets, that it knows what the consumer requires, and whether this uirement is being satisfied [40].

:tition

Competitive activity should also be studied, and an attempt should ıde to define the strengths and weaknesses of each competitor. langer here is lack of objectivity by those carrying out the study, .t is too easy to underestimate the competition. Potential compe- ›n from new entrants to the industry should be considered. An ;try which requires little capital or technical knowledge is always vulnerable than one which is more difficult to enter. In this ıcular part of the investigation it is the degree of risk that has ↄ assessed [40].

ɛitutes

One area of competition that is most important and most difficult ɛudy is that coming from outside the traditional industry. The ɜny must assess the vulnerability of its main products to substi- s, since unless it does this, it may one day find itself in grave iculties. It is significant that so many substitutes are developed ther industries. Each company must keep continuously aware of new lopments and must always look out for this sort of opportunity from own research work [40].

omics

Every company is affected by the economics of the countries in h it operates, but not all companies mirror the ups and downs of trade cycle. The effect of economic changes on the company must be tified, since without this, it becomes difficult to assess the ıerability of future profits. Few companies have power to change course of the economy, but all can alter their own balance of :s by diversification, or by extending their sales areas into ːerent countries [40].

ırfirm Comparisons

The performance of other companies in the same industry should be lied. The objective is to assess the reason for variances, not just ıstablish that they exist. This can be accomplished by an analysis :ompetitors' strengths and weaknesses. If a company can spot an ı where its competitors are weak and it is strong, then these suggest ıselves for a concentration of R & D effort [65].

:k Market Valuation

Also of vital interest is an assessment of the company's vulner- .ity to takeover. To make this, the investigator should look at its record, financial policies and balance sheet, against the backgroun ıctivity in the market. Of course, if the company wants to be ıired, it may develop a strategy that makes it more attractive to th .ng eye of the hunter [40].

Preparing the Report

As listed above, the elements to be examined suggest a chain ıtionship, with item neatly following item. Of course, reality is like this at all, and the key elements have a sort of spider's web ıtionship, with a tangle of crossed lines but all with a central ıe leading to a focal point: the uncovering of the corporate identit

With the data obtained, it will be possible to write down a series actual statements about the company, together with the strategic ications. How these statements are formulated depends on the com- ity of the company, and the personal approach of the investigator. s important that they be written, since in most companies there likely to be areas of dispute and emotions will be involved. It is easier to make an objective decision if all the evidence is fully nented. The reports may not always be pleasant. This sort of study be approached with integrity, for without a genuine attempt at st appraisal the whole exercise may become a meaningless gesture.

Also important is the consideration of alternative strategies to d on what is discovered. There is little point in deciding that oottom is about to drop out of your market, and then sitting back watching it happen. The final report should show clearly the strong weak points of the company. It should assess the vulnerability of company to likely changes in the environment, and should establish company's "risk balance." It is at this point that the company is y to think seriously about its future objectives, and the ways in h it will reach them [40].

CHAPTER III

ESTABLISHING COMPANY OBJECTIVES

The Need for Company Objectives

Having recognized and assessed company strengths and weaknesses, company can now define meaningful objectives and goals in accordanc ı its strengths and weaknesses. As with any other aspect of plannin arch planning should begin with the establishment of the targets activity is to shoot toward--over-all organizational objectives. after these objectives have been established can a company develop ingful research strategies.

Setting over-all company objectives--a function only top managemen perform--is a vital step in research planning. For all research is good research. A company should support a research program only if rovides the least expensive or most effective means of accomplishin mpany's particular goals. Over-all objectives help to define the e, degree, and timing of the company's technological needs. Withou objectives the research program will inevitably drift toward ies that fascinate individual scientists, toward pet projects of objectives, or toward sales service actions which bear little tionship to long-term needs.

Proper goals will stiumulate research in the right directions but restrict the scientific approaches used in their achievement. Thus, managers must define what research is to contribute, not how it is ɔ the job. This is a critical point for the research and develop- manager. Furthermore, many top managements do not maintain a ər balance between their short- and long-term goals. These manage- s allow their companies to respond only to short-term "competitive ssities." The longer-term, perhaps more important, opportunities dangers are forgotten under the day-to-day pressures of market etition.

Although development work can sometimes solve problems which arise short-term operating difficulties, applied and fundamental research ɔnly support objectives which remain stable for three to seven years ntil their results can be exploited. Hence, top management must ide meaningful long-term objectives for such research [57].

Defining Company Objectives

Objectives are targets or goals. They state the results that the nization or any of its components should accomplish. Objectives do take just one form. They should exist at all levels in the organi- ɔn in a definite hierarchy. At the top of the hierarchy are the tively permanent "value objectives" of the total organization. ə link together the value premises which should guide the organiza- 's actions. They state the firm's desire for employee happiness, ə of products, honesty to all, profits to stockholders, etc. These selected by the owners or general management for the whole organiza- and generally express some distillation of the moral values of the s. While value objectives may well serve as guides for potentially nt managers, they are of relatively little use in planning.

Immediately subordinate to the value objectives, there is a group ver-all business objectives" which are critical to the planning ss. These establish the intended nature of the specific business prise and the directions in which it should move. These over-all ess objectives are somewhat less permanent than value objectives, evertheless usually stand for years. General management should lish these objectives because they are targets for all elements of rganization.

Below this level are a series of less permanent goals which define ts for each organizational unit, its subunits, and finally each ity within the subunit. The critical objectives here are those at over-all business objective" and the "organizational objective" s. Formulation of both is a top management responsibility. Below level, top management's concern is just to see that those who estab- goals keep them consistent with higher level objectives [58].

Defining Objectives for Research

There are three reasons for setting clear objectives for research: bjectives provide the only usable criteria for judging the adequacy search plans. If present or proposed programs will not propel ompany to its goals, they must be replanned; (2) objectives allow planning in creative organizations. They do not constrain action other plans, such as policies, procedures, or methods. Properly lished, objectives tell the organization what it is to accomplish, ow to do it. Creative persons are thus left free to select their pproaches to needed solutions; and (3) objectives provide the only eria by which actual research performance can be judged [58].

Establishing Company Objectives

Granted the need for objectives, how do they come into being in an nization? They can originate in three different ways: (1) by gement's carefully assessing the organization's future purposes and unicating these in an organized system; (2) by subordinate groups' itting proposals to management until its pattern of decision indis that an organizational objective exists; and (3) by outside sures such as the government, labor unions, or the international ation forcing the company in certain directions. In most complex nizations, objectives originate by all three methods.

Consistent management decisions are the only way to keep an estabed objective in existence. Once decisions begin to contradict rstood objectives, the organization cannot direct itself toward the with confidence. At this point the utility of the objective, no er how clearly and how often enunciated, has ceased. Enough decis consistently contradicting a given goal will eventually create a goal. Until then, confusion reigns. Consequently, all key deci makers must have a clear idea of the firm's objectives and back e with consistent decisions throughout the organization [58].

Problems in Establishing Objectives

Let us look at some of the major causes of failure in establishing ectives for research. The most common failures can be classified he following categories.

ctives Change Too Often

Managements allow "urgent competitive pressures" to dominate sions. Therefore, the whole organization becomes oriented to the fit now" objective and overdiscounts future needs until they become ent realities. Thus, longer term fundamental and applied research er lack guidance altogether or are essentially converted into t-term service activities supporting current marketing or productior s [58].

ctives Are Distorted by the Organization

This problem can never be completely overcome. For each time an ctive is transmitted from one person to another, the person receivir transmission reinterprets the objective within his own framework. , small distortions introduced by somewhat inconsistent top-level points are likely to be amplified by each link in the chain of orities transmitting the objective down into the organization. archers can only self-direct themselves meaningfully if these dis- ions are minimized by careful management action [58].

ctives Are Too General

A most common problem where objectives are enunciated formally is xpress them too vaguely for use as planning guides or criteria for ing action. Such overgeneralized goals usually take the form of ue objectives." But too frequently, even "over-all business objec- s" are thought out in such vague terms as "growing as rapidly as ible," or "diversification in any profitable direction," etc. Whil imposing constraints on research, such objectives do not help ulate research in desired directions [58].

ctives Can Be Too Specific

Some organizationally immature operations overplan research by ing goals in too great detail. Such goals take either of two s: (1) specific materials, pieces of hardware, test measurements, onents, etc., demanded by operating groups; or (2) step-by-step rimental goals. Such goals occur when operating or staff groups inate the research function. The obvious result is that research is strained in its approaches to problems, since it is told how to do job, not what is to be done [58].

Types of Objectives Needed

Fortunately, the kinds of objectives which are most vital to earch planning can be established to avoid the pitfalls noted above. following will illustrate what "over-all business objectives" are t critical to research planning and what issues these should resolve maximum effectiveness.

Kinds of Business Most Advantageous to Company

So often when it considers this question, management thinks in ms of specific industries. But such definitions state the means for viding goods or services--not the nature of goods for services the pany wants to produce.

To stimulate creative research in critical directions, top managers ld look at the functions their products perform, rather than the icular technique by which a product achieves its purpose. Research ners can then look at each field of science to see how it could ibly achieve the same purpose better, or otherwise potentially ct the company's intended operations [57].

Desired Rate of Growth

A company's financial capacities, management skills, market dities, and so on generally limit the rate at which the company can istically hope to grow without developing stresses which could roy it. This growth rate in turn affects total research program and the internal balance between short- and long-term offensive defensive research.

The often repeated objective of "growing as fast as we can" is ess as a guide to research planning (or to long-range planning of sort). A company needs to determine a growth rate which is feasible erms of its particular limitations. Then it must develop its inter- resources, including technology, to specifically meet this goal

.

Overall Direction of Growth

Should the company develop vertically toward its markets or raw- rial sources or horizontally into new areas at the same level of facture or distribution? Should it cultivate new fields or further trate traditional markets? Should cyclical investments be hedged he company entering countercyclical fields? Should the company be road line" operation or should it specialize in limited fields? major considerations vastly affect the scope of the research pro- and its emphasis on specific knowledge areas, offensive versus nsive spheres, and specific product lines [57].

Intended Method of Growth

Does the company intend to grow by acquisition, internal develop- , merger, or a combination of these approaches? Research, as a ribution to internal development, is only one of many possible ces of growth. But the "research approach" carries with it certain ue commitments.

The payback period on the growth investment is likely to be longer in acquisition strategies. Operating and functional departments be more technically oriented and highly coordinated to appreciate arch technology and be ready to exploit research achievements as become available. Research often requires a greater investment on less certain information than do alternative approaches. The l organization must be planned to grow primarily through internal lopment rather than through acquisition of entire experienced ating units from outside the company. Finally, a more flexible tal plan must be inaugurated to provide funds for the unpredictable stment spurts and long investment cycles that are characteristic esearch.

If growth through research is intended, top management must adjust whole posture of the company accordingly. The size and orientation he R & D program, the position and effectiveness of research in the nization, the long-run stability of the program (and hence its ıctivity), and the degree to which research results are exploited, depend on how specifically management expresses and follows up its of growth through research [57].

Desired Company Image

The amount of uncommitted, or non-product-oriented, research is n affected by "how progressive" the company wants to appear. Any any may decide it needs an image of technical progressiveness to: attract top-flight technical personnel; (2) increase public confi- e in its products; (3) withstand critical attacks on the company use of its large size or dominance of a particular market; (4) le its scientists--because of the company's reputation for scien- c contributions--to have better access to the fundamental knowledge thers; and (5) allow the company access to desired locations and a e, friendly labor pool [57].

Allowable Dependence on Supplies

Management must decide how much of a risk it is willing to take upplier relationships. A company can often gain some degree of rol over its supply markets and individual suppliers by obtaining rior knowledge of the properties of purchased materials, processes manufacturing purchased items, or possible substitute items. The any's goal of "independence of supply" affects research program e and emphasis [58].

ind of Capital Structure

Particularly in smaller companies, the desired capital structure ts the length of time the company can wait for research pay-offs, mount of technology the company can exploit without damaging ship goals, the degree of risk the company can assume on projects, These, in turn, influence total program size and balance on long- versus short-term projects [58].

egree of Stability

Because of stock price considerations, ownership needs, banking ionships, etc., a given company may desire earnings and sales lity as opposed to more rapid but risky growth. The degree of lity needed will affect the emphasis placed on more "sure-fire" ed projects and smaller impact technology which may sacrific poten- y greater gains for lower risk [58].

Company Objectives

Other objectives commonly stimulate or restrict certain research rams. These include the allowable degree of government control, percentage of market to be held in total and by geographical areas, degree of technical flexibility desired, the price-volume and profit ne markets the company wants to be in, the degree of decentralizatio nded, the company's desired size, and the rate of return on invest- . Properly establishing key company objectives is one of the first s top management must take in the multistage process of total ning for research. Obviously, initial decisions made at each stageluding the establishing of objectives--can be modified as informatio m later stages becomes available. However, orderly efficient total nning must proceed and final decisions be made in the general order icated [57].

The Relationship of Company Objectives To Long Range Planning

Determining a set of objectives for the company is not an easy k. Although some sense of corporate direction is needed in order initiate the planning process, the final resolution of objectives as much an output of planning as it is an input. Early in the plan- g process, as parameters of interest are identified, it becomes sible to define tentative objectives. Later these can be tested as feasibility, and appropriate modifications made. In addition, new elopments uncovered in successive plans may make it necessary to er objectives previously established.

In spite of the intertwining of objectives and long range planning final responsibility for approving objectives must remain with top agement--not with the planning staff. Indeed, stated objectives a useful check on the planning function itself as to whether it is ing the firm in the proper direction. In addition, the give and take cess of developing objectives constitutes a communication link of siderable importance between top management and the planning staff.

In a multidivisional company where operations are highly decen- ized, the objectives established at corporate headquarters should imited to those of corporate-wide interest. The strategy evolved implementing these broad corporate objectives becomes the basis on ı the divisions may develop their own operating goals and supporting tegy. Now that the organizational objectives have been established, ;ompany can proceed to determine its research and development tegies [69].

CHAPTER IV

FORMULATING RESEARCH AND DEVELOPMENT STRATEGIES

General Company Strategies

Once company objectives have been identified, the research and 'elopment manager can formulate a set of R & D strategies while .ying within the limits of overall company objectives, goals, and ategies. The formulation of a strategy demands a high degree of agement judgment. The strategy and the plans which will be develope m it will not by themselves ensure a successful outcome for what is entially a creative activity. It is not possible to list definitive hods for formulating the strategy itself, but a careful considera- n of the factors discussed below can help in the selection of a ategy which will enable resources to be utilized in the full knowled t projects for new products are initiated only after taking account all relevant information.

A company can aim either to be first in the field with a techno- ical innovation (an offensive strategy), or to follow a defensive itegy. The choice of strategy for a particular new product depends ı many factors most of which are related to corporate strengths and :nesses. To be first in the field, it is not sufficient to possess original idea and a strong research team, if the financial and :lopment resources are inadequate to carry the innovation through to

.rketable product. There are many cases of companies which have .d themselves in financial difficulties during this phase in the :lopment of a product which subsequently proved a commercial success a competitor.

Marketing and production weaknesses may also prevent a company from .oiting a technical success through its inability to generate a :umer demand, or to meet demand through manufacturing inadequacies. .uch cases a competitor which has adopted a defensive strategy but reacted quickly with a slightly improved product backed up with :eting and manufacturing expertise will gain the commercial success a product.

An absorptive strategy is where the company opts out from the :arch and development work but will utilize the research done by rs through license arrangements, take over, or mergers with the vative company, or even careful navigation round the patent laws. companies will adopt a mix of all three strategies. However, a .ce must be made of where to place most emphasis and this choice .ld follow a careful appraisal of all the company's strengths and :nesses [65].

An Analysis of Research and Development Strengths and Weaknesses

As was discussed in the previous chapter, examination of possible D strategies will not lead to an optimum choice unless we relate alternatives to the overall company situation. Before a decision .ade, a careful and realistic appraisal needs to be made of the :ngths and weaknesses throughout the company.

However, the research and development department will have its strengths and weaknesses, and these must also be taken into account :e the identification of a technological opportunity does not neces- ily imply that there is the capability within the company for its :essful realization.

Some of the most important factors to be considered are: (1) the sting resources within the department both in terms of its numerical ength and the capability of its personnel; (2) the technologies in :h it has expertise; (3) evaluation of past performance in the elopment of entirely new products; (4) the extent to which it is istomed to working at the frontiers of knowledge; (5) the mix of earch and development; (6) the product life cycles and the gestation iods of new products which have been developed in the past; and (7) organizational relationship between the R & D department, and the : of the company, particularly marketing [65].

The Relationship of Risk to Research and Development Strategy

Although cost/benefit analysis is an essential part of any project ection procedure, we need to examine the relationship between risk benefit in a rather different light when trying to establish a itegy for research and development. In general, the more innovative jects are likely to present the highest opportunities for profit, bu ' also contain the greatest risk; the less risky projects on the er hand have a higher likelihood of profitability but a lower gross ire.

In many cases, conventional risk analysis will suggest that for articular choice between two projects the more risky should be sen because of its greater expected benefit. However, the company's rall financial position may dictate that it could not entertain the sibility of loss. Whereas a large company undertaking numerous earch projects will be prepared to accept high risk because it ieves that the overall contribution from those that succeed will e than outweigh the losses from failures; a smaller company with er projects may prefer to opt for more certain though less spectacul fitability.

These considerations should be reflected in the overall research development strategy since the degree of risk which is acceptable likely to influence the allocation of resources between new or sting technologies and between new or existing products [65].

Research and Development Strategies

The two concepts of "research" and "development" have become so sely linked in management thinking by the expression "R & D" that ortant differences between them are often ignored in executive ision making. This becomes particularly apparent when companies empt to apply the lessons of their research experience to problems development, or vice versa. The terms "R-intensive" and "D-intensiv l be used to denote a tendency toward the basic and experimental on one hand, and a tendency toward commercial product design on the er. Most companies fall somewhere in between, but they can best be cribed in terms of the two extremes.

:ensive Companies

These companies work with indefinite design specifications. Since ɟement can usually identify the problem but cannot specify the :ed solution, the task of the R-intensive organization is to dis- : and evaluate alternative solutions, rather than to implement a le solution.

They tend to "broadcast" objectives and market data among technical le, rather than channel specific kinds of information to indivi- s. Being unable to present specific requirements to research, use broadcast communications to stimulate generation of alterna- s that will be consistent with top management's objectives and tegy.

R-intensive companies are nondirective in work assignments. Since gn specifications in these companies are less definite, and techni- insight and potential contribution are individual rather than group ibutes, managers must permit freedom for individual initiative and ress rather than assign individuals to specific parts of a well- ned solution.

They maintain a continuing project evaluation and selection pro- . Research is constantly turning up alternative solutions of ing worth, and these supersede previous solutions. Moreover, a move competitor, or results achieved on another project, may obsolete a e of research or change its priority. This calls for a continuing sion of the project portfolio to permit changes in the slate of ects, even within the normal routine planning period.

R-intensive companies stress the perception of significant results. ·e a research problem has not been tightly structured, the solutions- ı if found--are not always obvious. An essential skill of the tech- ıl manager is his ability to recognize technically or commercially ıificant results. The history of invention is replete with instances ·e a flash of insight into the possibilities of wholly unanticipated ·rimental results led to great discoveries that might otherwise have ı missed.

They value innovation over efficiency. Economy in performing ·arch is less important than achieving a markedly better solution ı clear market or profit advantages. Innovation is therefore prized, ı when it entails the sacrifice of efficiency in organization ıcture, planning, or control [3].

ıtensive Companies

These companies have well-defined design specifications. With the ·arch essentially complete, the development objective is reasonably ır, and performance tests can be specified early during design. The ınical task is not to create new alternatives but to reduce availabl· ·rnatives to a single solution for implementation.

They have highly directive supervision. The work to be done is ıly interrelated from the beginning of design to successful testing, ıgers tend to specify objectives, give orders, and carefully measure formance. The relatively large number of people in the D-intensive ınization--designers, test engineers, draftsmen, production engi- rs--also call for a more structured management approach than is uired in the R-intensive company.

D-intensive companies have a sequential arrangement of tasks. e organizations require a disciplined sequencing of tasks, with isticated controls to ensure that technical objectives are achieved in planned time and cost limits. Scheduling tends to be thorough precise, as in manufacturing. When faced with trade-off decisions een efficiency and innovation, managers will usually opt for effi- cy and higher output.

They are vulnerable to disruption by change. Given its relatively manpower commitment, its sequencing of tasks, and its relative imity to actual production in the new product development process, D-intensive organization can be severely affected by managerial dministrative changes ordered in specifications or objectives in tream.

Given these differing characteristics, the hazards of managing intensive organization with management concepts and controls suited he R-intensive company, or vice versa, should be apparent [3].

Downstream Coupling Strategies

Another important characteristic of high-technology businesses is degree of downstream coupling, that is, the extent to which the ess of the company's product introduction process depends on communi on and cooperation between the R & D and the manufacturing and eting functions, which are further "downstream" toward the customer. rly, industries differ in their downstream coupling requirements. need a great deal of information and interaction, with as little ering as possible; others need little or none. Being aware of the ling requirements and managing it properly not only can avert the ctions that are so frequent at the marketing-engineering interface, also can channel the familiar conflicts between manufacturing and ineering toward more productive ends.

tical Balance

It is useful to distinguish three degrees of coupling: high, erate and low. High coupling requires close interaction among the hnical, manufacturing, and marketing functions of the business. urate and detailed market information is essential to adequate produ e planning. The selection of R & D projects is influenced heavily manufacturing costs, availability of raw materials, abilities of the keting organization, and countermoves by competition. Minimizing disruptive effect of new product introductions on manufacturing is tical. Tight control of product quality is essential to successful tomer applications and minimum service engineering effort. Finally, e pressure on all functions is usually acute.

In such companies, management must maintain a constant balance of luence among development, production, and technical service to the tomer. In a highly coupled organization, correct balance among se three technically competent functions is dynamic rather than tic. Changes in the company's competitive situation, technical engths, and capacity utilization, among others, force management to p readjusting to current conditions [3].

erfunctional Control

In a highly coupled organization, functional dividing lines may ate serious problems. Since objectives on either side of the keting-engineering interface can and often do drift apart, some kind results-oriented interfunctional control is needed to keep pulling m back together. Sending two men, one from each function, on custo- complaint calls is one way. Organizing functionally, with cross- ctional responsibilities for project completion, is another. Givinç ior executives corollary duties that straddle functional lines can o help to reduce the problem. This can take the form of making the e president for R & D responsible for training technical service ; or of giving a marketing staffer the job of coordinating all func- ns to complete an application project [3].

ical Planning

Still another "problem" interface, especially in moderately couplε panies that lack the formal controls characteristic of highly couplε anizations, is joint product planning by marketing and engineering. ior executives can do much to prevent conflict among departments in duct planning by insisting on a logical process for new product nning. Since coupling is essentially an interfunctional problem, ever, no single functional vice president can manage it success- ly. A general manager, whether a president or a division head, must vide the necessary direction and arbitration [3].

Product Life Cycle Strategies

Product life cycles may vary in length from a few months to years even to decades. In technology-intensive businesses, the length of cycle may have initial strategic implications, particularly in the e of planning and control.

t Life Cycles

The need for speedy management action and response, high concurrenc ctivities in product introduction, and approximation rather than ision in technical objectives is characteristic of short-cycle anies. As a matter of strategy, an alert company should plan to be g the first to bring out a new product or break into a new market, e competition thereafter will generally force prices down fast, essing profit margins and return on investment.

Functional planning in a short-cycle business is usually overlappi simultaneous. Manufacturing may begin to frame its plan and marketi set target dates for product introduction, before R & D planning is plete. This, in turn, means that the input to technical plans from keting and manufacturing is mugh higher than in the long-cycle pany.

Plans are often remade in the short-cycle company; the result is eries of increasingly accurate approximations of introduction dates duct specifications, and detailed plans for market introduction made the engineering-change department. Short-cycle companies need close pling between product marketing specialists and technical staff. keting managers tend to be knowledgeable about technology, and they en contribute substantially to product definition and development [3

g Life Cycles

In this type of business the converse is generally true. With quate time to learn about competitive market developments, and to n to counter them, there is no need for unusual market sensitivity.

:he long-cycle company emphasis is on established procedure and :ine. Organization is usually functional. Managerial decisions ılly favor economy and efficiency at the expense of rapid response.

Planning is usually sequential, that is, detailed R & D is com- :ed before the manufacturing and marketing planning is begun. Manu- :uring and marketing are seldom deeply involved in technical plannin(:act, the technical staff may include market research specialists to › with the long range R & D planning. The marketing group tends to ʼolume-oriented rather than response-oriented, since new technical ›lems are rare and coupling between marketing and technical people .ow [3].

Investment Ratio Strategies

There is no generally accepted measure of R & D investment. The .liar practice of expressing R & D investment as a percentage of ›s has been declining, since the results of R & D are not realized ›diately and, in fact, affect sales instead of being affected by ı. Measures that begin to do justice to R & D's mission of protecti: ›orate assets from technical obsolescence treat the R & D investment ı percentage of total investment or of profits or cash flow.

However measured, the ratio of R & D investment/expense is impor- :. High ratios are characteristic of technically intensive industri(ı as pharmaceuticals, chemicals, and electronics; low ratios are :acteristic of nonintensive industries such as food, lumber, and ›nt. Most industries fall between these extremes.

ıh Investment Ratios

High investment ratios require a serious and continuous evaluatioı technology procurement alternatives: (1) whether to buy technology :ough licensing or through hiring consultants; (2) whether to buy a ıpany in order to acquire the latest technology in an unfamiliar ɜld; (3) whether to hire top people with the specific technical com- :ence desired; or (4) whether to develop additional technical compe- ıce by internal training in order to stay competitive. Higher ratio: ıracteristically allow less lead time and make the acquisition of :hnology a more attractive alternative.

They usually accelerate product and process change. This, in turı ıuires an adaptive organization, which can quickly shift to new ɾels of efficiency and effectiveness as technology changes the work done. In a company with a high R & D investment ratio, a major ıterion of organization is therefore the ability to adapt to new :hnology without sacrificing market share or efficiency.

High investment ratios usually mean a dynamic product market. Su :kets, where products readily substitute for one another and where ɔhasis rapidly shifts from new product development to low unit cost ı vice versa, impose three special requirements. The first is clear ɜibility of resources, permitting management to cut off a developmen ɔject quickly or to switch resources into a new technology. The :ond requirement is explicit strategy formulation. An explicit :ategic framework permits clear definition of project alternatives ı enables managers to choose more wisely among them. The third

:ial need is a well-developed planning system to permit the company redirect its resources promptly and effectively.

Higher ratios require closer supervision of technical efforts. ce the company is highly dependent on technology for competitive vival and therefore commits proportionately more resources to the ort, the senior managers need to know more about technical problems performance. They should be aware of the long-term corporate ects of lower level decisions and have a good grasp of the time and t implications of particular technological developments [3].

Investment Ratios

In general, the effects of low R & D investment/expense ratios the converse of those described above. Technology can be developed ernally within competitive lead times, or in some industries, pursed with the capital equipment into which technology has been incorated by the manufacturer. Organization structure need not be highly ptive; since technical developments are evolutionary, only occasiona nges in functional structure will be needed. Resources need not be cially identified because historical accounting data on expense and estment adequately reflect the impact of product or process replacets. Finally, marketing does not have to be closely coupled with the hnological functions, since marketing needs can be communicated via mamagement or through formal planning and control mechanisms [3].

Marketing Strategies

We have examined the characteristic parameters of technically ensive businesses and their impact on strategic, administrative, and rating problems of top managers. By way of summary, we will conside impact of these characteristics on a strategic issue; the timing of technologically intensive firm's entry into an emerging industry. alternatives may usefully be grouped into four major marketing ategies, recognizing that most companies will adopt a blend of these ording to their respective markets or product lines.

st to Market Strategy

This risky but potentially rewarding strategy has a number of ortant ramifications throughout the business: (1) a research-ensive effort, supported by major development resources; (2) close stream coupling in product planning, and moderately close coupling eafter; (3) high proximity to the state of the art; (4) high R & D estment ratio; and (5) a high risk of failure for individual product

The company must recruit and retain outstanding technical personne can win leadership in the industry. It must see that these techni-people are in close and useful communication with marketing planner identify potentially profitable markets. It must often risk large estments of time and money in technical and market development out any immediate return. It must be able to absorb mistakes, draw, and recoup without losing its position in other product lines. important, top management must be able to make important judgments iming, balancing the improved product development stemming from a yed introduction against the risk of being second into the market low The Leader Strategy

This marketing strategy implies: (1) D-intensive technical effort moderate competence across the spectrum of relevant technologies; exceptionally rapid response time in product development and mar-ing on the basis of finished research; (4) high downstream coupling R & D with marketing and manufacturing; and (5) superior competitive elligence.

The company that follows this strategy is an organization that s things done. It uses many interfunctional techniques and responds .dly to change. It has few scientists on its payroll, but some of best development engineers available. Its senior executives are stantly concerned with maintaining the right balance of strengths ng the technical marketing, and manufacturing functions so that the pany can respond effectively to the leader's moves in any of these s [3].

.ication Engineering Strategy

This strategy requires: (1) substantial product design and engi-ing resources, but no research and little real development; (2) y access to product users within customer companies; (3) technically eptive salesmen and sales engineers who work closely with product gners; (4) good product-line control to prevent costly proliferation considerable cost consciousness in deciding what applications to lop; (6) an efficiency-oriented manufacturing organization; and (7) air for minimizing development and manufacturing cost by using the parts or elements in many different applications.

The applications-engineering strategy tends to avoid innovative orts in the interest of economy. Planning is precise, assignments clear, and new technology is introduced cautiously, well behind the nomic state of the art. Return-on-investment and cash flow calcula-ns are standard practice, and the entire management is profit-ented [3].

Too Strategy

This strategy is distinguished by: (1) no research or develop-t; (2) strong manufacturing function, dominating product design; strong price and delivery performance; and (4) ability to copy new igns quickly, modifying them only to reduce production costs.

Competing on price, taking a low margin, but avoiding all develop-t expense, a company that has adopted this strategy can wreak havoc h competitors following the first-to-market or follow-the-leader ategies. This is because the me-too strategy shortens the profitabl iod after market introduction when the leaders' margins are most stantial. The me-too strategy requires "low overhead" manufacturing administration, and a direct hard sell on price and delivery to the tomer [3].

Relationship of Research and Development Strategy

To Long Range Planning

Research and development strategy is both an input and an output o porate long range planning. Research and development strategy may formulated early in the planning process either before or in respons a need identified as the plan is developed; or the plan itself may ine the consequences of a number of alternative strategies. In er case, the plan is likely to be the vehicle by which R & D strateg rticulated and communicated.

Good R & D strategy of necessity provides for some degree of flexi- ty to allow for the deviation of actual events from the forecast ern. This can take the form of hedging in the operating strategy lf, or laying plans for alternate courses of action so that a final itment may be safely delayed until additional information is avail- . The choice of major R & D strategy is a responsibility of top gement that should not be delegated to staff planners. It is equal rtant that top management avoid the opposite extreme of choosing tegy arbitrarily and without staff consultation. The corporate lon e plan constitutes a useful testing ground for evaluating a propose) strategy in the context of the total company.

It should not be inferred from this that R & D strategy can reliab hosen solely on the basis of its economic results as indicated by long range plan. Research and development strategy is too open ed and estimates of the future too uncertain to permit this. None- less, the plan does rough out the long run picture in a quantified that provides a point of departure for the judgment and insight of informed management [69].

CHAPTER V

UNCERTAINTIES IN RESEARCH AND DEVELOPMENT PLANNING

Project Measurement and Evaluation

At this point in the development of the research and development anning model, it seems appropriate to prepare the R & D manager for anning uncertainties which may be encountered in the forecasting and lection stages of the model. Perhaps the most obvious uncertainty i the capital budgeting aspect of R & D planning, where the potential ›jects are measured and evaluated for their investment merit. There· :e, this subject will be covered first, followed by methods for ›ating project uncertainty, uncertainties associated with R & D :ounting practices, market uncertainties, the risks of defining ›earch objectives, scientific and technical risks, and resource :ertainties.

To begin the discussion, if interesting results are obtained from iece of basic research, a decision must be made whether or not to ceed with the development of the idea to full-scale commercializatio ernatively, a firm may have ideas for several possible projects, but y the financial and technical resources to develop a few of them. ɜr decisions also recur throughout the development stages of a pro- :; whether to carry on or whether to stop and cut possible losses in light of changing circumstances; and if to carry on, what should be next. In order to make these decisions, it helps if a project can ccurately measured and evaluated.

omic Evaluation

The economic evaluation consists of weighing what is involved in :loping an idea to the commercial level against the eventual bene- ; expected from it. To compare development effort with the ultimate :fits quantitatively, they must both be measured in the same units, the universal units are those of money. Thus, price tags are ıched to all phases of the project. The economic evaluation is basec :stimates, estimates of the cost of bringing the project to the poin› profitable exploitation and of the profits which will then be ıined.

In an economic evaluation of a project in its early stages, it is ealistic to consider only the cost of research and development ıout reference to the other activities needed for its successful Loitation. Perfecting a piece of technology may be of little value ess the financial and other resources are available at the right e to exploit it, and so enable the financial benefits to be reaped. earch and development should be considered in terms of what it may e possible which will benefit the organization as a whole. In these ns, and R & D project is to be regarded as a first stage in an egrated project which extends through to production and marketing.

All the expenditures necessary are therefore included in the luation; the cost of the applied research and development program elf, and capital investment in plant, machinery and other facilities order to forecast profitability, information on such items as :rating costs and product price and demand are needed. The coopera- n of many departments may be required in making the various estimate .

:h Flow Analysis

Another important factor which will affect the evaluation besides actual money involved is the time when it will be spent or received timing of expenditure and income for a project can conveniently be wn by means of a cash flow analysis. It shows the cumulative cash ition of a project throughout its life. The financial attractivenes a project is a function of the shape of its cumulative cash flow ve.

There are several different economic criteria in use for measuring attractiveness of a project. Each of these identifies various tures of the cash flow pattern and converts them into a simple erical measure. The measures fall into three broad categories ording to whether their units are those of cash value (present worth e (payback time), or a rate of return (discounted cash flow return). be realistic, the measure or economic criterion should take account the complete pattern of cash flow. Present worth and discounted cas w return do this, and they also take account of the time-value of ey by discounting future cash flows back to the present. The counted cash flow return is the value of discount rate which makes sent value equal to zero. Generally speaking, the larger a project' sent value, the greater will be its investment value. These capital eting techniques will be discussed in greater detail in the selec- stage of the model [2].

itivity Analysis

Any forecast of the future is bound to be uncertain, and any sion based on forecasts will have a degree of risk associated with The third major element in project evaluation is how to take unt of uncertainty in the constituent forecasts and estimates, and to interpret the resulting risk. Errors in some of the constituent casts and estimates for a predicted project cash flow will be of ter significance than comparable errors in others.

The relative sensitivity of a project's measure of economic activeness to errors in individual forecasts can be found by nsitivity analysis of the cash flow analysis. This sensitivity lysis may show, for example, that a 10 percent decrease in the imated product price has a more serious effect on potential profit- lity than a 25 percent increase in the initial capital outlay ired. Thus, it indicates the areas where the effect of error uncertainty is greatest, and so establishes the relative impor- ce of different estimates. It can be seen from a cash flow analysis t in an attractive project the cash inflows must considerably eed the cash outflows. The potential profitability is therefore siderably more sensitive to the two components of cash inflow, ely selling price and sales volume, than to individual cost items ch contribute to cash outflow [2].

Probabilistic Methods for Treating Project Uncertainty

The uncertainty in a project can be measured in terms of the nces that a forecast project performance will be achieved, and so can be represented by a probability. For novel projects, it should recognized that this cannot be a statistical probability based ectly on past experience as there is none. Uncertainty in a novel ject will be discussed in a latter section on credibility forecasts. re are several probabilistic methods for treating uncertainty which l be discussed at this time.

hnical and Commercial Risk

Uncertainty and the resulting risk can conveniently be broken dowr o two types: technical and commercial. Technical risk is measured the probability that all technical problems of research and develop-t will be solved successfully, and commercial risk by the probabilit t market conditions will allow the anticipated profit to be made. calculated value of the evaluation criterion is multiplied by the probabilities (between 0 and 1) to arrive at a new, less attractive ue which now incorporates the risk element [2].

ernative Forecasts

Another approach is to make several alternative forecasts covering whole possible range, and to assign a subjective probability to h so that the sum of the individual probabilities is one; the actual uation when it occurs is then bound to be within the range covered.

:her method is to play safe and select the project which minimizes possible loss, however remote its occurrence may be [2].

:inuous Probability Distributions

A more sophisticated method of measuring uncertainty is to generat‹ ›ntinuous probability distribution for the evaluation criterion by ›ining probability distributions of component forecasts. In some :ricted instances this can be done analytically, but a more general ıod is by using Monte Carlo simulation. In this, a value in the :ribution of each forecast is selected at random, and these values used to find the cash flow and to calculate a value of the evalua- ı criterion. This procedure is repeated many times in such a way : forecast values are selected with a frequency corresponding to .r probability distributions. In this way, a distribution for the .uation criterion is built up by sufficient repetition. This method be accomplished with the appropriate computer program [2].

Limitations of Probabilistic Forecasts

The advantage of using probability in forecasts is that it pro- ›s a quantitative measurement of uncertainty which can be handled reniently by mathematical methods, and which is sufficiently general flexible for a large variety of applications. It is, however, :hwhile to consider the limitations of a probabilistic forecast.

Many types of forecasts are concerned with unique events or ıations where there is inadequate information for the derivation of :istical probabilities. The probabilities used in these cases are ective probabilities. Their numerical values are assigned by

:ect judgment, bearing in mind any indirect information which is ısidered relevant. A novel project comes into this category as it is advance into a new field, and it has unique features for which there no comparable past experience.

If one alternative prediction is not foreseen and is omitted from :orecast, the probabilities of the remaining alternatives will still arranged to add up to one. Hence, the omission of one alternative ı affect the probabilities assigned to other, and the only way to ›id this is to ensure that the list of alternatives is complete in first place. In novel situations this may not be possible, and in case there is no way of knowing if and when the list of alternative complete.

In early stages of a novel project, the grounds for differentiatin ween the subjective probabilities of alternatives may be very doubt- . If, through lack of information, equal probabilities are assigned alternatives, their value is determined by the necessity for them to up to one. In this type of situation, probability is not a very isfactory measure of uncertainty. In treating such uncertainty with hematical precision by using probability and applying statistical ision theory, the initial formulation of subjective probabilities omes the weakest part and may nullify any advantages otherwise ered [2].

Credibility Forecasts for Treating Project Uncertainty

Another way of treating uncertainty exists, which is particularly evant to the forecasting problems of novel projects. In this, ability is replaced by another parameter called credibility. Each rnative prediction in a forecast has an associated degree of ibility between zero (for incredible) and one (for completely ible).

The properties of credibility differ from those of probability in ral important respects. Unlike probabilities, the credibilities lternative predictions can be assigned independently, as they do interact and are not subject to a summation rule. The credibility ne prediction does not affect the credibility of any other. If a p of alternative predictions are combined, the credibility of the osite forecast is the highest credibility of an individual predic- within the group. The only restriction is that in an exhaustive cast, at least one alternative prediction must be completely credi- to make the forecast as a whole credible [2].

Credibility also differs from probability in the way dependent ictions are combined. The credibility of a combination of predic- s, each of which is affected by the outcome of the previous one, he lowest credibility of each considered independently, given that previous one occurs. Whereas probability is a distributional rtainty variable, credibility is non-distributional. It cannot be ected to the mathematical operations applicable to probability, instead follows appropriate selection rules [2].

The situation in the early stages of a novel project is one that ants the use of credibility rather than probability. Uncertainties be large and credibility ranges consequently wide. A function of arch and development should be to provide information which will ce uncertainty, and so reduce the ranges of credibility forecasts ıt later stages of a project. Reduction in the range of any ponent forecast will lead to a reduction in the uncertainty of the ject as a whole as measured by the credibility range of the evalua- ı criterion [2].

Credibility as a means of measuring uncertainty is intended to be plementary to probability. In a probabilistic forecast, there ıld be a valid basis for assigning different relative probabilities. :hrough ignorance this cannot be done, credibility may be used. libility provides a ready and realistic means of representing uncer- ıty in forecasts about novel situations, and it can take into account information, and the lack of information, that is relevant. Credi- .ty forecasts can be combined in a straightforward manner and provide ans of accumulating uncertainties in individual forecasts so that resultant uncertainty for the project as a whole is apparent [2].

Accounting Uncertainties

Certain decisions are as essential in determining accounting ciples for research and development as in determining accounting ciples for inventories or other items. The basic questions to be ered within the R & D accounting system are: (1) what activities ld be described as research and development in financial state- s? (2) should a portion of research and development costs be rred? and (3) how should deferred costs be amortized? Answers to e questions will remove much of the accounting uncertainty in R & D ect planning.

ning Research and Development

Some of the problems in accounting for research and development s can be attributed to the absence of a satisfactory definition of arch and development for accounting purposes. The extent to which nditures are classified as research and development may affect the urement of periodic net income under present accounting conventions. available evidence indicates that expenditures that some companies sify as research and development are classified by other companies ither production or selling costs. Frequently, the costs of techni- support--work performed by research scientists or engineers in sup- of production or sales--are classified as research and development s. The extent to which costs of technical support are classified esearch and development costs is difficult to determine, but com- tive analysis of financial statements both between companies or periods may lose much of its meaning if classification of expendi- s by function varies [35].

rred or Immediate Recognition

Another important accounting problem is to determine the portion, ny, of the expenditures for research and development that should be rred and associated with the future revenue expected to result from expenditure, and the portion that should be recognized as expenses incurred. Generally accepted accounting principles require revenue e recognized when realized and costs to be associated with related nue. Thus, costs incurred in one period to produce an expected fit in a future period are expenses of the future period and should efore be deferred. In theory, costs deferred to future periods ed not necessarily be assigned to specific products as costs of ventory, but may be merely assigned to the related future period. I her words, the deferral of costs to a future period is intended to rmit association of the total costs of the period with the total venue of the period, although the costs may or may not be attributed specific products [35].

:hod and Period of Amortization

Finally, if costs of research and development are deferred, a :ollary problem is to determine the method of amortization and the :iod of amortization. The difficulties of the problem are accen- ıted because deferred research and development costs are intangible ;ets that do not always have a clearly determinable life. A similar blem arises in accounting for the cost of a patent, except that a ent has a life limited by law. The problem, however, may be more oı s the same for deferred research and development costs as it is for atent, because the useful life of a patent may be shorter than its al life [35].

Market Uncertainties

In planning research and development, an assessment needs to be ɘ of the market which it is expected the new product or service will ısfy. On a long time-scale and especially in areas where the tech- ɔgy is changing rapidly, any attempt to assess demand quantitatively ɜs severe problems.

This point is specifically recognized by some companies, who :ribe this long-term planning function as "needs research." This

an explicit attempt to describe those functions or performance
ameters of a system for which there is evidence of future need,
to examine which of the range of possible technological develop-
ts seem most likely to be able to satisfy that need at an acceptable
ce. The assessment of future demand for improvement in the perfor-
ce of particular systems requires both the imaginative prediction of
likely future preferences of society, economic and social, and an
lity to relate these to the potential of emerging technologies [9].

Risks of Defining Research Objectives

There is a good deal of evidence that research and development is
t effective when it is most closely identified with clearly defined
ectives. This is certainly true of large-scale development projects
one of the peculiarities of research is the difficulty (and dangers
defining too rigidly at the outset the objectives of the work and
criteria of success.

In many research projects, it is not always possible or desirable
establish precise objectives because of the nature of the work. An
maginative adherence to the first defined objective may cause some
discovery to be discarded because it does not approach the target
rovement specified. Such a procedure can fail to make use of the
ormation derived from the research which may have significance for
er new ventures [9].

Scientific and Technical Risks

It is characteristic of many research and development situations,
ticularly those at the research end of the spectrum, that there

ld be uncertainty as to which approach to an objective is most ly to succeed. In such cases one or more of three alternatives may pen.

The R & D manager can reduce the uncertainty of a particular vity by undertaking a preliminary piece of research before the sion to go ahead with the whole project is taken. The cost of cing the uncertainty by this means will be to delay the completion he project and hence reduce, in present worth terms, the benefits cted from successful completion. The R & D manager can initiate lternative method of reducing the uncertainty in case the original vity fails to do so. This will lead to increased cost of the pro- , thereby reducing its net profitability. Also, the R & D manager take steps to obtain externally generated information which will le the activity, at present uncertain, to be undertaken with greater ainty at the time at which it will be required [9].

Resource Uncertainties

In planning any major investment, estimates are required of the urces needed to achieve the objective, so that the costs of the osed programs may be compared with the benefits likely to accrue result of successful completion.

In estimating resource requirements for research and development, onal recollection of the type and quality of resource used in ious situations may often be used without necessarily producing curate estimates. The major disadvantage is that the reasoning on h the estimate is based is not communicated, and cannot, therefore, hecked or debated. More systematic methods are being developed and which, while they still inevitably rely to a degree on personal ment, expose the assumptions about and analyses of historical data cally.

Another possible way to estimate resource requirements is to ern from past records the most similar previous activity and base estimates of the costs of a new task on this "near-neighbor" arison. This method can be further refined by allowing for price ges in the inputs (e.g., wages and materials), or by introducing a plexity factor" to account for the technological advance or the size he new task relative to its predecessor. Alternatively, a simple of thumb ratio may be used to express the relationship observed in ious projects between two tasks in the same overall program, either erms of costs, or of factor inputs [9].

Summary and Conclusions

A major cause of uncertainty in research and development planning ıe imprecise nature of the needs which the work is supposed to sfy. Clarification and quantification of needs necessarily in prob- istic terms, or in statements of conditional demand brings two r benefits. The first is the opportunity to define the targets of research and development program in terms which can be clearly ed to future needs; the second is that only by paying close atten- to the likely magnitude of the needs can any useful estimate be of the profitability of a research and development program designed tisfy them.

The definition of objectives in a research environment is not a -for-all operation. In order to obtain the maximum benefit from

ːarch and development resources, objectives need to be identified ːarly as possible. This ideally should be done, however, without ·sing so rigid a system of program selection and control that ıercially valuable innovations are discarded solely because they .ot happen to conform to the previously defined objectives.

The major factors in planning decisions, markets or needs, program ctives, resource costs and timing, are highly interactive. There danger that by concentrating on those factors which appear to be amenable to mathematical analysis, a great deal of scarce planning rt can be used, without a compensatory decrease in uncertainty.

Finally, one of the main advantages of trying to use formal selec- and estimating techniques in research and development is not that ificant, precise, quantified results emerge; but rather that lex situations are shown to be capable of logical analysis; implicit mptions about the various aspects of the problem are exposed; vant historical evidence is marshalled; issues on which intuitive nical and commercial judgment are identified; and, insofar as tification is possible, the dimensions of uncertainty are estab- ed on consistent statistical rules [9].

CHAPTER VI

MONITORING THE ENVIRONMENT FOR TECHNOLOGICAL CHANGE

Anticipating Technological Progress

With the policy stage of the model completed, emphasis shifts to forecasting stage which consists of monitoring the environment for nological change, technology assessment, and identification of et opportunities. This chapter will be concerned with searching environment for signals that may be forerunners of significant nologicl change. This should be achieved concurrently with a tant appraisal of societal needs. The following chapter will be erned with identifying the possible consequences of these new vations or changing technologies.

There are certain factors present in the process of technological vation which should be understood. A radical new technological nce is made visible to society first in written words, then in easingly refined, enlarged, and more effective material forms, long re it achieves widespread usage. Social, political, and ecological ges may alter the speed and direction of the innovation's progress. vation may be abruptly influenced by decisions of key individuals control supporting resources or determine policies that affect application. Also, technological capabilities or parameters ease exponentially over time once bottlenecks are broken, but will ı to level off if they encounter scientific, economic, or social iers. With these innovation factors in mind, we can proceed to individual environments, and attempt to detect significant techno- ːal advances for management's use in research and development sions [12].

Technological Environment

Within each environment many types of parameters and events serve ndicators of potential change. Time series of technical parameters figures of merit (combinations of technical and economic parameters) very suggestive when projected into the future. Reflections of rest in certain areas, problems, or phenomena also provide signals. mpany may announce that it is establishing a laboratory to develop rtain innovation. An executive may state in a speech that his any sees opportunity within a certain industry. This technical vity should be monitored to determine its true worth.

Demonstrations of new products, announcements of research progress, nt awards, and trade paper and professional society reports of rialization of new technolgoy deserve scrutiny. Monitors should, ver, be wary of over-optimistic statements, no matter how sincere, t forthcoming technology.

Performance data on technological improvements also must be scruti- d. These data are often mentioned in trade journals, professional ety papers, technical reports of government agencies, and adver- ng literature. When related to earlier achievements in a time es, they reveal (possibly) the state of the art, and they may est rates of technical progress. One of the benefits of such rts is identification of problem areas and limitations, which s to show what critical technical-economic factors must be moni-l and where bottlenecks lie.

Usage and applications data provide information on value and ıt of adoption of a device with which to build estimates of techno-:al needs and opportunities. The nature of usage can sometimes : the way to other technologies that must be created. Consider the ing use of plastics to replace metal. If plastics are to compete cold-rolled steel sheet, vacuum-molding equipment must be developed :oduce shapes of appropriate size and form for end-product applica-s. The signal is there, and the industrialists concerned should be :oring further progress [12].

:conomic Environment

Time series of costs point to relationships that are promising--'e intolerable. Time series of production, consumption, and sales 'ity point to volumes of production and services which create new .s of facility and material needs that cannot be satisfied without changes. Industrial and governmental financial commitments, :ts, and allocations indicate the support that will be given to a ıology. Presumably this foreshadows its progress. There are, of :e, many powerful signals emerging from economic trends, such as series of costs, capacities, demand, available resources, rates 'oduction, and consumption, among other data [12].

Social Environment

Population trends are a prime source of signals relevant to the to 30-year horizon. Hindsight reviews of technological forecasts gest that population figures are very neglected and unappreciated criteria for assessing the economic significance of technical nges. Business and government should give much more consideration the use of the most complete and recent demographic data in assessing significance of new technology and in corporate planning.

Measures of activities, such as leisure time usage, education, upational interests; measures of social conditions, such as the idence of disease, poverty, crime, and air pollution; and measures values, such as consumer attitudes, preferences, and interests, and itical opinions; all these can provide useful parameters of social nge. We must also recognize the formation of special interest ups, the delivery of speeches, the appearance of personalities uring public attention, and the publication of controversial, nical books.

When assessing social attitudes, the manager or analyst must not ly his own value system. He must keep in mind that a controversial son's influence on technological progress stems from the attitudes t they create, and not from the accuracy or completeness of their tements. The industrialist, secure in his technical-economic logic easily underestimate the force of public opinion when it differs n his perception of what is true [12].

;e Political Environment

Today it is the political environment in which many technological :ections are initiated, resources are committed, and use is deter- ıed. So governmental actions that support technological development ierwrite development or finance utilization, or prohibit or limit ›lications must be watched very closely. Early signals may be avail- Le, since formal government actions almost invariably are preceded major committee reviews and recommendations, and by reports of ›ates about alternatives.

Occasionally one can look beyond these public modes of decision :ing to their instigators. There may be a strong signal in the ›ointment of a certain person to a department or bureau, from which can influence the activity of a major agency. Identifying the :erests, opinions, aims, and even obsessions of such individuals can .p determine what technology is likely to be explored and supported.

Many technological refinements are offered to solve some problems l most never materialize in economic form. There are more contender: ın winners. Therefore, we must monitor many developments, realizing ıt only time will tell which is the truly significant technology. ›ng with this continuous monitoring of technological change, there ›uld be a simultaneous effort in the area of social forecasting to :ermine not only what man can do, but also what man wants and needs :].

Forecasting Societal Needs

Technological forecasting can estimate the technically feasible :ure, but this alone does not indicate what technologies are likely ɔe developed. The development of a technology is determined both by technical efficiency and by what might be called its social iciency. The social efficiency of a technology is its effectiveness responding to public needs and demands.

In certain ways, social forecasting is easier than technological ecasting. (1) Social changes are self-limiting processes with siderable internal damping and delay. The organizations of large erprises are usually resistant to change, because of their internal stituencies and institutionalizations. This tends to make social nge lag behind technological change. (2) Innovations in the social a are diffused and adopted slowly. Social innovations, unlike entific discoveries, must overcome widespread social norms independtly of the merit of the innovation. (3) Social change data, parilarly in the advanced nations, is more available than technical a. Social and economic change data is openly published, while new nological developments are often kept secret because of nation or istrial competition [1].

Fundamental Approaches to Social Forecasting

Four fundamental approaches may be followed in social forecasting: gment, analysis, extrapolation, and speculation. Judgment is the common and simple means of social forecasting. It can be very irate and sometimes cost-effective, when a single "wise man" does it l. Judgments on the social future have long been made and are ely available, although their value is uncertain.

Analysis uses models that are essentially theories based on torical data. The analytic approach seeks to identify the underlyin

ses of social development, so that future developments may be fore-
t on the basis of a knowledge of their causes.

Social changes can be forecast by looking at a series of historica
a and projecting the trend into the future. Extrapolation works
rly well for short-term (less than five years) forecasts, but
omes increasingly unreliable as one tries to forecast for the more
tant future. In addition, extrapolation requires that one determine
most relevant variables or indicators.

Speculation can augment extrapolation, where extrapolation cannot
used to forecast a change in the system or discontinuity (a depar-
e from the established trend). One simple way to speculate is with
enarios" based on knowledgeable judgments. Scenarios, which outline
eries of related events, have the weaknesses of the judgment approac
add to the forecasting process the imagination of the person making
judgment. The forecaster is thus freed from the artificial need to
e a single forecast, and can instead define multiple contingencies
evaluate their relative probability. Speculation represents a
or improvement over simple judgment and short-term extrapolations by
ening the forecaster's awareness of consequences and interactions.

All these approaches are useful for social forecasting. Judgment
t-cuts the selection of the variables for extrapolation, the
eration of scenarios, or analytic modeling. Obviously, it would be
ibitively costly to run multiple correlations of almost everything
lefine the variables of interest. Extrapolation serves short-term
ning needs and also suggests the areas of maximum uncertainty and
ct that require more sophisticated techniques. Speculation can
tify the contingencies that offer the greatest benefits, costs, and

ks. Speculation thus defines the field for the difficult and costly more precise analytical approach [1].

Procedure for Social Forecasting

The procedure which follows is a simplified description of an lytical process for social forecasting: (1) identify those social iables that appear to be strongly related to the technological elopments that one is interested in; (2) collect longitudinal data series of data spaced in time) on the social variables that seem evant, extrapolate them into the future for the period to be fore- t, and extrapolate their incremental positive and negative margins uncertainty to form an envelope of probable maximum and minimum ues of these variables; (3) from the relevant social variable time ies, select out those variables which seem to be changing most idly and use these in generating scenarios; (4) select major factors determining the value of social variables by means of factor analysi one lower level of detail; (5) generate scenarios for social vari- es by many random combinations of the subvariables identified by factor analysis performed in (4), and screen these for intuitive usibility; (6) design causal models of those processes that seem to important in the light of the results from the generation of narios; and (7) put the range of social variable values into the sal models and look for outputs that seem most significant on the is of their being determined by many forces. These values and binations of social variables constitute the social forecast [1].

Analyzing the environment and recognizing those key technical, nomic, and social trends which are and will be important to the ng-term development of an enterprise presents one of the most critic d hazardous aspects of the long range planning process. Environment recasting is a continuous process, keeping abreast of changes in tlook as they occur. To insure adequate monitoring, critical points the long range plan should be identified in advance. Changes in ccessive plans can also constitute a check on the adequacy of the anning process itself. This completes the environmental monitoring ocess, and leads to the next step in the model which is to assess ese newly discovered technologies for their possible environmental pact.

CHAPTER VII

ASSESSING THE CONSEQUENCES OF TECHNOLOGICAL CHANGE

Definition of Technology Assessment

Once emerging technologies have been recognized, they should be sessed for possible environmental consequences. Technology assess-nt is the process of taking a purposeful look at the consequences technological change. It includes the primary cost/benefit balance short term localized market place economics, but particularly goes yond these to identify affected parties and unanticipated impacts in broad and long range fashion as is possible. It is neutral and jective, seeking to enrich the information for management decisions. th "good" and "bad" side effects are investigated since a missed portunity for benefit may be detrimental to society just as is an expected hazard [18].

Procedure for Technology Assessment

A procedure for technology assessment should utilize techniques veloped in past assessments and should also seek to apply and extend decision-aiding tools developed in the last decade such as opera-ons research, cost-benefit analysis, systems analysis, and computer nulation. The generalized procedure developed here consists of seve eps.

ne the Assessment Task

The first step consists of discussing relevant issues and any major lems, establishing the scope (breadth and depth) of the inquiry, developing project ground rules. The definition of the task should eviewed periodically during the course of the study, because new ghts will be forthcoming as to what aspects of the technology or its equences are most important and can be researched effectively [42].

ribe Relevant Technologies

The second step includes describing the major technology being ssed, describing other technologies supporting the major technolo- , and describing technologies competitive to the major and supporti nologies. It is possible to proceed immediately to a technology essment without analyzing the technology itself, but there is a dan- that such assessment may overlook some of the most important equences of the technology [42].

lop State of Society Assumptions

In the third step, state of society assumptions are developed by ntifying and describing major nontechnological factors influencing application of the relevant technologies. Nontechnological factors elerate, dampen, or otherwise affect the development and application technology. In many cases, technological and nontechnological fac- s interact to such an extent that it is difficult to separate the ects of one from the effects of the other [42].

tify Impact Areas

The fourth step consists of determining the societal characteris- that will be most influenced by the application of the assessed nology. The following analytical framework of six categories can sed by an assessment team in developing its own specific impact klists. The first category, values and goals, includes personal, unity, and national. The environment category consists of air, r, open space, quiet (noise), olfactory, weather, and sunlight. demography category includes the total society, major segments, and s. The economics category consists of production, income, employ- , prices, trained manpower, and national resources inventory. The al factors category includes national security, economic growth, rtunity (class relations and poverty), health, education, safety me), transportation, leisure-recreation, and other amenities. The category, institutional factors, consists of political, legal, nistrative, organizational, custom-tradition, and religious [42].

Preliminary Impact Analysis

In the fifth step, a preliminary impact analysis is made by ing and integrating the process by which the assessed technology s its societal influences felt [42].

tify Possible Action Options

The sixth step identifies possible action options by developing analyzing various programs for obtaining maximum public advantage the assessed technologies. An action option is a public or privat rvention into the process of technology development and application n effort to accelerate, dampen, or otherwise redirect the normal se of events. There are a wide variety of ways to intervene, and action option should be evaluated in terms of its controllability, h, priority, effectiveness, cost to the sponsor, cost spillover to ety, nonfinancial problems, institutional obstacles (political, l, and administrative), and the amount of uncertainty existing tive to all data inputs regarding this action option [42].

lete Impact Analysis

The seventh and last step analyzes the degree to which each action on would change the specific societal impacts of the technology g studied. If these seven steps are followed in adequate fashion, cy makers will have a basis for making a rational choice among the ous action options at their disposal [42].

Limitations of Technology Assessment

Technology assessment has been called a social science or political nce invention; if so, its innovation and diffusion into everyday use ikely to be far more tortuous than any of the natural science ications (television). The following difficulties and limitations apparent with technology assessment.

Most important of all, technology assessment does not make deci- s; the decision maker cannot abdicate his duty since assessments provide and structure alternative actions according to the avail- factual information. The comparison of options may show that one learly outstanding. However, the results should be presented with- advocacy permitting the political process to add its context to a cal objective assessment.

Priorities must be assigned among candidate assessments. Techno- assessment is an expensive undertaking. No decision making nization, nor indeed society itself, can perform in-depth analysis ll the problems which it confronts. Some of the criteria for gning priority are: (1) the number of persons or the area of the ronment affected are large; (2) great economic damage would result; potential benefits to society are large and highly probable--great al utility; (4) the momentum of a new technology is high and will y it into application; and (5) a societal problem demands immediate tion involving alternative technologies [16].

Social science techniques are inadequate. Many, if not all, ssments require the so-called "soft" data of attitudes, public ion, social costs and benefits. These inputs are vital to the eration and comparison of alternatives in technology assessment, they are the hardest kinds to collect.

Technology assessment must be incorporated in the early stages of research-innovation sequence. Ultimately, it cannot be an add-on vity after the application is ready for widespread use. The indus- l sector, especially, must ask its scientists and engineers to ider broad implications as they select emerging lines of research emphasis.

The coincidence of expertise with vested interest is common when ssment participants are being chosen; and yet it is clear that we ld opt for the expert rather than the totally disinterested person little knowledge of the problem. One way out is to construct a essional environment for the assessment, and then choose experts a variety of inferred biases. They will tend to keep one another ;t and will cancel out non-objective opinions.

Finally, implementation channels must be ready when the technology ;sment results come in. An industry must be able to adjust its /ities to accord with the evaluation from a competent and thorough ;sment [16].

Technology Assessment by Cross-Impact Analysis

At this point in the planning model, technological forecasting is Lzed in the form of a cross-impact analysis. "Cross-impact" is a :ic term for a family of techniques that try to evaluate changes in Lihood of occurrence among an entire set of possible future events :rends in light of limited changes in likelihood of occurrence among ıtire set of possible items in that set. These limited changes :esult from actions which are consciously pursued, or from the :rence of events which are thought to be possible but cannot be pre-ed with certainty. Each of these changes may affect more than one /idual outcome; indeed, it may affect the probabilities of all of Ltems in the set.

It is this aspect of the cross-impact analysis that makes it Lcularly relevant to the problems faced in technology assessment. technique requires the development of a model in which the causal ages among many important possibilities are described. It then this model to identify the more important chains of possible :rences, and the degree to which the occurrence of each possible : changes the likelihood of occurrence of the others. With these ;hts it is generally easier to synthesize and assess actions which ear likely to have not only desirable first-order effects, but also irable second- and third-order effects as well [27].

Construction of the Cross-Impact Model

In a cross-impact analysis, an internally consistent model licitly based on the couplings between events is created and then d to evaluate outcomes considering the implementation or non-lementation of actions and the occurrence or non-occurrence of nts. This requires the following information: (1) a set of possibl nts which are thought to be important to the issue being explored; estimates of the probability of occurrence of each of these events some future point in time; and (3) estimates of how these probabili-s would change given the occurrence of the other events in the lytic set [27].

These data are used to create an analytic model, which in turn is d to assess the pervasive impact of alternative actions, and of the urrence (or non-occurrence) of exogenous events. In other words, ir ross-impact analysis a model of elemental possibilities and coup-gs is constructed and verified; this model is then exposed to ernative actions which appear attractive and is used to compute the work of changes in likelihoods of occurrence that these actions se.

In constructing a cross-impact matrix, judgmental inputs are used define the events, their expected probabilities of occurrence over time interval being considered, and the conditional probabilities t comprise the matrix itself. In compiling this information it is ortant to avoid double accounting of impacts. Double accounting may ır when both indirect and direct impacts are included [27].

Analysis of the Cross-Impact Matrix

Once the cross-impact matrix has been constructed, the analysis :eeds in the following sequence. (1) The information contained in matrix is used to compute the changes in probabilities that would ılt from the non-occurrence of each event in the set. (2) The ıged probabilities are used to compute cross-impact factors for use :omputing revised probabilities. (3) An event is selected at lom and its occurrence or non-occurrence is "decided" on the basis .ts assigned probability. (4) The probabilities of the remaining ıts are adjusted in light of the result of step 3, using the cross-ıct factors. (5) Another event is selected from among those re-ıing and is decided (using its new probability) as before. (6) This :ess is continued until all events in the set have been decided. The :ome in terms of the events deemed to have occurred is then recorded, all intermediate computations are purged. (7) The matrix is .yed" in this way many times, so that new probabilities can be com-:d on the basis of the percentage of times that an event occurs .ng these repeated plays. These seven steps constitute a "run" of analysis. The first time a matrix is analyzed, no perturbations introduced into the input data. This is called the "base-run", and ntended to test the internal consistency of the judgmental data uded in the matrix. If the data are completely consistent, then probabilities computed in the base run are identical with the ial inputs. If not, adjustments are made in the matrix to make it cally consistent. (8) Steps 1 through 7 are repeated using erent initial probabilities provided by the experimenters, to test effects of alternative actions. Of course, the matrix is limited he basic laws and assumptions of probability which demand input abilities to be logically balanced [27].

Once the events of cross-impact model are balanced, the matrix be solved for all permutations and combinations of occurrences of ts. A representative random sample is generated through the Monte o technique. The matrix is then solvable, however, it is also actical for large numbers of events. One difficulty is keeping k of the various probabilities that are generated when an event or ts are "decided." The matrix can be solved exactly; however, the tion would require such extensive calculations as to make such an oach impractical for a large number of events [27].

Limitations of the Cross-Impact Method

There are a number of limitations to the cross impact method of nological forecasting. Information derived from the analysis is etter than the information supplied as input into the matrix. If e are errors or improper assumptions in the data used, then the errors and improper assumptions will be reflected in the data ut. Perhaps a more serious limitation is the assumption of some he causative relationship among the elements, particularly if value ges are not included as elements in the matrix. In other words, e the occurrence of one event may make another event more techni- y feasible, it is not intuitively obvious why the probability of second event should increase if the event is constrained primarily ack of public acceptance. Finally, it should be emphasized again even though there is the use of sophisticated computer methodology, validity of the output is directly related to the validity of the t; and no matter how pains-takenly derived, remains a man-made, ective, judgmental opinion.

CHAPTER VIII

IDENTIFYING MARKET OPPORTUNITIES

Forecasting Research and Development Projects

The next phase in the forecasting stage of the model consists of ntifying market opportunities which could materialize into R & D jects. Technology based industries, such as pharmaceutical manufacers, have a particular interest in long-range forecasts that might them some insight to the field of medicine 10 to 20 years from now. se forecasts would aid manufacturers because of the long lead time, cally about 10 years, between the start of a research program and probable marketing of a new medicine resulting from it. In plannin earch, it is therefore essential to predict likely patterns of morty and therapy (psychological, biofeedback, acupuncture, or nological) at least a decade ahead [61].

In health service planning, the problem is similar. Because of length of medical training, manpower needs must again be forecast 10 years ahead. If entirely new training facilities, such as a medical school, are to be provided, plans must be started at least ears ahead of anticipated demand. Health service building, also, s to be started five to ten years before it will be actually ired. New hospitals, for example, are usually not ready for servic l about eight years after the architects' plans are first issioned [61].

The remainder of this chapter will present some basic technological casting methodologies. Since the purpose of this paper is to develo ltistage R & D planning model, this chapter will stress the fore- ing methods rather than the results of the individual cases being ented. It is important that the R & D manager use several of the casting methods presented, rather than any one particular technique.

The Delphi Technique

This experiment with the Delphi forecasting technique correlates opinions of experts about likely developments in the field of icine. The study was conducted for a report by Smith, Kline & Frenc oratories in the United States as an aid to the planning of a phar- eutical company. Two internal questionnaires encouraged the formu- ion of an extramural Delphi to probe the future of five areas: medical research, diagnosis, medical therapy, health care and medi- education. The Delphi Technique uses a sequence of questionnaires feedback from them to elicit predictions from a number of individua erts and specialists. The evaluation is carried out by mail, and contributions of each participant are known only to the person ducting the study [7].

ramural Delphi

Before conducting the Delphi study reported here, which used a el of experts outside Smith, Kline & French Laboratories, the tech- ue was first tested with a panel chosen from the company's scientifi ff. Two questionnaires were sent to 196 members of the R & D staff. first questionnaire asked the participants to list advances, ntions, breakthroughs and trends in the areas of biomedical arch and drug therapy which they regarded as urgently needed and sible within the next 50 years; the second questionnaire asked the icipants to indicate when they felt there would be a 50 percent ability that the event would be implemented or widely accepted. results of this internal study proved most interesting and encour- l furthering the uses of the technique with an outside group of rts [7].

amural Delphi

In formulating the present Delphi, the study was divided into five sections which were felt would be most helpful in planning for the re of a pharmaceutical company. The sections were: biomedical arch, diagnosis, medical therapy, health care, and medical educatio five sections were considered so closely related that a single pane xperts could be used, rather than a separate panel for each section

Questionnaire one offered a brief working definition of each sec- n and requested the participant to list important discoveries, akthroughs, changes in methodology and other events which he thought ht occur for each section within the next 50 years. In questionnair , the statements were grouped not only by the five main sections of uiry, but also by areas within each main section. For example, the tion on biomedical research was subdivided into 18 areas.

To provide a means of evaluating the level of expertise of panel bers, each participant was asked to rate his own knowledge of each a by describing it as derived from "awareness", "reading" or rking." For each statement within the area, the participant was l to rate the medical need and the social-ethical desirability of lescribed event. He was also asked to estimate when the event had percent and 90 percent chance of occurring. If the participant the event would never occur or would not occur within the next 50 s, he simply marked the "never" column [7].

onse of Extramural Participants

One hundred and eleven people whose primary occupation suggested rtise in the various sections of inquiry were contacted by mail and d to participate in the study. Seventy-eight agreed to participate received the first questionnaire. Forty-two of these responded and ested a total of 867 statements or predictions for the five sections xpected, many of these statements were similar and could be combined ormulating the second questionnaire. The second questionnaire was to all of the 78 who had originally agreed to participate, whether ıot they had completed questionnaire one. Forty-one participants ırned the second questionnaire of which 35 were suitable for ılation [7].

:ription of Panel

Thirty-three members completed the personal data form which was .uded as part of the second questionnaire. All panel members were ; and ranged in age from 34 to 62 years, with an average age of 47.5 :s. As a whole, the group was quite educated; 21 were M.D.s and 12 ; Ph.D.s. In addition to having received an M.D. or Ph.D., two of group also held Doctor of Science degrees and one a Doctor of ;rinary Medicine degree.

All major biomedical disciplines were represented. The discipline h the greatest representation was internal medicine (ten mentions) lowed by biochemistry and microbiology. The shortest time any membe spent in his current work was three years, while the longest time 31 years. On average, the group had spent 17.5 years in their sent occupations.

The most frequently mentioned activity to which the group gave bstantial effort" was teaching, which was mentioned 29 times. This followed by biomedical research (22 mentions), clinical research administration (21 mentions each) and clinical practice (ten menns). Other areas of substantial effort were animal behavior, animal rition and physiology, basic biochemical work, environmental physiol , pharmacology, medical licensure and consultation [7].

inition of Consensus

This was stated to be agreement among at least 60 percent of the pondents that the event had a 50 percent or 90 percent probability occurring within any ten-year period [7].

sensus Events

Almost 90 percent of the statements in questionnaire two were ed as medically necessary and socially and ethically desirable. The ongest exception to the statements was taken in areas involving mical or electronic control of human behaviour and development, trol of sexual development, artificial insemination, using genetlly superior donors, predetermination of sex of children, Federal trol of the pharmaceutical industry, time actually spent by doctors atient care, and the role of medical schools in research. In tion, the panellists expressed reservations about research on aging, ronmental control and the application of genetic research to human nic programs, fetal malformations, and other congenital problems.

One way of using data from a forecasting study is to take these ements for which consensus was obtained, choose a suitable time od and construct a scenario. After the Delphi Technique was com- ed, consensus statements for 1978-83 were used to construct such a ario which attempts to portray portions of the education, training, tice and research of an American student entering medical school t 1978 and entering practice in the early 1980s. The authors con- r this to be an interesting way to compare the "then" with the "now" to estimate whether expected changes will be revolutionary or utionary.

From the above information, potential opportunities are selected he basis of commercial and technical considerations. These "areas pportunity" are reviewed by research management, which selects from list the ones which it wishes to have analyzed further in terms of r technical and commercial feasibility, and the rewards that might ssociated with various levels of investment [7].

Trend Extrapolation Techniques

Trend extrapolation is based on the development of a historic time es for selected technological parameters. It is assumed that the ors influencing the historical time series in the past are likely ontinue into the future. The trend under study should be capable uantification in order that it can be portrayed numerically, and an uate data base should exist on which to establish an adequate trend :. Also, data points should be plotted as far back into time as ible, or at least as far back in time as the forecast will be ected into the future.

The R & D manager should fully understand the shortcomings of this nique. Trend extrapolation cannot show unpredictable interactions. ecedented demands will not be shown, nor will the technique indicate potential of new discoveries. Also, the technique does not con- r the causative factors for the trend pattern or possible constraint .

tant Percentage Rate of Improvement

The rationale for this method is that improvement of technological ormance at a constant percentage rate begins with the intuitive ef that prior rates of improvement are significant to future ctations. In brief, progress in most technical areas will proceed nentially, that is, at constant percentage rate of improvement, use this is the pattern evident in our technologically oriented eties.

The logical method of developing a forecast of technological ormance which increases exponentially is to plot data for past per- ance on semilogarithmic graphs, with time as the abscissa. Constant entage rates of increase may then be plotted as straight lines ed to the data for past performance. The forecast is simply an nsion of the established trend at the same percentage rate of ease [20].

th Analogies

Many processes proceed initially at an exponential rate which ually slows as some ultimate limit is approached. These processes, uding autocatalytic chemical reaction and biological growth patterns been used frequently as analogs for technological progress. lopment of a forecast using any one of the analogies which describe esses expanding to an upper limit naturally starts with selection he desired analogy.

In the absence of any better reason, the selection of the desired ogy may be based on the forecaster's familiarity with the analog ess, or his belief that qualitative logic supports a comparison een the model and the parameter of progress to be forecast. Data the past performance of the parameter to be forecast are then introd into a proper transform of the existing formula for the analog l. Graphic presentation of the forecast, on a semilog plot with as the abscissa, ordinarily results in an initially straight line esenting exponential increase, followed by a gradual curve approach- an asymptotic limit [20].

elation with Precursor Trends

Any situation in which the attainment of particular values by a n quantity have regularly and consistently preceded the attainment he same values by a related quantity offers the possibility of ecasting future values of the dependent quantity on the basis of ently attained values of the initial quantity. This method thus ides a forecast into the future equal to the lead time of the ial quantity over the dependent quantity.

Preparation of a precursor trend forecast requires finding a ıtity whose variations have regularly preceded similar variations in quantity to be forecast. The relationship may be developed mathe- .cally or graphically to establish the basis for a forecast. For ›hical presentation, a plot of the two quantities, with time as the ıon abscissa, and with appropriate ordinate scales, will depict the .tionship. The forecast is then made by extending the dependent able as far into the future as it ordinarily lags the independent able [20].

hesis from Interrelated Trends

A common and valid criticism of forecasts made by extrapolation of le trends is that such forecasts often produce absurd results at point of extension. The best answer to absurdities created by mited trend extrapolation is to use the apparent trends in an ative synthesis which takes proper account of known relationships een the factors being forecast. The physical relationships between ous parameters which represent technological progress in a given d are well known to design engineers, and may be used effectively onjunction with trend analysis to forecast future progress [20].

ysis of Competitive Processes

This method outlines the rates of technological advance which would xpected under various assumptions for competitive actions and tion. For example, Competitor A initiates a new product. When this uct is disclosed, Competitor B initiates action to develop a better uct (assumed here to be 20 percent better), while A concentrates on uction of the initial product. When B discloses his product, this ulates A to attempt a 20 percent improvement over B's product. "leap-frogging" continues as long as competition is maintained.

This example can be developed to provide a new technique for oratory forecasting. With this concept, progress is a function of: number of competitors; (2) length of time for development of new ls; (3) timing of responses; (4) percentage of advance attempted; (5) probability of success. Historical values of these quanti- can be ascertained for various technical areas, with the aid of ession analyses. These values can then be combined in equations, sed in models, to forecast future rates of progress or to permit examination of alternative possibilities. For example, the effect ompetition on progress could be quantified from past experience, then projected for various levels of competition in the future [20].

elation with Cumulative Production Quantities

The essence of this approach is that technological progress is elated to cumulative production quantities of technological arti- s. The rationale is that technological progress is analogous to 'learning curve" function. Improvement through repetition (in the ning process) is equated with improvement (progress) in technology ugh repetition production.

This approach is supported by several factors inherent to indus- . societies. One is that the margin of return on industrial uction permits investment in research and development of new ucts. Thus, increases in production quantities should support ter R & D investment, leading to higher rates of technological ance. Also, technological progress is supported by large numbers of hly skilled engineering, management, and production personnel, who elop such skills primarily by employment related to production. refore, higher production quantities provide a larger base for tained technological advance [20].

Substitution Model

New markets which can have extremely attractive growth rates are ated when a new technological development satisfies an existing ket need more effectively than has been possible with old technology growth rate which can occur in the market created by the substitu- n of the new technology for the old can be far greater than the wth in the overall market of which the substitution is a part.

For a firm which spends large sums on R & D, substitution markets form the basis of a strategy for selecting candidate new ventures. h a strategy would encompass the following steps. First, an audit ld be conducted to evaluate the currently existing technological e, and applications of this technology would be sought in those ket areas which are relatively backward technologically, and which ld be vulnerable to technological substitution. The new product didates which would supply the needs of the market sector, and which compatible with the existing technology base, would then be identi- d and the rate of market substitution would be projected. All new hnology would be developed to supply the needs of future new product cepts which are designed to supply future market needs.

The key to such a strategy would be exploitation of existing hnology in market areas where the probability of success is high, the development of new technology tailored to new product concepts .gned to satisfy well-defined market needs. Such a strategy would ›redicted on finding customer-satisfying applications of new ınology in a wide variety of different markets and substituting the technology for the old [11].

Structural Forecasting Techniques

The structural forecasting techniques can be classified by purpose .ormative or goal-oriented rather than exploratory. Normative tech- .es begin with an objective or goal and work backward to the present .n effort to determine the optimum, or if not possible, an accept- approach to achieve the predetermined objective. The R & D ger should use the normative methods presented to optimize alloca- of resources and selection of R & D proposals, from the standpoint aximizing expected return, both in the form of revenue and technical s-fertilization.

hological Analysis

Morphological analysis is a method for systematically exploring the possible solutions to a given problem, and predicting the ntial that can be realized from a given development. The analysis ists of four steps necessary for achieving the technical objective. first step is to make an exact statement of the problem to be ed. The second step consists of identifying the important parameter ınctions upon which the problem depends. The exact statement of the lem to be solved, or the precise definition of the class of sub- ems or functional components to be studied, will automatically ɜal the important characteristic parameters. The third step involve: ɜxamination of all the atlernative technologies, that are either ilable or anticipated as being available, which will perform the ividual function. The final step of the analysis consists of an nination of the usefulness of all solutions through a determination :heir performance values in regard to some desirable purpose. This nits a selection of those solutions which have a high level of rability from the standpoint of performance and cost [5].

sion Tree Structure

The decision tree focuses upon branch points where decisions must iade. The tree is a horizontal development of decision points, iches of alternatives, and uncontrollable circumstances. The deci- ı tree begins with a specific decision which is not viewed in .ation, but rather as a dynamic process which influences all future .sions in that area. From this decision block, branches representin ı alternative solution are depicted. Proceeding on a time line, an ontrollable event occurs, and the various alternative situations ich off from this event. At this point another decision is made, or utcome is determined, and the process continues to completion [5].

vance Tree Structure

The relevance tree structure is designed especially to illustrate degree of importance of various inputs to the achievement of a ific goal. Once all the variables or inputs have been described a hierarchy has been established for each level, an overall struc- of the higher ranked inputs of each level can be connected to form relevance tree. In this manner, technology is directed in bringing ut the most wanted, higher ranked, inputs of each level to obtain goal.

The relevance tree begins by obtaining a clear-cut objective and ping out the possible paths of technological progress. Basic to development of a relevance tree is the functional array which pro- es groups of relevant variables organized on a comprehensive basis, is composed of three areas of concentration: environmental, func- ıal, and technological. The environment area is made up of luencing factors which cannot be controlled by the decision maker litical, social, and economic). The functional area is formed by tw -areas: environment-oriented (intrinsic nature of the product ernatives) and technology-derived (actual characteristics of the luct alternatives). The technological area is composed of the known nological systems for a specific field [45].

:extual Mapping

Contextual mapping evolved by necessity from application of the phi Technique. Mapping allows the decision maker to anticipate possible innovations which may obsolete his products or the way in :h he produces them, and also alerts him to the opportunities for and more profitable utilization of the resources which he has grammed for the future.

The preparation of a map begins with establishing the boundaries :he area to be mapped and the layout of an appropriate coordinate :em. The second step of mapping, the reconnaissance step, establish :icient "triangulation points" in those subcategories of particular

:ern. Triangulation points are anticipations of the future which be uniquely related to a specific category of the map. Reconnais- :e data should be in the form of resource allocations, events, and :ndencies between events and allocations. The third step involves ısfer of the reconnaissance data to appropriate portions of the map. final step of mapping is topography to provide details of the ter- ı and the relationship between features of the map [14].

The Selection of a Forecasting Technique

When determining the technological forecasting method to employ, :hould be kept in mind that no single one of the techniques is :t." The R & D manager should use several of the techniques simul- :ously, because each technique is best suited for certain types of :casts which are required for a research and development planning :l.

Although no one technique is optimum for every purpose, there are :e major requisites of a good technological forecast: (1) a .able data base, which normally consists of the knowledge bases of :ntific specialists in the subject, as well as any supporting data; astute judgment and common sense on the part of the forecaster; (3) an understanding of applicable forecasting techniques, and of and why to apply them [14].

In regard to the selection of the various techniques, the most sfactory choice will depend on the circumstances under which the :caster is working; his needs; the reliability, completeness, and .titative precision of the data base; the purpose of the forecast;

length of the forecast period; and the time and effort that can be
ested in preparing the forecast.

This chapter has presented a brief introduction to many of the
ic technological forecasting methodologies. For a more detailed
cription of the techniques, it is suggested that the reader refer
the references given for each method.

CHAPTER IX

PROJECT SELECTION AND INVESTMENT CRITERIA

Factors Influencing Project Selection

After identifying various market opportunities, the firm is faced h the decision-making process of project selection and capital geting. As the R & D planning model has suggested, project selecn is based on prerequisite planning such as determining company engths and weaknesses, company objectives, R & D strategies, and the act that new technologies and potential projects will have on the ironment.

This chapter will be concerned with the selection stage of the D planning model and will discuss the factors influencing project ection, the actual project evaluation procedure, and the investment teria for final resource allocation. Numerous factors relating to ernal elements of the research organization, or the corporate anizational environment in which R & D operates have impact on ject selection. The elements discussed below apply primarily to loratory research for the technology based company.

agement Style

The management style of the top research administrator often luences how project selection is carried out within a R & D ganization. A director having a prolonged exposure to or philosophi(finity toward the academic research environment may resist pressures om marketing or other functional areas, and also oppose the institu- on of various quantitative business analysis techniques in project anning and selection methodology. He may feel that the best researcl sult will evolve from hiring the most qualified scientists and givin(em maximum freedom to pursue research in their area of expertise. ch a management style exists in several major pharmaceutical firms l has a tendency to influence project selection "thinking" in others

On the other end of the attitudinal and style spectrum in ploratory research, the R & D director may feel that research is mos oductive when it has clearly defined objectives and is closely align and influenced by marketing concepts, as well as carefully programm ntrolled, and constantly reexamined using the most modern management cision-making techniques. Such an environment, where highly sophist ted project selection programs are carried out, may be found in a fe armaceutical firms but is not characteristic of the industry [30].

mmunication Networks

Efficient communication networks within a firm are a prime factor promoting successful project selection. A free flow of information l open decision-making techniques encourage an integrated organiza- on capable of examining all alternatives and making the best decisio th regard to project activities. The research organization charac- rized by pockets of isolated units and sub-optimization finds it fficult to bring the judgment of its best brains to the challenging oblem of selecting the right projects and programs [30].

porate Policy

In some cases top corporate management decides to have research elop a particular product or line of products. This mandate will in t instances override any formal exploratory research project selec- n mechanism within the research-marketing organization. When such ior management decisions are made, then project selection criteria ome established insofar as the type of projects are concerned. In t firms of the drug industry, large research and manufacturing enditures on drugs moving toward commercialization undergo corporate agement review and approval. The degree of corporate involvement ds to increase as projects move through the R & D process [30].

ior Research Committee

In most research organizations there is usually one committee or up, composed of senior research administrative personnel and top- el representatives from marketing or other functional areas, which responsible for the key decisions regarding project selection. This up, invariably headed by the research director, usually has prime hority with regard to the allocation of research resources to variou jects or programs [30].

Research Budget

Project selection and initiation is in all instances related ner directly or indirectly to the yearly research budget. Increas- ly in the pharmaceutical industry, top corporate management is oming more watchful of research investments as evidenced by a growin erest in the funding of specific research projects and program as. However, most research operations maintain sufficient flexi-ity that exploratory projects may be initiated at any time without nal budgetary approval outside of research administration. The rall profile of projects and research programs is affected directly the funds provided to the R & D function. Therefore, project ection and initiation are often integrated into the annual budget roval process [30].

petitive Activity

Project selection is often influenced by environmental pressures considerations. For example, competition may introduce a new duct which causes a flurry of activity to create a similar or erior one. Although the drug industry is less sensitive to competi-e achievements and characterized by long range research commitments goals, it does at time reorient research programs either to counter ompetitive challenge to an existing product, or to establish researc grams in an area that a competitor has found rewarding [30].

ulatory and Related Governmental Forces

In the pharmaceutical industry, for example, increasing govern-tal regulatory activities in the area of drug research has had her profound impact on project selection rationale within most drug ms. Recent Federal Drug Administration views on the extent of dies required to develop and introduce a new oral contraceptive nt have forced companies to reexamine the risk and rationale for h research activities. Also, new rulings on combination products influenced decision making with respect to projects and development ıch products.

Federally supported health and drug research activities are having :ing influence on the nature of drug research and project selec- One example: The recent governmental decision to invest several ·ed million dollars in a crash program to find a breakthrough in :reatment of cancer will undoubtedly affect the current anti- ır research programs and projects within industry. Perhaps a more .borative relationship will evolve in which federal dollars will be to finance major cancer research projects within drug companies. ·ic prescribing pressures will heighten industry concern for break- :gh new products. Other threats include possible compulsory .sing and short patent life [30].

<u>mic Environment</u>

The recent economic slow down will have a negative impact on the of growth of R & D investments. The result is that companies have more selective to insure that the limited funds are allocated for ·est payoff with emphasis on the short term [30].

<u>ration of the Entire Research Process</u>

Project selection, which is one phase of the research process, is woven with other steps of the process and dependent upon them for cessful research outcome. The working system for selecting pro- in many organizations is related and affected by the procedures lished for promoting and evaluating creative ideas, the project trol mechanisms, and the impact of the results of assessing completed jects on future selection parameters [30].

Procedure for Project Evaluation

To create an overall research program having maximum output poten-l, an analytical framework and perspective is needed with regard to evaluation of current research projects, and the assessment and ection of new programs and activities. The following factors should considered concurrently with the project uncertainties discussed in pter Five when evaluating a research project.

porate Objectives and Strategy

1. Compatibility with company's current objectives and strategies
2. Consistency with company's desired image
3. Effect on attitudes of company personnel
4. Impact of governmental, public opinion, and other environmental pressures

earch and Development

1. Compatibility with company's R & D strategy
2. Probability of technical success
3. Patentability or exclusivity of discoveries from project
4. Time required to achieve project objectives
5. Estimated cost of the project in the coming year and to completion
6. Availability and/or utilization of existing research talent and resources
7. Interrelationship with other research activities

8. Value as a means of generating experience for future research activities

9. Time lead of competition in this area of technology

keting

1. Total size of the market

2. Estimated market share

3. Projected sales and profits

4. Estimated product life

5. Probability of commercial success

6. Effect upon company's current product line

7. Product competition from other companies

8. Pricing, quality, and customer acceptance

9. Compatibility with existing distribution channels

10. Promotional and advertising requirements

11. Market seasonality and stability

12. International marketing opportunities

ance

1. Capital investment required

2. Revenue expense during the development phase

3. Availability of financing and interest rates

4. Effect upon other projects requiring financing

5. Potential annual cash flow

6. Anticipated profit margins

7. Time to break even and maximum negative cash flow

8. Compatibility with company's investment criteria
9. Income tax requirements

duction

1. Availability of raw materials
2. Requirements for additional facilities and equipment
3. Available outlets for non-merchantable byproducts
4. New processes involved in production
5. Air or water pollution problems
6. Safety problems
7. Freight costs
8. Running royalty costs

Procedure for Project Selection

After evaluating the proposed projects, the following method can used to select projects which will produce an optimum R & D program: estimate the costs of each step of the project; (2) relate expected D expenditures to expected profits for the whole series of steps; then decide whether it is worthwhile to continue; (4) compare the ures thus developed for all projects, so that; (5) all R & D effort l be maximized to produce an optimum program [38].

In addition to the cost of R & D, the time required must be esti- ed. Research and development, like any investment which takes time pay out, should show a rate of return above that of savings banks, ernment bonds, or low-risk business, and should at least equal the pany's present cost of capital, if the money being risked on an D venture is to be justified. The remainder of this chapter will

›sent several methods for evaluating the true worth of a capital ›enditure.

Criteria for Investment

Criteria commonly applied to capital investments may be applied ıally to R & D investments. Expenditures are projected far enough .o the future to include a reasonable number of income-producing .rs. Some of the elements of a good criterion are: (1) time value money; (2) depreciation and taxes; (3) total profits of the company; anticipated benefits of the project; (5) simplicity; (6) ability to ıpare various projects in order to maximize the whole program; and inclusion of all R & D costs, such as exploratory research, ›porting services, and overheads [38].

Many different methods are used to evaluate capital expenditures. y vary in complexity, thoroughness, and accounting treatment; ever, they share a common objective: to provide a meaningful method ranking investments.

back Period

One of the more commonplace methods of evaluating a capital enditure is the payback method. In this procedure, the cash pro-ds produced by an investment are equated to the original cash outlay uired by the investment, arriving at some multiple of the cash ceeds that would be equal to the original investment. Measurement usually in terms of years and months. For example: if the cash ceeds generated from an investment are constant from year to year, payback period is determined by dividing the total original cash

:lay by the amount of the expected annual proceeds. If, however, : proceeds from an investment are not constant, the expected proceeds · the successive years must be added until the total is equal to the .ginal investment. The advantages of the payback method are that it ıks investments and is simple to use. Its disadvantages are that it .ls to consider proceeds earned after payback date and to account for 'ferences in timing of proceeds [52].

:rage Earnings on Original Investment

Average earnings on original investment are the total proceeds 'ided by the number of years over which they are earned, and these :rage earnings are divided by the original investment. In calculatinç ›ceeds, no charge is to be made for depreciation. The reason for .tting depreciation is that the analyst is viewing an original invest- .t and not the depreciated value of the investment in making the ıputation. Simplicity is the principal advantage of this method. Its ;advantages are that it has bias for short-lived investments with high :h proceeds, does not consider duration of proceeds, and does not ;sider the timing of cash proceeds [52].

:rage Earnings on Book Value of Investment

Average earnings on book value of investment are the average annual ›ceeds less depreciation as a percent of average book value of the 'estment (essentially, half of the cost). The advantages of this .hod are that it ranks investments in accordance with the typical .io used to evaluate the firm's performance; that it is a simple .culation understandable by most individuals; and that it uses terms on to the financial statements of firms. The disadvantage is that ails to take into consideration the timing of the proceeds [52].

ounted Cash Flow

Discounted cash flow is a method of evaluating investment opporties that assigns certain values to the timing of the proceeds the investment. The assumption, based on current interest rates, hat a dollar earned today is more valuable than a dollar earned a from now. There are several ways of using the discounted cash flow ept for evaluating capital expenditures. The two most popular are net present value of an investment and the yield from an investment ernal rate of return).

In calculating the net present value of the proceeds from an stment, one must relate the stream of the proceeds year by year, ounted by a selected interest rate (which usually reflects the orate cost of capital) to the outflow of cash that is required by investment, again discounted by the same interest rate. Should the ent value of the proceeds exceed the present value of the outlays, r discounting at a common interest rate, the investment meets the pted criterion. If the present value of the proceeds does not ed the present value of the outlays, the reject criterion is hed [52].

In calculating the internal rate of return, one must equate the ent value of the proceeds to the present value of the cash outflow ired by the investment. The procedure is to determine the rate of rest that will, when applied to the proceeds and the outflow, make e two streams of cash equal. This is usually accomplished in a l-and-error method applying one interest rate to the two cash flows, then determining whether or not a positive or negative present value flow is achieved, adjusting that interest rate upward or downward l such time as the proceeds and the outlays equate. The advantages he discounted cash flow method are that it ranks investments and iders timing of investment and proceeds. Its disadvantages are lexities of computation; results that cannot be traced to published ncial statements of the firm; and the implication that on shorter- assets the proceeds can be reinvested, at the end of the life of asset, at an equal-to or greater-than return [52].

Risk Analysis in Capital Budgeting Decisions

A growing number of firms have developed risk analysis systems to st the manager in understanding capital expenditure risks. These ems have in common the ability to combine the variabilities related ll key estimates supporting a capital expenditure decision. This ccomplished through computer-assisted simulation of outcomes in rdance with their estimated probabilities of occurrence [69].

Two basic steps are required to make such a system work. First, mates of the range of values for each key assumption supporting oject, along with the likelihood that each value will occur, must repared. Normally, functional experts are called upon to make e estimates. The marketing manager may prepare market forecasts the potential R & D projects, and so on. Firms using risk analysis found estimates of this type relatively easy to prepare. A eting manager, for example, may be much more willing to forecast a e of possible share of market positions if it relieves him of the

:t impossible task of "going on the line" with a single budget ıate. Each forecast must, of course, be related to the other R & D :ct forecasts where the variables are interdependent. Forecasts ıarket share must, for example, be related to selling prices.

Second, the estimates generally must be run through a computer-:ted simulation due to complexity. This involves the selection and nation of all of the R & D project variables at random, and the tation of financial data for each random combination. This is done ally hundreds of times to arrive at the odds of the occurrence of possible return rate. In addition, the expected outcome of the expenditure decision is arrived at by figuring the average of the s of all outcomes weighted by the chances of each occurring.

The system can be rerun to test changes in assumptions on the ble outcomes. New data on market shares, for example, might be to determine the sensitivity of this new set of assumptions on inancial consequences of the R & D capital expenditure evaluation.

The risk analysis system just described is both time consuming elatively expensive to use, and therefore is normally applied to a s larger or more complex R & D investment decisions. Other more e tools can be applied to lesser projects to give management more ed, but adequate information on risk. For example, each project ption can be changed plus or minus ten percent to determine its t on project measures such as payback, return on investment, and unted cash flow. Simple computer programs have been developed ickly perform the mathematics required to compute these new project res, given new assumptions. These programs have proven to be ble working tools to help with the infinite number of "What

. . .?" questions which arise in the early stages of R & D project
ıluation [69].

While risk analysis forces a more rational segmentation of the ᵊments of the R & D decision, the basic input remains the subjective ıgment of the functional managers involved. Although these judgments ᵌ no doubt the best available, they are also subject to error. For ıs reason, a usual final step in the use of risk analysis is a review the elements of the decision in order to determine which individual ıgments were the most important in terms of producing the final ᵌult. Armed with this information as to sensitivity, the wise mana- : will then review these critical assumptions and the basic factual ›port. This review may point up the need for further research into .tical aspects of the R & D project. The risk analysis system can combined with the methods for treating uncertainties (presented in ıpter Five) to aid the R & D manager with the difficult task of ısuring, evaluating, and selecting R & D projects which will maximize ᵎ company's long range investments.

Relationship of Capital Budgeting to Long Range Plans

It is important that the capital budgeting procedures for R & D .ate to the firm's long range plans. Capital budgets are really one the ways of implementing the long range plans, and so they must be ısistent with those plans. The firm that has a reasonably clear idea what its business is--and will be--should be able to draw broad 'ameters covering general economic conditions, potential markets for . products, probable market shares and prices, and the costs that st be incurred in order to achieve market objectives and subobjective wever, the experience of most R & D departments shows that the use of e R & D capital budget as the primary investment decision tool prodes less than satisfactory results, since the scope of activities lated to the capital project is frequently too narrow to take into nsideration the broader ramifications of related decisions.

Stated another way, R & D capital projects tend to lose the qualit independence when viewed over a longer span of time, and for this ason the top managers of many larger companies have shifted emphasis ward greater use of the long range plan and R & D planning models, ch as the one proposed in this paper. Accordingly, capital investmen self has been relegated to a subsidiary role in the planning process, l R & D capital budgeting per se has become, or can be expected to come, a decision tool of lesser importance when viewed in relation each stage of an R & D planning model. In other words, all stages the planning model are viewed with equal importance. Thus, in a npany with a reliable long range planning process, the R & D capital lget's greatest usefulness lies principally in enabling optimization the long range plan, as well as helping to achieve company jectives [69].

CHAPTER X

IMPLEMENTING THE RESEARCH AND DEVELOPMENT PLANNING MODEL

The Process of Innovation

Once an optimal portfolio of R & D projects has been selected, the D manager has the responsibility of guiding the individual projects ough the development phase of research and development, to the pro- tion stage in the total process of innovation. The purpose of this pter is to implement the R & D planning model in an organizational ironment which lends itself to the total process of innovation. The lication stage of the R & D planning model will be concerned with the ditions for technological creativity and the organizational struc- e which maximizes innovative output.

Individual steps of innovation are dynamic components of the cess normally labeled "advancement of technology." Although innova- n is a principal concern of the technology based company, it is the t difficult action to bring to successful conclusion. Successful ovation includes market acceptance of the new product; therefore, successful solution of the "need" and "means" relationship must be nd. The company must invent (application of means) that which, when is introduced into the market, will be accepted (satisfaction of l) to the extent required to realize the projected growth and fit [52].

The Role of Research in Innovation

In total innovation, research is only part of the total process. provides the new knowledge, but other specialists at other functional els must apply the knowledge to achieve different prime objectives performance, cost, reliability, and timing. Because these tasks uire knowledge and creativity beyond the relevant science--knowledge technology, economics, and sociology--men in innovation processes ɔ must specialize either in basic or applied research, in develop- t and design, in manufacturing, or in sales and service. But if all se specialized efforts are to add up to a unified whole for a common pose, they must be coupled together. If specialists are to be pled together for cooperative effort in the total process of innova- ı, they must be able to communicate with and understand one another. re must exist overlap understanding at the interfaces between their cializations. Thus, in this structural dimension of the research cess, people must specialize in their respective functional areas, then couple together with constructive feedback. When feedback available, the total R & D planning system becomes goal-seeking and or-correcting, perhaps even adaptive [53].

Characteristics of Creative Individuals

Researchers have not been able to enter the minds of creative viduals to study what actually occurs. Instead, they have been ed to base their beliefs on investigations of the attributes of a tive individual, such as the way he spends his time and his onality. Existing research lends to the following conclusions t the creative problem-solving process: (1) creative problem-solving ars to be a high risk activity, that is, often erratic and edictable; (2) creative people appear to have a detached devotion heir work; they have a deep commitment to the problem they are ng to solve, yet they are not so deeply immersed that they are le to see the problem in a broader perspective; (3) creative people receptive to all kinds of ideas; (4) creative people rely on free oration in that they actively go out and search for new ideas from de variety of sources; (5) creative individuals appear to commit selves to a specific solution to their problems later than their creative counterparts; (6) creative people tend to be non-ormists and question authority and existing problem solutions [44].

Characteristics of Creative Organizations

The environment in which the individual participates has an rtant influence on his creativity. Consider Gresham's Law of ning--routine drives out planning--which implies that when a person eeply involved in a very routine activity, he is not likely to lve himself in creative problem-solving. This indicates that an nization which keeps employees immersed in very routine activities ot likely to be a very creative one [49].

The innovative organization will be characterized by structural eness with less emphasis on narrow, nonduplicating, nonoverlapping nitions of duties and responsibilities. The organization will v that diversity of inputs needed for the creative generation of s. Long periods of preentry, professional training, and wide usion of ideas within the organization, including a wide diffusion roblems and suggested solutions, will provide the variety and ness of experience required. Included should be a wide diffusion ncertainty, so that the whole organization is stimulated to search, er than just a few professional researchers. Involving larger s of the organization in the search process also increases chances cceptance and implementation. This wide diffusion, in turn, will nd upon ease and freedom of communication [64].

k Innovation

Slack conditions occur when the organization is rather contented itself. Under these situations one expects to find wide search on part of the organization for new ideas. The search carried on in firm will be external to the organization's structure and people. search will be supplementary, R & D laboratories looking for new ucts, new processes, or a new group to add to the organization [44].

ress Innovation

A company in an unsuccessful position is likely to search for erent types of changes than it would in a slack situation. Internal ges will occur rather than changes in products or processes. The any does not have the excess resources to look outside. It cannot rd the risk and high cost of introducing a new product or process, instead, the company will emphasize cost-reduction projects in an rt to become successful again.

Under conditions of mild distress, the organization behaves cally. That is, the organization adopts moderate rather than eme steps or great alterations. If these do not work, the company oys more radical measures. These more radical moves are seen as ıg necessary and functional as the company finds itself seriously ɜatened, and in greater need to find a significant performance ꞇovement to save itself [44].

Organizational Structure

Research and development activities have normally been performed way of the project or team approach. This approach is generally ıght of as hierarchial in nature with successive layers of decision ıority, each mindful of its own motives and goals. Reaction time ls to be lengthy, ideas are blocked, and essential details are lost their way up the organizational ladder. This has caused organizaıal members to be unimaginative and unable to cope with changing cumstances.

In the proposed R & D structure, general guidelines of policy and get are established by a central R & D manager. Within this struc- e exist several decentralized managers who are free to manage profit innovation centers. Power is distributed equally among the mana- s; thus, communication is maximized, feedback is increased, the idity of information is greater and commitment to organizational ls becomes more intense [46]. The central manager's main duty is of mediation between the technical core and the other organizational isions and the external environment. Another advantage of this anic management system is the elimination of levels of command [15]. ı manager reports to the central R & D manager without passing ough a series of filters. This facilitates a two-way flow of ormation, decreases the absorption of uncertainty, and allows ıings of change or crisis to be perceived sooner [49]. Other 'antages include the benefits of increased lateral communication, :cess through diversity rather than conformity, and an increased ›bability of decision-making which recognizes innovative opportunitie

Descending from the overall organizational structure of an R & D 'ision to the organization of its components, it is known that indi-.uals are more creative than groups. The reason for greater crea-'ity is that even in a group of two, one must compromise, adjust, l get along wtih the other person if any progress is to be made. As : size of the group increases, the necessity to discard ideas based y on intuitive feeling increases. It has been suggested that if the ject approach must be implemented, due to the magnitude of the igned task, the size of the project teams should be as small as sible to minimize the need for compromise. These small teams could low different paths, rather than just one, to afford a greater bability of success [56].

Despite evidence favoring individual creativity over group ativity, there is also evidence that specially trained creative ups drawn from throughout the organization can serve as catalytic nts with each other, and with others in the organization. They can p to change attitudes, shape the thinking, and infuse their enthu-sm in the rest of the organization. Another group serving a similar pose is a small basic research element. Even though the work of the anization is in applied research, a basic research element can serve an additional stimulus [56].

Organizational Leadership

In no other form of business is leadership as important and fficult as in R & D. Men just cannot be commanded to produce new ventions on a given schedule. The qualifications of an R & D leader e both technical and managerial in nature. Lacking a technical ckground, he will not be able to understand the technical jargon, ich will cause a loss of respect of the people he is supposedly ading. On the other hand, he must possess all the normal management ills to cope with the realities of the exterior organization [56].

Functionally, the R & D manager serves as a buffer between his own vision and the remainder of the organization, walking the narrow line tween fighting management to protect researchers, or giving in to nagement and risking damage to research. The leadership he exerses must be both participative and supportive to secure maximum eativity.

In the organic management system, leadership will be democratic, ualitarian, permissive, and group-oriented. The central R & D nager will provide general rather than close supervision and his ncern will be the effective use of human resources through participan. In this leader-member relationship, the position of leadership uld be molded to fit the leader. The central manager will be ationship oriented, and will derive his major satisfaction from ablishing close personal relations with his group members [33].

Finally, it will be the central manager's responsibility to steer least some of the project groups toward the dominant competitive ues, and to integrate these groups with other divisions in the anization [47]. In this same vein, the manager will attempt to keep

R & D department at the nexus of several necessary streams of ion, ready to react to contingencies in the environment. This can accomplished through opportunistic surveillance, a monitoring avior which does not wait to be activated by a problem, and which, refore, does not stop when a problem solution has been found [63].

Organizational Stress

The next organizational aspect to be considered in connection with ativity is that of stress. The literature is rather clearly divided two groups concerning the importance of stress. One side says the best thing to do is leave the researcher completely alone; the er states that the pressure of deadlines, competition from other panies, or the desire for recognition are excellent incentives. On ser examination, it appears that the basic researcher imposes his stress by his pressing curiosity and innate need to solve the blems he himself sets up [64].

To aid the basic researcher, the creative atmosphere should be e from excessive external pressure. A person is not likely to be ative if too much hangs on a successful outcome of his search activis, for he will have a strong tendency to accept the first satisfactor ution. Thus, he needs indulgence in time and resources, and particuly in organizational evaluations of his activities.

In the field of applied research, it appears that the researcher s react favorably to an optimal external stress level when the stress of certain well defined acceptable types. Any stress imposed by a nt for position and status rather than the job obviously detracts

the effort as does concern over budget cuts, administrative
.ls and organizational structures [49].

The stress that does seem to pay off is that occasioned by peer
ıs, competition with other similar groups, and stress coming from
:ification with overall organizational goals. Also, optimal levels
›nflict can stimulate innovation. A healthy level of conflict
:ates problems and uncertainties and diffuses ideas. Conflict
.es pluralism and forces coping and search for solutions, whereas
ːntrated authority can simply ignore obstacles and objectives.
ıal conflict, therefore, encourages innovations [64].

In summary, instead of the usual extrinsic organizational rewards
ıcome, power, and status, rewards most conducive to innovation will
from a satisfactory search process, professional growth, evalua-
in terms of publications, and the esteem of knowledgeable peers.
ı intrinsic rewards, the researcher should respond more favorably
:ises because he will feel closer to them.

Organizational Communication

Another facet of creativity related to organization is a structure
ɟned to aid communications. By nature, a researcher is not likely
ːek contact with other members of the organization as he is more
ıt up in his specific task, and tends to be thoroughly involved in
It is only through briefing on the overall aims of the organization
he can be expected to develop a larger view.

Also, committees of scientists should be invited to observe the
ɾities of the R & D department in an attempt to establish symbiotic
:ions with R & D departments of other organizations. On an even

ger scale, communication channels can be opened to research and keting firms, universities, governmental agencies, and other impor- t information producing and distributing agencies. These strategies uld be used to increase advance information, which should increase g-run viability by adapting to changing environmental contingencies. se are only a few ways of achieving organizational goals, but effec- ely used, they can further creativity by showing specific needs and eloping optimal levels of stress through competition [62].

Probably the most important aspect of organizing for communications to allow the R & D groups to report directly to the authority with power to approve projects and allocate funds. If each of the pro- t teams must report through numerous layers, none of which can rove, but each can disapprove, then creativity is obviously stymied. principal effort involved in acceptance of a new project becomes t of attempting to pass it along through channels, and defending it each step of the way. This leaves little time or enthusiasm for elopment of other ideas.

Finally, no matter how competent an R & D division is, it must ll cope with a lack of understanding or even suspicion on the part the rest of the organization. The R & D division turns out no ognizable product on a regular basis. Showing results for funds ended is a difficult process, and after awhile, top management ins to get nervous. Therefore, a component essential to the organi- ional structure is the interest and understanding of top management. order to understand what is going on, top management should make ular visits to their R & D division to find out what work is being e, and evaluate it at first hand. These visits have a double benefit the point of view of the researcher. They acquaint the researcher company objectives, and in many cases the direct suggestions of ıanagers are the greatest stimulus to the creativity of the ırchers [56].

Administrative Services

Final considerations on internal organization center on the ınce of an administrative services unit and experimental facilities. or complaint of scientists is the time required for non-scientific ities such as reports and records. An administrative services .on can absorb many of the requirements normally passed on to scien-. However, the best practice would be to reduce administrative to an absolute minimum. The presence of a pilot facility is also ıportance in aiding creativity. Otherwise, many ideas might be ted as too costly or infeasible. The ability to prove out a con- will be a strong boost to the perseverance of those whose creative are so radical that they might otherwise be discarded [56].

External Organizational Factors

In addition to overall commercial success and success of the prise, the feedback of success to the individual researcher or rch team must be assured by some type of product development group dividual to help the new innovation along the way. Organiza- lly, this can be achieved by a new product team composed originally e research team. As the innovation or product develops, the tists would be replaced gradually by engineers or production men, n an increasing number of personnel from the marketing division, il all of the scientists were phased out.

Another solution would be to pass control of pilot facilities hin the R & D division to a new product group until the product was ven and full scale production assured. Another solution would be establish a small, new company to exploit the product. This company ld be owned in large part by the R & D division. Additional ideas lude a staff group at corporate levels, a top executive with authorit cut across channels, individual researchers as entrepreneurs, or ally, an overall research coordination committee. This last group ld provide another key to success by ensuring that all parts of the anization were planning for change, and prepared to accept it when it e [56].

Summary and Conclusions

The application stage of the R & D planning model was developed for purpose of describing an organizational environment in which results ained from the R & D planning model will maximize the company's long ge planning effort. Also, this stage can be useful in understanding technological innovation is managed effectively. One can hypothe- e that an economic environment in which needs are clearly defined, opposed to being heterogeneous or diffuse, will tend to stimulate hnical innovation in firms. Similarly, mechanisms which communicate ds or change the perception of needs by firms, contacts with custo- s and competitors, and efforts toward product planning and need essment will stimulate innovation.

On the other hand, successful innovation will be enhanced by an ironment of technical information in which information is available ally in easily accessible form, in which discussion is encouraged, in which at least some key members of the firm have wide-ranging sonal and/or reading contacts with outside technical information rces. In general, it appears that the greater the degree of communi- ion between the firm and its environment at each stage of the process innovation, the more effective the firm will be in generating, eloping and implementing new technology [67].

With respect to internal systems transfer characteristics, it ears that diversity in work assignments and environment as well as elopment of individuals' skills in the synthesis of diverse stimuli l encourage the generation of new ideas. Concentration in one tech- al or problem area, maintenance and development of technical skills hin the firm, and clear communication of project demands and respon- ilities apparently tend to improve chances of success in problem ving. Explicit provision for internal linkage between phases in the ovative process and functions within the firm seems to be a critical tor in complex and rapidly changing technical and economic environ- ts in determining the firm's effectiveness in innovation [67].

In closing, it should be emphasized that there is "no one best " for designing and managing innovative organizations. There are a e variety of appropriate organizational designs, relationships ween variables and subsystems, and management practices. It all ends on the particular circumstances in a specific situation.

CHAPTER XI

CONCLUSION TO THE RESEARCH AND DEVELOPMENT PLANNING MODEL

The Research and Development Planning Model as a Subsystem of Long Range Planning

Long range corporate planning is a highly personalized and sub-:ive activity through which a company charts its future course of .on. The particular approach taken to planning must be sensitive :he nature of the company's business and its environmental setting, organizational structure, its position relative to competitors, its ›urces and capabilities, and its own style of management.

The proposed R & D planning model has been developed as a ;ystem of the total long range planning process. The model has ı tailored to the needs of a company subject to high rates of tech-›gical change, and is composed of a network of interrelated sub-:ems, each subsystem contributing to the efficiency and improvement :he R & D function, and therefore the company profit and growth.

Problem Areas in Research and Development Planning

Even among companies that have engaged in long range R & D planning : a number of years, it is frequently the case that the practice does measure up to its potential. Most of the difficulties encountered

.l into one of three categories: (1) insufficient interrelationship :ween top management and the R & D planning effort; (2) unwillingness take R & D planning seriously; and (3) inadequate performance in the ; D planning process itself. Specific problem areas, arranged roughl} order of decreasing frequency and importance, are listed below.

ɜufficient Top Management Support

Research and development planning requires top management involve- ıt and support on a continuing basis, and a consistent management ientation toward the long range point of view in the face of recurrin‹ ɔrt term crises is essential. It is important that good three-way mmunication be maintained among top management, operating management, d the R & D planning staff, if long range planning is to be timely, alistic, effective, and oriented toward the objectives of the mpany [69].

adequate Line Involvement

Operating management must be committed both to the development d to the implementation of realistic and challenging R & D plans. ch commitment becomes particularly difficult if too much emphasis placed on short term operating performance. Line management must willing to share its problems and its aspirations with the R & D anning staff [69].

ck of Relevance

Research and development plans should be addressed to the problems at confront the firm and to the firm's long range objectives. It is

l too easy for R & D planners to lose contact with the realities of
e business [69].

ck of Direction

Indecisiveness and vacillation among successive long range R & D ans may reflect inadequate or conflicting objectives, or a failure communication from top management as to what are the actual objecves. Special studies of strategically sensitive areas may be cessary [69].

ck of Realism in the Plans

This may stem from inadequate forecasting and insufficient infortion used as input to the R & D planning process, weakness in alytical reasoning, a general lack of objectivity, or insufficient tention to the practical politics of corporate organization [69].

sufficient Recognition of Contingencies

No matter how excellent the environmental forecasting may be, re is always the possibility that events will turn out to be ferent than anticipated. The development of alternate plans and ging maneuvers may be indicated. Plans should be used with due ard for the uncertainties involved. It is all too easy to extrapte both internal and external trends without making conscious ices among future alternatives and considering the underlying errelationships among the factors involved [69].

ıadequate Feedback and Control

Control of long range R & D plans is more than a question of how əll the plans prove out in practice; it also includes the larger ıestion of how well the plans carry the company in the direction of :s long range objectives. Effective R & D planning cannot be done on piecemeal basis, nor without integration and feedback among the majoı ɔmponents of the total long range planning system. In terms of goal-:iented planning, the total has more meaning than the sum of its ırts [69].

ɔo Much Attention to Detail

A penchant for detail in long range R & D planning is not only a .ste of time and effort, but can obscure important trends and under-.ne confidence. Also, too much emphasis on achieving the precise ːsults shown in the R & D plan tends to undermine creativity and causɛ ccessive plans to be less challenging [69].

Conclusions

Within a company, R & D is undertaken in the expectation that the jectives of the company will be realized sometime in the future. The lue of R & D to the company will not, therefore, be measurable until product, process, or service is being sold on a significant scale and a price which meets the company's commercial objectives. Research d development is, therefore, the first stage in a complex industrial ɔcess; the time taken to carry out the research and development is portant to the company's goals, but not more important than the time en by the other components of the process (engineering, manufacturing marketing).

From this, a number of conclusions can be drawn. First, R & D is , but only one, of the essential components of a company's long ge plan to expand or defend the markets for its products. Second, h of the uncertainty which is believed to attach to R & D arises ause it is at the beginning of a long innovative process, not because the peculiar nature of R & D itself. Lastly, the R & D manager has easy means of shortening lead-times in other parts of the innovative cess. The responsibility for timing control of the total process s with the central management, and any effective long range plan essarily pays particular attention to this.

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VITA

Warren L. Edmundson

Candidate for the Degree of

Master of Business Administration

ıesis: AN INTEGRATED RESEARCH AND DEVELOPMENT PLANNING MODEL FOR A COMPANY SUBJECT TO HIGH RATES OF TECHNOLOGICAL CHANGE

ıjor Field: Business Administration

.ographical:

Personal Data: Born in Stillwater, Oklahoma, February 17, 1947, the son of Arthur B. and Rose Marie Edmundson.

Education: Graduated from C. E. Donart High School, Stillwater, Oklahoma, in 1965; received the Bachelor of Science degree from Oklahoma State University, with a major in pre-medical science and microbiology, and a minor in chemistry, in May, 1971; engaged in graduate study toward the degree of Master of Business Administration, with a major in finance, at Oklahoma State University, Stillwater, Oklahoma, from June, 1972, to the present.