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EVALUACION DEL PERSONAL DOCENTE

CURSO: "PRONOSTICOS TECNOLOGICOS Y PLANEACION ESTRATEGICA"

FECHA: 16, 18, 23, Y 25 DE MARZO/1982

CONFERENCISTA	DOMINIO DEL TEMA	EFICIENCIA EN EL USO DE AYUDAS AUDIOVISUALES	MANTENIMIENTO DEL INTERES. (COMUNICACION CON LOS ASISTENTES, AMENIDAD, FACILIDAD DE EXPRESION).	PUNTUALIDAD	
1. M. EN I. ARTURO GARCIA TORRES					
2. M. EN I. ENRIQUE MEDINA RAMOS					
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ESCALA DE EVALUACION: 1 a 10					

EVALUACION DE LA ENSEÑANZA

SU EVALUACION SINCERA NOS AYUDARA A MEJORAR LOS PROGRAMAS POSTERIORES QUE DISEÑAREMOS PARA USTED.

	TEMA	ORGANIZACION Y DESARROLLO DEL TEMA	GRADO DE PROFUNDIDAD LOGRADO EN EL TEMA	GRADO DE ACTUALIZACION LOGRADO EN EL TEMA	UTILIDAD PRACTICA DEL TEMA	
1.	PLANEACION ESTRATEGICA					
2.	INFORMACION INDUSTRIAL					
3.	PLANEACION TECNOLOGICA					
4.	PRONOSTICO TECNOLOGICO					

ESCALA DE EVALUACION: 1 a 10

EVALUACION DEL CURSO

CONCEPTO		EVALUACION
1.	APLICACION INMEDIATA DE LOS CONCEPTOS EXPUESTOS	
2.	CLARIDAD CON QUE SE EXPUSIERON LOS TEMAS	
3.	GRADO DE ACTUALIZACION LOGRADO CON EL CURSO	
4.	CUMPLIMIENTO DE LOS OBJETIVOS DEL CURSO	
5.	CONTINUIDAD EN LOS TEMAS DEL CURSO	
6.	CALIDAD DE LAS NOTAS DEL CURSO	
7.	GRADO DE MOTIVACION LOGRADO CON EL CURSO	

ESCALA DE EVALUACION DE 1 A 10

1. ¿Qué le pareció el ambiente en la División de Educación Continua?

MUY AGRADABLE	AGRADABLE	DESAGRADABLE

2. Medio de comunicación por el que se enteró del curso:

PERIODICO EXCELSIOR ANUNCIO TITULADO DIVISION DE EDUCACION CONTINUA	PERIODICO NOVEDADES ANUNCIO TITULADO DIVISION DE EDUCACION CONTINUA	FOLLETO DEL CURSO

CARTEL MENSUAL	RADIO UNIVERSIDAD	COMUNICACION CARTA, TELEFONO, VERBAL, ETC.

REVISTAS TECNICAS	FOLLETO ANUAL	CARTELERA UNAM "LOS UNIVERSITARIOS HOY"	GACETA UNAM

3. Medio de transporte utilizado para venir al Palacio de Minería:

AUTOMOVIL PARTICULAR	METRO	OTRO MEDIO

4. ¿Qué cambios haría usted en el programa para tratar de perfeccionar el curso?

____

____

____

5. ¿Recomendaría el curso a otras personas?

SI	NO

6. ¿Qué cursos le gustaría que ofreciera la División de Educación Continua?

____

____

7. La coordinación académica fue:

EXCELENTE	BUENA	REGULAR	MALA

8. Si está interesado en tomar algún curso intensivo ¿Cuál es el horario - más conveniente para usted?

LUNES A VIERNES DE 9 A 13 H. Y DE 14 A 18 H. (CON COMIDAS)	LUNES A VIERNES DE 17 A 21 H.	LUNES, MIERCOLES Y VIERNES DE 18 A 21 H.	MARTES Y JUEVES DE 18 A 21 H.

VIERNES DE 17 A 21 H. SABADOS DE 9 A 14 H.	VIERNES DE 17 A 21 H. SABADOS DE 9 A 13 Y DE 14 a 18 H.	O T R O

9. ¿Qué servicios adicionales desearía que tuviese la División de Educación Continua, para los asistentes? ______________________________

____

10. Otras sugerencias:

____

____

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DIVISION DE EDUCACION CONTINUA
FACULTAD DE INGENIERIA U.N.A.M.

C U R S O : "PRONOSTICOS TECNOLOGICOS Y PLANEACION ESTRATEGICA"

DENTRO DEL PROGRAMA DE SUPERACION ACADEMICA DE LA FACULTAD DE INGENIERIA DE LA U. N. A. M.

M. EN I. ENRIQUE MEDINA RAMOS.
M. EN I. ARTURO GARCIA TORRES.

DEL 16 AL 25 DE MARZO DE 1982.

SEMINARIO DE

PLANEACION TECNOLOGICA

FACULTAD DE INGENIERIA

UNAM

PREPARADO POR:

ING. GILDARDO VILLALOBOS

ING. ARTURO GARCIA TORRES

ING. ENRIQUE MEDINA RAMOS

MARZO/1982

LECTURAS SELECTAS

PLANEACION ESTRATEGICA

Documento 1.- A National Strategic Planning Model Bar-Zakay, Long Range Planning, August 1981.

Documento 2.- The Frontiers of Strategic Planning: Intuition or Formal Models?, Fox H., Management Review, April 1981.

Documento 3.- Strategic Planning: Tapping the Engineer's Know-How, Zimmerman Mark, Machine Design, August 9, 1979.

Documento 4.- Understanding the Forces of Strategic and Natural Competition, Henderson Bruce, Journal of Business Strategy, Winter, 1981.

INFORMACION INDUSTRIAL

Documento 5.- La Función de Información Tecnológica, Medina Enrique, Documento interno, Octubre 5, 1981.

PLANEACION TECNOLOGICA

Documento 6.- Generating Effective Corporate Innovation, Roberts B. Edward, Innovation/Technology Review.

Documento 7.- Users as Innovators, Van Hippel, Innovation/Technology Review.

Documento 8.- Metodologías para Investigar los Proyectos de Innovación, (Proyecto Sappho, Universidad de Sussex).

PRONOSTICO TECNOLOGICO

Documento 9.- Introducción to Technology Forecasting, Bright J.*

Documento 10.- Intuitive Forecasting, Bright J.*

Documento 11.- Trend Extrapolation, Bright J.*

(*) Del libro Practical Technology Forecasting Concept and Excercises, James R. Brignt, The Industrial Management Center, Inc., Austin, Texas.

A National Strategic Planning Model

Samuel N. Bar-Zakay, Director of Strategic Planning Advancement, Israel Aircraft Industries Ltd.

If we could first know where we are and whither we are tending, we could better judge what to do and how to do it.

Abraham Lincoln, 1858

Can nations choose among several possible futures, or is the future pre-determined on the basis of geographic, demographic, cultural, economic and political features? The author maintains that newly developing patterns may well change the traditional deterministic characteristics of society, and that it is possible for nations to be masters of their own future. This will depend on the development of sophisticated and democratic national planning processes.

Introduction

For various reasons, both the developed countries,[1] and the less developed countries[2] have during the last two decades become concerned with two important questions:

- What national image are we striving for in the long run?
- What must we do in the short run in order to achieve the desired image?

To answer these questions means to engage in a process of national strategic planning and to determine national priorities. Yet, this process is in its infancy.

A philosophical practical problem may be raised: Can nations indeed choose among several possible futures or is the future pre-determined on the basis of geographic, demographic, cultural, economic and political heritage?

There are indications in the literature that nations which differ drastically in their characteristics seem nevertheless to follow similar development patterns.[3] Yet it is possible that the aspirations of the recent 'possible futures movement',[4] the impact of the balance of terror,[5] and the call for a new International Economic Order,[2] coupled with new developments in science/technology[6] and social sciences,[7] will change some of the deterministic development characteristics of society. The recent divergence of energy consumption patterns of nations may serve as an encouraging sign of the possibilities.[8]

Just as important is the possible analogy between the development of national character and that of human character. It is by now established that a human character is to a great extent determined during the very early years of life. Is that true for nations as well?

This question is far from theoretical for a country like Israel. Due to wars and other outside pressures, the Israeli politicians spend most of their time and resources dealing with short range foreign policy issues. In the meantime the nation is acquiring some characteristics which, to many people, are far from desirable (e.g. emigration of talented youngsters, lack of respect for the law, materialism, etc). If the analogy to human development holds, then neglect of concern for these issues today will not enable a change of the undesirable national characteristics in the future. The discussion of the latter philosophical questions is beyond the scope of this paper but it should be pointed out that the author is of the opinion that nations can be masters of their own future rather than it's slaves.

This optimistic non-fatalistic view will depend

The author was formerly Adviser for R[illegible] and Planning to the Prime Minister's Office, Government of Israel. The paper was written while the author was a Visiting Professor of M[illegible] at the Graduate School of [illegible] University of [illegible]. [illegible] should not be interpreted as reflecting the views of the Israeli Government or Israel Aircraft Industries Ltd. The author's address is 42 Tagore Street, Tel Aviv, Israel.

It is claimed that all economic, technological and social activities are aimed at satisfying these 13 social needs. Put differently, there are some basic social activities which are present in all societies and are permanent. Hence, they provide a useful raw material for the national strategic planning model.[16] The definitions of the 13 functional domains are given here in the Appendix.

The analysis calls for* aggregating SIC (Standard Industrial Classification) information according to the definitions of the functional domains. This is far from an easy task. Certain industrial products, economic activities and the like can easily be categorized as belonging to one functional domain or another. For example, all the food items belong to the Food Domain. Yet there are certain items, such as raw materials that cannot be placed in one domain or another before a careful search is conducted (with the aid of input/output tables) to find out which function they serve. For example, chemicals which are used in the food industry will be included in the Food Domain, while chemicals used in fuel will be included in the Energy Domain. After laborious work all industrial and economic activities will be classified into the 13 Functional Domains.

Researchers have for long found the functional analysis to be a useful one. Functional notions were used by the pioneers of modern Anthropology and Sociology. Emile Durkheim, W. Robertson Smith, Bronislaw Malinowski, A. R. Radcliffe-Brown and others.[17] 'The functional view insists upon the principle that in every type of civilization, every custom, material object, idea and belief fulfills some vital function, has some task to accomplish, represents an indispensable part within a working whole.'

The analysis of the functional domains will also attempt to show that in the long term the industries of the future will organize along the 13 Functional Domains. This discussion will be included in a separate paper.

The essence of the model is shown in Figure 1* labelled Determination of Priorities. (For the sake of simplicity only 3 domains are shown in Figure 1 rather than 13.) The model calls firstly for finding out the Domains Mix in the Gross National Product 'GNP' of a nation in the past and present. Next, through careful analysis of past trends of this mix (with the aid of Input/Output Tables) an attempt is made to determine what the mix would be 20 years hence, say in the year 2000. These figures are marked in Figure 1 as 2000A.

The aim of the process is to determine through the use of the model a desired mix for the year 2000. This is marked in Figure 1 as 2000B. Although the mixes in Figure 1 represent absolute values it should be obvious that one is interested mostly in the orders of magnitude, relative values and directions of change.

The national priorities emerge from the desired mix (Figure 1): In the example Domain 3 is of high priority while Domain 1 is of low priority.

The main question is what criteria should be used in order to decide upon the desired mix? The criteria should be based on the overall objectives of the national strategic planning process which are:

(1) Achieve long term national goals.

*As will become clear hereafter, the Functional Domain can be described in other dimensions as well. For example, the allocations in the national budget may be aggregated according to the Functional Domains, etc.

*Figure 1 is an enlargement of one box from Figure 3. It is shown first so that the reader will become aware of the essence of the process before plunging into the methodological details.

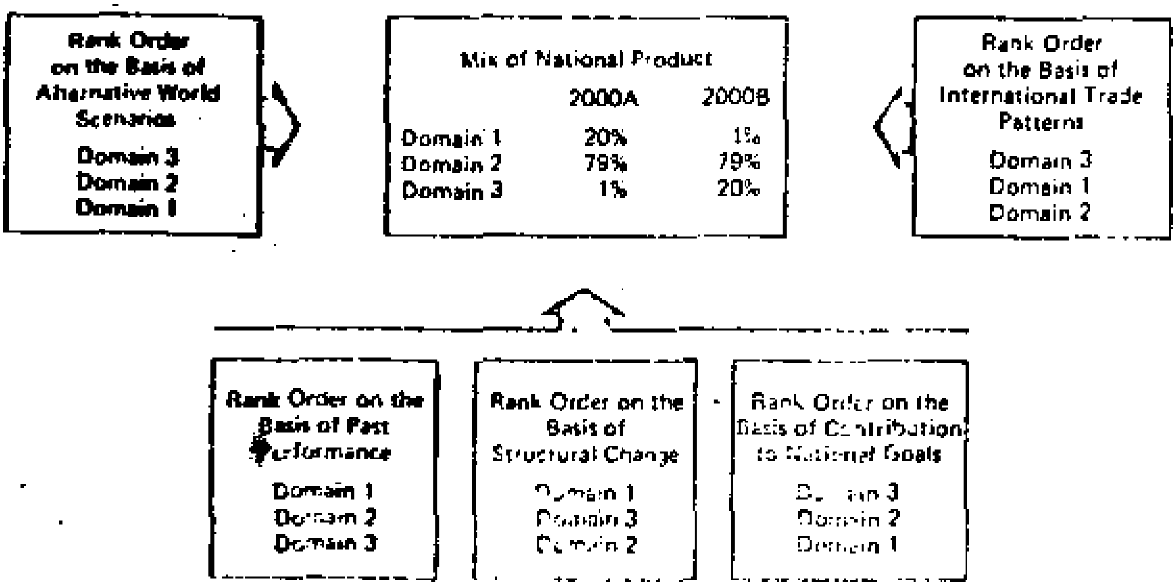

Figure 1. Determination of priorities: Example with three domains

(2) Improve the efficiency and effectiveness of national resource utilization.

(3) Reduce the need for national crisis management.

These objectives are translated to operational criteria. Five such operational criteria are shown in Figure 1. These are:

(1) Rank order on the basis of contribution to national goals.

(2) Rank order on the basis of past performance.

(3) Rank order on the basis of structural change.

(4) Risks/opportunities balance on the basis of international trade patterns.

(5) Risks/opportunities balance on the basis of alternative world scenarios.

The usage of these five criteria will be described in the following pages.

The Five Criteria

The first criterion calls for a list of National Goals. Such a list, as is well known, is quite scarce in all nations. The analysis is to put together such a list, which could later on be changed through public discussion. Several indicators for each national goal are chosen and their development over time is recorded, preferably, with comparisons to other nations.[14] Next, a matrix is constructed in which the goals constitute the rows and the 13 Functional Domains constitute the columns. Such an example for the State of Israel is given in Figure 2. Using the Delphi Procedure,[15] teams of experts, public representatives and decision makers, after careful [illegible]

National Goals	[illegible]	Indicators	1	2	3	4 Defence	5 Education	6	7	8 Energy	9	10	11 Tourism	12	13
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 2. [illegible]

preparation are asked to fill in the cells of the Matrix row by row. They are asked to address the following question: Assuming that the same amount of resources will be invested in each
4 Domain, what would be the relative contribution of each Domain, to the specific National Goal? (The answer could be given in a ranking of − 10 + 10.)

It turns out that different Delphi teams translate the word 'investment' to different terms. One group may use capital investment. The other may consider investment in professional/qualified personnel. Another, input of technology and yet another a combination of all the three types of investments. But in each case each group uses an identical criterion for all the domains and for the total matrix.

After the 325 cells are filled by every responder, and there are usually 30 answers for every cell, the median of every cell is calculated and is entered in the final matrix. The medians for each column are summed up and thus a basic rank order of the Functional Domains is achieved, assuming that all the national goals have the same weight.

In a subsequent stage, groups of decision makers are asked to give weights (Wi in Figure 2) to the national goals. The medians of these weights are then used as multipliers for all the medians in all the cells in each row, and a new summation is performed in all the columns. In this way a new rank order of the Functional Domains is arrived at, which takes into account the value judgments of the decision makers.

Two theoretical points regarding this procedure will be clarified here: one concerning Arrow's work and the other relating to possible manipulations of the input data.

The above procedure does not satisfy the four conditions of the General Possibility Theorem of Arrow,[20] but it certainly satisfies the Pareto principle. It is believed that the proposed procedure, making the choices explicit and the discussion focused, is an improvement over existing government decision processes. As Sen has put it,[21] "Purity is an uncomplicated virtue for olive oil, sea air, and heroines of folk tales, but not for systems of collective choice."

The reader is also aware that for the final 'social welfare function' (in the terminology of the latter two references) namely for the determination of the 'functional domains' mix in the GNP, no formal procedure is proposed.

Manipulation of the input data may be of two types. The first type concerns the relative contribution of the Domains to each national goal. A responder may color his judgement in a way which will increase the contribution of his Domain of choice. His explanation for being outside the interquartile range may be that since the Functional Domains are defined in broad terms he was thinking, for example, of a capital intensive Domain rather than labour intensive one. This type of manipulation can be overcome by conducting several rounds of the Delphi and/or by specifying in advance a more exact nature of the Functional Domains in the particular nation concerned.

The reader may be interested to know that preliminary tests of this procedure, namely of filling the 325 cells (without giving relative weights to the national goals) indicate that the rank order of the Domains with different Israeli groups was found to be quite stable.

The second type of possible manipulation of the input data involves the relative weights of each national goal. A responder (e.g. a politician) may give a higher weight than he himself believes in, to his goal of choice in order to advance it. This manipulation can be overcome, by modifying the traditional Delphi's anonymity rule and by calling (in advance) every responder to defend his relative weights in the open. Admittedly such a procedure does not seem to be realistic with todays' politicians who make every possible effort not to commit themselves to anything and to keep all their options open. It is therefore necessary to insure that among the responders the whole spectrum of political opinions will be represented.

The second criterion calls for rank ordering the Domains on the basis of their past performance in the particular nation. Although this criterion is quite self-evident, a variety of sub-criteria can be used here. In the case of Israel the sub-criteria are:

(1) Added value per employee.

(2) Added value per unit of capital invested in fixed assets.

(3) Export percentage of total output.

The third criterion calls for Rank Ordering the Domains on the basis of the structural change induced by increasing or decreasing their share in the mix of the national economy. Although the wording structural change has a specific meaning in economic literature,[22] the meaning of this criterion is quite simple. It calls for an estimation of the difficulties associated with increasing or reducing the share of each domain in the GNP mix. When one attempts to move 50,000 workers from one economic activity to another, these people may have to move from one location to another, sell their homes, make new friends, etc. This could be viewed as social cost as opposed to the social benefit of achieving the national goals. Through the construction of an input/output table including the domains, it will become possible to determine quantitatively the structural change in the economy associated with the change of each domain. (See the following chapter on The Methodology.)

The fourth criterion calls for finding out the balance of risks and opportunities to the nation on the basis of international trade patterns.

The analysis calls for aggregating all the commodities involved in international trade into 13 Functional Domains. It further calls for trend extrapolation of the growth patterns in constant prices with subsequent perturbation of these trends when additional information will become available from the fifth criterion. Preliminary analysis has shown that due to the high aggregation of the commodities, the international trade trends of domains exhibit stable patterns over long periods of time and can be rank ordered on the basis of their growth rates. In the final stage of this analysis the Functional Domains are rank ordered on the basis of the balance of risks and opportunities posed by the international trade patterns.

The fifth criterion calls for analysing a multitude of alternative world scenarios with subsequent analysis of the risks and opportunities which they pose for each domain in the specific nation concerned. Sophisticated tools for developing such alternative scenarios have been developed during the last decade, such as Cross-Impact Monte Carlo Simulations.[13]

Here again the Functional Domains are finally rank ordered on the basis of the balance of risks and opportunities posed by forecasted/assumed alternative world scenarios.

The information accumulated during the analysis of the five criteria constitutes the preliminary "agenda for discussion" mentioned earlier.

The Methodology

The Schematic Diagram of Methodology is shown in Figure 3. In reading the following pages the reader will find it useful to refer to this figure. Ten levels are shown from bottom to top and these should be followed in this order. In the first level the objectives of the process are defined. In the second level six groups of constraints on the process and on the research are listed. These must constantly be kept in mind:

1. The scarcity of national strategic planning models in the professional literature.

2. Limitations due to the inter-disciplinary nature of the analysis. Everything seems to be relevant when discussing National Priorities and one has to develop a logical filter such as the one presented here.

3. Limitations connected with the limits of scientific knowledge: socio-economic forecasting is today not yet a science, but an art.[14] Nevertheless there are scientific tools which could be useful in achieving the objectives of the process and the analyst must identify these tools and the methods for using them.

4. Limitations of data: national and world. Not all the data necessary for determining national priorities is available and the data which is available is not always in the form which enables international comparisons. During this study there was a need, for example, to develop concordances between the various economic classifications used by various organizations. These are described in Figure 4. It shows concordances between SITC which stands for Standard International Trade Classification, BTN, which is the Brussels Trade Number System, ISIC, the International Standard Industrial Classification and the Israeli Standard Industrial Classification, etc.

5. Limitations of Time and Resources indicate that once the decision maker has agreed to search for national priorities, he will probably be inclined to ask for the results (yesterday) without consideration for the conceptual and technical problems facing the research.

6. Limitations imposed by social reality indicate the well known fact that priorities based solely on rational inputs will probably be difficult to implement.[15] The analyst must accommodate and include different values of different decision makers, etc., as was described before.

Taking into account the limitations which were briefly mentioned above, a strategic conceptual framework is developed in the third level as is shown here in Figure 3. It is beyond the scope of this paper to discuss it in detail and it is almost self-explanatory.

The five criteria for determining the Mix of the Domains are the major output of the strategic conceptual framework and were described earlier. These dictate seven paths of analysis which are listed in Level 4 (Figure 3). Two assumption paths, one for the world and one for the nation. Two monitoring paths, one for the world and one for the nation. A quantitative analysis path, a qualitative analysis path and a creative path. The title Creative Path does not imply that creative work should not be performed in other paths. Rather it tends to emphasize that the development of the concept of the Functional Domains which is dominant in the Creative Path, is not based on any previous works or publications. This fact obviously has its virtues and drawbacks.

An analogy could, however, be drawn between the concept of Functional Domains and the concept of PPBS: Planning, Programming, Budgeting, Systems.[16] The analogy stems from special aggregations of existing data to ensure more meaningful decision making.

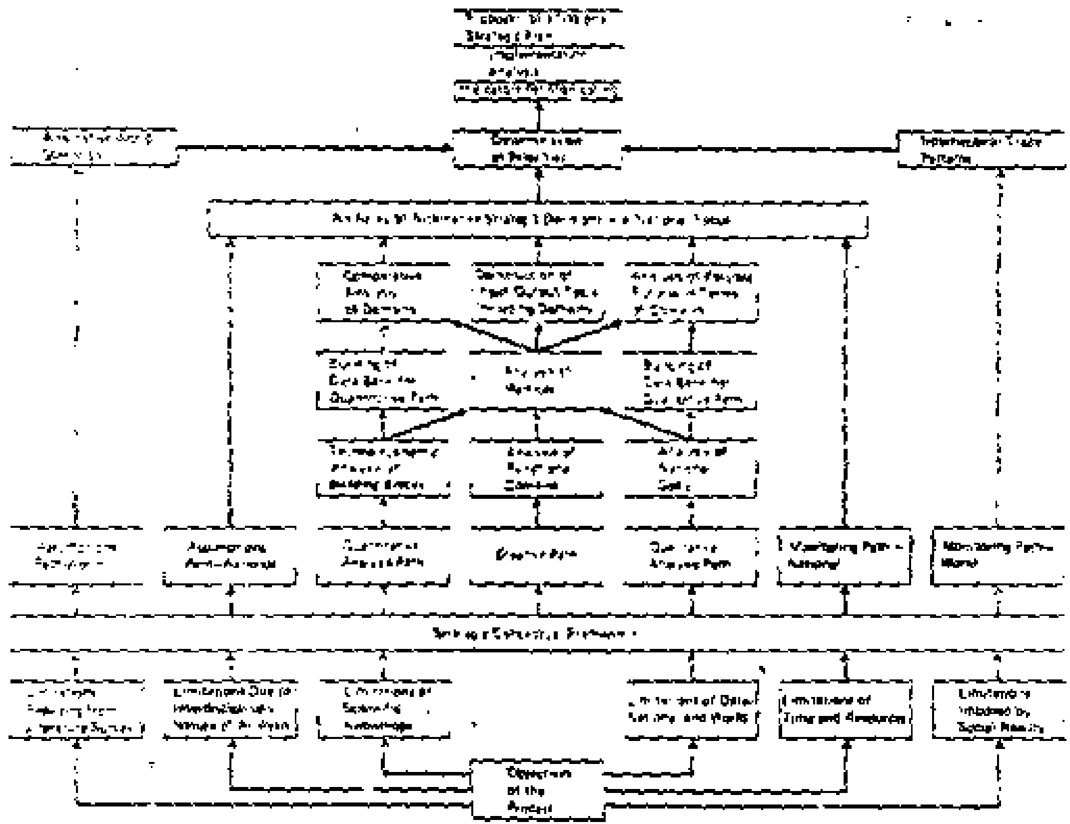

Figure 1. Schematic diagram of methodology

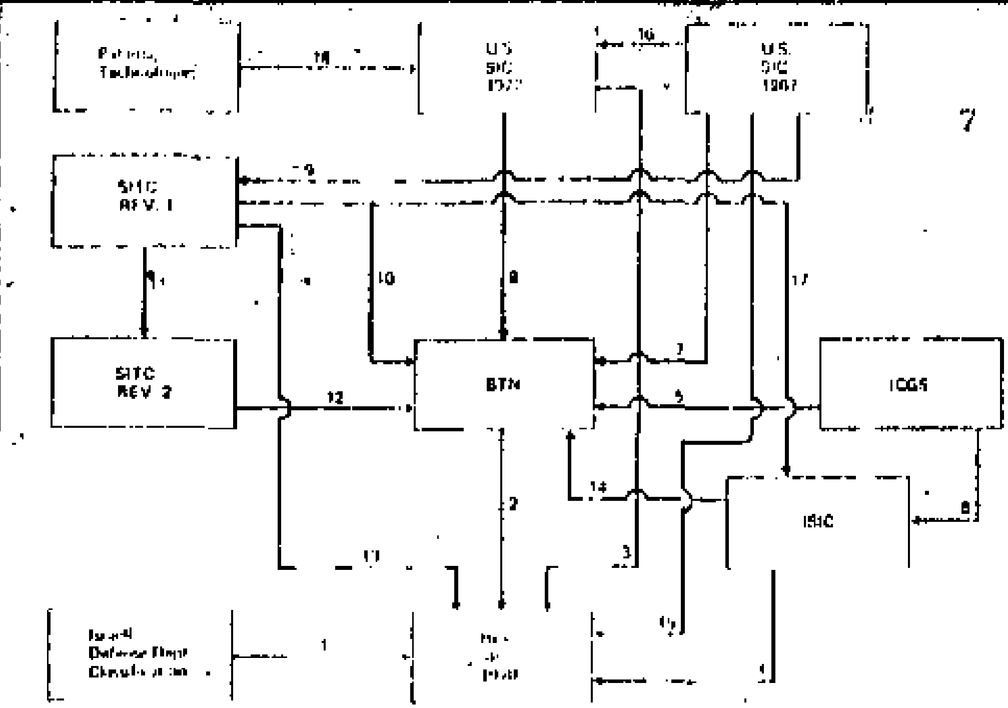

Figure 4 Relationships between various classifications

At the fifth level (Figure 3) three activities are carried out.

The preparation of a list of national goals, the choosing of indicators for each goal, analysis of the indicator's behaviour over time, international comparisons of the indicators, cross support interactions among the goals, etc. The latter is schematically shown in Figure 6. The analysis of the cross support inter-relationships is useful, but it should, however, be remembered that for the purposes of model the fact that some goals are inconsistent with others is not important. We say this because our main objective here is to use the goals as a means of discriminating between the domains. In a similar way Professor Dennis Gabor once said:[12] "Far be it from me to consider the IQ as fully characteristic or even very important in assessment of a man or a woman. ... But I find to defend the IQ as the only available quantitative measure of the inequality of men, as the expression of the fundamental fact that one man cannot be replaced by any other man." This point is an extremely important one and surpasses other important issues such as the question of constancy of the goals over time. It is quite possible that certain goals will change over time and new ones will appear in future generations. It is even more likely that the weights of goals in the eyes of the decision makers will change over time. Yet empirical evidence and philosophical arguments suggest that certain basic strategic decisions concerning the domains can be made. Furthermore, one should always keep in mind that one cannot be slightly pregnant: if one engages in strategic planning the decisions made will have advantages and disadvantages. It is shown in Level 10 how the disadvantages can be guarded against. Institutionalizing the process may also help in protecting the nation against surprises.

At the fifth level (Figure 3) the model also calls for techno-economic analyses of the building blocks. The building blocks are the familiar industrial and service branches which exist in every country, and are marked SIC or Standard Industrial Classification. These SIC's are chosen as building blocks for two reasons. Firstly all statistical data in all countries is aggregated along the SIC classification. Secondly the industries of the future will emerge from the industries of the present. The method of converting SIC information according to the definitions of the Functional Domain was explained earlier.

In the sixth level (Figure 3) data banks are constructed for the quantitative paths. The quantitative data bank in the case of Israel has some 500 variables broken down to 15 domains. These variables include export, import, number of employees, government subsidies, investments in

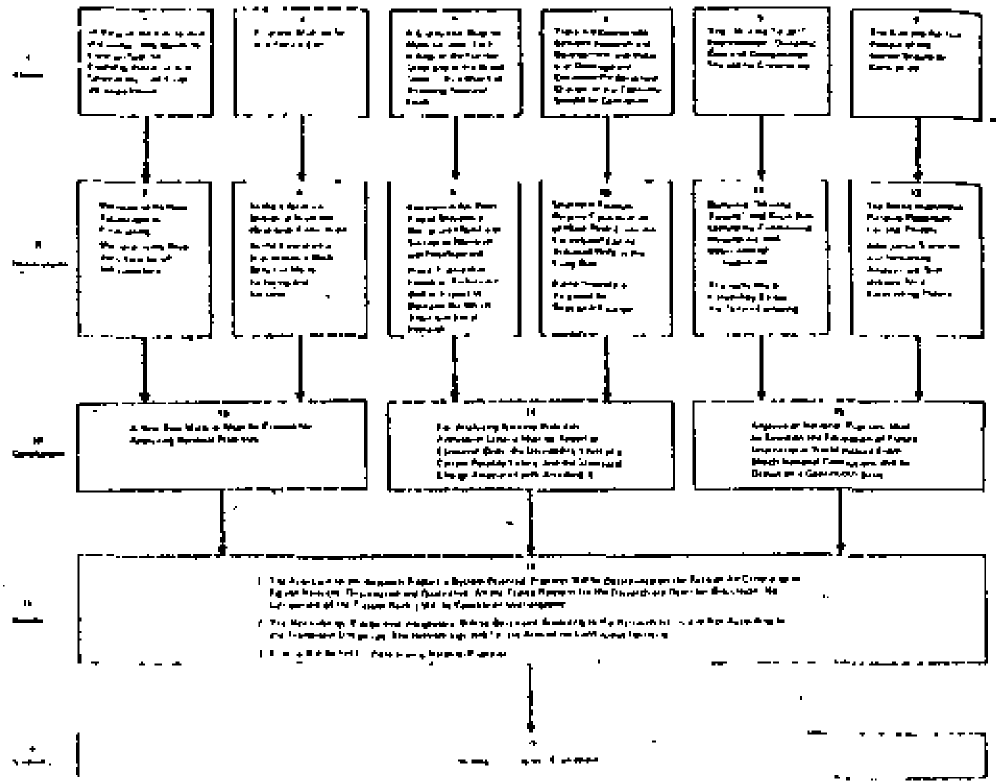

Figure 5: [illegible] conceptual framework

buildings and machines, investments in research and development, etc. The qualitative path's data bank contains data on the development of social indicators for the goals over time.

The most important work in level 6 is the analysis of matrices. There are two main matrices. One, the matrix of goals/domains, shown in Figure 2, and the other is the matrix of SIC's/Domains, which is shown in Figure 7. The latter calls up[illegible] experts opinions, knowledgeable about past and present trends as well as potential scientific, technological, economic and social breakthroughs in the future. It is clear that these experts should not be the ones who know a lot about narrow fields, but rather intelligent and travelled individuals with a strategic view.

In the seventh level (Figure 3) comparative analysis of domains can be carried out on the basis of the composition of SIC's in each domain. Also analysis of possible futures in terms of domains could be carried out on the basis of the relationship between the goals and the domains. In other words, increased share of one domain in the GNP Mix will mean the enhancement of certain societal achievements, on the basis of the goals/domains Matrix (Figure 2).

In the seventh level (Figure 3) another activity takes place, namely, the construction of the Input/Output Table including domains. This table is meant to serve three purposes. Firstly, to identify the inter-relationships among the domains. Secondly, [illegible] the structural change in the economy induced by increasing or decreasing the share of certain domains in the GNP mix. Thirdly, to identify the impact of alternative mixes of final uses of domains on the requirements for primary inputs. All this is shown schematically in Figure 8. The mathematical relationships are listed below:

[illegible]

Matrices [illegible] and B (Figure 8) come from available input-output tables. Matrices C, D, [illegible] have to be estimated [illegible] of the information [illegible] from Figure [illegible] [illegible] is [illegible] [illegible]

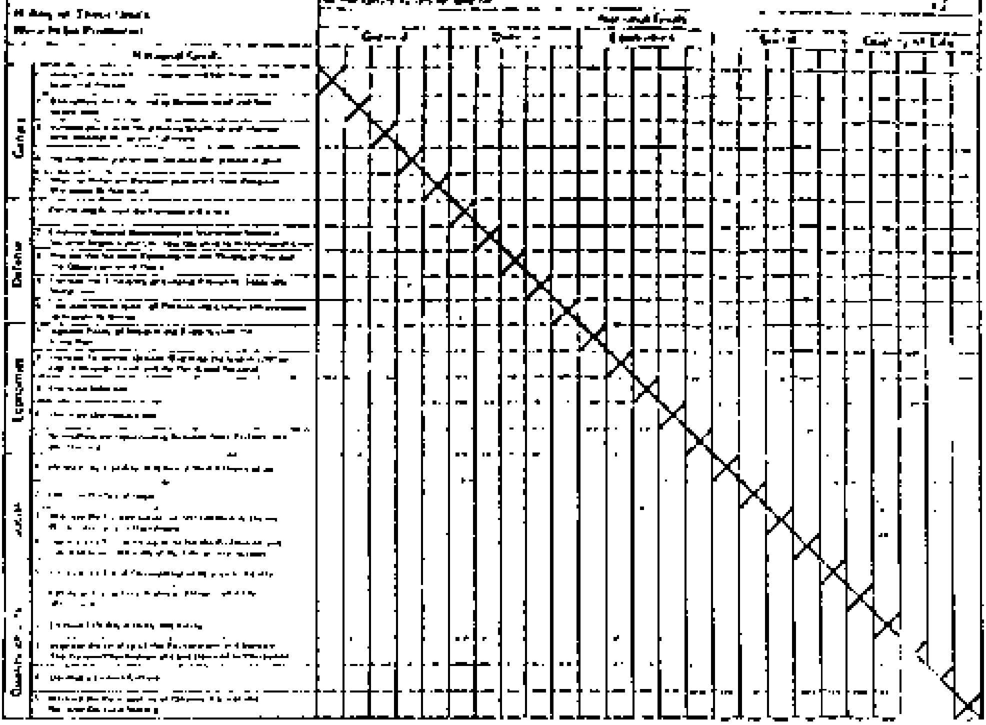

Figure 6. Cross support worksheet—goals

Figure 8. This means that we imagine that no SIC will be selling directly to final demand, but that only domains will be selling to final uses. This argument is consistent with the whole model described here, which attempts to look at the world through the eyes of the 13 Functional Domains. In Vector g we insert normatively the alternative final uses of domains, and perform sensitivity analysis.

On the eighth level (Figure 3) an array of alternative strategic decisions with a national focus will emerge. These will be further clarified by inputs from the Assumptions Path (National (for example, in the case of Israel peace between Egypt and Israel) and from the Assumptions Path (National (for example, in the case of Israel do the oil explorations indicate the possibility of easing the dependence on foreign oil or not?).

Yet the national focus is not enough for the determination of national priorities. In the ninth level (Figure 3) the interactions of the nation with the world are analysed. It has two major elements. One is concerned with the trade relations of the nation with the rest of the world. For this analysis international trade patterns in the 13 Functional Domains are plotted on semi-log paper. The past trend should be of at least the same number of years for which the planning horizon is attempted. Namely, if the strategic plan is concerned with the next 20 years data for the last 20 years should be plotted. These past trends could, as a first approximation, be simply extrapolated, but as a second stage they must be perturbed on the basis of information that will emerge from the other activity in Level 9, namely, the development and analysis of alternative world scenarios. It was already mentioned that cross impact analysis could serve for this purpose. This relationship is drawn schematically in Figure 9.

International trade theories may suggest national priorities. Israel and its international patterns should simply follow the comparative advantage principle. This principle states that it is advantageous for a productive activity to be carried out by an inferior producer, provided that the superior producers are even more superior at doing something else.

This simplistic approach should be rejected for various reasons. Firstly, there are at least seven theories attempting "to explain" international trade

	Functional Domains																																						
Industrial Branches or Standard Industrial Classification (SIC)	Information			Health			Food			Defense			Education			Construction			Apparel			Energy			Transportation			Recreation			Tourism			Personal Services			Pub and Comm Services		
Year	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
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Figure 7. Industrial branches domains matrix

	SIC	SIC	SIC	Domain	Domain	Domain	Final Uses	Total Production
SIC	A		Given		C		I Empty	
SIC								x
SIC								
Domain								
Domain	D		Empty		D		II Normative Sensitivity Analysis	y
Domain								
Primary Inputs	B		Given		[illegible]		III Empty	z

Figure 8. Input/output table including domains

patterns and there is no decisive evidence in favour of one of them.[17] Secondly, and most importantly, in view of the difficulties of calculating relative prices in the complicated modern world system, economists are actually calculating Revealed Comparative Advantage[18] which may serve to perpetuate past national mistakes rather than alleviate them.

Comparative Advantage data should therefore be used as input but with considerable caution.

All the information accumulated up to now provides the basis for the determination of priorities which was described earlier in Figure 1.

But the task does not end here. Addition

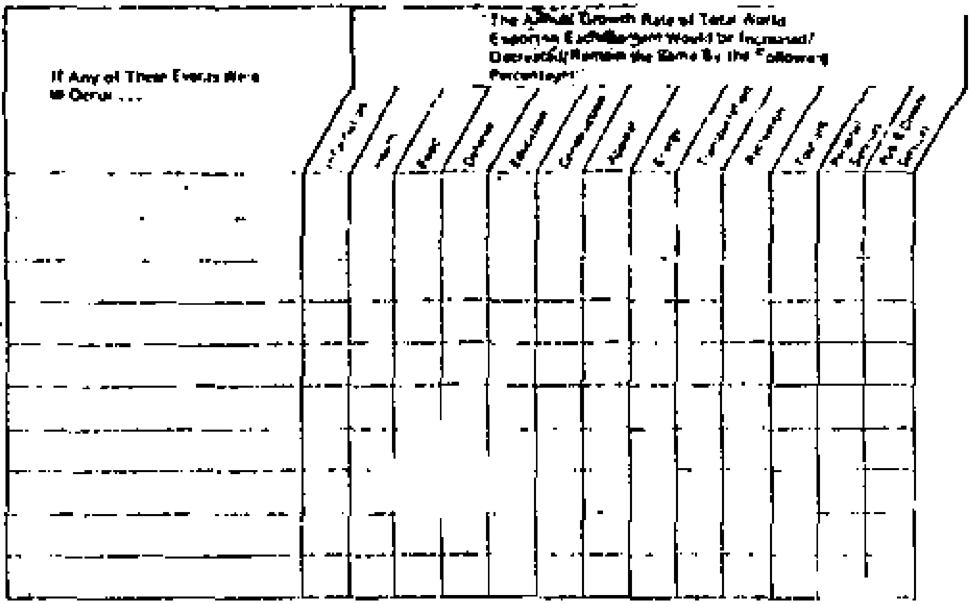

Figure 9 International trade worksheet

must be done as shown in the tenth and last level of Figure 3. Firstly, indicators for monitoring the environment must be supplied by the National Strategic Planning Team. These indicators will be followed closely in the years to come in order to verify or arrest the assumptions on which the national priorities were based. In supplying these indicators for monitoring the environment in advance, one increases the probability that an early warning system will indeed be established and not be forgotten.

In the tenth level (Figure 3) it is also important to perform implementation analysis of the National Priorities and the Domains Mix which evolved in the ninth level. One must admit that implementation analysis is in its infancy. However, some work has been done already and can be consulted.[19-22]

The task of implementation analysis is to assess the feasibility of alternative strategic decisions in order to ensure, to the extent possible, that the desired outcome will be reached and that the co-operative effort of all parties in implementing the policy has been guaranteed.

Only at the end of the laborious work described up to now can a proposed national strategic plan be summarized.

Due to the hierarchical structure of the Functional Domains, any decision concerning these will automatically concern industrial branches (SICs) and technologies. This is shown schematically in Figure 10.

Public discussion can take place at any stage of the model activities, but it would probably be of more value at the ninth to the tenth levels (Figure 3). At this point enough information has accumulated to make the discussion useful and interesting to both the public and the decision makers. Furthermore, implementation analysis will probably reveal a multitude of actions which have to be carried out to ensure implementation, such as pieces of legislation, regulations, changes in personnel appointments, changes in taxation, etc. There will, therefore, be strong pressure at this point, by people who feel threatened, to stop and/or hide the whole process. Yet, by publishing it in a late stage as the ninth or tenth levels the probability of stopping the process decreases. An opposite tactic may be to involve the decision makers and possibly the public from the very early stages of the process.

Concluding Remarks

There will probably be more than one reader who will be puzzled at the exorbitant amount of work suggested here for determining National Priorities. These should be reminded of the insignificant cost of carrying out the process compared to the economic and social costs of national errors.

A quote from the conclusions of Bernal in his Science in History may be appropriate here: "The

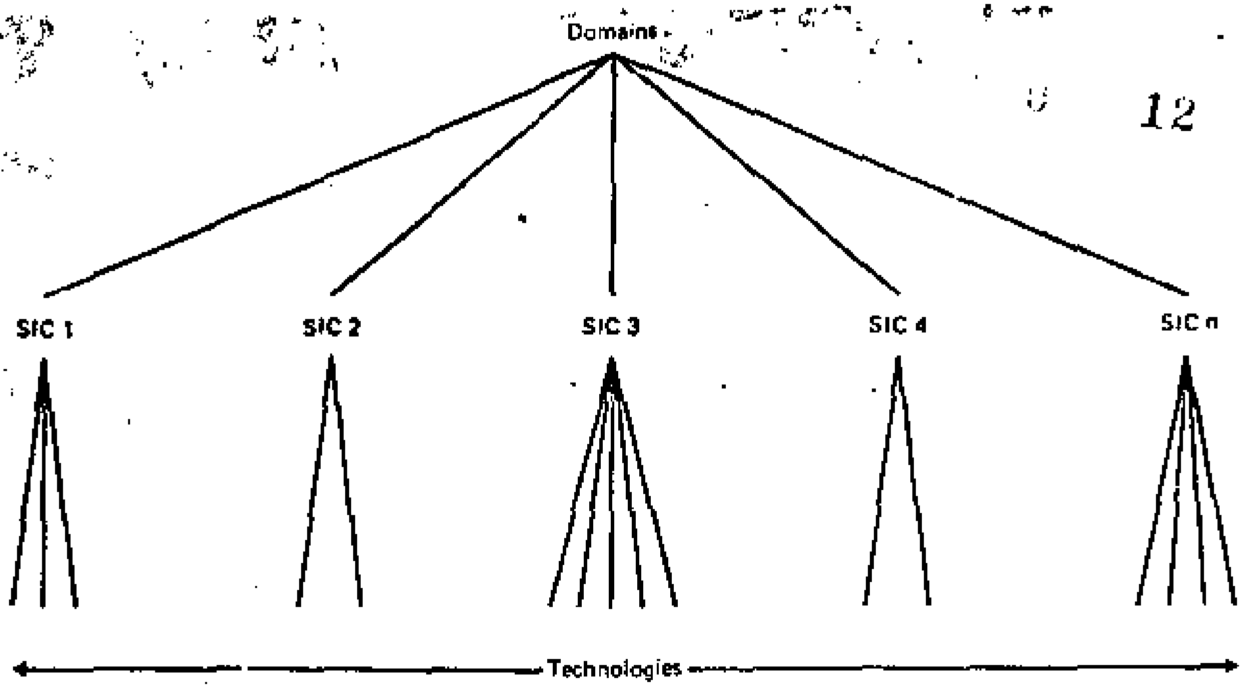

Figure 10. Hierarchical data structure

effort expended in finding out scientifically what to do, will tend to be as large as that used in doing it'.[33] Furthermore, it is clear that when ten well intentioned diligent persons pull a cart in ten different directions the cart may not move at all.

Therefore the importance of operating the model far transcends 'the numbers' in any one matrix or another: the public discussions that will emerge from the process are important in contributing to a national focus and national drive. A division of the national budget to the 13 Functional Domains may reveal that 'the cart is being pulled in ten different directions' without anyone being aware of it.

Thus, above and beyond the desire to better use scarce national resources lie the two questions which opened this paper. It takes years to raise them to public attention and may take generations to answer them, for the difficulties are many.[34] But the reward is high: the fulfilment of man as capable of free choice.

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Appendix

Definitions of Functional Domains

Note: In the following, the definition of Technology is Products, Processes and services which were, or will be, developed by the human race.[35]

(1) *Food*. The domain includes all the natural resources, technologies, and manpower in the country engaged in the production, processing, storage and distribution of fresh and processed products.

(2) *Defense*. The domain includes all the natural resources, technologies and manpower in a country engaged at time of peace in the prevention of and protection from external threats such as war and internal threats such as [illegible].

(3) *Apparel*. The domain includes all the natural resources, technologies, and manpower in a country engaged in the production, storage, and distribution of clothing and shoeing.

(4) *Construction*. The domain includes all the natural resources, technologies, and manpower in a country engaged in the modification of the physical habitat in general and in the building of shelters for human beings in particular.

(5) *Health*. The domain includes all the natural resources, technologies, and manpower in a country engaged in identifying, preventing, relieving and curing of disabilities, illnesses and aging phenomena in all living forms.

(6) *Energy*. The domain includes all the natural resources, technologies and manpower in a country engaged in the discovery, generation and distribution of potential and kinetic energy.

(7) *Education*. The domain includes all the natural resources, technologies and manpower in a country engaged in the development of human intellectual capabilities, moral judgment, human skills and human awareness of the surrounding environment (natural and human).

(8) *Transportation*. The domain includes all the natural resources, technologies and manpower in a country engaged in moving people and things from one place to another.

(9) *Recreation*. The domain includes all the natural resources, technologies and manpower in a country engaged in the delivery of various forms of physical, emotional and spiritual relaxation from work.

(10) *Information*. The domain includes all the natural resources, technologies and manpower in a country engaged in the collection, storage, processing and distribution of data in all forms.

(11) *Tourism*. The domain includes all the natural resources, technologies and manpower in a country engaged in the delivery of services to travelling local citizens and foreign nationals.

(12) *Personal Services NES**. The domain includes all the natural resources, technologies and manpower in a country engaged in the delivery of personal services, aimed at satisfying citizen's needs, which are not included in any of other domains and are not provided by local or national government.

Examples: Finance and insurance institutions, lawyers, bankers, etc.

(13) *Public and Community Services NES**. The domain includes all the natural resources, technologies and manpower in a country, which are not included in any of the other domains and are provided by local or national government for the daily welfare, safety and smooth operation of society.

Examples: Elections, taxation, police, post office, firemen, etc.

*NES = Not Elsewhere Specified, namely not mentioned in any other domain.

The frontiers of strategic planning: Intuition or formal models?

Striking a balance [illegible] may be the answer to the [illegible]

HAROLD W. FOX

Harold W. Fox is George A. Ball distinguished professor of business at Ball State University in Muncie, Indiana. A former executive with General Foods Corporation and the Canteen Corporation, he lectures and consults on business strategy and management issues.

FORMAL PLANNING has always had its critics, especially among shirtsleeved managers and entrepreneurs who tend to place greater faith in intuition than in academic models. But now some of America's most prominent companies are foundering, whether or not they pursue formal planning, and the debate is keener than ever.

Is there solid evidence to confirm or deny the utility of strategic planning tools? And can managers, operating in an uncertain, erratic economic climate, use strategic planning tools with any expectation of success?

Intuition vs. formal planning

A number of consultants, notably McKinsey & Company, fault formal planning for restricting consideration to mundane proposals, depersonalizing resource allocation, and abdicating managerial imagination to quantitative criteria. Instead of dominating resource allocation, quantitative planning methods "are often most useful . . . for confirming hypotheses that have been conceived with a liberal dose of hunch, intuition, judgment, and experience," says Frederick W. Gluck, a McKinsey director.

Quincy Hunsicker, managing director of McKinsey & Company's Zurich office, concurs. Lambasting the "almost mechanistic" diagramming of data on "market size, growth rate, competing share, and so on," he concludes that "the main lessons of experience are that . . . analytical tools can supplement, but not supplant, good thinking, and that a successful strategy cannot be developed without creative ideas a

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beginning and management commitment at the end."

Finally, Thomas J. Peters, a McKinsey & Company principal, reports in *The McKinsey Quarterly* on the common attributes of 37 well-run organizations including IBM, Procter & Gamble, and 3M. "None of those attributes depends," he notes, "on 'modern' management tools or gimmicks. . . . All that is needed is time, energy, and a willingness on the part of management to think rather than to make use of management formulas."

Unfortunately, this finding, along with the other conclusions developed by McKinsey executives, would be more compelling if it were based on a random selection (using the *Fortune* 500) of comparable firms with and without formal resource allocation. After all, for every example of a spectacular success that has stemmed from managerial intuition and creativity, there is the counterexample of a firm foundering for lack of formal planning. By deducing a superior approach from companies selected for their vision's proved success, the consultant's appraisal ignores other examples where the same approach seemed ingenious but failed.

Need for creativity

Formal planning does cause excessive delay, caution, and machinations at many companies. But so do competing visions of the future. In the 1980s, American business needs to stress unfettered creativity in strategic plans along with their implementation via traditional precepts.

Planning concepts and tools reach prominence, fade from view, and sometimes reappear in slightly altered forms. In the 1960s, the most popular strategic planning tool was time-adjusted return on investment (ROI).

At that time, the top executives of such conglomerates as American Standard, Avco, and Litton Industries concentrated on mergers and internal financial controls. Control over operational activities was left to division managers.

The higher the ROI in firms acquired at a low price/earnings ratio, the higher rose the earnings per share of the parent company. A rise in the price of its stock usually followed. Stock prices of many conglomerates zoomed until collapses at the operating divisions caught Wall Street and top managers by surprise. The rosy ROI signals had been misleading. Be-

"Formal planning repels many action-oriented executives. In fact, some executives are apt to pervert planning tools and activities by exploiting them to justify, after the fact, how and why a decision was made."

latedly, chief executives recognized that their involvement in operations was essential.

Just when the need for a tool summarizing complex strategic relationships among the operating units and the operating environment became most evident, portfolio analysis emerged. ROI's perceived inadequacies were responsible for giving it a back seat to portfolio analysis at many companies during the 1970s. Now during the 1980s, ROI is making a major comeback.

A look at four major and still valid reasons for the initial eclipse of ROI by portfolio analysis should enable us to understand both tools better and should also provide an insight into how these rival strategic approaches should fare during the coming decade.

One complaint about ROI concerned the difficulty most people have understanding any time-adjusted technique. The formulas are not intuitively obvious, and disputes over discounted cash flow versus present value or other variables only heighten the confusion.

A second complaint is that ROI results are misleading. The theory of capital budgeting holds that corporate decision makers should allocate funds to contending proposals in order of profitability. However, this dictum favors mature or obsolete products. In the ROI equation, the numerator is high because production has been honed to top efficiency, and marketing runs largely on accumulated customer loyalty. Also, the denominator is low because most fixed facilities have been depreciated; inventories and receivables are relatively low because the products are mature or declining.

Actually, long-range growth prospects for these types of products are apt to be poor. The company instead should be supporting replacement entries. Unfortunately, new products incur both current and near-term losses; hence they tend to be rejected under an ROI program.

A third problem with ROI is that it tends to encourage deception. Managers are usually confident about their own projects and eager to see them implemented. This may lead them to estimate profits earlier and higher than an objective analysis warrants. In many companies, capital budgeting has degenerated into a game of false estimates.

Fourth and finally, even if ROI worked as intended, it would guide decision makers to approve a variety of projects that might be independently profitable but incompatible with one another. In other words, projects tend to be evaluated outside the context of the total corporation under an ROI program.

Altogether, many administrators found that the time adjusted ROI strategic tool generated false estimates and meaningless or misleading computations. Debacles at leading conglomerates and other ROI-oriented corporations in the late 1960s dramatized the need for an additional managerial tool. A brilliant concept, pioneered by the Boston Consulting Group, seemed likely to fulfill that need. Therefore, during the 1970s, numerous companies rushed to adopt the technique of portfolio management.

Portfolio management

Essentially, portfolio management involves cross-classifying products or other units according to market growth and relative market share. The results of this analysis appear in a 2 x 2 table or matrix.

In Figure 1, the industry's growth rate separates the upper (high-growth) from the lower (low-growth) cells. In a diversified company, the dividing line is the company's desired growth rate. Products plotted in an upper cell have above average market growth, and vice versa. The farther left a product appears in the matrix, the more dominant its market share is in proportion to its closest competitor. Products plotted on the right side have a lower market share than the industry's leader.

If staff personnel or operating executives assign major products to appropriate cells, estimates of market growth and market share can be fairly precise. However, since astute

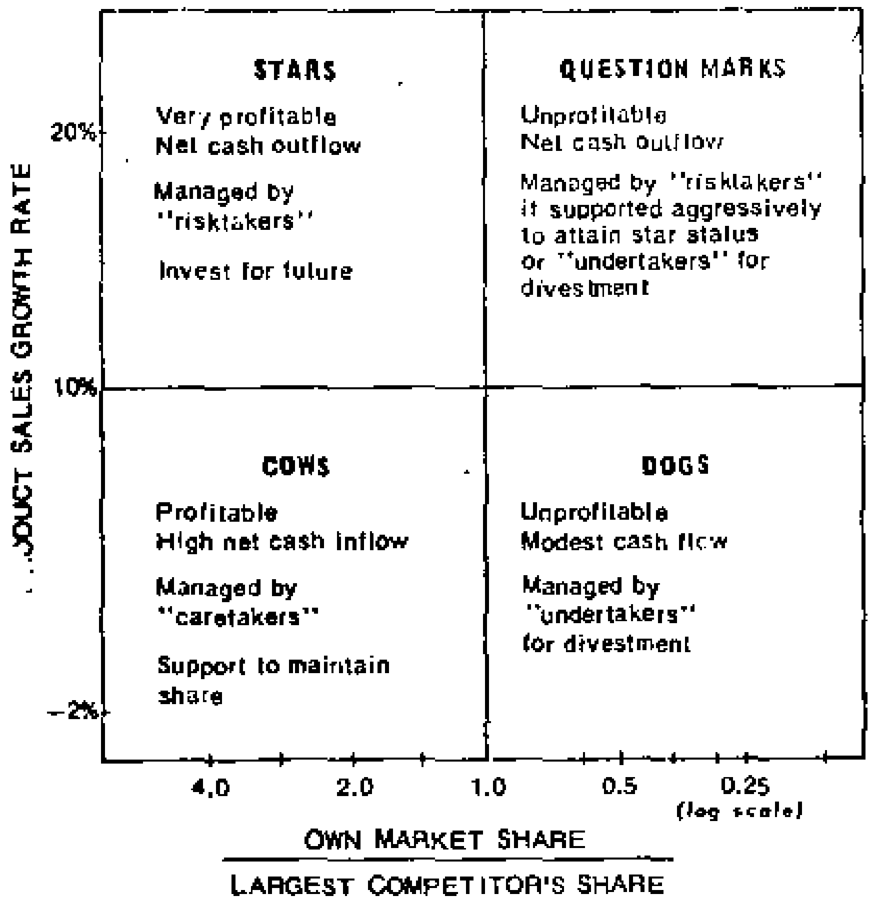


Figure 1

GROWTH-SHARE PORTFOLIO

(BOSTON CONSULTING GROUP)

executives generally know how fast their industry is growing and what their product's standing is, approximations usually suffice.

Portfolio management does not have the flaws that mar ROI as a planning tool. The model is simple and clearly summarizes important strategic relationships. A time perspective can be added by plotting rojects periodically on the same or erlaid charts. In addition, the results of portfolio analysis are grounded in operating logic. The method integrates such key factors as demand, competitive position, market strategy, near-term cash flows and accrual-basis profitability, internal organization and executive assignments, and overall corporate soundness.

Third, inputs are objective data or easily verifiable estimates, and results have standard interpretations. That is, the theory of portfolio management describes what each cell's financial implications are and where prudent decision makers should deploy or divest resources (see Figure 1). Estimates of future time-adjusted ROI are either omitted or used as supplements. Fourth, and most important, portfolio management contemplates a corporate structure whose components make balanced contributions subject to unlike criteria.

No wonder this pow ool captivated planners and a strators. During the 1970s, exp ons such as "cows," "dogs," and "experience curves" became part of the language of business. Consultants and executive seminars espoused portfolio management. But as the 1980s dawned, criticisms of portfolio management—muted for a decade—began to grow.

The flaws in portfolio mana nt

The key problem wit rtfolio management is that it was ersold. In America's diverse economy, no single business approach has universal validity. Also, managers tend to place too much faith in the value of tools. Executives—not techniques—are ultimately responsible for strategic planning.

The very points that cont ute to portfolio management's stren h also disguise hidden weakness For example, the simplicity of the model makes it a clearer tool. But managers run the risk of indulging in oversimplification. In use, a 2 x 2 grid is necessarily incomplete. Portfolio analysis excludes such important strategic variables as risk; vulnerability to inflation and economic fluctuations; social, political, and ecological pressures; continuity of supply;

technological change, human factors and labor unions; and a firm's special competences and weaknesses. Yet these very forces will dominate the course of American business in the 1980s.

Another problem is that although the logic of portfolio theory seems impeccable, it is not necessarily relevant. After all, the course of human events is not especially logical, and empirical outcomes contradict theoretical predictions with embarrassing frequency. For instance, contrary to portfolio theory, many companies remain successful by eschewing star products and confining themselves to cows. Bic Pen, Procter & Gamble, and Philip Morris come readily to mind.

A third problem with portfolio theory is that its top-down approach can dampen the enthusiasm of operating managers, affecting their initiative and acuity. Texas Instruments fell victim to this problem. TI's managers reportedly continued to use experience-curve pricing long after changing circumstances had rendered it inapplicable. They kept reducing prices on semiconductors during periods of capacity shortages, thereby depriving the company of millions of dollars of profits.

Lastly, even if portfolio management worked as intended, it would guide decision makers to choose only among available options—the ones on the grid. Thus, Swiss watch companies missed the inroads of Timex, which at first appealed to different market segments via new channels and much lower prices. Timex, in turn, missed the inroads made by digital watches.

Portfolio management by itself is less appropriate in the 1980s than it was during the last decade. The bottom line has become the key criterion of corporate success, and the time span of measurement has shrunk.

When investment status and creditworthiness as well as executive compensation and advance-

Figure 2
Profitability vs Competitive Advantage

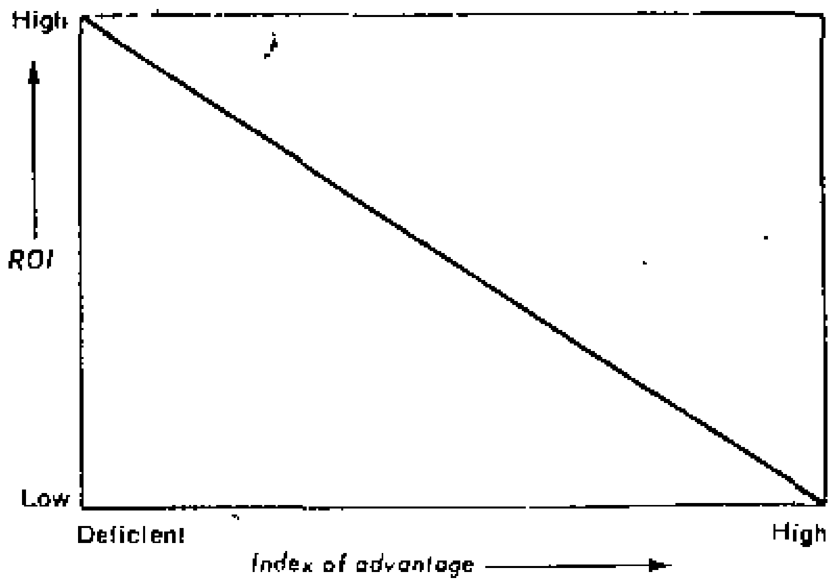
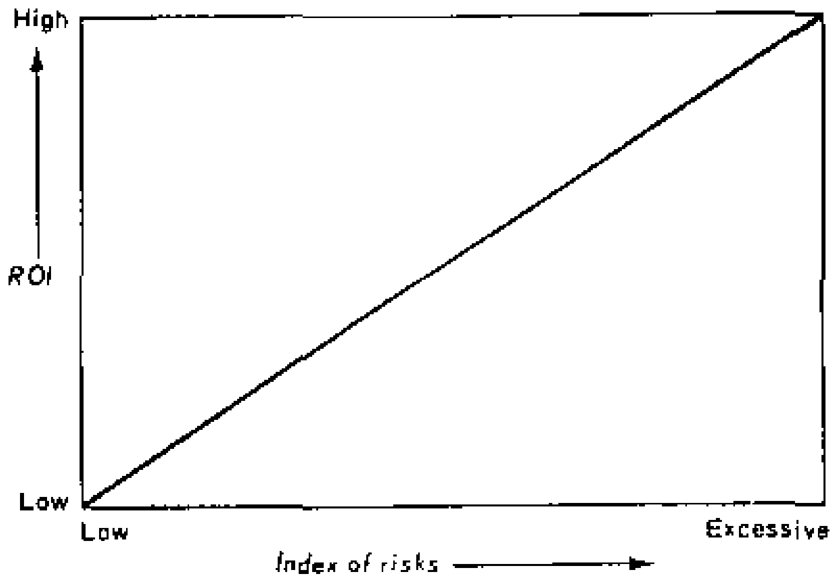


Figure 3
Profitability vs External Risks



Adapted from charts developed by Hayes/Hill Incorporated.

—depend largely on quarterly financial results (ROI), the distant prospect of stars must yield to current realities. Moreover, portfolio management does not cover many factors that are particularly important in today's business environment.

The answer: extended models

Does this mean that portfolio management is no longer applicable? No. It is a helpful tool when used in concert with others. For example, management consultants Hayes/Hill Incorporated use it as a point of departure for strategic planning. In contrast, McKinsey & Company relegates portfolio analysis to the end of the strategic planning process.

Hayes/Hill attempts to improve the fiscal predictions of portfolio theory and to introduce the dimension of risk by using the method described in Figures 2, 3, and 4.

The base dimension in Figure 2 is the company's index of advantage—its competitive superiority vis-a-vis other companies in an industry. This general measure is developed by staff analysts or outside consultants who study such factors as entry barriers, product differentiation desired by customers, internal strengths, costs, risks, and management effectiveness.

When requests for resource allocation are analyzed and plotted on Figure 2, each appears as a circle whose diameter is proportional to resources or sales. Circles falling below the diagonal are apt to be rejected. On the left side of the chart are projects for which the firm lacks an economic rationale. Those at the top left promise high profits, but offer no sustainable competitive advantage—they appeal only to firms seeking temporary opportunities. Decision makers give preference to projects in the upper right corner. Preferred proposals are then subjected to risk analysis.

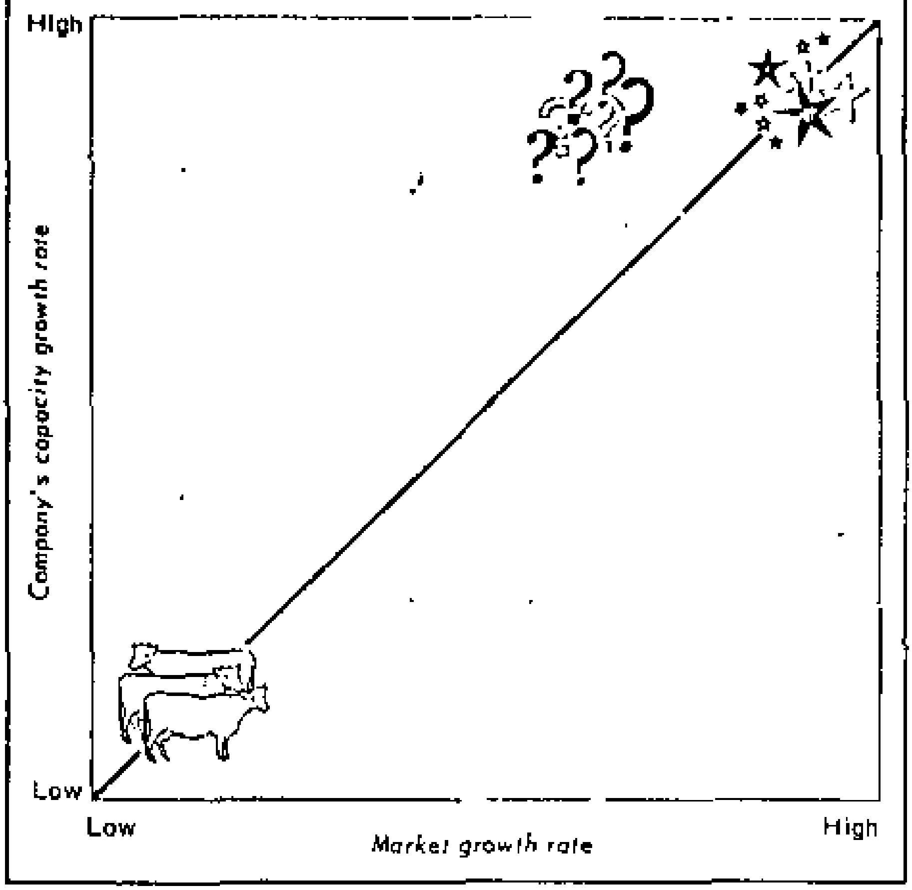


Figure 4
Company Growth vs Market Growth

Even though a company may be well situated to undertake potentially profitable projects, these ventures may harbor more external risk than decision makers are willing to tolerate. Therefore, in Figure 3, such elements as volatility of demand, dangers to health and safety, interruptions in supply, labor problems, technological obsolescence, and so forth, are combined into a risk index. Decision makers give preference to proposals in the upper left corner. Proposals above the diagonals on Figures 2 and 3 move to a final display on Figure 4.

The final chart quantifies how much should be invested in each of the contending projects. On Figure 4, a diagonal aligns two growth rates: (1) the company's production and marketing capacity and (2) market (or demand) growth. (The range of rates is appropriate for the company and industry; it could include negative rates.) Cow products usually appear on the diagonal in the lower left section of Figure 4; stars are located on the right. Depending on whether management seeks to gain, hold, or relinquish market share, stars appear respectively above, on, or below this diagonal. If any questionmarks survived the prior analyses, they should appear far above the diagonal line. The plots show how much real capacity is needed. This is then translated into dollars.

The last step involves comparing the recommendations suggested by Figure 4 with available internal and external funds. Typically, the sum of requests far exceeds the money available for investment. Which projects should take priority? And which should be relegated? While an ROI approach would dictate apportioning the total cash in order of profitability, portfolio management suggests merely maintaining the cows, and investing heavily in the star products (including potential stars still under development). Any residue could be channeled to questionmarks (see Figure 4). The prospects of dogs are analyzed separately. Presumably, the company will divest, harvest, or simply continue the dogs, confining their support to essentials.

This method overcomes three of the four major objections to the sole use of the portfolio matrix. First, the procedure is not simplistic. Any relevant factor that the portfolio matrix omits can be incorporated into the index of advantage or index of risk. Second, the procedure substitutes explicit ROI estimates for the arguable fiscal predictions that stem from portfolio categorization.

Third, the procedure combines centralized and decentralized approaches. It begins with portfolio analysis (at headquarters), subjects eligible projects to ROI estimates together with advantage and risk placements (at the firm's business units), and ends with allocations according to corporate strategy (back at headquarters). This alternation centralizes selection of candidates with investment potential, decentralizes their analysis according to relevant operating factors, and centralizes the final decision on resource allocation. If analyses for Figures 2 and 3 are conducted ahead of Figure 1, nomination of candidates is delegated also.

The reaction of managers

Management must weigh these benefits against the reactions of the executives concerned with contending projects. Some welcome participation and precision, but others find the plethora of analyses and charts too burdensome. Formal planning repels many action-oriented executives. In fact, some executives are apt to pervert planning tools and activities by exploiting them to justify, after the fact, how and why a decision was made.

This danger poses a dilemma. It is important to record and monitor the assumptions and conclusions from which the indices and other determinants of chart position were derived. If this is not done, the company may commit resources without updating for environmental changes. Also, the allocation system could fall apart if false data or political considerations find their way into the decision criteria.

Realistically, however, few managers have the time or patience to review former inputs and assess them retrospectively for acuity. This work is usually delegated to a staff group whose very presence affects the work climate and planning methods. Some executives are more comfortable with decisions that are logically justifiable than with options representing grander visions for which defensive documentation is needed and not available. This is the reason that consultants McKinsey & Company use portfolio analysis only at the end of their planning process as a corroborative tool.

The operating environment

ROI, portfolio analysis, and other strategic planning tools continue to help many executives make their companies successful, but case studies do not really prove or disprove the tools' enduring efficacy.

Certainly, the evidence for seeking different planning approaches is compelling. From a position of international preeminence during the 1950s, American industry has fallen behind in many foreign and some domestic markets. To what extent have formal methods of strategic planning influenced this decline? It is impossible to answer this question.

Companies trapped in a restrictive and highly competitive environment, probably have less need for sophisticated planning techniques than for sensitivity to emerging technology, demand, and regulation. But how can far-flung companies with thousands of employees and transactions in billions of dollars eschew computerized documentation, formal ROI analyses, and unimaginative administration?

Perhaps some companies that share a brilliant history—including some of America's largest manufacturing and merchandising organizations—have simply outgrown the human capacity for enduringly effective management in the present climate, with or without formal planning tools. ■

STRATEGIC PLANNING:

TAPPING THE ENGINEER'S KNOW-HOW

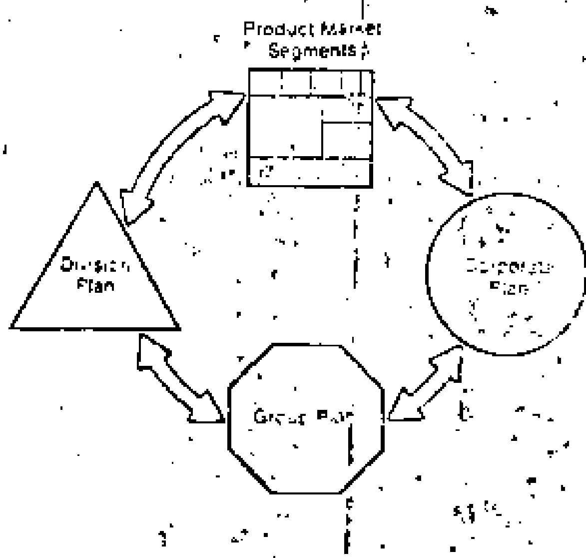
Not satisfied with traditional planning techniques, a growing number of companies are turning to strategic planning. This new approach relies heavily on input from the engineering function to allocate the company's resources and chart its future growth.

MARK D. ZIMMERMAN
Staff Editor

THE increasingly complex business environment of the 1970s has forced many industrial firms to restructure their internal operations. One result has been the emergence of strategic planning which brings together input from all major operating sections of the company. Because of the nature of the process, it relies heavily on

Eaton's Nonstop Planning Process

Eaton Corp. depends on strategic planning to keep over 600 corporate building blocks (called product-market segments, akin to strategic business units) on target. Each block-like segment generates its own revenues, operating costs, investments, and strategic-action plans. Closely related segments belong to divisions which, in turn, report to major groups. Divisions and groups prepare profit and strategic plans on a continuing basis. Monthly plans are incorporated into a rolling forecast that is crystallized each December as the year-ahead forecast (or fixed plan). By the time a corporate plan undergoes its final top-side review, strategic plans for the subsequent year in some divisions are being finalized.



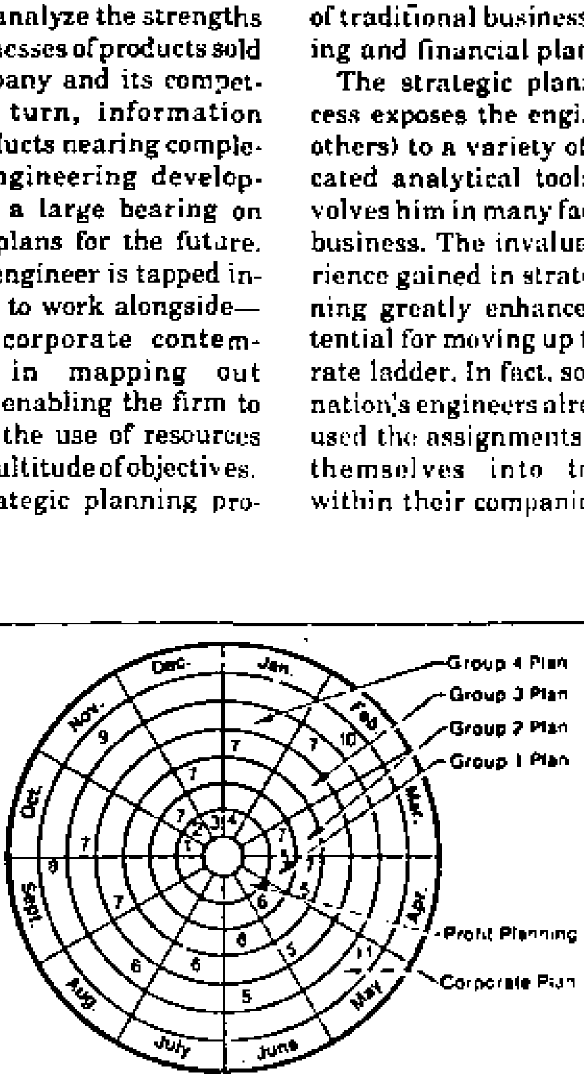
engineering expertise to assess a company's overall competitive position and utilize its resources more effectively.

More Status, Clout for the Engineer

The importance of the engineer becomes more evident as companies key in on individual product lines. For example, input from the engineer is essential to analyze the strengths and weaknesses of products sold by a company and its competitors. In turn, information about products nearing completion of engineering development has a large bearing on company plans for the future. Also, the engineer is tapped increasingly to work alongside—or lead—corporate contemporaries in mapping out strategies enabling the firm to maximize the use of resources across a multitude of objectives.

The strategic planning process draws on many skills and attributes possessed by the typical engineer. The nature of his work requires him to analyze forecasts, trace trends, project technical developments, and commit himself to short and long-term programs. These qualifications provide a sound basis for participation in the strategic planning process, particularly today as firms see more clearly the inadequacies of traditional business forecasting and financial planning.

The strategic planning process exposes the engineer (and others) to a variety of sophisticated analytical tools and involves him in many facets of the business. The invaluable experience gained in strategic planning greatly enhances his potential for moving up the corporate ladder. In fact, some of the nation's engineers already have used the assignments to propel themselves into top spots within their companies.



1 — First look at profit plan
2 — Second look at profit plan
3 — Set profit plan
4 — Support schedules for profit plan
5 — Submit divisional strategic plans to world headquarters
6 — Review group strategic plan with executive committee
7 — Group reviews with executive committee
8 — Executive committee review of corporate plan
9 — Management committee review of corporate plan
10 — Board of directors review of corporate plan
11 — Managers' conference review of corporate plan

Keeping Business Units on Target

Strategic planning provides the discipline and methodology to make a sophisticated assessment of a company's capabilities relative to those of its competition. It helps the company to develop plans that enable it to strengthen its position in promising markets. Equally important, strategic planning may be used to identify the need to abandon markets in which the potential does not justify continued effort.

A critical first task in implementing strategic planning is to break down a company into measurable business units that have independent and unique markets. These units, called product-market segments or strategic business units (SBUs), are the basic entities for which a company develops a business review, strategic plan, and operating plan.

A breakdown by product lines is essential when a company attempts to determine why it is strong in some markets and weak in others. Product segmentation also helps to analyze why a competitor's product dominates the market or is produced at lower cost. Beyond these considerations, an SBU is evaluated in the context of company objectives in order to reconcile the unit's role in the overall framework of a company's long-term goals and objectives.

The strategic planning process forces a company to ask itself tough questions such as: Where are we today? What are the company's resources, market position, and plans for growth? What do we want to be tomorrow? What actions are needed to make us more competitive in specific markets?

How do we get to where we want to be in six months, five years, or even by the year 2000?

The precise answers to these questions depend on an assessment of nine major strategic influences on business operation. These influences consist of investment intensity, productivity, market position, growth of market served, quality of product and/or service, innovation differential, vertical integration, cost-push factors, and current level of strategy efforts.

Strategic planning thus entails many dimensions which set it apart from conventional planning activities. For example, traditional forecasts and plans produce growth plans closely keyed to increases in population or of the Gross National Product. But these "macro" measures no longer accurately reflect, nor can they be used to develop effective plans of action for, an ever-changing marketplace.

Consequently, strategic planning entails far more than extrapolation of historical trends. Through strategic planning, a company can analyze and evaluate the total environment in which it operates—today and in the future. The process includes an assessment of external business factors and internal operating strengths and weaknesses—in marketing strategy, pricing, design, quality, manufacturing capacity, and efficiency as well as customer and supplier relationships.

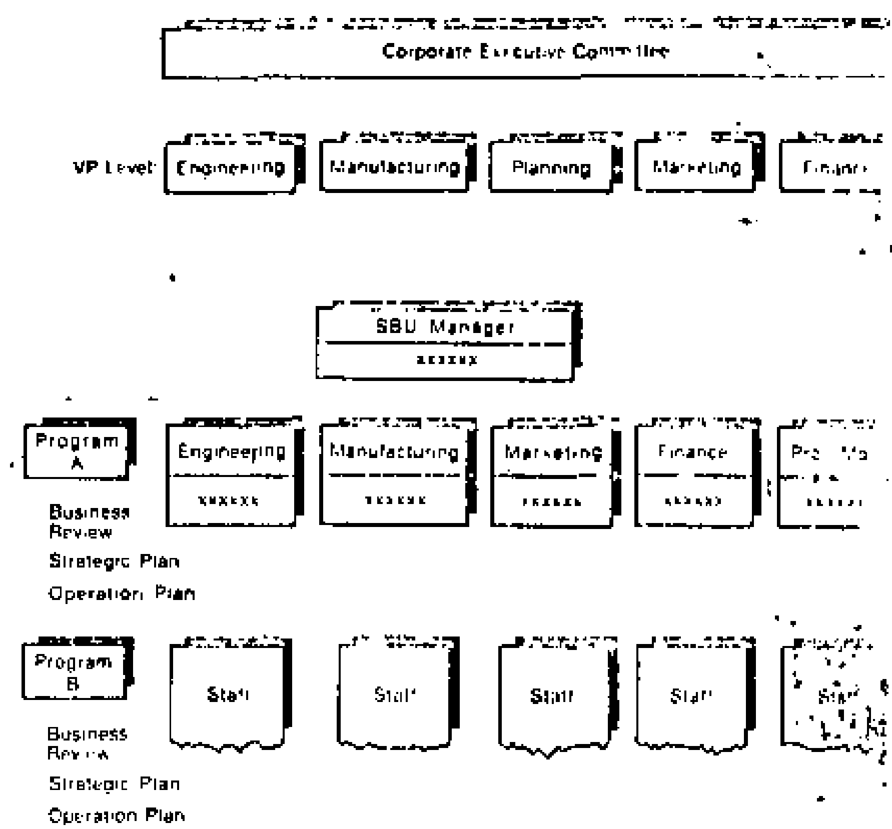
The process also entails a careful analysis of market share and an evaluation of competitor strengths and weaknesses. This analysis outlines a product's expected life cycle, capital expenditure trends, technological trends, economic conditions, availability of manpower, and even social and political pressures.

One expert in strategic planning simplifies the process by distinguishing between the "pull" of external forces and the "push" of internal actions. The pull side represents social, political, and economic factors in the external environment over which a company has no control. The push side encompasses intentional actions that can be effected to make a company move counter to, or faster than, the pull factors alone would accomplish. By understanding and manipulating these forces of change, a company can pinpoint the type and extent of difference they make in business operations.

The self-analysis resulting from strategic planning enables a company to better understand its internal structure and external environment. This knowledge helps the company to set more precise objectives and achieve a unity of direction based on its statement of mis-

Integrated Organization Structure Aids Planning

An interlocking organizational structure maintains an ongoing interface between engineering and other business functions in companies such as Eaton, GE, GM, and International Harvester. This structure facilitates the strategic planning process by constantly meshing, or integrating, all activities within [illegible] It also permits bringing "doers" together to function as "plan[illegible] -term strategies and of short-term operating plans. In many case[illegible] f a strategic business unit also have line responsibilities to resp[illegible] " within their functional specialties, conforming to the two-boss syst[illegible] herent in matrix management.



sion objectives, list of alternatives for reaching objectives, outline of basic program, description of strategic programs, and an evaluation of program viability.

Plugging into Sophistication

Growing numbers of companies are expected to follow industry leaders in applying strategic planning to products such as aircraft engines, electric motors, engine valves, farm tractors, lift trucks, and truck axles. The acknowledged pioneer of strategic planning, General Electric, has over 40 strategic business units that range in size from small to large entities. The primary product areas of International Harvester are covered by about six SBUs. Another multinational firm, Eaton Corp., presently boasts over 600 product-market segments (or SBUs).

The engineering function becomes much more visible and influential as it meshes with other business functions in a strategic business unit, reports International Harvester. The company recently used a combination of matrix management and strategic planning to coordinate engineering, manufacturing, marketing, finance, and project management of a program that moved a new tractor from concept to consumer in 12 to 18 months less time than would have been possible with conventional management techniques. A matrix arrangement is used by IH to bring "doers" together on a monthly basis to function as "planners" of long-term strategies and of short-term operating details.

Companies realizing the potential payoff from a thorough strategic analysis can tap outside expertise to launch their strategic planning efforts. Management consulting firms such as Boston Consulting Group, Arthur D. Little, and McKinsey can be retained to formulate the first strategic plan for a company.

Another source of help is the Strategic Planning Institute, established by Harvard Business School along the lines of research pioneered by General Electric. The Institute has identified 37 basic factors that affect profitability of a business, compiled a data base from information supplied by 600 companies, and developed a standard set of profit-predicting equations for use by participating firms.

Companies eventually become sufficiently adept at strategic planning that they can circumvent the data base and plug in data generated by one of their own businesses. This presently is being done with a system known as Profit Impact of Market Strategies (PIMS), which can be used to evaluate the impact of profitability (return-on-investment) on variables such as market share and R&D spending. The PIMS system also can be used for other combinations of factors.

Recruiting specialists report a strong demand for professionals of varied backgrounds who can provide a business with desired skills in strategic planning. Some firms are even using the planning function as a means of attracting and identifying individuals they can groom for top management posts in the future. As a rule, strategic planners tend to be better educated and broader thinkers than the financial planners from whom the strategic planning function evolved, say recruiters.

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SBU Agendas Leave Nothing to Chance

Detailed agendas for meetings of strategic business units (SBUs) are highly confidential because they contain profiles of market areas, rundowns of present and future products, and other closely guarded data. Nonetheless overall topical outlines for SBU meetings (one is shown here as the table of contents of a definitive report) give some idea as to the breadth and depth of subjects covered by strategic planners. Preparation for monthly two-day meetings of an SBU in one company requires up to 700 to 800 man-hours of staff effort. Participating planners also may bring staff experts to meetings, call impromptu get-togethers, and converse almost daily by telephone.

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UNDERSTANDING THE FORCES OF STRATEGIC AND NATURAL COMPETITION

Bruce Henderson

How can today's business executive ensure that his company outlasts the competition? Darwin and the theory of natural selection may provide some surprising answers.

Strategic competition leads to time compression. Co titive shifts as a result of strategy can take pla. n a few short years. The same evolution by natural competition might require generations.

Strategic competition is a relatively new phenomenon in business. It may well have the same impact upon business productivity that the industrial revolution had upon individual productivity.

The basic elements of strategic competition are:

- The ability to understand competitive interaction as a complete dynamic system that includes the interaction of competitors, customers, money, people, and resources.
- The ability to use this understanding to predict the consequences of a given intervention in that system and how that intervention will result in new patterns of stable dynamic equilibrium.
- The availability of uncommitted resources that can be dedicated to different uses and purposes in the present even though the dedication is permanent and the benefits will be deferred.
- The ability to predict the risk and return with sufficient accuracy and confidence to justify the commitment of such resources.
- The willingness to deliberately act to make the commitment.

This description of strategy sounds like the basic requirements for making any ordinary investment. It is that. But it is far more. Strategy is all encompassing in its commitment. Strategy by definition involves the commitment and dedication of the whole firm. Failure of any competitor to react and then deploy and commit its own resources against the strategic competition of another competitor can result in a complete inversion of the competitive relationships and a major shift in the equilibrium between them. That is why strategic competition leads to time compression. Natural competition has none of these characteristics.

How Economic Competition Parallels Biological Competition

Natural competition is the basic form of competition between living organisms or organizations for their necessary life resources. Success in this competition leads to growth in the population of the winner. This growth progressively preempts the required resources from other competitors. This results in a process of natural selection which was

Bruce ... derson is Chairman, Boston Consulting Group, Inc.

first identified and described publicly in 1859 by Darwin and Wallace.

These ideas were not new even then. Both Darwin and Wallace reported that Malthus' picture of the pressure of human population upon subsistence provided the key element leading to the idea of evolution by natural selection in the struggle for life.

Yet the parallels between biological competition and economic competition had already been noticed before Malthus, who, on the first page of his "Essay on the Principle of Population," said, "It is observed by Dr. [Benjamin] Franklin that there is no bound to the prolific nature of plants and animals but what is made by their crowding and with each other's means of subsistence."

In a system of natural competition, the coexistence of competitors is dependent upon the existence of differences between them. These differences must be of sufficient value and magnitude to provide each with a unique and significant advantage over all competitors in some subsection of the environment in which they can preempt the required resources.

This principle was demonstrated in biology by Gause. Small animals that could exist indefinitely in a bottle with a given sufficient amount of food could not coexist with another similar species. This law of mutual exclusion is now known as Gause's Principle.

Natural competition results in both strata of competiton and a hierarchy of competition. Within each stratum, the competition is for resources that are needed in common. But each stratum is itself the resource for the next higher level in the hierarchy. This hierarchy is the equivalent of the ecological food chain.

Over long periods of time, natural competition creates very complex populations with a wide spectrum of characteristics. But for this complexity to develop, there must be a variety of resources and environmental conditions that can be traded off against each other so that each competitive group can become uniquely superior by specialization in some segment.

Key Differences Between Strategic and Natural Competition

Strategic competition includes natural competition and more. Strategic competition is the integration of logic, game theory, system dynamics, sensitivity analysis, the laws of chance, and cultural evolution with the patterns of natural competition.

Strategic competition is not an alterna[illegible] or substitute for natural competition. It is the [illegible]erate prediction and management of the higher orders of the controlling variables.

Strategic competition also incorporates Lamarckian evolution as a dependent variable of Darwinian evolution. Darwinian evolution by natural selection functions at all levels of complexity and development. It depends upon the innate capabilities of the competitor which are inherent in successive generations. Lamarckian evolution depends upon acquired skills and abilities which can only be perpetuated by cultural training and pressures.

Cultures can change rapidly if subjected to severe environmental stress. But the inherent abilities cannot change except slowly through natural selection and elimination from one generation to the next. Furthermore, innate abilities set the limits on how far cultural evolution can go and be effective.

Strategic competition is the commitment of resources for the achievement of long-term objectives with full comprehension and understanding of the total characteristics of the competitive system.

Expediency vs. Deliberateness

Natural competition is wildly expedient in its moment-to-moment interaction. However, it is inherently extremely conservative in its change in characteristic behavior. By contrast, strategic competition is deliberate, carefully considered, and tightly reasoned in its commitments, but the consequences may well be radical change in a relatively short time.

Evolutionary vs. Revolutionary

Natural competition is evolutionary; strategic competition is revolutionary.

Natural competition is really low-risk incremental trial and error. Small changes that seem to be beneficial are gradually adopted and maintained. Other small changes are tried and added. It is learning by trial and error without the need for either commitment or foresight. It is the adaptation at the time to the way that things are at the time. It is the basic pattern of evolution. It is Darwinian natural selection. It functions even if controll[illegible] pure chance or pure expediency. For these [illegible] reasons, it is inevitably very conservative and gradual and it produces nearly imperceptible change near term regardless of the consequences long term.

Strategic competition by its very commitments seeks to make a very large change in competitive relationships. Its revolutionary character is moderated only by two fundamental inhibitions. Strategic failure can be as sweeping in its consequences as strategic success. And characteristically an alert defense has a major competitive advantage over the attacker. Strategic success usually depends upon the culture, perceptions, attitudes, and characteristic behavior of competitors and their mutual awareness of each other.

Strategic success usually depends upon the culture, perceptions, attitudes, and characteristic behavior of competitors and their mutual awareness of each other.

This is why in geopolitics and in military strategy as well as in business strategy the pattern of competition contains long periods of natural competition punctuated by relatively sudden and major shifts in relationships as a result of strategy. It is the age-old pattern of war and peace, even though competition continues during peace.

Current Business Behavior: Between the Two Extremes

Currently normal modern business behavior seems to fall between the extremes of these two modes. However, a shift toward strategic competition seems to be the secular trend. The successful use of strategic competition by the most aggressive direct competitor can make the same foresight and dedication of resources the prerequisite for survival of others. Eventually the mastery of strategic competition will be a requirement for adapting to that kind of environment in which most of the change is the result of strategic commitments.

Natural competition should be respected. It is the process that produced the infinite and exquisite complexity, variety, and interaction of all the forms of life on planet Earth. This was accomplished by pure chance with no plan, foresight, or objectives. The starting point was the equivalent of sterile chemical soup. However, it took millions of years of nearly infinitesimal changes and adaptations.

Looking at the Survival Factors

Natural competition must be completely understood. It is the foundation. It is the system and pattern of interaction upon which any form of strategic competition must build and modify. Understanding of natural competition is required in order to predict the effect on those relationships as the result of intervention in the feedback loops of that system.

Differences between competitors is the prerequisite for survival in natural competition. Those differences may not be obvious. But competitors who make their living in exactly the same way in the same place at the same time are highly unlikely to remain in a stable equilibrium. However, any differences may give one competitor or the other an advantage over all others in some part of the common competitive environment. The value of that difference becomes a measure of the survival prospects as well as the future prosperity of that competitor.

There are nearly an infinite number of combinations of competitive factors in an environment that has a large number of variables. It should not be surprising that the world is filled with a vast variety of competitors, all different, which seem to exist in a moving but stable equilibrium. The range of size, behavior, and characteristics is not accidental; it is inevitable. It is also stable even though ever changing in detail. Those differences are the a priori requirement for the survival of each and every one of them in their particular subsection of the environment. That is natural competition as it always has been.

Toward a New Theory of Business Competition

Strategic competition is not new. The elements of it have been recognized and used in warfare since the human race became able to combine intelligence, imagination, accumulated resources, and deliberately coordinated behavior. The distilled wisdom of many centuries has been expressed in many maxims, such as "Concentrate strength against weakness."

But most military strategy has been focused on the battle itself or the war rather than on the equilibrium of the relationship that continued through both peace and war. Geopolitics is this larger perspective of the continued competition of this dynamic equilibrium over time. Yet there is still a very limited general theory about geopolitical dynamic equilibrium.

Competitors who make their living in exactly the same way in the same place at the same time are highly unlikely to remain in a stable equilibrium.

The general theory of business competition is almost certainly in its infancy. But the elements of a general theory that integrates all of the elements seem to be developing. The integration itself is the critical development.

Classic Theories Too Simple and Sterile

The classic economic theories of business competition seem to be so simplistic and sterile that they are obstacles to progress and understanding rather than contributions. They seem to be based on views of competition as a static equilibrium in a static economy rather than a dynamic equilibrium. They are based on theoretical concepts of cost behavior that have never been observed in reality and that directly contradict observable and quantifiable evidence. They make assumptions about competitive behavior that are neither observable nor useful in predicting competitive behavior. The frame of reference of "perfect competition" is a theoretical concept that has never existed and probably could not exist. Unfortunately, they have been used to develop public policy that is equally unrealistic.

The Critical Hypotheses

Development of the general theory of business competition will permit the prediction of the consequences of any kind of business competition. It can be the base of both strategic competition and constructive public policy. The general public would benefit on both counts. The development of a general theory of business competition will require the testing and revision of many interlocking hypotheses.

We would now hypothesize that:

- Effective competition will result in a range of sizes of competitors from very large to very small. This spectrum of size will be stable over time.
- Competitors who survive and prosper will have unique advantages over any and all other competitors in specific combinations of time, place, products, and customers.
- For any given competitor, there will be different competitors who will provide the constraints for almost every combination of relevant factors. Therefore, the frontiers or boundaries of competitive parity will be constantly changing as any one of the competitors changes, adapts, grows, or redeploys.
- Perpetual conflict will exist along those frontiers where competitive ability is at parity.
- Very little conflict will exist where there is clear superiority that is visible. The military analogy of the battlefront is useful in visualizing.
- Business competition is an inherently multiple front with a different competitor on each front.
- Any redeployment of resources will change the balance of competitive parity on at least two fronts. If one is strengthened, others will be weakened.
- Whenever a front or zone of competitive parity becomes stable or static, then "bourgeois" competition will develop. Such "bourgeois" competition exists when the defense always acts as a hawk and the offense always acts as a dove. This is a mutual recognition of mutually predictable behavior.
- The fewer the number of competitive variables that are critical, the fewer the number of competitors. If only one factor is critical, then no more than two or three competitors are likely to coexist. Only one will survive if the available market shrinks. This is the "rule of three and four."
- The more variables that can be important, the larger the number of competitors that will coexist, but the smaller their absolute size.
- The more variable the environment, the fewer the number of surviving competitors. In this case, the ability to cope with the greater change in the environment becomes the overriding and controlling factor.

The new entry or the development of a new competitor depends upon the ability of that competitor to develop and identify a clear superiority compared with all other existing competitors in some subsection of the total market. Sequence of entry is important.

These and other hypotheses are direct derivatives from the observable facts and generally accepted theories of evolution in the biological and ecological sense. They are the pattern of natural competition.

The earlier work of the Boston Consulting Group attempted to develop a general theory of competition based on:

- Observable patterns of cost behavior;
- Considerations of the dynamics of sustainable growth and capital use;
- The role of the capital markets in permitting these effects to be leveraged or discounted; and
- The relationship between these in a system of competition.

We recognized early the inappropriateness of accounting theories developed for other purposes as a model of economic behavior. We then developed the concepts that can be summarized as "Cash in and out is all that counts."

From this start, the concepts of the experience curve, the growth share trade-off, and the product portfolio were developed. These were further extended by analysis of shared experience, business risk versus financial risk trade-offs, the cost of proliferation, and cultural and behavioral extrapolation for competitors.

Many of these ideas are now commonly accepted assumptions and part of the business language.

This conceptual framework of business competition is far from complete. The knowledge and insight into competitive systems are expanding at an exponential rate. The growth is paralleling the expansion of our knowledge and insight into the physical sciences in the last century.

Linking Science and Economics: The Path to Understanding Competition

The potential for developing a general theory of competition from sociobiology has been substantial since Darwin's *The Origin of Species*. However, for nearly 100 years, biological competition and economic competition followed different paths and little or no exchange of ideas occurred between them. This happened even though philosophers such as Oswald Spengler perceived Darwin's contribution to be "the application of economics to biology."

Over seventy years ago Alfred Marshall, in his *Principles of Economics*, observed that "economics has no near kinship with any physical science. It is a branch of biology broadly interpreted."

More recently, Hirshleifer observed that:

> The traditional core of compartmentalized economics is characterized by models that: (a) postulate rational self-interest behavior on the part of individuals with preferences for goods and services, and (b) attempt to explain these interactions among such individuals that take the form of market exchanges under a fixed legal system of property and free contract.
>
> Only a very limited portion of human behavior can be adequately represented by such constraints. In recent years economics has begun to break through these self-imposed barriers.
>
> From one point of view the various social sciences devoted to the study of mankind taken together constitute but a subdivision of the all encompassing field of sociology.[1]

For whatever reason, economics has been sterile in its ability to conceptualize competition. The concepts of perfect competition or of L-shaped and U-shaped marginal cost curves are of questionable validity. Nor are they observable phenomena in the broad sense.

To understand competition and its homeostasis, we must be able to integrate its entire system. The quantification of sociobiology has demonstrated the power of analysis when competition is viewed as a dynamic, ever-changing system.

If competition is fully understood as a system, the benefits in rationalization of public policy with respect to antitrust, regulation, and international trade can be far-reaching.

I believe that insight into strategic competition has the promise of a quantum increase in our productivity and our ability to both control and expand the potential of our own future.

[1] J. Hirshleifer, *Journal of Law and Economics*, 1977. See also E.O. Wilson, *Sociobiology*, Ch. 27

LA FUNCION DE INFORMACION TECNOLOGICA

POR

ENRIQUE MEDINA RAMOS

MEXICO, D. F.

5 DE OCTUBRE DE 1981

I N D I C E

INTRODUCCION

El objetivo de este documento es mostrar la importancia que las actividades de información industrial tienen, para que la función de Gestión Tecnológica se efectúe, más adelante, incluso existen algunos ejemplos y prácticas que intentan mostrarles de manera más pragmática las experiencias que en México tenemos sobre como manejar las fuentes informativas en apoyo de algunos problemas de administración de la tecnología.

Antes de pasar adelante es necesario acordar algunos significados y conceptos que pueden ahorrar malos entendidos:

Gestión Tecnológica.- Es la función dentro de la empresa encaminada a administrar eficaz y eficientemente la tecnología ya que junto con las actividades de Finanzas, Mercadotecnia y Personal es determinante en el desarrollo o estancamiento de las empresas.

Tecnología.- Es el conjunto de conocimientos y habilidades que aplicados en forma sistemática a la producción, permiten generar bienes y servicios. Es saber cómo se hacen las cosas a diferencia de ciencia que es porqué suceden las cosas.

Información.- La posición competitiva de las empresas depende en gran parte de la información de que ésta disponga y de su habilidad para convertirla en productos y servicios que el mercado necesita, solo mediante la aplicación sistemática de los conocimientos que la información transfiere, podrá crearse un clima favorable a la innovación y a la creatividad para desarrollar una tecnología propia. Cada vez es más aceptado el hecho de que así como una empresa requiere para operar de recursos financieros, maquinaria y equipo, gente, etc., también requiere de conocimientos tanto de mercado para producir lo que la gente necesita, como tecnológicos para producirlos con las características más ventajosas de calidad tanto para los usuarios como para la empresa misma, y estos conocimientos vienen implícitos en la información tecnológica.

PROBLEMATICA DE LA INFORMACION

Una enorme cantidad de conocimientos tecnológicos (información) existe en el mundo y su acumulación crece más día a día. De alguna manera los países en desarrollo deben ser capaces de localizar, seleccionar, evaluar y adaptar estos conocimientos para ser aplicados con fines productivos.

Para tener una idea mejor de esta problemática revisemos algunos aspectos referentes a la explosión de la información.

<u>Desarrollo Histórico:</u>

- En los siglos pasados especialmente del siglo XVIII hacia atrás los conocimientos existentes sobre Ciencia y Tecnología, debido a su reducido número podian ser adquiridos con cierta facilidad por una persona dedicada al estudio. Esto propició que en el Renacimiento algunos fueran considerados como genios. Leonardo Da Vinci por ejemplo dominaba las artes y las ciencias naturales y logró acumular la mayor parte de conocimientos de su época.

- En la actualidad ésto ya no es posible pues a medida que la humanidad profundizó en los distintos campos de la ciencia, se generaron nuevos conceptos y conocimientos, que sirvieron de base a otros posteriores o nuevos.

- Esto ha dado como resultado que en nuestra época sea imposible adquirir y aprender todos los conocimientos tan solo de una disciplina o rama de la ciencia.

- La creatividad del hombre, la investigación, las necesidades de la industria, etc., han hecho que los conocimientos se multipliquen con una velocidad tal, que resulta difícil incluso, no solo su asimilación, también su organización, localización y recuperación.

La Explosión de la Información.

¿Pero cuál ha sido el desarrollo de la información Científico-Tecnológica en la historia de la humanidad?

Los siguientes datos nos permiten apreciarlo:

- En 1665 se publicó la primer revista de carácter científico. (en Francia primero denominada Journal des Scavans) posteriormente llamada Journal des Savants. En el mismo año en Inglaterra se publicó la primer revista de Philosophical Transactions. En 1682, Alemania publicó Acta Eruditorum.

- En 1800 había aproximadamente 100 revistas de investigación en el mundo.

- En 1900 el número se había elevado a 10,000 con la adición de una revista de resúmenes.

- En la actualidad la tasa de crecimiento del número de publicaciones periódicas de carácter Científico y Técnico se duplica cada 10 años.

- Para el año 2000 se estima que se publicarán 1×10^6 de revistas.

- Actualmente se publican más de 100,000 revistas técnicas.

- Se publican al año cerca de 4×10^6 artículos de carácter Científico Tecnológico.

- En el mundo entero se registran más de 300,000 patentes diferentes al año.

- En el mundo existen más de 500,000 personas dedicadas a la investigación.

- Chemical Abstracts, obra dedicada a la localización y organización de los documentos en esa área de la ciencia reseñó en 1977, 500,000 artículos sobre investigación, reportes técnicos, patentes, conferencias y otros documentos de aproximadamente 14,000 revistas.

- Es importante para los países en desarrollo estimular a la industria hacia la aplicación de la Información Técnica.

- Los catálogos industriales que constituyen una fuente de información importante e indispensable para el ingeniero y el técnico representan el doble del volumen de las publicaciones científicas y son difíciles de aprovechar de manera racional.

LA EXPLOSION DE INFORMACION

(CONTAMINACION DE LA INFORMACION)

- EN LOS CAMPOS CIENTIFICOS Y TECNOLOGICOS EL CRECIMIENTO DE LA INFORMACION SE DUPLICA CADA 10 AÑOS.

- 100,000 REVISTAS : 4 M. ARTICULOS TECNICOS.

- 2,000 FUENTES SECUNDARIAS.

- 80,000 LIBROS C Y T/ AÑO (20% DEL TOTAL).

- 20,000 REPORTES TECNICOS / AÑO (120 M. PAGINAS).

- MUCHA INFORMACION / POCO TIEMPO.

- EJECUTIVOS DEDICAN 4 H/ DIA A LECTURA.

GENERACION DE LA INFORMACION

La información se genera en las actividades de investigación y experimentación que se realiza ya sea en laboratorios públicos o privados de todos los países desarrollados ya sea mediante investigación básica, investigación aplicada o desarrollo experimental; respecto a nuestros países, y en especial refiriéndome a México podría comentar, que el proceso de industrialización se ha llevado a cabo en gran parte con tecnología importada pero que cada vez es mayor el número de empresas industriales que están realizando Investigación y Desarrollo en sus campos industriales.

Sin ningún interés de abundar más respecto a los tan discutidos porcentajes de investigación, es consenso generalmente aceptado que para países en desarrollo lo mejor es:

APROVECHAR EL NIVEL DE CONOCIMIENTOS TECNOLOGICOS DISPONIBLES Y NO TRATAR DE DESCUBRIR LO QUE YA SE DESCUBRIO.

Nos es más fácil apoyar a las industrias, sobre todo a las pequeñas y medianas en una progresión de actividades que van:

Seleccionar Tecnologías

Adaptar Tecnologías

Modificar Tecnologías

Crear Tecnologías

A nivel macro, se debe dar preferencia a las actividades de Investigación y experimentación que aceleren la introducción de productos y procesos ya existentes y probados en otros países, que sean compatibles con nuestro patrón de desarrollo o que se puedan adaptar o modificar sin muchos problemas.

ESTRUCTURACION DE LA INFORMACION

Los técnicos, ingenieros y empresarios, son totalmente dependientes de su habilidad para adquirir y manejar la información técnica disponible, como marco de referencia para los conceptos que manejaremos posteriormente, la figura No. 1 muestra, los canales y fuentes de información involucrados en la satisfacción de las necesidades de información por parte de la industria.

Es interesante mostrar en esta figura el progreso de un artículo de información a través de una variedad de medios de comunicación, desde que se descubre hasta que se acepta dentro del acervo de conocimientos registrados.

Los canales más usados para la comunicación son indicados con líneas más gruesas mientras que las punteadas representan canales con menor probabilidad de ocurrir.

En el eje horizontal se muestra la disponibilidad de la información a la comunidad y en el eje vertical se representa el tiempo relativo requerido para aparecer y difundirse desde que se descubre hasta que se imprime o difunde en cada medio de comunicación.

Algunos aspectos interesantes de esta figura son los siguientes:

Comunicación Interpersonal.

- La comunicación interpersonal es quizá uno de los canales más importantes de información para los ingenieros y técnicos, y se refiere a la discusión con los colegas y tiene la ventaja de que es información que se adquiere rapidamente con pequeño esfuerzo y es selectiva, tiene la posibilidad del diálogo para evitar malos entendidos y es información que lleva implícita la experiencia personal del colega.

  En un estudio de ingenieros en un ambiente industrial fué demostrado que ciertos individuos son reconocidos como buenas fuentes de información y se confía en ellos como "gate keepers", ya que cierran el puente entre los colegas dentro de una empresa y los canales formales e informales del exterior.

Literatura Primaria.

El primer registro de nueva información está en la forma de un reporte de investigación, término que cubre cualquier cosa desde un cuaderno de laboratorio o bitacora de registros diarios, hasta documentos más formales que han sido producidos como resultado de una obligación contractual a cambio de fondos para investigación.

Conferencias.

Ya sea a nivel nacional o internacional proveen un enlace adicional entre canales de comunicación formales e informales.

Patentes.

El sistema de patentes garantiza por definición que se trata de nuevos descubrimientos, y en el cuerpo de la especificación generalmente engloba y comunica importante información.

Tesis o Disertaciones.

Se pueden considerar como una forma especializada de reporte y contienen información bastante completa.

Revistas (Journals).

Han sido el principal medio para la revelación del nuevo conocimiento de los últimos 300 años, y al mismo tiempo son considerados como el registro fundamental de ciencia y tecnología.

Literatura Secundaria.

Existen aproximadamente 2,000 revistas y servicios de Indices y Resúmenes, los cuales proveen la clave para accesar la literatura primaria, este tipo de obras, dado el crecimiento vertiginoso de revistas, tienden a especializarse, existiendo obras en los campos de la ingeniería como el Engineering Index, en el campo de la química como el Chemical Abstracts, en el campo de la industria alimentaria; como el Food Science and Technology Abstracts, etc., también existen bases computarizadas para casi cada una de estas fuentes. Con estas fuentes se recuperan los documentos.

Existen también otras fuentes secundarias que nos permiten recuperar información directamente como, monografías, manuales, handbooks, enciclopedias, libros de texto, normas, etc.

Revistas de Servicios de Alerta.

Pueden tomar la forma de reproducción y difusión de las tablas de contenido de fuentes primarias como por ejemplo, Current Conts.

Fuentes Terciarias.

Este tipo de guías de información nos permiten tener una panorámica de las fuentes primarias y secundarias de algún campo determinado o sector industrial, y pueden servir de primer punto de referencia para iniciar el planteamiento de un proyecto.

Barreras a la comunicación.

El sistema tiene imperfecciones o problemas dentro de los que destacan:

- El volumen tan extraordinario de información con el consiguiente problema no solo de aprovechar esta información, aún solo de clasificarlo.

- Existe duplicación de la información ya que los individuos son acreditados dependiendo del número de publicaciones que han realizado.

- Existe también información contradictoria y desde luego errónea, por eso es muy importante criticar y evaluar la información.

- Las barreras del idioma, el 80% de la información está en inglés.

- La falta de conocimiento de las fuentes y de como usarlas efectivamente.

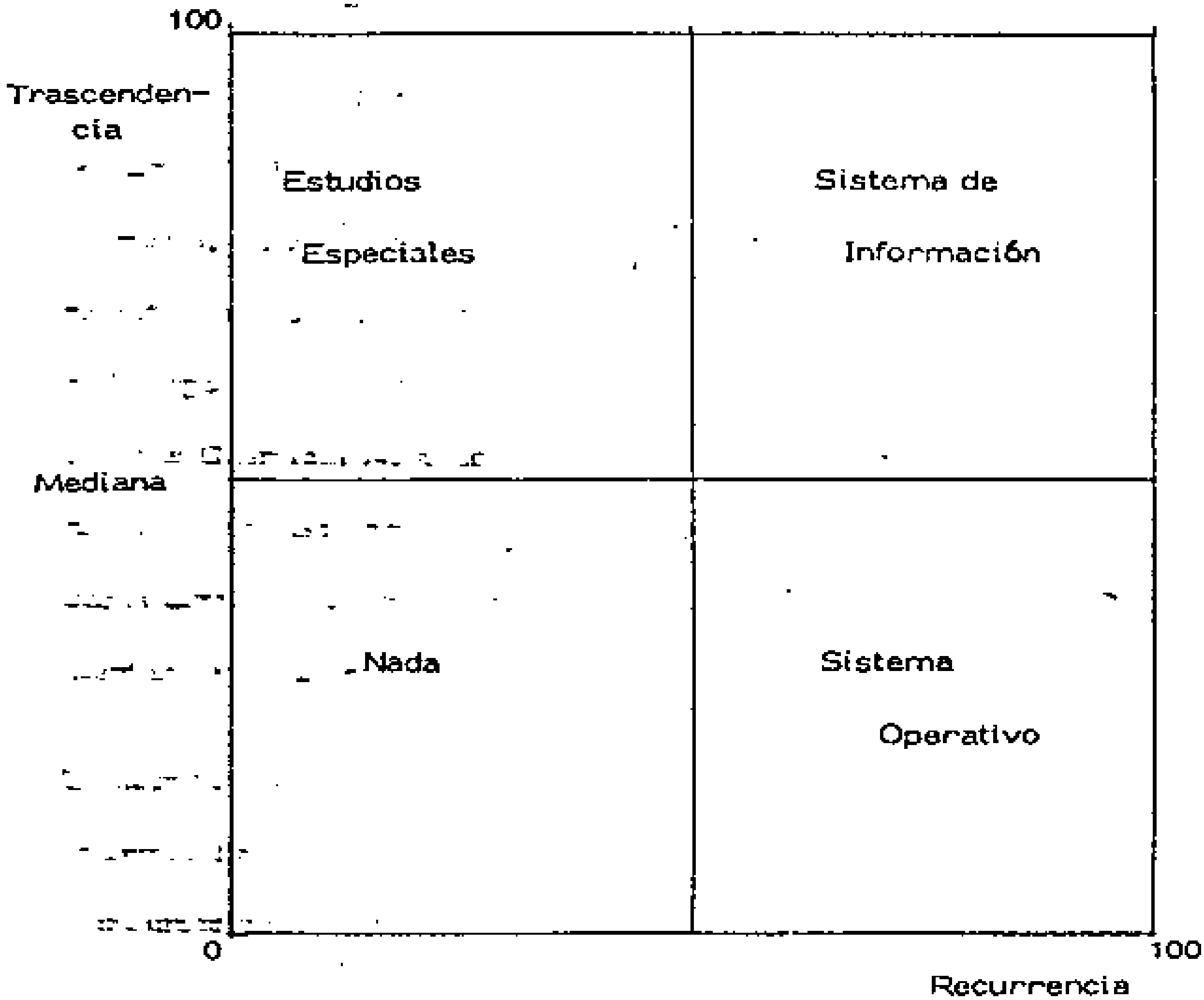
UTILIZACION DE INFORMACION EN LA EMPRESA PARA RESOLVER SUS PROBLEMAS

La información es un insumo básico para que la industria pueda tomar decisiones en la solución de problemas de distinta índole como:

- Que tipo de maquinaria y equipo es el que me conviene adquirir.
- Como debo distribuir mi planta (lay-out) y manejar mis materiales.
- Que nuevas líneas de productos debo introducir y como debo diversificar las actuales.
- Como puedo incrementar mi productividad.
- Como aprovechar oportunidades de mercado.
- Como resolver problemas técnicos.

Podríamos continuar con una lista muy larga de problemas y necesidades de información que tiene la industria, siendo más útil el establecer un modelo que nos permita identificar el tipo de problema o necesidad, lo cual hacemos a continuación.

Análisis de las necesidades de información para la toma de decisiones:



De este modelo es importante destacar los siguientes aspectos principales.

- El eje horizontal es el de recurrencia, es decir mientras más veces se presenta la necesidad de información de la empresa, más a la derecha debe situarse.

- El eje vertical se refiere al impacto o trascendencia que tiene esa necesidad para la empresa.

Existen 4 alternativas o cuadrantes que son:

- alta recurrencia alta trascendencia.- Para necesidades de este tipo es recomendable crear dentro de la empresa un sistema de información, este tipo de necesidades son las de tipo estratégico para la empresa.

- Alta trascendencia baja recurrencia.- Este tipo de necesidades puede satisfacerse de manera adecuada con estudios especiales ya sea realizados por personal dentro de la empresa o por servicios de asesoría y extensionismo tecnológico.

- baja trascendencia alta recurrencia.- Son las necesidades de tipo táctico, operativo que se resuelven con sistemas de tipo operativo basadas en información interna de la empresa.

- Las necesidades caracterizadas por baja trascendencia baja recurrencia son necesidades sin importancia.

modelo que nos permita ...

cual hacemos a continuación.

<u>Sistemas de Información-Innovación-Tecnología.</u>

Los sistemas de información para la empresa es el mecanismo por medio del cual la empresa posee la capacidad de monitorear su entorno y detectar tanto oportunidades como amenazas que le puedan afectar, identificando de esta forma conocimientos útiles para sus proyectos de desarrollo tecnológico y creando así un ambiente propicio para que la innovación tecnológica se presente.

Algunas funciones formales que deben cumplir son:

1.- Sistematizar y organizar el flujo del conocimiento del exterior a la empresa de tal forma que éste sea usado en el desarrollo de la misma.

2.- Proporcionar información al personal profesional que permita desarrollar una <u>capacidad intelectual</u> que se aplique a la creación de productos y a la penetración de mercados. El desarrollo profesional de los individuos que prestan sus servicios en la compañía se realiza <u>mediante la difusión metódica y racional del conocimiento</u> contenido en documentos, revistas y reportes técnicos, estudios de instituciones de I & D, etc., de acuerdo a las necesidades de información de la empresa y de cada uno de los usuarios del centro informativo.

3.- Colaborar en la solución de problemas de tipo operativo y de tipo estratégico.

4.- Analizar tendencias en los diferentes entornos (tecnológico, económico, etc.) que permita a la Dirección y a los responsables del proceso de innovación tecnológica y organizativa detectar a tiempo el advenimiento, el progreso y las consecuencias de cambios en los entornos que presenten oportunidades de negocio o amenazas para la empresa.

5.- Organizar la capacidad profesional de los colaboradores de la compañía de tal forma que sea utilizada en el análisis y evaluación de información que permita contar con un clima de innovación a todos los niveles.

6.- Organizar el uso de la información generada internamente de tal forma que exista una armonía organizativa.

Los sistemas de información para la innovación son recomendables crearse en empresas en las cuales:

a) Se encuentran ubicadas en una industria en la cual el dinamismo tecnológico es moderado y alto.

b) Las necesidades de información son recurrentes e importantes.

c) El tamaño de la empresa es mediano y grande.

d) La Tecnología es un recurso competitivo estratégico.

Las principales etapas que se deben efectuar en la creación de un servicio de información-innovación-tecnología son:

1.- Apoyo de la alta dirección.- Difícilmente tendrá éxito un sistema que no cuente con recursos y apoyo de los altos directivos.

2.- Identificación de las áreas estratégicas de negocio.- Permite la ubicación general del sistema tanto en servicios como en recursos necesarios.

3.- Identificación de necesidades de información de los usuarios potenciales.- Definición de expectativas y requerimientos personalizados.

4.- Definición de servicios que se proporcionarán a los usuarios,

- Monitoreo
- Diseminación selectiva de información.
- Grupos de evaluación.

5.- Identificación y selección de las fuentes informativas documentales y no documentales que constituirán el acervo.

6.- Adquisición, catalogación, almacenamiento y recuperación del sistema.

7.- Evaluación y retroalimentación del sistema. Como está la calidad (precisión) el tiempo de respuesta y el costo del sistema.

Algunos comentarios adicionales a estas etapas son:

Algunos errores comunes en el establecimiento y operación de sistemas de información dentro de empresas son:

1.- No definir claramente las necesidades de los usuarios.

2.- Comprar sistemas de información caros y sofisticados cuando equipos más simples y baratos hubieran sido igualmente útiles.

3.- Ignorar la necesidad de gente capacitada en biblioteconomía/documentación.

4.- Subestiman el problema del idioma.

5.- Gastar muy poco en el acervo de información.

6.- Fallar en el control de las revistas.

METODOLOGIAS DE BUSQUEDA DE INFORMACION

Desde el punto de vista general, las necesidades de información tecnológica para una empresa por parte de sus ingenieros y técnicos puede presentarse en tres formas:

1. Información para la actualización. Como ya se ha mencionado antes, dada la explosión del conocimiento es necesario que los ingenieros y técnicos estén alerta de los nuevos descubrimientos y avances en sus campos de acción, el medio más común para esta actualización es el contacto con colegas dentro o fuera del lugar donde trabajan, así como la asistencia a conferencias, y desde luego la lectura de revistas en sus campos de acción.

2. Información para la Operación.- En las actividades operativas diarias de la industria es muy frecuente la necesidad de datos o hechos como la viscosidad de un fluído, o las propiedades físicas de un material, generalmente se aplica la regla del menor esfuerzo en la adquisición de estos datos, como se muestra en la siguiente figura, es decir en la fuente informativa que primero se encuentre lo buscado se detendrá la búsqueda.

Información Exhaustiva.- Este tipo de búsqueda de información es la encaminada a satisfacer las necesidades de información a nivel estratégico como la selección entre varias alternativas tecnológicas para fabricar un nuevo producto, buscar nuevas oportunidades de mercado, conocer las tendencias tecnológicas de un proceso de producción, etc.

Es este tipo de necesidades el objeto principal de las prácticas que realizaremos más adelante.

Se muestra en la figura siguiente una secuencia o metodología recomendable para recuperar información, de la cual algunos aspectos relevantes son los siguientes:

Etapas:

1 - 2 · Las dos primeras etapas son muy importantes en cualquier búsqueda pues si no se entiende perfectamente lo que se está buscando no se encontrará información debemos definir; limitaciones técnicas, capacidades, fuentes de información utilizables (patentes, reportes, normas, artículos técnicos, etc.) retrospección o período de búsqueda, forma en que se esperan los resultados; documentos bibliografía etc.

3. Esta etapa es válida solo cuando la persona no tiene los conocimientos necesarios, en cuyo caso debe recurrirse a fuentes secundarias de tipo informativo.

4. Se refiere a la planeación de las fuentes que se utilizarán para obtener la información de manera más fácil y rápida, listando las fuentes en el orden en que serán usadas. Las fuentes terciarias son de inestimable valor en la definición de las fuentes que se utilizarán, sobre todo cuando no se conoce bien el campo de búsqueda, es preferible usar primero las fuentes secundarias especializadas, es necesario definir en esta etapa los descriptores o palabras clave usando catálogos de palabras clave o thesaurus.

5. Con objeto de probar la estrategia de búsqueda, es recomendable realizar un sondeo para probar si está correctamente planteada la búsqueda en caso positivo se debe emprender la búsqueda principal de información.

6. El éxito en la búsqueda de información depende de varias características; experiencia, creatividad, perseverancia, entrenamiento, de parte del investigador.

7. Una vez identificado los documentos, es necesario recuperarlos para lo cual se debe acudir a servicios como el BLL en Inglaterra, Information Unlimited o North Carolina en Estados Unidos de América.

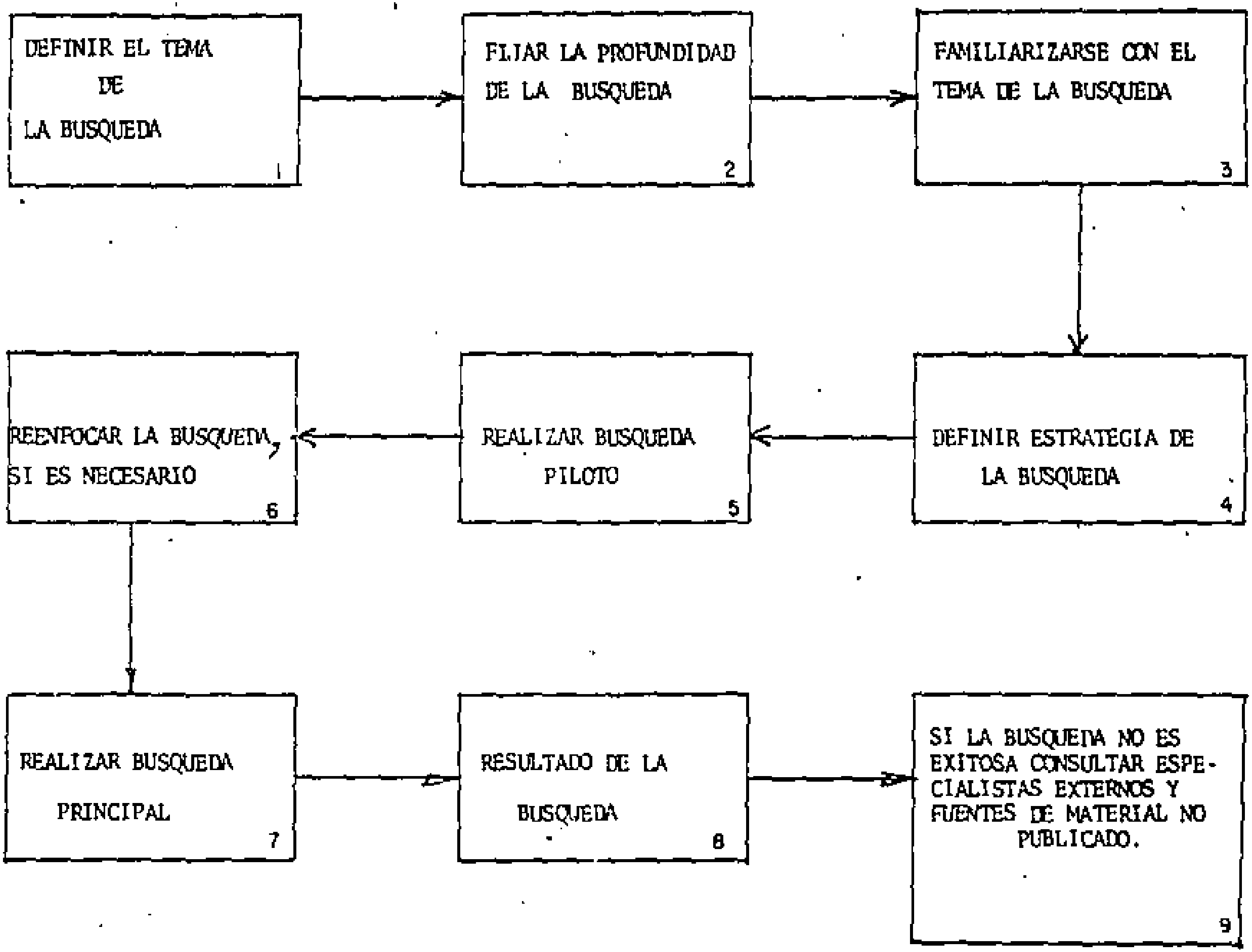
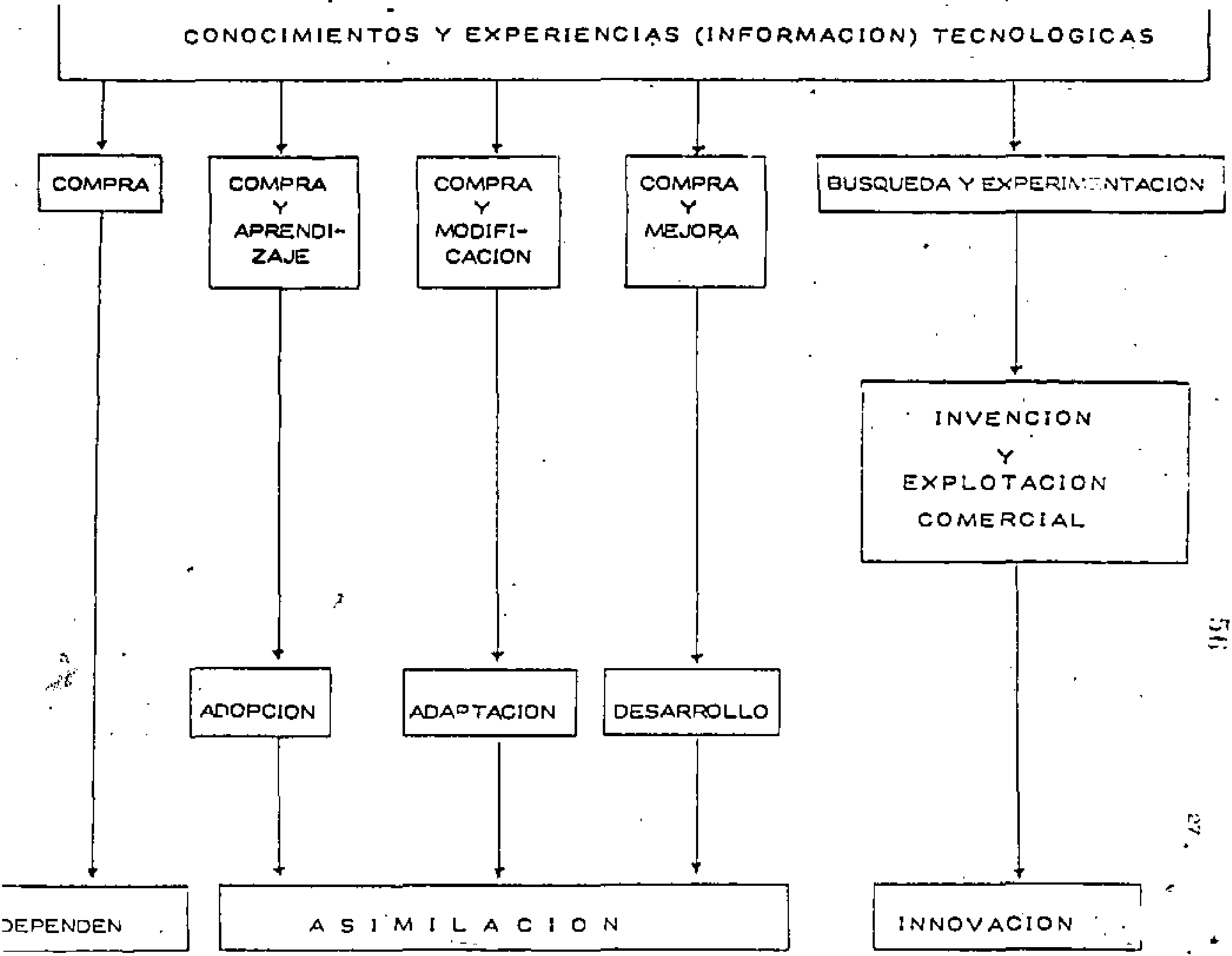

DEFINIR EL TEMA DE LA BUSQUEDA 1
FIJAR LA PROFUNDIDAD DE LA BUSQUEDA 2
FAMILIARIZARSE CON EL TEMA DE LA BUSQUEDA 3
DEFINIR ESTRATEGIA DE LA BUSQUEDA 4
REALIZAR BUSQUEDA PILOTO 5
REENFOCAR LA BUSQUEDA, SI ES NECESARIO 6
REALIZAR BUSQUEDA PRINCIPAL 7
RESULTADO DE LA BUSQUEDA 8
SI LA BUSQUEDA NO ES EXITOSA CONSULTAR ESPECIALISTAS EXTERNOS Y FUENTES DE MATERIAL NO PUBLICADO. 9

FIG. No. 4


CONOCIMIENTOS Y EXPERIENCIAS (INFORMACION) TECNOLOGICAS
COMPRA
COMPRA Y APRENDIZAJE
COMPRA Y MODIFICACION
COMPRA Y MEJORA
BUSQUEDA Y EXPERIMENTACION
INVENCION Y EXPLOTACION COMERCIAL
ADOPCION
ADAPTACION
DESARROLLO
DEPENDEN
ASIMILACION
INNOVACION

LA NECESIDAD DE INFORMACION PARA LA GESTION TECNOLOGICA

La figura No. 5 muestra un modelo para conceptualizar las distintas opciones para desarrollo de la tecnología en una empresa, así como las implicaciones y relaciones con la información tecnológica.

Como se puede observar la opción de compra (lado izquierdo) en cualquiera de sus formas Asistencia Técnica, Maquinaria y Equipo, Patentes, Entrenamiento mediante relaciones contractuales crea una dependencia peligrosa para la empresa, así como una rápida implementación.

En el extremo opuesto se encuentra la opción activa o creativa que conduce a la innovación, mediante la búsqueda, experimentación y explotación comercial, desarrollando tecnología propia.

De manera intermedia se tienen las opciones que conducen a la asimilación variando en grados de pasividad, actividad, adopción, adaptación y desarrollo.

La utilización de una u otra de estas alternativas depende de numerosos factores entre los que cabe destacar; la naturaleza del producto, grado de sofisticación tecnológica del proceso de producción, tiempo disponible para su implementación, etc.

Pero indiscutiblemente de la forma como se administre la tecnología de la empresa el conocimiento y experiencia que se encuentran implícitas en la información tecnológica son insustituibles en el proceso de administrar la tecnología.

Las industrias de países en desarrollo principalmente las medianas y pequeñas necesitan de servicios de información que no resultan costeables ni eficientes si se organizan en cada centro de producción o en cada empresa, por el alto costo de los recursos que se requieren.

Estos servicios deben ser generadores de un flujo de conocimientos tecnológicos hacia las empresas, que les permitan identificar áreas potenciales de desarrollo tecnológico a través de oportunidades de mercado, identificación de problemas operacionales o desarrollo de nuevos productos.

A continuación les comunicaré a ustedes las experiencias de desarrollo y operación de un Servicio de Información y Asistencia Tecnológica.

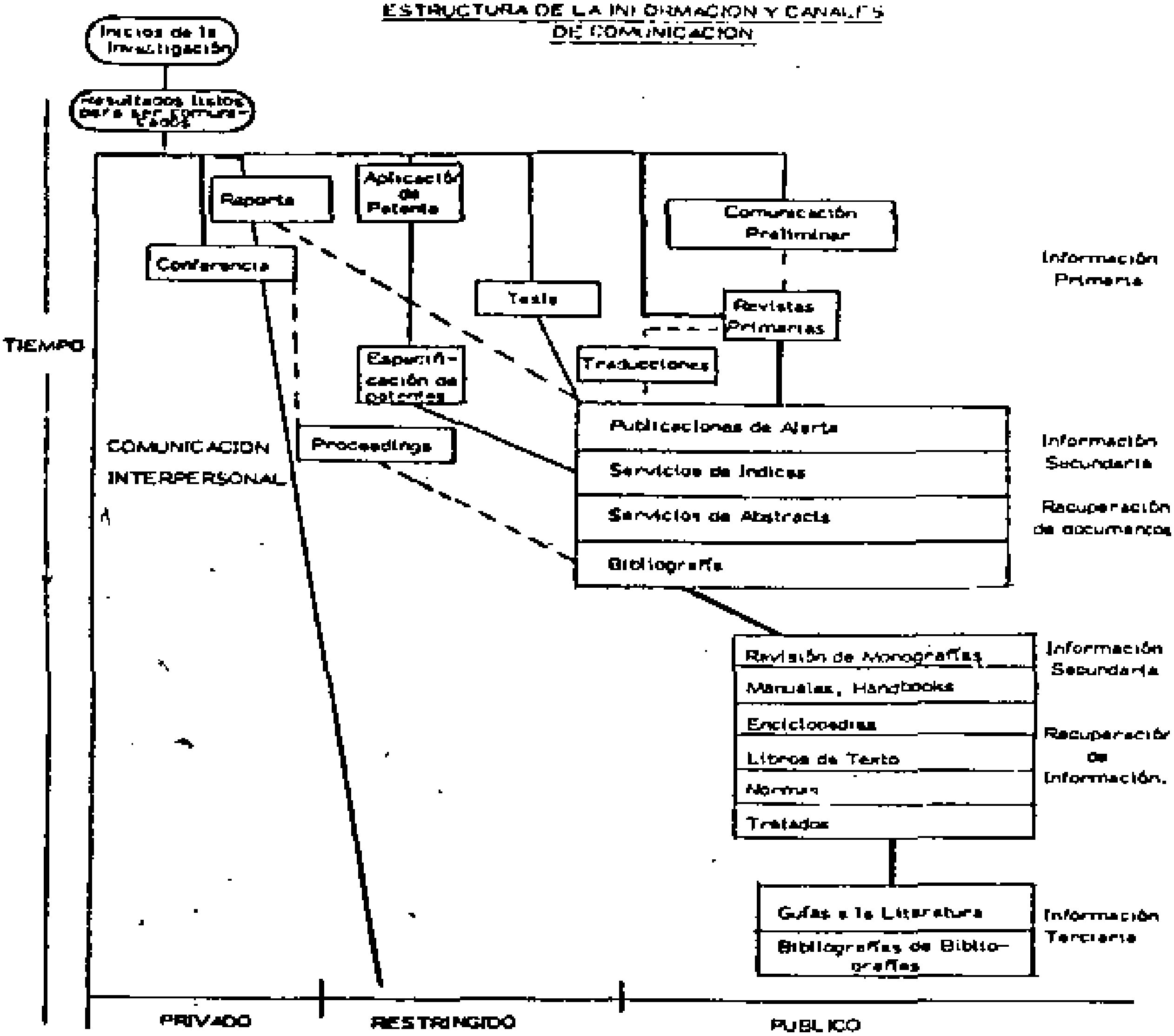
TRABAJOS PRACTICOS

OBJETIVO: Sensibilizar a los participantes en las metodologías de acceso a la información.

PRESENTACION DE LAS FUENTES:

Tomando como punto de partida la figura 1 de canales de comunicación de la información se pretende presentar de manera concreta algunas de las más importantes fuentes de la información y posteriormente realizaremos algunos ejercicios.

ESTRUCTURA DE LA INFORMACION Y CANALES DE COMUNICACION



FUENTES SECUNDARIAS

. RESUMENES E INDICES

Existen en la actualidad más de 2000 servicios de resumenes e indices cubriendo la ciencia y la tecnología, desde mi punto de vista la utilidad más grande que presentan es el evitar tener toda la literatura publicada en un área específica, ya que estas fuentes precisamente nos permiten saber en donde se encuentra la información que necesitamos.

También pueden considerarse herramientas útiles en la actualización profesional y como acervos completos de conocimientos pasados. Con respecto a este último punto es importante mencionar, que la tecnología desde mi punto de vista, generalmente se le evalua considerando principalmente su obsolecencia pero tomando como punto de referencia los países desarrollados. Especialmente para nuestras pequeñas y medianas empresas, este es una parametro no aplicable ya que nuestro patron de desarrollo es diferente de el de los países industrializados, y volviendo a nuestros servicios de resumenes, son precisamente estos los que nos pueden ofrecer las distintas alternativas tecnológicas para seleccionar la más adecuada de acuerdo a las características de la empresa, el mercado y el país.

A continuación les presentare a manera de ejemplo de estas fuentes, cinco servicios de los que considero más aplicables.

Engineering Index

Anual 1985 Mensual 1962 Computarizado 1970

Es el mayor servicio de resumenes interdisciplinario del mundo de la literatura de ingenieria, en 1974 aparecieron 85000 resumenes y anotaciones extractadas de más de 2,000 revistas, reportes, conferencias, simposios, libros, estándares.

Practicamente cubre todos los campos de la tecnología y los resumenes son arreglados alfabéticamente por encabezados, de acuerdo a una lista de 12,000 terminos aproximadamente denominada SHE (Subject Headings for Engineering).

La aplicación de la información contenida en esta fuente tiene aplicación prácticamente en todo tipo de industrias y en especial para la realización de funciones de Ingenieria, Investigación y Desarrollo, Tendencias Tecnológicas, Planeación.

Aparece mensualmente y puede ser consultado en forma computarizada desde 1970.

Metals Abstracts

1968

Es publicado por la American Society for Metals cubriendo aproximadamente 1000 revistas en los siguientes temas relacionados con la transformación de los metales: Maquinado formado, forja fundición, soldaduras, selección de metales. Puede consultarse por computadora.

Chemical Abstracts.
1907

Resumens bibliográficos de artículos seleccionados de aproximadamente 14000 revistas cientíFicos y Técnica procedentes de más de 150 países y publicadas en más de 50 idiomas; resumenes de patentes registrados en 26 países resumenes de nuevos libros, disertaciones, conferencias e informes técnicos sobre temas de o relacionados con la química especificamente Bioquímica, Química Orgánica, Química Macromolecular, Química aplicada e ingenieria química.

Applied Science & Technology Index
1958-

Es la continuación de el Industrial Arts Index y es publicado mensualmente con recopilaciones anuales. La manera de consultarlo es por encabezados alfabéticos con referencias cruzadas, es decir un artículo se puede encontrar buscando bajo distintas palabras clave, cubre solo revistas en Inglés.

66

Food Science and Tecnnology Abstracts

1969-

Resumenes bibliográficos de artículos seleccionados de aproximadamente 2000 revistas científicas y técnicas precedentes de más de 50 países y más de 43 idiomas; resumenes de patentes registrados en más de 20 países cubre aspectos como, Maquinaria y equipo para el procesamiento, conservación, estándares, aspectos económicos y estadísticos en el área de Ingeniería de alimentos.

Patentes

Se estima que a nivel mundial existe un volumen de 17 millones de patentes de las cuales 4 millones todavia estan vigentes.

Algunas de las ventajas que tiene el uso de patentes como fuentes de información son la siguientes:

- La información técnica obtenida de los patentes es muy completa dado que es necesario incluir suficiente información para evitar rechazos por "insuficiente revelación".

- Estan limitadas por definición a contener solo nuevos desarrollos, datos e ideas.

- En la sección correspondiente a especificación discuten las dificultades asociadas con investigaciones previas, técnicas productivas y ofrecen métodos específicos de solución esto en ocasiones no se publica en revistas y libros.

- Normalmente revelan las innovaciones tecnológicas antes que otras fuentes de información.

- El sistema de clasificación por su

consistencia permite recuperarlas con facilidad y rapidez una vez que se conoce la clase objeto de la busqueda, la recuperación de información de patentes puede realizarse por cualquiera de los tres sistemas siguientes:

Sistemas Oficiales Nacionales, esto es, si se efectuan busquedas utilizando la información generada por gobiernos en materia de-patentes, como por ejemplo, la Oficina de Patentes de EUA.

Sistemas Oficiales Internacionales, esto es, si se efectuan busquedas utilizando la información generada por organismos internacionales en materia de patentes como por ejemplo la Oficina Mundial de la Protección Intelectual (OMPI)

Sistemas Privados, esto es, si se efectuan busquedas, utilizando la información generada por organismos internacionales en materia de patentes, como por ejemplo Derwent Publications LTd (Inglaterra), IFi Plenum (Estados Unidos), Chemical Abstracts (Estados Unidos).

Ademas es posible enfocar la metodología de la recuperación de información de acuerdo a si se hace manual o por medios computarizados.

A continuación se muestran algunas de las fuentes de acceso a las patentes.

Sistema Oficial de E.U.A.

En la actualidad tienen un volumen superio a los 4 millones.

Es importante mencionar la gran importancia de este acceso, ya que algunas estimaciones presentan esta fuente como el más completo a nivel mundial por el interés que el mercado industrial de los EUA tiene para otros países lo cual motiva el registro de sus patentes en esta fuente.

Para la recuperación es importante considerar la existencia de 3 elementos:

1.- El Boletín de Clasificación.(Official Gazette)

2.- El Indice de Clasificación

3.- Manual de Clasificación

Estructura.- El sistema consiste de 355 clases y más de 100 000 subclases.

Para el acceso es necesario consultar primero el Indice de clasificación, y afinar la clase en caso de que sea necesario en el manual de clasificación otros accesos existentes es por lista de patentes.

World Patente Index

Está fuente de información contiene los resúmenes de patentes en los campos mecánico, eléctrico y general, otorgados por los principales países industrializados desde 1974 entre los que destacan Unión Sovietica, Reino Unido, Alemania Oriental, Alemania Occidental, Japón, Francia.

Este banco está computarizado y la manera de recuperar la información se puede efectuar por:

- Tema
- Compañía
- Patente
- Clasificación Nacional
- Clasificación Internacional

Claims Gems.

Este banco cubre patente en EUA. desde 1975 a la fecha y sólo registra patentes sobre Mecánica y Eléctricidad, las patentes pueden ser localizadas:

- por tema
- por nombre de la compañía
- por patentante
- por clase y Subclase.

IMPADOC.

Es un banco de patentes muy importante, propiedad del gobierno Austriaco que tiene un registro de 8 ó 9 millones de patentes a nivel mundial.

Su misión es registrar y ordenar los datos de bibliográficos de las patentes para que puedan ser aprovechada la información de patentes.

ESTANDARES.

Es una importante fuente de información tecnológica, que permiten en muchos casos identificar áreas en donde mejoran la confiabilidad, calidad, seguridad de los productos o de la maquinaria o equipo utilizado en las empresas, ya que definen requerimientos mínimos, métodos de prueba y métodos de uso. Encontramos estandares de dos tipos:

a) Internacionales.- Las dos organizaciones más importantes son: The International Organization for Standarization (ISO) y the International Electrotechnical Comission (IEC), aun cuando existen otros que agrupan algunos países como European Committe for Standarization CEN.

b) Nacionales.- La mayoria de los países y sobre todo los industrializados tienen una gran cantidad de normas que son un valioso apoyo informativo.

CATALOGOS

La información de catálogos es de un volumen dos veces mayor que el de los artículos de revistas técnicas. Las empresas generan este tipo de información para facilitar la comercialización de sus productos, pero constituyen indudablemente un elemento informativo de enorme utilidad.

Los catálogos pueden conseguirse escribiendo directamente a las empresas fabricantes o distribuidoras en otros países, actividad para la cual es indispensable contar con Directorios Industriales Internacionales como los Kompass que nos permiten determinar la empresa, dirección y tamaño aproximado por número de obreros o volumen de ventas.

Existen también servicios que se dedican a vender colecciones de catálogos industriales como Information Handling Service (de EUA.) o Berliner (tambien de E.U.A.).

SERVICIO DE DOCUMENTACION

Para la recuperación de los documentos una vez conocida su utilidad, existen servicios que se dedican a tener colecciones completas de revistas, o a conseguirlos en otras bibliotecas de los servicios que considero más importantes por su confiabilidad está el British Lending Library quien en base a un sistema de cupones puede conseguir prácticamente cualquier artículo patente o conferencia, sin embargo existen otros servicios en E.U.A. como Information Unlimited y North Carolina.

Considerando la intervención de estos servicios para la recuperación de documentos, es importante destacar que las actividades de información tecnológicas en una empresa no deben encaminarse al almacenaje de documentos, sino al diseño de servicios que permitan estar alerta de las amenazas y oportunidades tecnológicas para la empresa y a la recuperación de la información verdaderamente útil y aplicable.

APOYO A LAS ACTIVIDADES DE GESTION TECNOLOGICA EN MEXICO.

EXPERIENCIAS DE INFOTEC

CONTENIDO

I.- INTRODUCCION.

El objetivo de este documento es mostrar las experiencias, el desarrollo histórico y las tendencias que tiene INFOTEC como servicios de información, asistencia técnica y extensionismo tecnológico (SIATE) en el apoyo de la Gestión Tecnológica de las empresas, tanto a nivel conceptual y filosófico como a nivel práctico y operativo.

Para este fin es necesario abordar aspectos sobre su concepción general, objetivos básicos, y sobre todo ejemplos prácticos que muestran claramente el tipo de apoyo y potencial que un mecanismo de esta índole presenta a la creación de una tecnología propia y a la innovación tecnológica.

II.- DESCRIPCION GENERAL.

INFOTEC es una organización de servicios tecnológicos principalmente para la industria mediana y pequeña del país , que realiza actividades de difusión de información, asistencia técnica y extensionismo tecnológico.

Se inició como un experimento dentro del CONSEJO NACIONAL DE CIENCIA Y TECNOLOGIA (CONACYT) a principios de 1972 con el fin principal de difundir la información científica y técnica a la industria satisfaciendo la correspondiente necesidad que en ella existía. Debido a la promoción y operación, paulatinamente esa necesidad se fue transformando en demanda, hasta el punto en que INFOTEC requirió su autonomía para el mejor desarrollo de sus funciones, y en 1975 se separo físicamente de CONACYT.

Para su operación recibe un subsidio de parte del Gobierno Federal que es administrado en fideicomiso por NAFINSA, y aportaciones de organizaciónes internacionales dentro de las que destacan OEA y ONU.

Su operación no persigue fines de lucro, sin embargo, los servicios y apoyos que proporciona a la industria se cobran, básicamente para recuperar los recursos utilizados en el servicio .

III.- FILOSOFIA Y OPERACION DE INFOTEC.

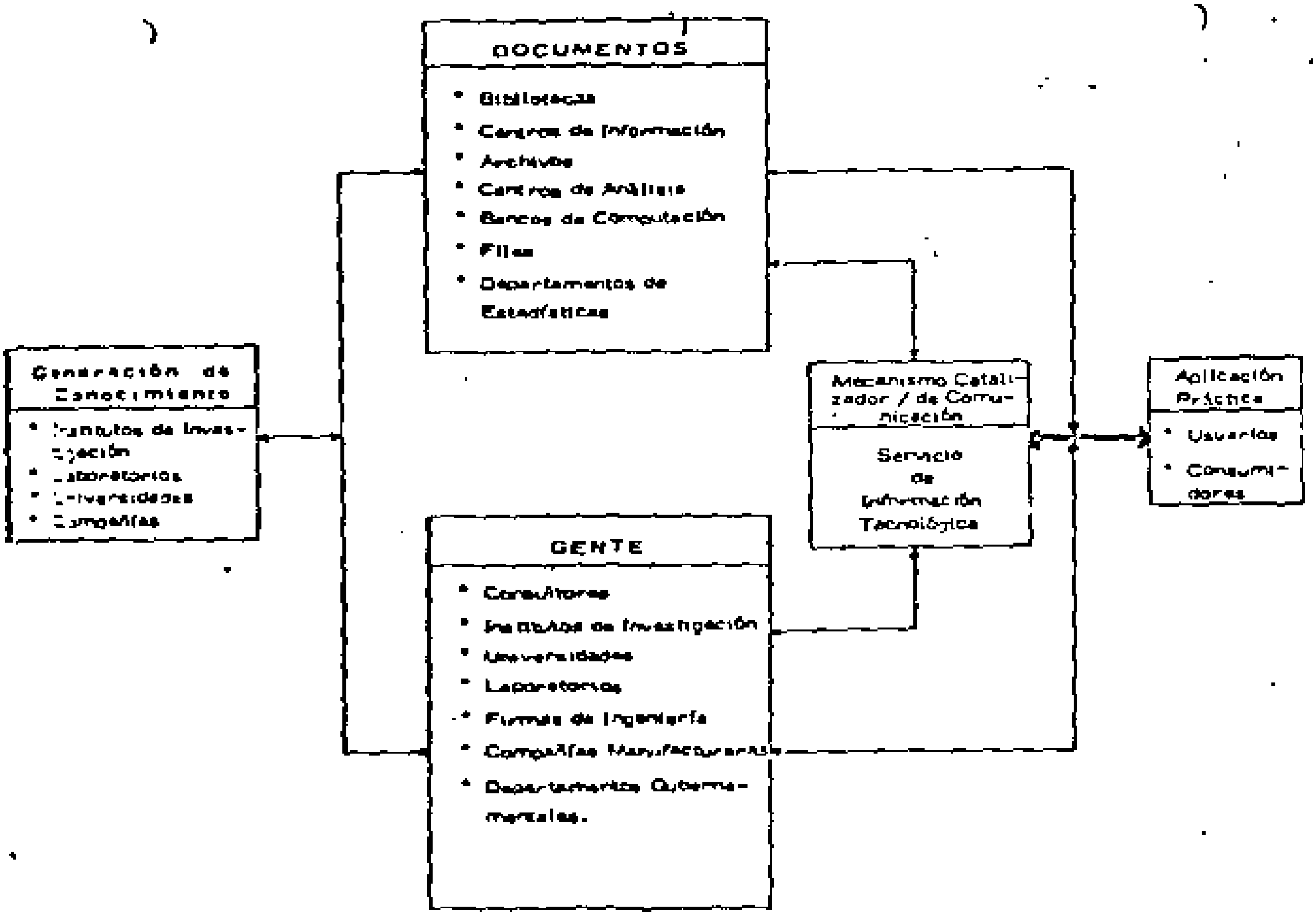
MISION: Contribuir el desarrollo tecnológico e industrial del país a través de facilitar y promover el uso del conocimiento en la producción de bienes y servicios.

FIN: Favorecer la creación de una capacidad tecnológica propia y de innovación en las empresas.

Algunos de los propósitos básicos perseguidos son:

° Resolver problemas técnicos y operacionales.
° Incrementar productividad.
° Mejorar procesos y productos existentes.
° Desarrollar nuevos procesos y productos.
° Aprovechar oportunidades de mercado.

En un contexto más amplio, el papel de INFOTEC como mecanismo de apoyo a la comunicación entre el sector industrial y la Infraestructura Cientifico Teconológica se muestra en el siguiente diagrama:



IV. SERVICIOS ACTUALES DE INFOTEC

Los servicios de INFOTEC pueden ser agrupados en cuatro categorías.

- Servicios de Información
- Servicios Técnicos compartidos
- Servicios de capacitación
- Servicios de Asistencia Técnica

Han sido diseñados para satisfacer, desde las más sencillas necesidades de información técnica, hasta los más completos casos de asistencia tecnológica para la industria con un enfoque multidisciplinario y flexible a continuación se muestran sus principales características.

Servicios de Información:

- Boletínes de Noticias Técnicas.- Se publican un conjunto de boletínes técnicos que constituyen un medio para mantener informados y al mismo tiempo incrementar los conocimientos de los profesionales.

- Servicio Express de Información.- Consiste en el servicio de consulta a bancos computarizados de información que permiten localizar y obtener información confiable en un mínimo de tiempo.

- Divulgación de información del National Technical Information Service (U.S.A.), se ponen al alcance de la industria los resultados de las investigaciones del Gobierno de los Estados Unidos que consisten en más de un millón de reportes en multiples campos de la ciencia y la tecnología.

- Servicios Editoriales.- Consiste en la publicación de aquellos libros que se consideran de interés para la industria.

- Servicio de Documentación.- Mediante este servicio la industria puede obtener practicamente cualquier documento publicado en el mundo.

Servicios Técnicos Compartidos

- Programa de Información Tecnológica.- En este servicio se integran una combinación de servicios de información y asistencia técnica basándose en los servicios mas usados en la mayoría de las empresas.

III.- Servicios de Capacitación

- Este programa está formado por un conjunto de cursos y seminarios encaminados a dotar a los individuos que manejan los conocimientos tecnológicos, de los conceptos métodos y técnicas que les faciliten administrar la tecnología.

Servicios de Asistencia Técnica

- Este servicio constituye un instrumento multidisciplinario da poyo técnico, que operando temporalmente como una extensión de la empresa, le proporciona servicios de ingeniería y consultoría en general; adaptandose a sus necesidades particulares, para lo cual previamente se presenta una propuesta que especifica el alcance, duración y costo del trabajo en cuestión.

F. Desde el punto de vista de necesidades de información para la administración de la tecnología dentro de las empresas, deben visualizarse 3 niveles cada uno teniendo diferentes necesidades. En INFOTEC estamos conscientes de está situación y nuestra gama de servicios para satisfacerlos, podríamos presentarlos así.

1.- Estrategía Tecnológica.- A este nivel se establece los planes a largo plazo de 5 a 10, se definen objetivos, políticas, etc. Los tipos de trabajo que hemos realizado son:

- Pronósticos y Tendencias Tecnológicas
- Consultoría en el desarrollo de sistemas de creatividad en la empresa.
- Asesoría en la organización y administración de la función de Investigación y Desarrollo
- Cursos de innovación tecnológica.
- Análisis de Vulnerabilidad.
- Exploración de oportunidades de negocios.
- Boletines de [illegible]

2.- Táctica Tecnológica.- Nivel en el cual se desarrollan los planes a corto plazo.

Incrementar [illegible]

Los tipo de servicios son los siguientes:

- Servicio [illegible]
- Asesoría en contratos de negociación de tecnología.
- Estudios de mercado de productos industriales
- Análisis de patentabilidad e Infringimiento de patentes.
- Estudios de factibilidad Técnico Económico.
- Identificación de proveedores alternativos de Tecnología [illegible] ces del Gobierno [illegible]

3.- Operaciones Tecnológicas. [illegible] de la ciencia y la [illegible]

- Diseño e Ingeniería de productos
- Proveedores de maquinari y equipo.

- Especificaciones de materias y producto terminado
- Procesos alternativos de fabricación
- Distribución de planta (Lay Out)
- Manejo de Materiales.
- Planeación y control de la producción.
- Laboratorios de pruebas y análisis.
- Cursos para formas Gate Keepers.

TENDENCIAS DE LOS SERVICIOS DE INFOTEC

A lo largo de su desarrollo, INFOTEC ha presentado una clara tendencia, como era de esperarse, a realizar trabajos más completos, con mayor valor agregado, y por lo tanto más interesantes.

Con un enfoque más orientado hacia la solución del problema que tiene el cliente, nos hemos ido separando del enfoque documentalista hacia el análisis, evaluación y en muchas ocasiones aplicación de la información para resolver la problemática industrial, proceso que en múltiples ocasiones ha requerido de apoyo institucional externo a INFOTEC, habiendo trabajado con consultores independientes especialistas en campos como; metalurgia, electrónica, empaque, abogados de patentes, etc., e instituciones tanto nacionales como internacionales como el Instituto de Ingeniería de la Universidad Nacional Autónoma de México, Standford Research Institute y Production Engineering Research Association.

Lo anterior no quiere decir que ya no se realicen trabajos de tipo documental, búsquedas bibliográficas, recuperación de documentos, etc. sino que estos se elaboran para empresas que tienen la capacidad técnica, como el tiempo para analizar e implementar dicha información.
En otras palabras la versatilidad de INFOTEC para atender las demandas de la industria ha cre-

cido.

Un comentario final que confirma la directriz que hemos tomado con respecto al cobro de servicios, es que el industrial debe estar consciente de que los servicios que se le proporcionan tener la posiblidad de ser autofinanciables, meta que estoy seguro que habremos de conseguir dentro de dos años a partir de esta fecha.

CASOS PRACTICOS

1.- Empresa fabricante de cilindros hidráulicos.

Problema:

En general producto deficiente, particularmente no cumplía con estandares (normas) al no mantener concentricidad interna, provocando fugas fuera de límites tolerables.

Trabajo de Ingeniería de INFOTEC:

a) Identificación de información técnica cubriendo los siguientes aspectos:
   - procesos alternativos de fabricación (3 en este caso)
   - materias primas
   - tolerancias de fabricación
   - espesor de cromado en el vástago
   - soldadura
   - control de calidad
   - estándares de fabricación y métodos de prueba

b) En base al proceso más adecuado se usó información para diseñar una herramienta especial que al mismo tiempo que corta, genera su propio soporte. La misma herramienta sirve para inyectar un fluído que desaloje la rebaba (viruta) que se produce en el corte.

c) En base a información sobre soldadura se identificó y adquirió un equipo para soldar por arco sumergido que elimina las imperfecciones de la soldadura manual. Este equipo se combinó en la operación con un torno para lograr una velocidad de depósito en la soldadura que dé como resultado uniformidad en todas las piezas fabricadas.

d) En base a información de máquinas y equipos usados por la industria de motores de combustión interna, se diseñó/adaptó un equipo para rectificado/pulido final los cilindros hidráulicos.

e) Adquisición de equipos para medir el acabado de la superficie (profilómetro) y en base a estándares se establecieron los rangos aceptables de calidad.

f) Se construyó un banco de pruebas para medir los productos de la empresa contra los estándares y contra productos de la competencia.

Resultados a corto plazo:

a) Ahorro de $80,000.00 (U.S.) en la compra de una máquina para rectificado/pulido final. Inversión que no se justificaba para el bajo volumen de producción de la empresa.

b) Se estandarizaron las dimensiones de los cilindros a fin de ofrecer productos de fabricación bajo especificaciones y evitar diseñar cilindros para cada aplicación.

c) Al cumplir con especificaciones, los cilindros de la empresa fueron aceptados por fabricantes de maquinaria de "precisión"; ampliándose considerablemente el mercado/ventas (en el primer año la empresa logró ventas de aproximadamente 300% a las que tenía antes de modificar sus procesos).

APOYO A LA INNOVACION TECNOLOGICA

Uno de los aspectos más débiles de los países en desarrollo es la falta de capacidad y de experiencia tanto a nivel macroeconómico como a nivel microeconómico para el manejo y administración de la tecnología o gestión tecnológica. Las experiencias mías dentro de INFOTEC muestran que la mayoría de las empresas tienen problemas en la incorporación del elemento tecnológico dentro de su planeación a largo plazo, en sus planes a un año a sí como en sus operaciones diarias. La incorporación exitosa del aspecto tecnológico depende fundamentalmente de un ambiente propicio y positivo a la innovación. INFOTEC ha venido desarrollando escencialmente servicios de consultoría orientados a resolver esta problemática, inicialmente con sistemas de información que sistematizan el flujo de conocimientos dentro de la empresa, creando un departamento de información, que deberá evolucionar a ser el departamento de planeación tecnológica que servirá posteriormente como núcleo del sistema.

Este enfoque requiere un proceso participativo dentro de la empresa a través del cual el personal de la empresa sea capaz de entender y usar la información tanto económica como técnica, y administrativa; formar grupos estratégicos de evaluación de negocios en los cuales se discuta la aplicación de la información y las necesidades adicionales de la empresa para llegar a resultados prácticos, esto constituye un instrumento ideal para llegar a detectar oportunidades y amenazas.

Generating Effective Corporate Innovation

There is no rule book. But here are some principles of staffing, structuring, and strategy setting which can be ignored only at the peril of any company intent on assuring its future through technological innovation.

Edward B. Roberts
David Sarnoff Professor of Management
M.I.T.

Effective corporate innovation requires the planned integration of staffing, structure, and strategy. This view arises from 15 years of research at M.I.T. and elsewhere on the problems of managing industrial research and development and the technological innovation process. The results of our studies focus on four different areas which relate both to conventional research and development programs carried out by most technology-based firms and to the more venture-oriented new-product developments being undertaken by increasing numbers of such firms. There are both similarities and differences in emphasis between these two very different areas of technical innovation, and I'll try to point out these differences and their implications.

The four critical areas are these:

☐ The *staffing* of technical organizations must provide for the several key functions necessary to achieve successful innovation.

☐ The organization must be *structured* to enhance the flow of technical and market information into research and development.

☐ The organization's structure must also assure strong links with *marketing*, to assure that innovations effectively move forward into commercial success.

☐ The company must adopt *strategic planning* methods that improve integration of top management's technical plans with other dimensions of overall corporate strategy.

Five different key staff roles must be fulfilled if innovative ideas are to be generated, developed, enhanced, commercialized, and moved forward in the organization:

☐ The *creative scientist or engineer*, the source of creativity within the organization about whom so much — perhaps too much — has been written.

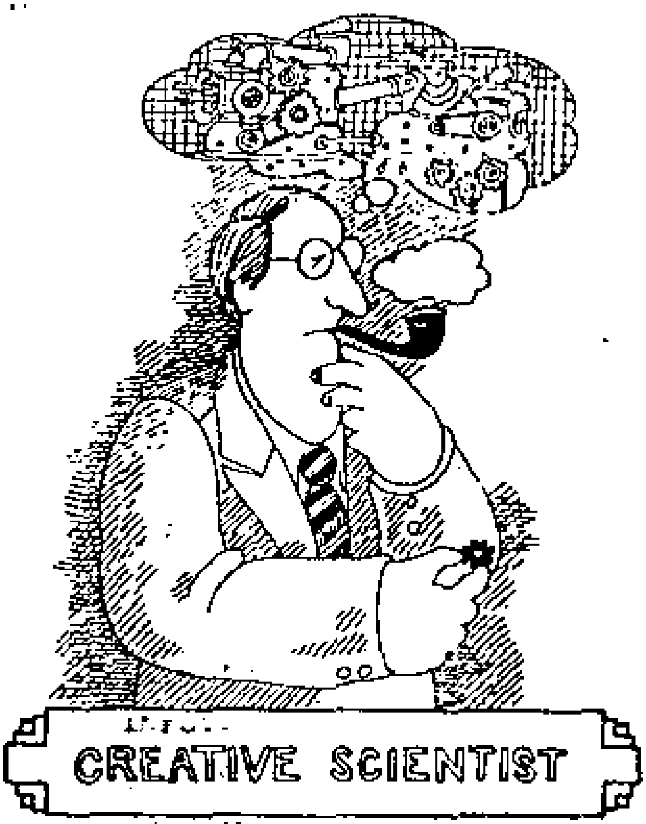
☐ The *entrepreneur* who pushes the technical idea (it may be his or someone else's) forward in the organization toward the point of commercialization.

☐ The *project manager*, who can focus upon the specifics of the new development and indicate which aspects will go forward, which can be economically supported, and which must be deferred and who can coordinate the needed efforts.

☐ The *sponsor*, the in-house senior individual who provides coaching, back-up, and large skirts behind which entrepreneurs and creative scientists can hide. His role is that of protector and advocate — and sometimes bootlegger of funds — so that innovative technical ideas survive past the birth stage to gain the confidence of the technical organization.

☐ The *gate-keeper*, who brings essential information into the technical organization. Gate-keepers come in two varieties: the technical gate-keeper and the market gate-keeper; both of them account disproportionately for the information that is used in developing innovative ideas and moving the resulting processes and products forward into manufacturing and the marketplace.

In studies of many research and development organizations over the last 15 years, we have observed deficiencies primarily in all but one of these key roles needed for organizational effectiveness. The role of creative scientist seems to be over-emphasized; organizations tend to assume that having creative people on the payroll guarantees effective development of new products, new proc-



esses, and product improvements. This assumption is far from correct, and it has tended to cause systematic neglect of the other functions necessary for effective innovation.

This observation is important in the light of our conclusion that each of the several roles required for effective technical innovation presents unique challenges and must be filled with very different types of people, each type to be recruited, managed, and supported differently, offered different sets of incentives, and supervised with different types of measures and controls. Most technical organizations seem not to have grasped this concept, with the result that all technical people tend to be recruited, hired, supervised, monitored, evaluated, and encouraged as if their principal roles were those of creative scientists. But only a few of these people in fact have the personal and technical qualifications for scientific inventiveness; a creative scientist or engineer is a special bird who needs to be singled out and cultivated and managed in a special way. He is probably a strong, innovative, technically well-educated individual who enjoys working on advanced problems, often as a "loner." In an industrial laboratory, he is likely to be among the minority of scientists and engineers with doctorates, but education itself is by no means the criterion for creativity.

The entrepreneur is a special person, too — creative in his own way, but his is an aggressive form of creativity appropriate for selling an idea or a product. The entrepreneur's drives may be less rational, more emotional than those of the creative scientist; he is committed to achieve, and less concerned about how to do so. He is as likely to pick up and successfully champion someone else's original idea as to push something of his own creation. Such an entrepreneur may well have a broad range of interests and activities; and he must be recruited, hired, managed, and stimulated very differently from the way a creative scientist is treated in the organization.

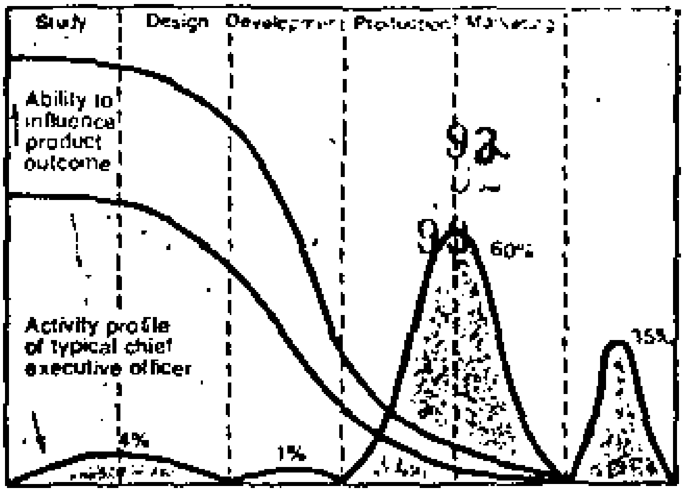
The project manager is a still different kind of person — an organized individual, sensitive to the needs of the several different people he's trying to coordinate, and an effective planner; the latter is especially important if long lead time, expensive materials, and major support are involved in developing the ideas that he's moving forward in the organization.

The sponsor may in fact be a more experienced, older project manager or former entrepreneur who now has matured to have a softer touch than when he was first in the organization; as a senior person he can coach and help subordinates in the organization and speak on their behalf to top management, allowing things to move forward in an effective, organized fashion. Many organizations totally ignore the sponsor role, yet our studies of industrial research and development suggest that many projects would not have been successful were it not for the subtle and often unrecognized assistance of such senior people acting in the role of sponsors. Indeed, organizations are most successful when chief engineers or laboratory directors take on this sponsor role as part of their natural behavior.

Finally, there is the information gate-keeper, the communicative individual who, in fact, is the exception to the truism that engineers do not read — especially that they do not read technical journals. If you're looking for a flow of technical information in a research and development organization to enhance new product development or process improvement, you have to look to these gatekeepers.

But those who do research and development need market information as well as technical information. What do customers seem to want? What are competitors providing? How might regulatory shifts impact the firm's present or contemplated products or processes? For answers to questions such as these research and development people need people I call the "market gate-keepers," engineers or scientists, or possibly marketing people with technical background who focus on market-related information and communicate effectively to their technical colleagues. Such a person reads trade journals, talks to vendors, goes to trade shows, and is sensitive to competitive information. Without him, many research and development projects and laboratories become misdirected with respect to market trends and needs.

The significant point here is that the staffing needed to cause effective innovation in a technical organization is far broader than the typical research and development director has usually assumed; our studies indicate that many ineffective technical organizations have failed to be innovative solely because one or more of these five quite different critical functions has been absent. *(For the most recent application of our measurement techniques to research and development staffing issues, readers may wish to see Richard G. Rhoades' unpublished master's thesis on "A Comparison of Laboratory Performance by Means of Critical Functions Analysis," Sloan School of Management, June, 1977.)*



The expertise of a chief executive can most influence any new technology-based product development program in the program's early stages — during preliminary study, design, and development. But current research suggests to the author that chief executive officers actually devote only trivial amounts of their time and attention to these early stages of such new-product programs. Instead, they typically have significant involvement only during production and marketing — when "it's too late to do anything that can influence the outcome," says Professor Roberts. (This illustrative figure comes from related work by Foster and Gluck of McKinsey and Co.)

The Social Aspects of Technology

The structure of an organization also affects the success of its creative efforts. The need, of course, is for an interrelationship which enhances the flow of the right kind of information into and through the technical organization, assures its appropriate use there, and encourages the flow of results of technical programs from the research and development group to the other parts of the organization where they can be made to count.

No research and development organization produces a profit. At best such organizations can produce the technical bases that will permit the firm's marketing and manufacturing activities to produce the profit. Thus the search for effective, profitable innovation must embrace the interface relationships that bring information into research and development and move its results forward to other parts of the firm.

My colleague Professor Thomas J. Allen is responsible for some of the best studies in the country on the factors that affect technical information flow in an organization. *(See "Communications in the Research and Development Laboratory," by Thomas J. Allen,* Technology Review, *October/November, 1967; and "Design for Communication in the Research and Development Laboratory," by Thomas J. Allen and Alan R. Fusfeld,* Technology Review, *May, 1976.)* He has found, for example, that if you separate two technical people by 60 or 70 feet, you've suppressed the likelihood of technical communication by two-thirds; separate them by another 70 feet and you've essentially eliminated 90 per cent of the possibility of technical communication between them; furthermore, he finds no difference in the impediment to communication between 3,000 miles and 3,000 feet.

He has also found that the social relationships between technical people are critically related to the technical relationships between the same people. The person with whom you go to lunch or dinner is also the person with whom you'll talk about new technical ideas; the sources of technical problem-solving ideas within the firm correlate strongly with the sources of information about the Sunday afternoon football game.

Professor Allen's approach emphasizes the social aspects of managing a technical organization, an area that technical managers have seldom considered. If technology is to be useful in product improvement, new products, and new business, we must take a broader, more cultural view of what in fact takes place in the creation and enhancement of technical information flows.

Another view of information flow related to innovation results from the work of Professor Eric von Hippel of M.I.T., who has described and analyzed a series of possible patterns for innovations. He concludes that user-dominated innovation — that is, innovation inspired and often created by a customer rather than a supplier — is far more prevalent than we have assumed; and he proposes that both technical and marketing organizations should adjust their strategies to capitalize on the user domination of much innovation. *(See "Users as Innovators," by Eric A. von Hippel, page 10.)*

Choosing Among a Spectrum of Venture Strategies

Thus far I have emphasized issues related to information flow in innovation — where the ideas really come from and how they reach that critical point within the firm in which they will be thoughtfully considered. Now we come to a still more crucial issue: if the information comes into the firm and if the firm has the technical

.ow-how and other resources for using that information, then what has to be done to cause those innovative technical products to be developed and to move forward into the marketplace? Organization structures to link research and development outputs to the market vary greatly, and I shall limit my discussion here to the so-called "venture strategies."

Firms have moved in many very different directions in their efforts to respond to venture opportunities — new products and new business areas — presented by technological innovation. The spectrum of the firm's possible involvements is wide, ranging from the low commitment of undertaking venture capital activities to invest in someone else's development of a new business idea all the way to the other extreme of intensive internal venture management typical of companies like 3M.

For any given opportunity, each firm must select from within this spectrum the appropriate approach, depending on the available staff, the firm's general strategy, the resources available to move products forward into the market, and the characteristics of the markets into which the new products are to be moved.

To make clear the nature of these alternatives and the process of choosing among them, let me trace one company's experiences over the past 15 years trying to develop broad new business bases.

This multi-billion-dollar corporation began its venture strategy organization in 1960. For the first four years it followed a venture capital approach of investing in the start-up phases of high-technology firms — a policy the management called "window on technology," designed to provide varied perspectives on the sources of new technology and on new market opportunities. After four years in which the firm invested in 11 companies, the management concluded that "window on technology" was not providing adequate information and insights on the launching of broad, ambitious new businesses. So the venture capital approach was replaced by an internal venture research and development organization — a special laboratory group to develop new technical ideas. The firm's principal business was in the field of materials, and the new group's goal was to develop new product systems heavily dependent on special materials properties and know-how which would be forward-integrated in the market relative to the company's other businesses. Over a five-year period the firm spent $40 million of corporate funds in this activity; the result was two new products, both of which failed.

So at the end of five years management concluded that it was time to close out on this internal venture research and development approach. But the firm was still committed to creating new products and new businesses, and so management conceived of an opportunities analysis group to study broad ranges of market opportunities and pinpoint global business areas into which the firm should move. During the next two years, this opportunities analysis group presented eight major new business proposals to the executive committee of the company, and they scored a perfect record: the executive committee rejected every one. At the end of that period, the company was ready to scrap this approach for getting into new businesses.

But management remained committed to the need for venturing forth into new markets, so the company adopted its present internal venture strategy of trying to develop small businesses based on off-the-shelf commercial exploitations to test on a pilot basis the company's ideas for different markets. And in fact, during the past several years this firm has been somewhat successful in entering a few new market areas.

My point is not to emphasize this last apparent success, which may, in fact, soon turn into a failure. My point is rather to emphasize how much work and time are necessary to create a basis for meaningful diversification, and how many different approaches are available from which to choose.

Looking back at all of our studies of venturing, I think we have learned a few — not many — things:

- First, long-term persistence is required for any success in venturing into major new business endeavors. The 15-year failure record that I just described is somewhat on the long side but not really an uncommon experience. New-venture development of new products and new businesses is not something to go into for a year or two or three or four; it's something to which you had better have a long-term commitment supported by the belief that it matters that you succeed.
- Second, almost every successful new venture strategy is somehow dependent upon either copying or coupling to the strengths of small-company technical entrepreneurship. This is true whether you're engaged in venture-capital investments in new, high-technology companies, or in joint ventures trying to combine the technical ideas of a small new firm with the capital base and distribution capability of a large firm, or trying to create an environment in your own large firm that mimics in important dimensions the creative, aggressive, entrepreneurial milieu of the small, high-technology-based enterprise. All these strategies emphasize the virtues of the small, high-technology firm; it's intriguing to me that large corporations trying to enter innovative new businesses are simply doing their best to imitate what the small companies have been doing for many years. This suggests to me that large companies wanting to venture into new products and new business areas — and even those seeking merely to improve existing products and processes — might deliberately and very specifically look at new enterprise formation and growth and at the entrepreneurs who achieve it. Our studies demonstrate that the kinds of people who leave large, high-technology firms to form successful new companies are the same kinds of people who, when they stay in the large firm, are the key entrepreneurs behind new venture development there. In other words, there seems to be a particular kind of person who is going to try to do his entrepreneurial thing — whether on his own hook with a few hundred thousand dollars from a New York venture capital firm or inside the bowels of a major corporation investing several million dollars in attempts to launch new businesses.
- Third, no generalizations are possible on the subject of which strategy for new-venture development really works. When we look at the few major corporations who have successfully moved boldly into new businesses through innovative technology, we find that each one's strategies for success are very different from the others'.

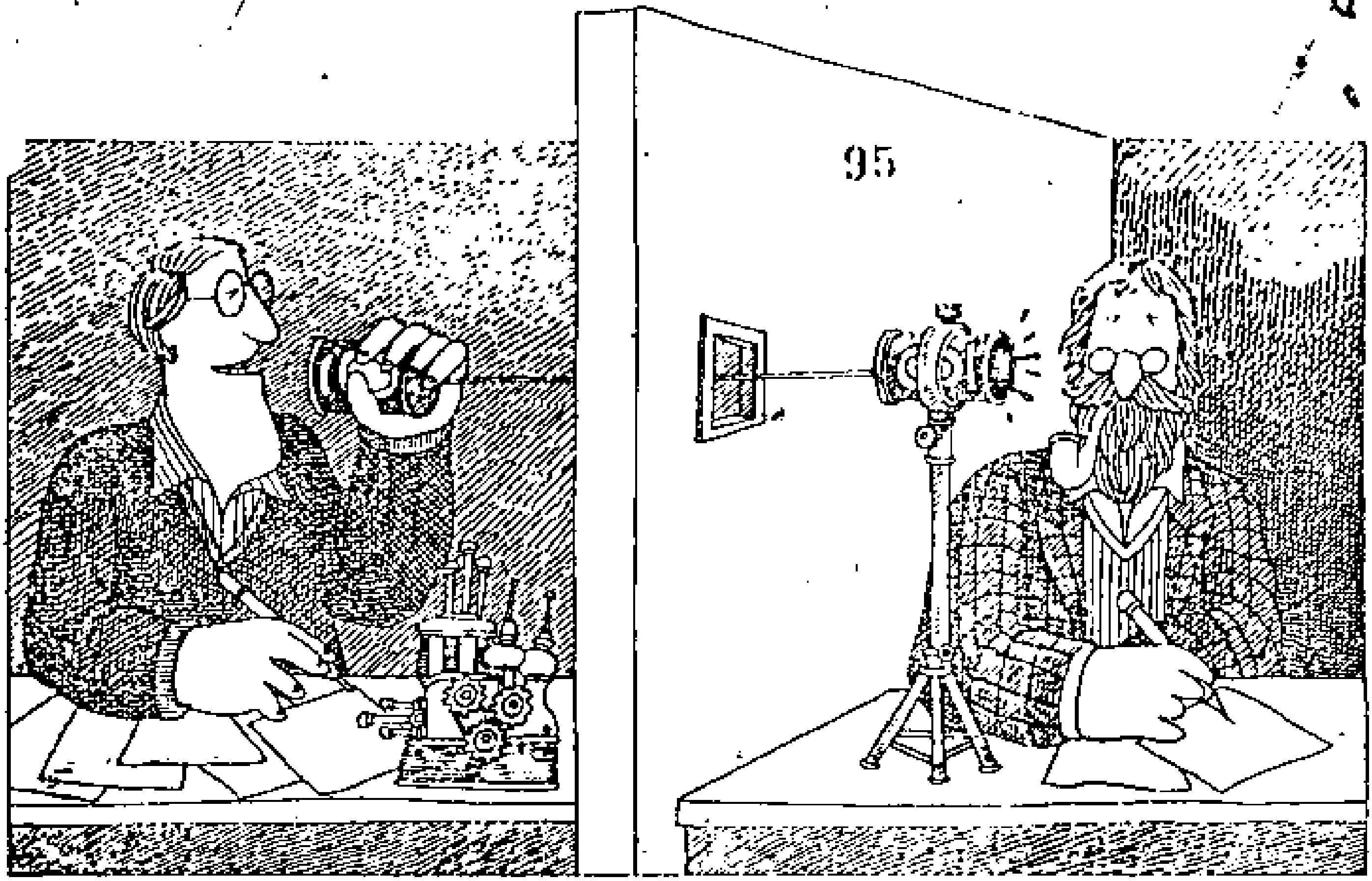
For examples, Minnesota Mining and Manufacturing Co. has for 30 years followed a strategy of depending upon internal venture stimulation with a beautiful organizational approach for creating and exploiting new ideas. In recent years Dow Chemical Co. has taken a very different approach, utilizing venture capital investment and outside technology acquisition as a strategy for building profitable new businesses. Through the medium of Exxon Enterprises — a still different strategy which appears to have strong merit and high possibility of success — Exxon is piecing together venture capital, joint ventures, and in-house research and development results into the base for significant new business entities.

These strategies are examples of success to be looked at carefully, but no individual or company can expect to be successful merely by mimicking any one of these strategies. The approach that works for one firm may not work for another, even if both firms do the right kinds of things about staffing and structure, because there remains the need to develop a formal technical strategy within the firm.

How to Win Profits by Planning Technology

Our studies reveal that most corporations have ignored technological strategy as an element of overall corporate strategy. For some reason, most firms limit their attention to financial and marketing strategies and planning, igr ing technology as a major area for assessment, plann and strategic development.

Two authors forthcoming in this series will focus on this issue in much greater depth — George R. White, Vice President of Xerox Corp., who will give evidence that at



'east one company does not ignore the technological mponent of strategy, and my colleague Alan R. Fusfeld of Pugh-Roberts Associates who will describe in much greater detail how technology planning considerations relate to strategy. But let me anticipate these discussions with the following comments.

No firm can divorce product from the technology embodied in that product. When we talk about the competitive positions of product lines two to five years hence, we are almost of necessity talking about the underlying technological basis of these product lines. An executive who wants to look at his firm's direction in the next half decade must start by profiling the competitive product positions of his company and studying the product and technology strategy options available to him.

What dimensions and approaches are relevant to monitoring technical performance? Which key projects need to be monitored by top management, and in what ways? For every product subcategory of the firm, where does the firm stand? Is the product's leadership clear? Are you in a product/technology parity position, or are you in a catch-up position with respect to your competition? Where were you with respect to those measures three to five years ago? Where will you be three to five years hence?

As you try to answer these questions for each major oduct or sub-product, you may be surprised and disayed at what is revealed about the technological strengths and weaknesses built into your technical posture. You ought to have a deliberate strategy for technological development in each product category, and you especially need strategies for those products where you find yourself somewhat frightened as you analyze your future position.

Research and development should not be done on good faith. You should do research and development for strategically justified reasons, according to a clear strategy that says what you are trying to achieve and that gives you some measuring points at which you will be forced to evaluate and further justify what is being done. Can you find a way to take the offensive, launching forward with new technology in a bold way? Or are you going to be adaptive and exploitative, countering whatever the competition does and trying to make the best of a weak technical position?

What about related product areas — not the ones you're presently in but those that are close to these familiar areas? Is your present posture well defined? Do you have a strategy for the future? Are you going to be aggressive? If your chief competitior branches into a related area where he hasn't previously been, how will you respond? What about new products and new technologies? Do you have a technical program that will support your posture and strategy? Do you have research and development resources that match these intentions?

What about major manufacturing processes? Do you change them because manufacturing people tell you they have problems, or do you have a strategy? Do you want to change your firm's present manufacturing process, or do you want merely to respond to whatever the competition does by keeping even on the cost per unit item?

How do senior technical and general corporate managers invest their time with respect to the major new products and new innovative activities of the firm? Do you, in fact,

Is This Conversation Necessary?

Conventional wisdom holds that research and development workers' performance improves with personal contact with professional colleagues.

Not necessarily so.

True, the effectiveness of scientists working in basic research correlates directly with the extent of their communication with colleagues working in the same field in other institutions and companies.

But for engineers developing industrial technology in the typical research and development laboratory, similarly extensive communication with outside colleagues has a negative effect on performance. In this case what's needed is that unusual research worker who is also a "born communicator" — the gregarious "gate-keeper" who not only can reach out to workers in the same field in other organizations but can interpret their work in the context of his own organization's assignments and needs, says Thomas J. Allen of the Sloan School of Management at M.I.T.

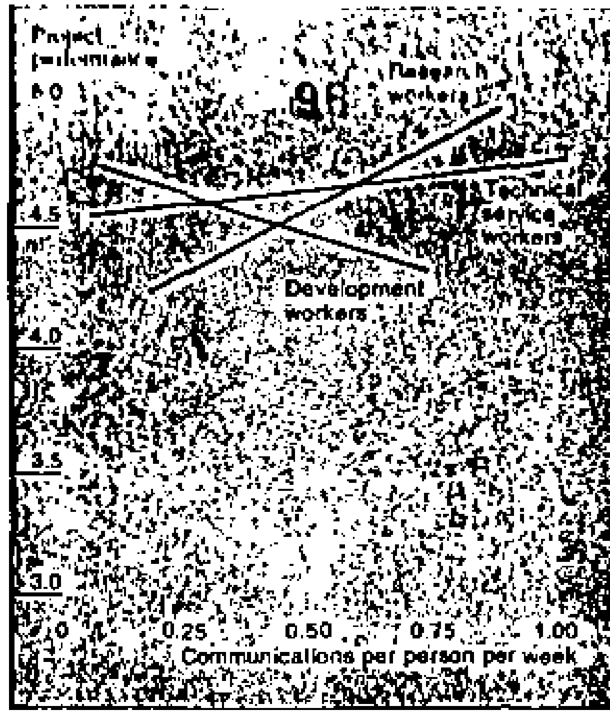
On the other hand, inter-company communication hardly figures for engineers in technical service work.

Professor Allen and his colleagues explain these different communication needs and strategies this way:

— Issues in basic science are defined in universal terms; everybody speaks roughly the same language and has the same goals. So almost everyone can communicate effectively with almost everyone else.

— Technological problems are usually defined in relation to corporate needs; the gate-keeper's ability to put others' work in the context of his own organization's assignments is crucial to his success as a communicator.

— Technical service problems are usually so well defined and closely coupled to organizational goals that outside inputs are unnecessary — and may even represent useless diversions. — *J.M.* ☐



The need for communication is not universal among research and development workers, says Thomas J. Allen of the Sloan School of Management at M.I.T. Those engaged in research — in contrast to development and technical service — will benefit from extensive professional communication with colleagues in similar work elsewhere. The average engineer engaged in development gains nothing from such communication. And communication with colleagues outside the organization has almost no effect on the performance of engineers in technical service projects.

involve the time of top management at the points of leverage that can affect the future of the firm?

At the very beginning of a new technology-based product development activity, a senior manager is able to influence the direction of the project in almost any way he chooses; he can stop it, enlarge it, accelerate it, redirect it, make it go for one piece of the market or another. The top manager's opportunity to be the bold innovator or the aggressive obsoleter of technology is greatest at that earliest stage. As the product moves forward into development, production, and finally marketing, the ability of the executive to influence the outcome goes down — eventually very close to zero.

But if you look at how managers typically spend their time, you find a very different pattern. Studies of this subject seem to indicate that chief executive officers spend trivial amounts of their time on the study and design stages of major new projects, the redirection projects of the firm. Instead the typical chief executive is primarily involved during the production and marketing stages of a project, when it's too late to do anything that can influence the outcome. The lesson from this is simple: if you want to affect the future of your firm, you need not only the right kind of staffing in your technical organizations and the right kinds of structures to enhance information flow in and transfer out. You need a strategic posture which displays critical points for paying attention to certain dimensions of product and technology, and you need to have an allocation of managerial time that brings the best talents of the company to bear on these focal points at the critical time. ☐

For Additional Information

In addition to the related papers mentioned by the author and others which will follow in this series in *Technology Review*, Professor Roberts suggests readings in the following:

Allen, Thomas J., *Managing the Flow of Technology*, Cambridge: M.I.T. Press, 1977.

Fusfeld, Alan R., "Critical Functions: Key to Managing Teamwork in the Innovation Process," paper presented at Innovation Canada 1976 (copies available from the author at Pugh-Roberts Associates, Inc., 5 Lee St., Cambridge, Mass., 02142).

Roberts, Edward B., "Entrepreneurship and Technology," *Research Management*, Vol. 11, No. 4 (July, 1968), pp. 249-266.

Roberts, Edward B., and Alan L. Frohman, "Internal Entrepreneurship: Strategy for Growth," *Business Quarterly*, Spring, 1972, pp. 71-78.

Edward B. Roberts holds four degrees from M.I.T. — in electrical engineering (S.B. and S.M. 1958), management (S.M. 1960), and economics (Ph.D. 1962); and he has been a member of the Sloan School faculty specializing in system dynamics, entrepreneurship, the management of research and development, and more recently health care management, for more than 15 years. Professor Roberts is co-founder and president of Pugh-Roberts Associates, Inc., management consultants, and he has worked for the success of several technology-based new enterprises as a member of their boards of directors. This article is based on Professor Roberts' remarks to a symposium on "The Management of Innovation" sponsored by the M.I.T. Alumni Center of New York in December, 1976.

Users as Innovators

Your customers may already have developed your next new products.

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Eric A. von Hippel
Sloan School of Management
M.I.T.

Conventional wisdom holds that customers articulate needs and manufacturers develop products responsive to those needs. But recent research on the histories of many innovative and successful new products has resulted in a different view: in some industries, most commercially successful products are developed by product users, not product manufacturers.

When the User Becomes the Designer

As a preview of what is to follow in this article, an example from our research data may be helpful.

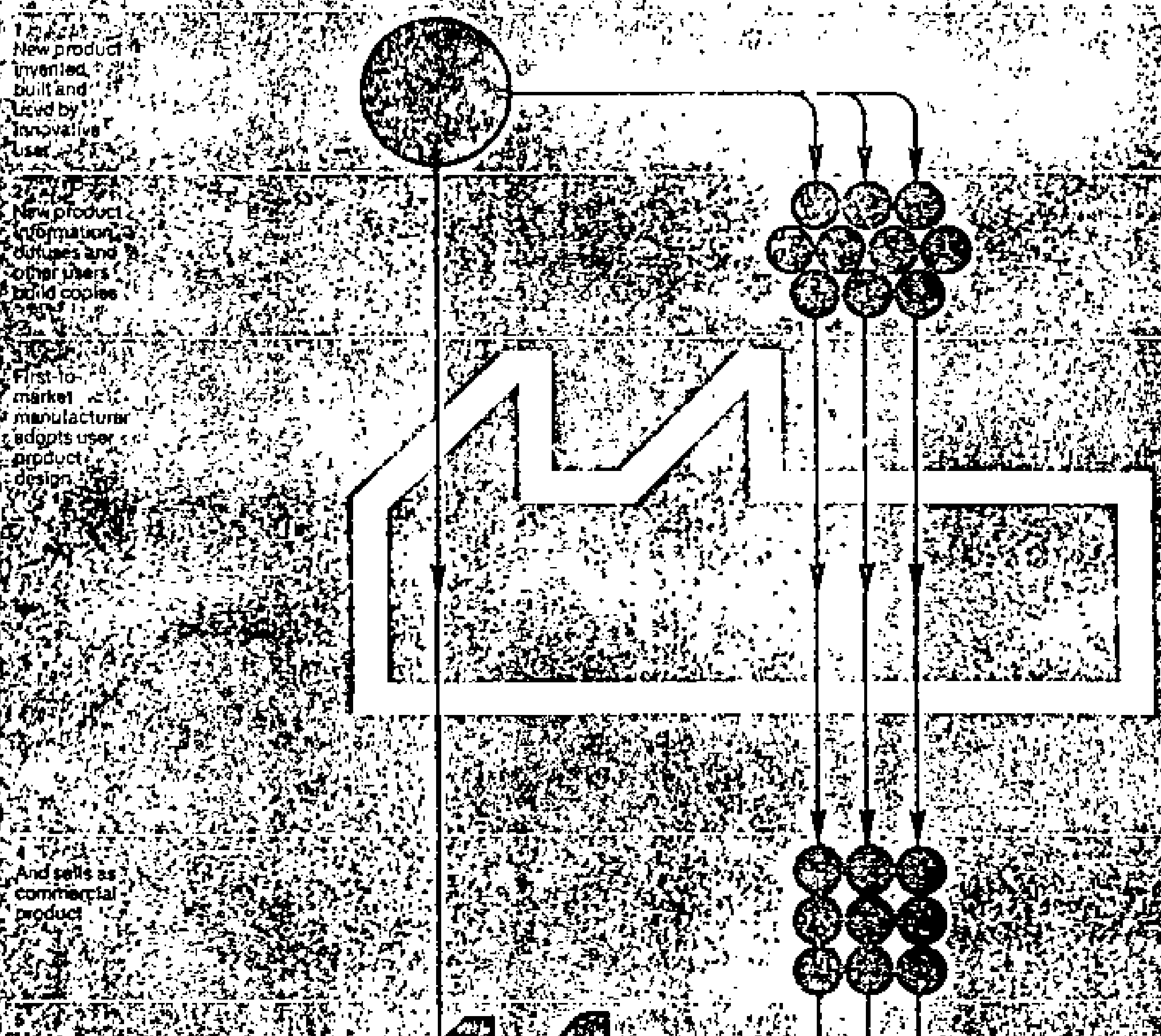
The methods used in the mid-1950s by semiconductor manufacturers to bond wires to semiconductor chips were quite unreliable. Three scientists at Bell Telephone Laboratories addressed the problem and developed thermocompression bonding — a greatly improved method which involved heating the semiconductor material and pressing the wire against it. When tests demonstrated the effectiveness of the method, the Bell System developed equipment to implement thermocompression bonding in production — no easy task given the precise control of position, pressure, and temperature required. The method was adopted by Western Electric starting in 1956-57. Other semiconductor manufacturers soon followed, all b[illegible]ng the required production equipment in-house.

[illegible]o years later, engineers from Kulike and Soffa, a firm specializing in the design and building of production equipment, began working for Western Electric on various production-machine problems. They concluded that machinery implementing several process innovations — including thermocompression bonding — could be sold commercially, so in late 1959 Kulike and Soffa became the first of several firms to manufacture thermocompression bonders for commercial sale. Kulike and Soffa retains a major share of that market today.

Does the pattern in the example seem familiar? It should be to readers whose business is in manufacturing process equipment or scientific instruments. In studies of the sources of innovation — we have been working on this topic at M.I.T. for the last half-decade — we have found that 60 to 80 per cent of the products sampled in those industries were invented, prototyped, and utilized in the field by innovative users before they were offered commercially by equipment or instrument manufacturing firms.

Scientific Instruments: Users Make What They Need

In the case of scientific instruments, we have studied three samples totaling over 100 commercially successful product innovations. The first sample consisted of the first-commercialized versions of four types of scientific instruments: the first gas chromatograph, the first nuclear magnetic resonance spectrometer, the first ultraviolet spectrophotometer (absorption photo-electric type), and the first transmission electron microscope; these are commercially important instruments widely used in the scientific and industrial communities worldwide. Next, we made a survey of expert users and manufacturers to determine a sample of 44 major improvement innovations — judged on the basis of incremental utility offered


1
New product invented, built and used by innovative user
2
New product information diffuses and other users build copies
3
First-to-market manufacturer adopts user product design
4
And sells as commercial product
5
Me-too manufacturers enter marketplace

(Below) Product manufacturer's conventional interface to product users. Market research, technical service, and sales departments are typically oriented to communications with users on their needs and the manufacturer's responses to those needs. There are multiple barriers, shown by the zig-zagged lines, to flows of information into manufacturers on user-developed products — "solution data," in the author's terminology.

(Right) Proposed manufacturer's [illegible] The reorientation of market research [illegible] by manufacturers of data on user's needs and solutions, and there are special technical service and sales forces to assure that solution as well as need data are embraced and even sought from innovative users.

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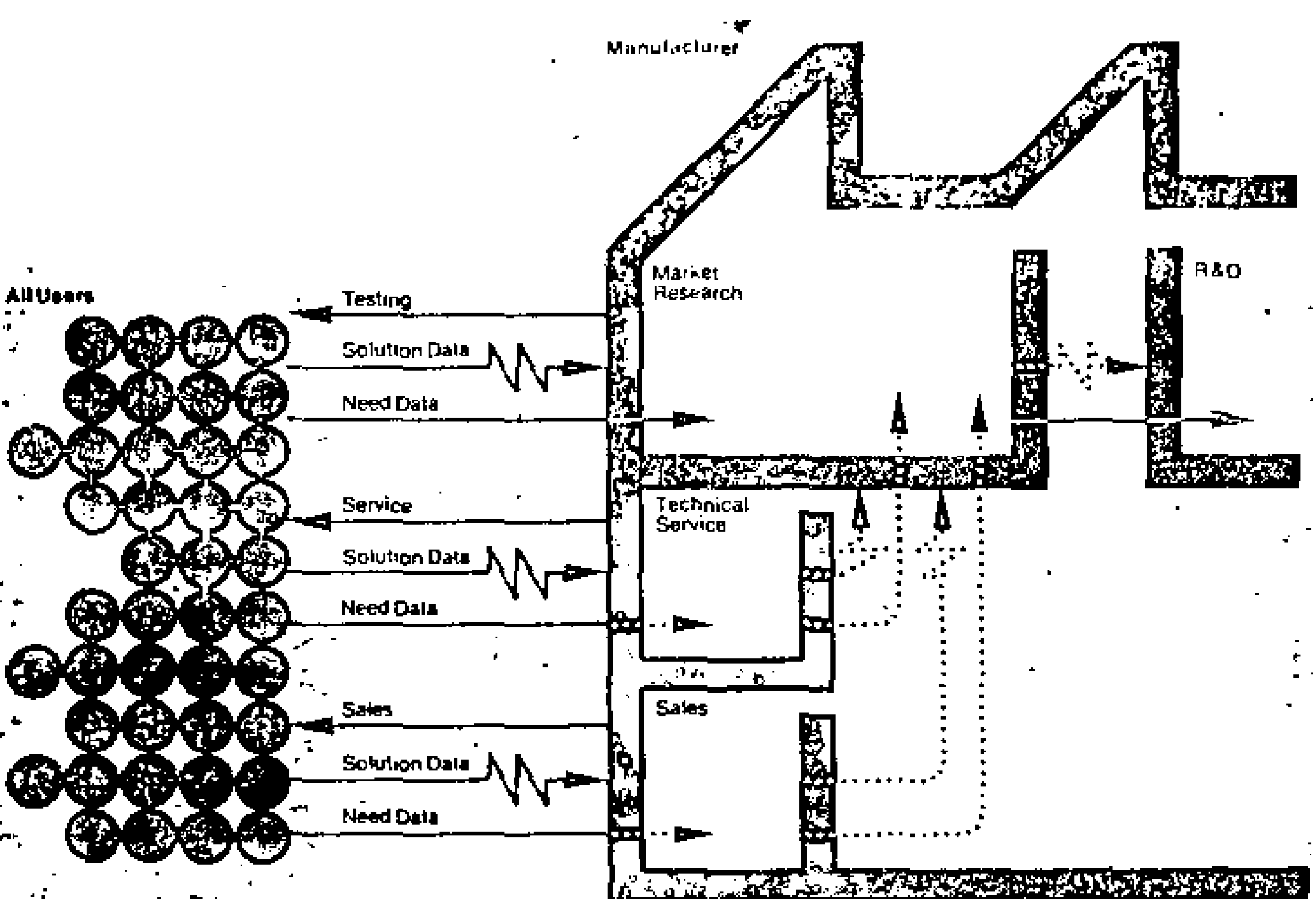
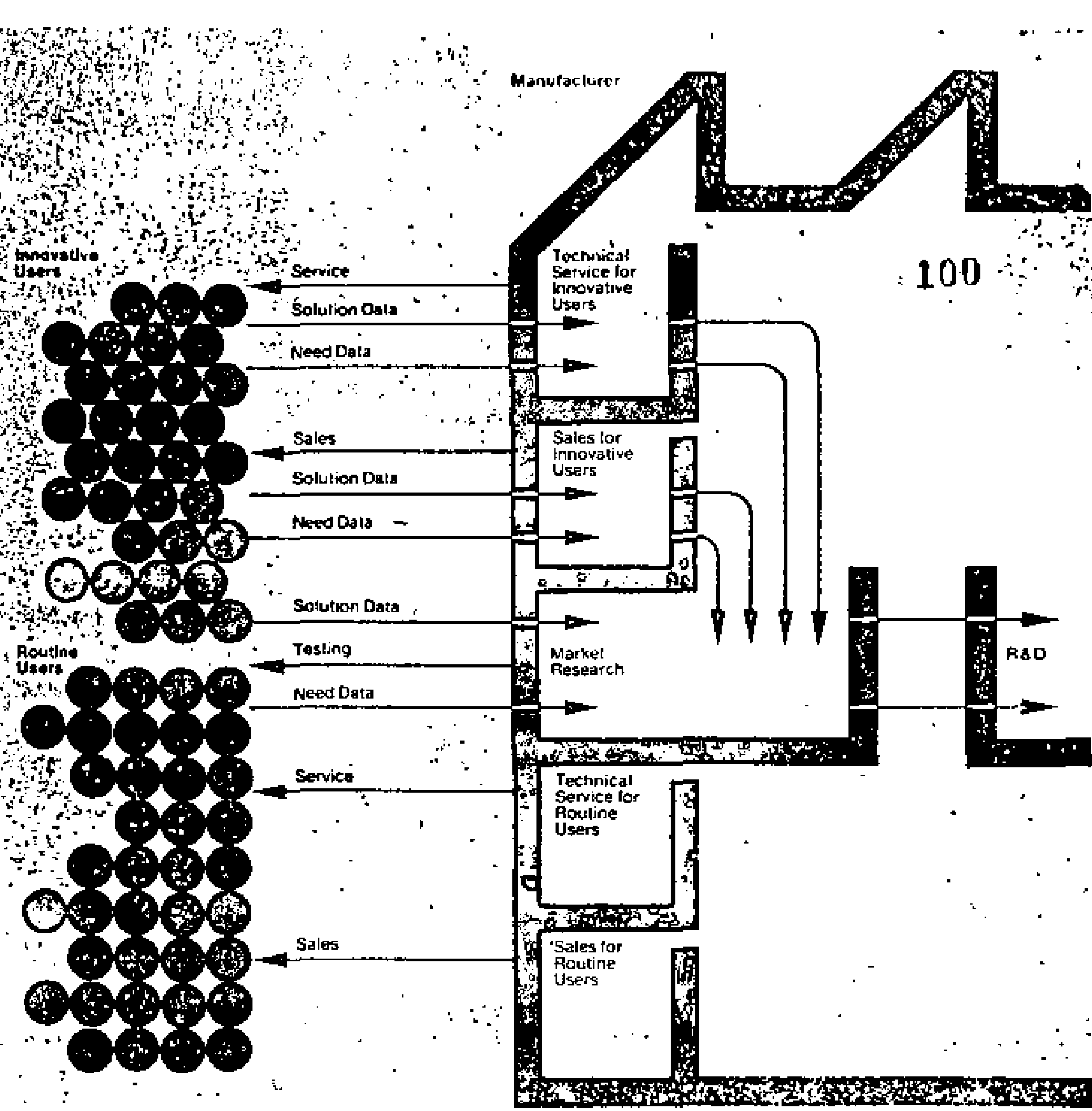


to the instrument user — to these four basic instruments. And finally, we selected a sample of 63 minor improvement innovations for transmission electron microscopy — the sampling consisting of all commercially successful innovations which offered any incremental functional utility to any subset of users.

The histories of each of these three samples of scientific instrument innovations (identified in the table on page 14 as "basic," "major improvement," and "minor improvement" innovations, respectively) were then carefully acquired. We started by identifying the firm which *first* manufactured the product for commercial sale, thus avoiding instances of "me-too" innovation. We then identified and interviewed personnel of manufacturing companies who were involved in the innovation work, and we also interviewed early users of the device. Related products and publications generated prior to the date of first-to-market commercialization were also collected and studied.

The result of all this work: in 81 per cent of all the innovation cases studied, we found that it was the user who perceived that an advance in instrumentation was required; invented the instrument; built a prototype; improved the prototype's value by applying it; and diffused detailed information on the value of the invention and how the prototype device might be replicated. Only when



all of these steps were completed did the manufacturer of the first commercially available instrument enter the innovation process. Typically, the manufacturer's contribution was to perform product engineering work which, while leaving the basic design and operating principles intact, improved reliability, convenience of operation, etc.; and then to manufacture, market, and sell the improved product.

The frequency with which this user-dominant innovation pattern appeared in our sample of scientific instrument innovations was, as the table on page 14 indicates, strikingly high for basic innovations and for major and minor improvement innovations as well. User-dominant innovation showed no statistically significant relationship to the size — and thus, presumably, to the research and development potential — of the manufacturing company. Furthermore, the pattern of user-dominated innovation appeared to hold for companies which were established manufacturers of a given product line — manufacturers who "ought" to know about improvements needed in their present product line and to be working on them — as well as for manufacturers for whom a given innovati[on] represented their initial entry into a product line.

Our data also showed extensive precommercial diffusion of significant user inventions through "home-built" replications by other users. Indeed, such "home-built"

	Field of innovations and sample selection criteria*	First device used in the field developed and built: By product user	By product manufacturer
[illegible]rumentation	*Scientific instrument innovations:*		
	First of type (4)	100%	0%
	Major functional improvements (44)	82	18
	Minor functional improvements (63)	70	30
Process equipment	*Innovations in semiconductor and electronic subassembly manufacturing equipment:*		
	First of type used in commercial production (7)	100	0
	Major functional improvements (22)	63	21
	Minor functional improvements (20)	20	29
Polymers	*All engineering polymer innovations developed in the U.S. after 1955 whose production in 1975 exceeded 10 million pounds* (6)	0	100
Additives	*All commercialized plasticizers and ultraviolet stabilizers developed after 1945 for use with four major polymers* (16)	0	100

* Numbers in parentheses indicate the number of cases in each sample

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After studying the sources of over 160 major and minor innovations in four fields, the author concludes that users of products, rather than their manufacturers, are often the developers of commercially viable new products. A predictive model is not yet available, but the author suggests how managers can determine whether product development by users is common in their industries and how they may capitalize on this source of innovations by establishing special sales and technical service activities.

replications were made and used to produce publishable results in every case where more than a year elapsed between the initial published description of a significant new instrument innovation by a user and the introduction of the first commercial model by an instrument firm.

User Innovations in Process Machinery

Having thus discovered a user-dominated innovation pattern in scientific instruments, we next sought to determine whether this was an isolated instance, or whether the pattern held also for other types of innovation in other industries. Because innovation in process equipment is related to [illegible] pressing national concerns as the rate of increase of industrial productivity and the international competitiveness of U.S. manufacturers, we decided to focus our next studies on process equipment innovations.

After discussions with people in a range of industries, we decided to work with two samples:

☐ Process equipment innovations related to the manufacture of silicon-based semiconductors; and

☐ Process equipment innovations related to the manufacture of electronic subassemblies on printed circuit cards.

These were chosen because we speculated that the amount of innovation by users might vary according to the novelty of the innovations they needed compared with the prior experience of equipment manufacturers traditionally serving those users. If such a relationship existed, we reasoned, a higher proportion of innovations in semiconductor process equipment than in electronic subassembly process equipment should come from users. The former industry was new; it had no established suppliers; the needed new equipment involved near-unique problems of controlling chemical contamination and providing precise, microscopic manipulation on a mass-production scale. Makers of electronics products, on the other hand, enjoyed established relationships with suppliers of subassembly process equipment in the period examined, and the problems to be solved in developing equipment for inserting components into printed circuit boards — for example — did not seem to us extraordinary.

The samples of process equipment innovations studied in each industry were analogous to those used in the scientific instrument study. We focused on a subset of the major process "steps" commercially used in each industry, and for each one of these (such as the insertion of component leads into printed circuit cards) we identified:

☐ Machinery (if any) used in the initial commercial practice of the process step;

☐ Major functional improvements made in the process machinery over time; and

☐ All minor functional improvements in the process machinery used in two process steps, one step taken from each industry examined.

Then, as before, we carefully reconstructed the histories of each innovation which was ultimately adopted in commercially manufactured process machinery. We searched the appropriate technical literature prior to first commercial innovation seeking references to experimental apparatus functionally similar to the commercialized innovation as well as other relevant work, and we interviewed authors of relevant articles. When we identified user-innovator firms we sought out and interviewed personnel in them; and if we had no information on the presence of user-innovators, we canvassed logical potential user-innovator firms to assure ourselves insofar as we could that such user-innovators indeed did not exist.

We found user-dominated innovation patterns very strongly present in the segments of the process machinery industry we sampled. As the table on this page shows, all of the novel machinery used in the initial commercial practice of a process step and more than 60 per cent of the improvements to that machinery were invented, prototyped, and used in commercial production by innovative users before they were manufactured and marketed by process machinery manufacturing companies. Interestingly, we found no significant difference in the proportion of user-dominated innovation present in the two process areas studied, so our initial speculation as to a reason for the occurrence of product development by users in some industries was not supported.

Note that our findings of a high level of user-dominated innovation considerably understate the total level of user involvement in the innovation process. This is because:

- Users can and do sometimes make a considerable contribution to the innovation process without carrying their work far enough to meet our criteria for user-dominated innovation. For example, in four process machinery innovations studied — attributed to the product manufacturer in our results — the users provided machinery manufacturers with the central technical concept used in the innovation; and
- Many process innovations are not embodied in innovative hardware. An example is the preparation of dislocation-free crystal for semiconductor substrate. Although "dislocation-free crystal growers" were eventually produced, initial commercial practice was a matter of modifying the technique used to operate conventional crystal growers. It is logical that users would have a very high involvement in innovations of this type, manufacturers having a role occasionally if the innovation promised additional sales of non-innovation hardware of their manufacture.

But User-Dominated Innovation Is Not Universal

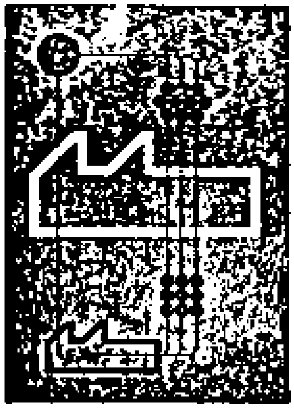
Not-yet-published research shows that user-dominated innovation is also characteristic of some process machine categories in addition to the two discussed above and of some types of medical product innovation.

But user-dominated innovation clearly is *not* common in all industries; in some, the conventional relationship of manufacturer responding to user needs by acting as innovator and product developer is strongly applicable. Studies by two of my students, Alan J. Berger and Julian W. Boyden, for example, show that all innovations in a sample of new engineering polymers and new additives for commodity plastics were developed by manufacturers of these products, not by users *(see the table on page 14)*.

In what industries is the user-dominated pattern common, and in what industries is it rare? A model which would quickly and economically answer this question for particular industries would be useful both to policymakers and to innovators. We are working hard to develop such a model, but it is not ready for presentation yet. Meanwhile . . .

What To Do Till the Researcher Comes

If you are not involved in the few fields we have examined to date and yet you want to know what innovation pattern prevails in your industry — and you can't wait until we have developed and tested a general model — it is quite possible to "do it yourself." Simply select a sample of innovations of the type in which you are interested and trace back their innovation histories as we have done. If



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User-Dominated Technological Innovation: Examples Abound

When you start to look for them, examples of user-dominated innovation are easy to find. The two noted below have not been independently documented; they are offered simply at face value.

The following is from *Business Week* for February 28, 1977:

"When Lockheed Aircraft Corp. was revving up to produce the titanium superstructure for its revolutionary SR-71 aircraft back in the 1960s, it pioneered a new machining technique to speed the removal of the supertough metal by up to 20 times. The key was a new face-milling tool that shears rather than chips the metal. But the development was kept quiet because the project was top secret.

"Now the tool is being introduced commercially by Cutters Unlimited Co., a tiny Gardena (Calif.) company. Just 15 months old, the company refined the Lockheed tool and expanded its applications to stainless steels and other hard-to-cut alloys."

Another example was described by Eastman Kodak Co. in an advertisement published in *Scientific American* for December, 1976:

"*N,N'*-bis[*p*-butosybenzylidene]-α,α'-bi-*p*-toluidine (BBBT) is a mesomorph, more popularly known as a 'liquid crystal,' a new addition to the long list of organic compounds that show interesting kinds of intermolecular association on the way from the solid to the ordinary isotropically liquid state as temperature rises. Beginning on p. 809 of the May, 1976 issue of *Analytical Chemistry*, workers at the National Cancer Institute tell how they prepared BBBT from a simpler Eastman organic chemical and why they have found BBBT better than any previously known substance when used as the stationary phase in gas-liquid chromatography for detecting and distinguishing geometric isomers of polycyclic aromatic hydrocarbons of interest as possible environmental carcinogens.

"On May 14, 1976, we logged in our first inquiry from a scientist who wanted to try BBBT but preferred to buy it instead of spending his time making it. He and all others who need it can now order it from lab suppliers as Eastman Organic Chemical No. 15076."
— *E. A. von H.*

"... the conventional interface which product manufacturers present to their customers offers multiple barriers ..."

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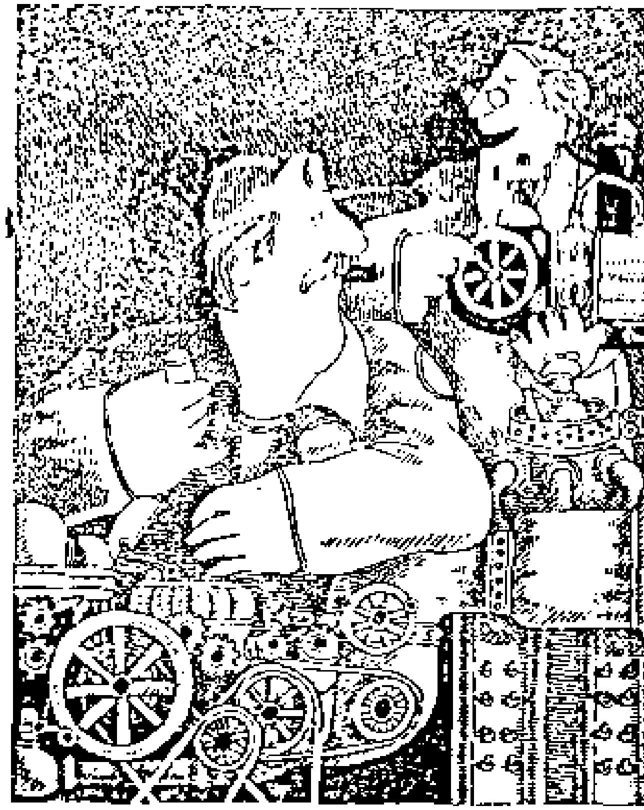


Technical service is interested in maintenance not new products

your findings are as clear as the ones we show in our table, you will have a good feeling for the prevailing pattern after studying only a few cases.

Two points of caution:

☐ When collecting your histories, obtain your information *independently* from users, from manufacturers, and from other innovation participants which your evidence identifies. If you ask *only* users, in effect, "Who invented this wonderful device — you or someone else?" they will quite naturally suggest that they are the true progenitors of everything in sight. If, on the other hand, you ask *only* manufacturer personnel — even yours — they will also claim paternity.

☐ Don't assume you know the innovation pattern which prevails in your industry before you have collected and carefully analyzed the data. Product manufacturers, especially — even in user-dominated industries — "know" they are the real product developers because it is the conventional wisdom; because manufacturer personnel are constantly exposed to their own product development efforts but only occasionally to those of users; and because prototypes developed by users or others are seldom manufactured as received. In other words, casual inspection of an innovation process tends to emphasize the manufacturer's role in it and to mask the value of the contribution brought in from outside the manufacturer's plant.

The Realm of User-Dominated Management

The fact that user-dominated innovation characterizes so many new developments need not be a cause for dismay on the part of those concerned about effective and efficient industrial innovation. Accurate understanding of user need is widely regarded as the most important single factor assuring the success of an industrial innovation. Clearly, users who innovate are in an advantageous position to perceive user needs accurately. User-dominated innovation should therefore have unusual potential for success.

But there remains the question of effective strategies for managing user-dominated innovation processes. If your manufacturing firm is in an industry which turns out to be characterized by user-dominated innovation, how should this finding affect your new-product-development effort?

The chart on page 10 indicates the position of the first-to-market firm in a user-dominated innovation process. In the following discussion we focus on the appropriate interface (colored in the figure) of the manufacturer to that process, in contrast to the interface which the manufacturer conventionally has with the user community.

First, consider the conventional interface *(page 12)*. In this interface, no distinction is made between innovative and non-innovative (routine) product users, with the result that personnel from market research, sales, and technical service (the three typical interface units) come

sales is interested in making sales, not accepting new products

market research can only accept need data

into contact with innovative users only a small proportion of the time. And when they *do* make such contacts, these units are inappropriately staffed and motivated to make much use of the information which may be available about user-developed products.

The dominant workload of technical services is typically field set-up, debugging, and servicing of existing products. Although minor product modifications are sometimes made by such groups for high-volume customers, the goal in general is to keep the customers happy with the existing products. If, in the course of their work — often performed on customer sites — technical service personnel should be offered information on user home-builts ("Why don't you people start building this? We're sick of making them in our shops."), they are not in a good position to take advantage of it because:

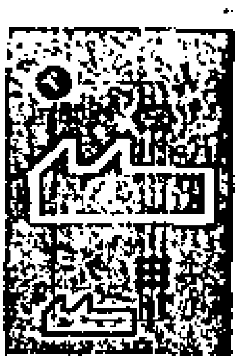
☐ Technical services is typically not staffed with people able to understand and make a good case for the commercial potential of a user-developed product; and

☐ Technical services typically has no incentive to gather such information or make such a case.

The typical sales force is set up to *output* information on existing products. It is true that sales people spend much of their time at customer sites, and so they ought to be in good positions to return information to their employers on promising user-developed products; but sales departments are typically not staffed with people able to do this job, and the typical commission and incentive schemes operating on them reward only sales of existing products. As a result, sales people have not only no incentive to accurately report on conversations regarding user developments which might have potential as commercial products; they have an incentive to deflect any such conversations towards the question, "What can I sell you of my present products?"

Finally, consider how the conventionally structured marketing research group would deal with data on user-developed products. Marketing research typically collects and analyzes data on user needs and then attempts to *generate* responsive new product concepts. "Have you any interesting new home-builts we should study?" is an alien question in such a setting. Indeed, any information on such home-builts which users, sales or technical service happens to bring to a conventionally oriented marketing research group's attention would probably be considered only as data on a user need, not as data on both a need *and* a potentially responsive solution. For example, if information comes to marketing research regarding a user prototype which functions better on some dimension than the product manufacturer's existing offering, net analysis methodologies such as multidimensional scaling would probably be invoked; these would ignore how the precision was obtained — the solution data in the user design — noting only that it was needed.

User Innovation in Nontechnical Fields



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User development of new products is not restricted to high-technology industries. Consider how the phenomenon occurs — and is managed — in the textbook publishing industry. Textbooks are almost invariably written by teachers — one class of users — and not by publishing houses — manufacturers. Many publishers manage this reality by setting up two sales forces. One deals with customers who buy but don't write, such as libraries and bookstores; this sales staff is trained and motivated to sell existing books only. The second sales force deals with teachers only, and is trained, selected, and motivated to (1) induce teachers to adopt existing texts for their classes as appropriate and (2) seek out promising manuscripts which may be under preparation. The type of incentive offered to salesmen to undertake this input *and* output role varies by firm.

Different groups often have different user-relationships to the same product. For example, while teachers use textbooks as teaching tools, students use them as learning tools. The manufacturer's problem in such instances is not to identify "the" user; nor is it often possible to do so. The problem is to identify the one or more categories in which innovative users are found so that the search for new products may be properly focussed. — *E. A. von H.*

And even if the conventional market research group included the user-solution data in its specification of a new product need, the conventionally organized research and development group receiving such a specification would tend to look at the data on a user's solution with a "not invented here" prejudice.

For these many reasons, the conventional interface, which product manufacturers present to their customers offers multiple barriers to the perception and use of information on user-developed products.

Interface Groups for Innovative Users

How should the market interface be modified in an environment in which user-developed home-builts are an important source of new products for the first-to-market manufacturer? The structure in the chart on page 13 suggests an answer to this question, based on our evidence that product users with a history of product innovation can be identified and separated from the mass of routine product users. For example, in our study of semiconductor process equipment innovations we found that all innovative users were among the top 25 per cent of all users in terms of their volume of semiconductor shipments at the time of the innovations. Accordingly, we propose separating innovative from routine product users and assigning to innovative users special sales and technical service sections whose organization, incentives, and staffing are appropriate for attracting and processing information on user-developed products.

It is true that some of the extra attention we propose paying to innovative users will be costly. But there will be compensating payback to manufacturers in the form of new products built upon research, development, and field testing performed by a user instead of by the manufacturer, the manufacturer thus saving much of the usual cost of these activities.

For innovative users, technical services should be expanded. Several types of activity — field-proven but not yet generally adopted — could be added by product manufacturers in industries characterized by user-dominated innovation. Among these:

☐ *User groups.* Commonly found in the computer software area and occasionally elsewhere, user groups are a mechanism by which users may exchange ideas and information on innovations they have developed. The cost to a manufacturer of sponsoring such a group is low, usually taking the form of providing a collection point for such information and disseminating it to members through newsletters and occasional meetings. The benefits in terms of access to the user-generated information is sometimes significant.

☐ *Applications laboratories.* In many industries, users are commonly invited to propose to manufacturers' applications laboratories their concepts for new applications for existing products. The manufacturer through the applications laboratory provides free or low-cost research and development help in working out the application. The user gains an effective new process while the manufacturer learns about the need and — often — is shown a user solution which can be developed into a salable new variation on existing products.

☐ *Custom product groups.* In industries where standard products prove to have usually started as custom products, it is often advantageous for a first-to-market manufacturer to offer good, fast, flexible help to that subset of users whose special needs have previously proved to foreshadow general demand. A good custom products group will induce such users to bring their developments to the sponsoring manufacturer.

A special sales force experienced in the technologies and problems of innovative users should be established to serve those users. As the staff of this sales force gradually prove their competence to the user firms, they will gradually obtain access to user-developed products which the user might wish to have built by an outside supplier, and they will have opportunities to bid on custom products with interesting commercial potential. Such a strategy is well established in some fields today.

Technical service and sales personnel assigned to a manufacturer's innovative users must work under compensation schemes which reward the sale of existing products, the sale of custom products, and information-gathering on user-developed products. Clearly, not all user prototypes or ideas for custom products have enough potential to be worth pursuing, but this problem can be dealt with in a screening process conducted by marketing research; it should not be dealt with by the all-too-common practice of discouraging all information inputs with a policy such as "we don't do custom products."

Marketing research should be encouraged to accept proposals for custom products and user-developed products from sales and technical services and should be organized so that information transfers of this sort are easy and routine. In industries dominated by user-developed innovations, marketing personnel may be able to proceed directly to an exploration of the market potential of the user-developed product itself, just as if the design had come from the manufacturer's own research and development group.

Channels and incentives should be set up to encourage the transfer of information on users' product designs as well as needs from marketing research to research and development. And the latter should be encouraged not to design all new products "from scratch" but to use user designs — often available free — when appropriate.

Management has a role in creating these new arrangements and in keeping an open mind as to the outcome. Many companies start what turn into profitable product lines by making custom products or building to customer designs, then decide that these lines have grown so big that further involvement with custom products could be an unprofitable distraction from the companies' main goals; later such companies wonder why they are having difficulty finding the bases for new product lines.

A Warning: Adopt Thoughtfully

Promising concepts for the management of innovations — and we believe that the management of user-developed products is one — are often prescribed too enthusiastically by researchers at a too-early stage — and then embraced too uncritically by practitioners. To avoid this, we wish to emphasize that strategies for the management of user-dominated innovation are not yet standardized. If you wish to apply the concept before it is routine, we urge you to approach the task flexibly and experimentally.

We are currently working with practitioners to apply these concepts; if you and your company are seriously interested, you are invited to talk with us about joining this joint research effort.

User Innovation as a National Resource

The discovery that user-dominated innovation patterns account for the bulk of innovations in industries as important to the national economy as process machinery and scientific instruments raises a host of questions for government policymakers concerned with innovation.

Two implications for government policy can be postulated on the basis of research to date:

☐ A user-dominated innovation involves an extra transfer step — from user-innovator to commercial manufacturer — not required in the case of a manufacturer-dominated innovation. If the user takes the initiative in this step, the time lag associated with it may virtually disappear; but if the initiative is left to the manufacturer, the time lag from first successful application by the user-innovator to first sale of a commercial version by an equipment manufacturing company is often several years. Some ways to reduce this delay are inherent in the concepts we suggest above for better management by manufacturers of the process of acquiring user-developed products. But at least one avenue is open to government policymakers. Users in many industries currently have no effective financial incentive to hasten the diffusion of their innovations to others in the user community. They may, in fact, have a disincentive, to the extent that sole use of their innovation assures a competitive advantage over competing firms. A positive financial force to induce diffusion by increasing the incentive of user-innovators to transfer their inventions to manufacturing firms could bring significant benefits for many industries; it might even induce users to undertake innovations whose benefit to themselves is marginal but which might pay out handsomely on an industry-wide basis.

☐ It is clear that process innovations made by users in the U.S. are first transferred to U.S. manufacturing firms. In order to retain the innovations which innovative users are likely to spawn, the government could make special efforts to induce such firms to remain in the U.S.

We feel that policymakers should be particularly interested in process equipment innovations because of the growing evidence that process innovations (of which process equipment innovations are a subset), rather than increases in capital investment or labor skills, are the major sources of improvements in industrial productivity.

Further Readings

The author recommends the following additional readings for those with special interest in the field.

Two publications give details on the methods used by Professor von Hippel to determine the sources of new products in the two industries indicated; readers should find them useful in planning how to determine the sources of new products in their industries:

von Hippel, Eric A., "The Dominant Role of Users in the Scientific Instrument Innovation Process," *Research Policy*, July, 1976, pp. 212-239.

von Hippel, Eric A., "The Dominant Role of the User in Semiconductor and Electronic Subassembly Process Innovation," *IEEE Transactions on Engineering Management*, May, 1977, pp. 60-71.

The following suggests the means by which user developed products are transferred to first-to-market manufacturing firms in one industry; it may give readers hints of possible patterns to look for in their own fields:

von Hippel, Eric A., "Transferring Process Equipment Innovations from User-Innovators to Equipment Manufacturing Firms," *R & D Management*, October, 1977.

Inputs from customers which are less than complete new products but nevertheless are useful to manufacturing firms are considered in:

von Hippel, Eric A., "A Customer-Active Paradigm for Industrial Product Idea Generation," Sloan School of Management Working Paper 935-77, May, 1977.

Before joining the faculty of the Sloan School of Management, where he is Assistant Professor of Management, Eric A. von Hippel was co-founder of a successful technology-based company and a consultant at McKinsey and Co., where he specialized in issues related to the man-agement of research and development. His academic degrees in economics, engineering, and innovation studies are from Harvard (B.A. 1964), M.I.T. (S.M. 1968), and Carnegie-Mellon (Ph.D. 1974), respectively.
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METODOLOGIAS PARA INVESTIGAR LOS PROYECTOS DE INNOVACION

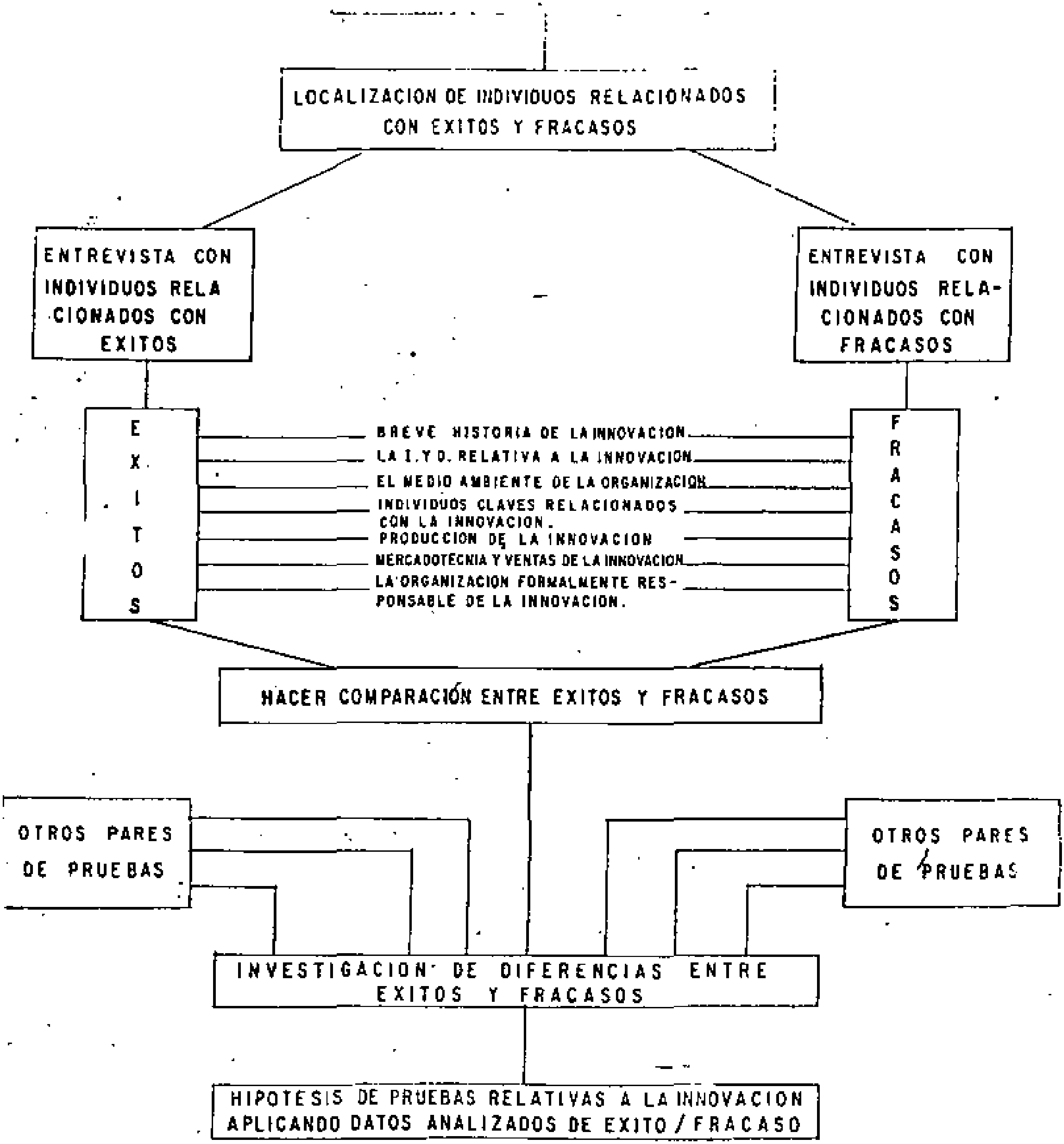
Un Caso: PROYECTO SAPPHO.

El proyecto SAPPHO estudia diferencias entre éxitos y fracasos en los procesos de innovación tecnológica. Este estudio realizado en la Universidad de Sussex adopta un nuevo enfoque en el estudio de la innovación y proporciona información relativa al papel y características de los individuos involucrados en su proceso. Resultados del proyecto muestran que los productos exitosos han contado con un empresario innovador, el cual es un factor crucial para el desarrollo del proceso. El proyecto presenta tres rasgos principales:

- A diferencia de otros estudios que solo analizan casos exitosos, el SAPPHO hace pares de pruebas clasificando exitosa comercialmente y fallida.
- El proyecto recopila información en todas las etapas del proceso de innovación, para R & D a través de mercadotecnia y ventas.
- Selecciona los pares de éxitos/fracasos para dos industrias, Química y de Instrumentos Científicos, de tal forma que permite observar diferencias y similitudes inter-industriales.

Los criterios que se utilizaron para determinar el éxito o fracaso de una innovación fueron: la participación en el mercado y la rentabilidad económica. Es decir, si una innovación había permitido obtener un gran número de ventas o utilidades altas (o ambas cosas) se consideraba exitosa, en el caso contrario era considerada una innovación fallida.

Información referente a la comercialización de la innovación hacia cada par, fue realizada primeramente por entrevista con la gente relacionada en el proceso. Esta fue apoyada con el análisis de la información disponible, así como información publicada o en forma de documento de trabajo, récord de compañías, etc. Una detallada historia de cada innovación fue establecida, esto hizo posible a los investigadores imponer el criterio de éxito o de falla utilizando múltiples criterios. El criterio usado sería utilizado después de un examen detallado de la literatura existente en innovación y tomando en consideración muchas de las hipótesis de casos de éxito, las cuales han sido previamente propuestas. Para descubrir las diferencias éxitos/fracasos se analizaron 43 comparaciones procedentes de 8 países, 22 en la industria de procesos químicos y 21 en la de instrumentos científicos.


LOCALIZACION DE INDIVIDUOS RELACIONADOS CON EXITOS Y FRACASOS
ENTREVISTA CON INDIVIDUOS RELACIONADOS CON EXITOS
ENTREVISTA CON INDIVIDUOS RELACIONADOS CON FRACASOS
EXITOS
FRACASOS
BREVE HISTORIA DE LA INNOVACION
LA I. Y D. RELATIVA A LA INNOVACION
EL MEDIO AMBIENTE DE LA ORGANIZACION
INDIVIDUOS CLAVES RELACIONADOS CON LA INNOVACION.
PRODUCCION DE LA INNOVACION
MERCADOTECNIA Y VENTAS DE LA INNOVACION
LA ORGANIZACION FORMALMENTE RESPONSABLE DE LA INNOVACION.
HACER COMPARACIÓN ENTRE EXITOS Y FRACASOS
OTROS PARES DE PRUEBAS
OTROS PARES DE PRUEBAS
INVESTIGACION DE DIFERENCIAS ENTRE EXITOS Y FRACASOS
HIPOTESIS DE PRUEBAS RELATIVAS A LA INNOVACION APLICANDO DATOS ANALIZADOS DE EXITO / FRACASO

Las técnicas estadísticas emplean una aplicación simplificada de la prueba de la binomial, la cual habilita el cálculo de la probabilidad que resulta de la observación de cada variable. Estas probabilidades son dadas entre paréntesis después de cada resultado.

Los resultados estadísticos apoyan la búsqueda de múltiples factores, aclarando los éxitos en innovación. Se agruparon 31 de las más importantes variables en áreas de competencia, mostrando así los 5 principales factores que determinaron éxito o fracaso de las innovaciones, ellos son:

- Capacidad de administración y características de los administradores.
- Conocimiento de las necesidades del usuario.
- Actividades de mercadotecnia y ventas.
- Eficiencia en el desarrollo del proyecto.
- Comunicaciones.

Un resumen de los resultados del proyecto, relativos al papel y características de los individuos, es presentado a continuación.

Resultados del Proyecto.

Cada comparación utilizó 122 variables que contenían la información esencial en lo que respecta a la empresa innovadora, sus actividades de mercado, su investigación y desarrollo, su administración, su - producción, etc. a cada una de las 122 variables en cada par se le dió una calificación (+1), (-1) o neutra ya fuera que la variable haya estado asociada al éxito, fracaso o a ninguno de los casos.

I. Capacidad de administración y características de los administradores.

Las empresas exitosas:

- encuentran menos oposición comercial a la innovación
- buscan la innovación en forma más deliberada
- encuentran menos oposición técnica a la innovación
- toman la decisión de innovar por razones de mercado
- desarrollan la mayoría de las actividades de R&D internamente
- ocupan más personal al inicio del proceso
- tienen menos gastos excesivos

que las empresas fallidas.

Los ejecutivos responsables de las innovaciones exitosas:

- tienen más poder
- tienen más responsabilidad
- tienen más variada experiencia
- tienen más entusiasmo por la innovación
- tienen mayor "status"

que sus colegas de innovaciones fallidas

II. Conocimiento de las necesidades del usuario.

Las innovaciones exitosas:

- necesitan menos adaptación por parte de los usuarios
- requieren menos modificaciones resultantes de la experiencia de post-venta

que las innovaciones fallidas.

Las empresas exitosas:

- entienden mejor los requerimientos del usuario
- ven los problemas del usuario antes

que las empresas fallidas.

III. Actividades de mercado.

Las empresas exitosas:

- ponen más énfasis en los aspectos de venta
- ponen más atención en la educación del usuario
- dan mayor publicidad a la innovación

que las empresas fallidas.

IV. Eficiencia en el desarrollo del proyecto.

Las innovaciones exitosas:

- tienen menos problemas de post-venta
- tienen menos dificultades técnicas en la producción

- tienen menos ajustes inesperados en la producción ,
- sufren menos modificaciones durante su desarrollo

que las innovaciones fallidas.

Las empresas exitosas:

- evalúan las perspectivas de éxito bajas al principio
- hacen mayor uso de ingenieros en la planificación de la producción

que las empresas fallidas.

Comunicaciones.

Las empresas exitosas:

- tienen mayor contacto con la comunidad científica y tecnológica de su área de interés
- benefician de tecnología externa durante la producción
- tienen mejores comunicaciones internas y externas

que las empresas fallidas.

Los Individuos y su papel en Innovación.

Como un resultado de la literatura que ha precedido al Proyecto SAPPHO, éste define ciertos papeles claves en innovación que pueden ser identificados.

Innovador Técnico: El "Inventor" o individuo que hace la mayor contribución al desarrollo y/o diseño de la innovación.

Empresario Innovador: El individuo que se responsabiliza dentro de la estructura administrativa, por el progreso de la innovación.

Jefe Ejecutivo: El individuo quien representa la cabeza de la estructura ejecutiva para la innovación.

Producto Líder: Cualquier individuo que hace una contribución a la innovación promoviendo su progreso activa y entusiastamente a través de estados críticos, si tiene responsabilidad administrativa para alguna parte del proyecto o no.

Los Empresarios en Innovación.

Los resultados del SAPPHO indican que los empresarios innovadores tienen:

- más poder (probabilidad = 0.0006) y alto status ($p = 0.002$)
- más experiencia ($p = 0.002$), muchas veces incluyendo experiencias de otros países ($p = 0.02$)
- más entusiasmo por (compromiso) la *innovación* ($p = 0.002$) que los administradores de las empresas fallidas.
- Más responsabilidad ($p = 0.001$)

Los ejecutivos responsables de las innovaciones exitosas tienen más edad que los de innovaciones fallidas ($p = 0.001$) y en la industria Química los responsables administrativos de los proyectos han estado más tiempo en la industria ($p = 0.05$). En el sector de instrumentos, los aspectos de experiencia, "status" y autoridad eran menos importantes, pero el responsable administrativo exitoso tiene más entusiasmo y dedicación y había estado menos tiempo en la empresa que su colega sin éxito ($p = 0.05$).

Los resultados del SAPPHO encuentran que los empresarios exitosos en innovación, para ambas industrias, tienen más variada experiencia aunado con la evidencia que los empresarios exitosos en la industria de instrumentos no han estado gran tiempo con las organizaciones. Esto deja una hipótesis tentativa, que en la industria de procesos químicos los empresarios innovadores podrían ganar experiencia por movilidad externa mientras que en la industria Química la misma ventaja puede obtenerse por movilidad interna.

Ciertamente la industria de instrumentos electrónicos tiene menor dimensión ambiental que la industria química y ésto no le permite una movilidad interna. Información detallada relativa a los ejecutivos responsables de la innovación es resumida en la siguiente tabla I.

COMPARACION DE CARACTERISTICAS DE LOS EMPRESARIOS INNOVADORES, EXITOS / FALLAS

CARACTERISTICAS	QUIMICA				INSTRUMENTOS				TOTAL			
	E>F	E=F	E<F	P	E>F	E=F	E<F	P	E>F	E=F	E<F	P
AUTORIDAD (PODER) EN LA ORGANIZACION	11	10	1	0.003	9	9	3	0.07	20	19	4	0.[illegible]8
RADO DE RESPONSABILIDAD ADMINISTRATIVA	12	10	–	0.0002	7	10	4	0.3	19	20	4	0.001
EXPERIENCIA DIVERSA.	10	11	1	0.006	10	7	4	0.09	20	18	5	0.002
ENTUSIASMO POR LA INNOVACION	4	18	–	0.06	10	9	2	0.02	14	27	2	0.002
TATUS EN LA ORGANIZACION	10	11	1	0.006	8	10	3	0.1	18	21	4	[illegible]
EDAD	10	11	1	0.006	7	12	2	0.09	19	23	3	0.001
TIEMPO DE PERMANENCIA EN LA INDUSTRIA	10	9	3	0.05	5	10	6	0.5	15	19	9	0.2
TIEMPO CON INNOVACIONES EN LA EMPRESA	8	8	6	0.4	3	8	10	0.05	11	16	16	0.2
NUMERO DE EMPLEOS ANTERIORES	6	11	5	0.5	4	15	2	0.3	10	26	7	0.3
EXPERIENCIA EN OTRO PAIS	4	18	–	0.06	6	13	2	0.1	10	31	2	0.02

TABLA I.

Innovadores Técnicos.

La investigación del papel de innovador técnico fué estimulada por la discusión de "inventor" en la literatura de innovación. Si una persona pudiera ser identificada como la que hace la mayor contribución al diseño o desarrollo de la innovación sería reconocido como el innovador técnico. El SAPPHO reconoce que hay muchos casos, en los cuales el "inventor" no podría ser encontrado dentro del proceso de innovación se encuentra en un grupo de apoyo. En suma, los "inventores" son encontrados más frecuentemente en la industria de instrumentos que en la química porque en alguna escala la tecnología es menos elaborada.

Innovadores técnicos fueron identificados en el 60% de todos los estudios de innovación, pero en la industria química fueron encontrados ligeramente más veces en fracasos que en éxitos, y en la industria de instrumentos sucedió lo contrario.

Sin embargo, estas diferencias pueden ser consideradas como significantes (Tabla III). Esto podría sugerir que en la industria química un solo innovador es menos efectivo que un grupo, mientras que en la industria de instrumentos la frecuencia de un solo inventor podría conducirla al éxito, pero ésto es solo hipótesis:

INNOVADOR TECNOLOGICO IDENTIFICADO EN EXITO, PERO NO EN FRACASO	[illegible]	[illegible]	12
INNOVADOR TECNOLOGICO IDENTIFICADO EN EXITO Y FRACASO	11	6	17
INNOVADOR NO IDENTIFICADO EN EXITO O EN FRACASO	3	4	7
INNOVADOR TECNOLOGICO NO IDENTIFICADO EN EXITO, PERO SI EN FRACASO.	7	2	9

TABLA II

POSICION DE INNOVADORES TECNOLOGICOS.

	QUIMICA		INSTRUMENTOS		TOTAL	
	EXITOS	FRACASOS	EXITOS	FRACASOS	EXITOS	FRACASOS
MIEMBRO DE LA ORGANIZACION	9	13	8	1	17	14
EXTERNO A LA ORGANIZACION	—	1	4	6	4	7
NO INNOVADOR TECNOLOGICO.	9	4	5	10	14	14

TABLA III

Otros Factores Asociados con el Proceso.

La influencia del jefe ejecutivo parece mínima excepto en aquellos casos en que él asume también alguno de los otros papeles, por ejemplo, administrador de la innovación. Las empresas exitosas en la industria química parecen tener departamentos de investigación y desarrollo de más antigüedad que los de las empresas fallidas ($p = 0.01$) pero, esto no pareció ser muy importante.

La teoría que califica científicos e ingenieros en mayor posición administrativa como elementos más importantes para éxitos fueron cuestionados, pues su presencia podría ser una condición necesaria para realizar la innovación, pero no tuvo un resultado significativo estadísticamente.

Algunos Aspectos que Señalan la Importancia entre la Innovación Tecnológica e Innovación.

La industria de instrumentos se caracteriza por la transferencia de tecnología, muchos de los avances significativos en instrumentación han sido originados en universidades y laboratorios de investigación antes de transferirlos a la industria. Un breve examen muestra, por ejemplo, que la mayoría de técnicas espectrométricas para análisis rutinarios fuera de la industria de instrumentos. Como, los espectrómetros infrarrojos y de absorción atómica, espectrómetro de mesa, espectrómetro de resonancia magnética, etc. Las innovaciones en las industrias de instrumentos del SAPPHO contienen ejemplos para muchos de los campos descritos anteriormente, junto con algunos desarrollos de impacto, los cuales han sido transferidos a las empresas y como mencionamos anteriormente, las innovaciones tecnológicas resultan de investigaciones fuera de la organización.

En el proyecto SAPPHO [16] (Universidad de Sussex), se analizaron 43 pares de innovaciones, (cada par formado por una innovación exitosa y una fallida) 22, de los cuales pertenecían a la industria química y 21 a la industria de instrumentos científicos. El estudio tenía el fin de identificar las características comunes en las innovaciones exitosas (es importante señalar que se estudiaron dos ramas industriales diferentes en cuanto a las dimensiones promedio de sus unidades productivas, ya que la industria de procesos químicos se caracteriza por el gran tamaño de sus empresas a diferencia de la segunda).

Se compararon los pares, utilizando 122 variables que contenían la información básica como actividades de mercado, su investigación, desarrollo, su administración, su producción, etc., dándoseles un punto (+ 1) (− 1) ó neutro, ya fuera que esta variable estuviera asociada al éxito o al fracaso de la innovación (o a ninguno de los casos).

B-1) CARACTERISTICAS DE LAS INNOVACIONES EXITOSAS.

Se nota que las variables que especialmente influyen en el éxito o fracaso de una innovación tecnológica pueden agruparse en torno a 5 campos principales:

I.- CAPACIDAD DE ADMINISTRACION.

Las empresas exitosas:

- Encuentran menos oposición técnica y comercial a la innovación.
- Buscan la innovación en forma más deliberada.
- Toman la decisión de innovar por razones de mercado.
- Ocupan más personal al inicio del proceso.
- Tienen menos gastos excesivos.
- Desarrollan las actividades de ID internamente, con jefes de más categoría.
- Además, los ejecutivos responsables de las innovaciones exitosas tienen mayor poder, más entusiasmo por la innovación que sus colegas de innovaciones fallidas.

II.- CONOCIMIENTO DE LAS NECESIDADES DEL USUARIO.

Las innovaciones exitosas:

- Necesitan menos adaptación por parte de los usuarios.
- Requieren menos modificaciones resultantes de la experiencia de postventa que las empresas

fallidas.

Las empresas exitosas:

- Entienden mejor los requerimientos del usuario.
- Ven los problemas del usuario antes que las empresas fallidas.

III.- ACTIVIDADES DE MERCADO.

Las empresas exitosas:

- Ponen más énfasis en los aspectos de venta.
- Ponen más atención en la educación del usuario.

IV.- EFICIENCIA EN EL DESARROLLO DEL PROYECTO.

Las innovaciones exitosas:

- Tienen menos problemas técnicos en la producción como ajustes inesperados.
- Sufren menos modificaciones durante su desarrollo.

Las empresas exitosas:

- Evaluan las perspectivas de éxito bajas al principio.
- Hacen mayor uso de ingenieros en la planificación de la producción que las empresas fallidas.

V.- COMUNICACIONES.

Las empresas exitosas:

- Tienen mayor contacto con la comunidad científica y tecnológica en su área de interés.
- Se benefician de tecnología externa durante la producción.
- Tienen mejores comunicaciones internas y externas que las empresas fallidas.

B- 2) CARACTERISTICAS DE LAS INNOVACIONES FALLIDAS.

Como variables que más coincidieron con el fracaso de las innovaciones se encontraron:

I.- NECESIDADES DEL USUARIO.

- No se realizaron encuestas sobre usuarios, o se hicieron mal.
- Se ignoró las respuestas de las encuestas.
- Hubo predisposición a un diseño determinado.

II.- ACTIVIDADES DE MERCADO.

- Se ignoró la investigación de mercado.
- Se descuidaron los aspectos de publicidad.
- Se falló en la educación del usuario.

- Hubo cambios inesperados en el mercado.

III.- INVESTIGACION Y DESARROLLO.

- Desarrollo pobre e incompleto del proceso de innovación.
- Dependencia excesiva de tecnología externa.
- Recursos insuficientes de ID.
- Inesperada superioridad tecnológica del competidor.

IV.- ADMINISTRACION.

- No se le dió la debida seriedad por parte de los ejecutivos o no se integró una estrategia definida.
- La evaluación y control del proyecto fueron inadecuados.
- El ejecutivo responsable era demasiado débil o sin experiencia.

Muchos de los factores que indujeron al fracaso se hubieran podido controlar si hubiera habido una buena administración, pero incluso se violaron reglas elementales de administración como: consulta a usuarios, estudio de mercados, evaluación adecuada del proyecto.

c) INDIVIDUOS CLAVES:

Procesos Químicos.- El responsable exitoso tenía más variada experiencia, mayor estatus, más responsabilidad, más autoridad que su colega fallido.

Instrumentos.- Experiencia, estatus y autoridad eran menos importantes, pero el responsable exitoso era más entusiasta y dedicado que su colega fallido.

3- 3.- En un estudio realizado por Brian Twiss[17], que confirma y complementa en algunos puntos el anterior, se señalan como características más determinantes:

[illegible]) UNA ORIENTACION HACIA EL MERCADO

- Es importante al innovar un producto tener bien claro en la mente las necesidades y preferencias del sector hacia el que se dirige el producto.
- Es necesario tener estrecha comunicación entre los diseñadores del producto y las personas que están en contacto con el cliente, discutir la forma final del producto analizándolo desde distintos puntos de vista, el de producción, el de comercialización, el de utilidades, etc., para determinar la más apegada

concepción a lo que el futuro cliente desea. 129

b) CONSISTENCIA CON LOS OBJETIVOS CORPORATIVOS DE LA EMPRESA.

- Definir claramente los productos y mercados en los que se apoya el futuro crecimiento de la empresa, poniendo especial atención en las capacidades de la organización en relación con las amenazas y oportunidades que han sido identificadas en el medio ambiente. Algunos nuevos productos potenciales, aún cuando sean atractivos, son inapropiados para su desarrollo, dado que la compañía no tiene los recursos suficientes o no desea entrar o extender sus operaciones en ciertos mercados.
- Decisiones sobre nuevos productos son tan fundamentales para el futuro de la compañía que no pueden ser ajenas a los objetivos de la empresa.

c) UN EFECTIVO SISTEMA DE SELECCION Y EVALUACION DE PROYECTOS.

- Es conveniente que se cuente con un método efectivo de selección y evaluación de proyectos y que éste se base en datos apegados a la realidad, existen algunas técnicas que van desde listas de comprobación hasta análisis cuantitativos basados en las técnicas de investigación de operaciones.

d) UNA EFECTIVA ADMINISTRACION Y CONTROL DEL PROYECTO.

Un control inadecuado resulta en aumentos en costo y retrasos.

e) UNA FUENTE DE IDEAS CREATIVAS.

La innovación exitosa ofrece algo por lo que el cliente está dispuesto a pagar. Esto tiene su origen en una nueva tecnología existente. La calidad de una innovación depende de la originalidad de mentes creativas de uno o varios individuos, sin creatividad no puede haber innovación.

f) UNA ORGANIZACION RECEPTIVA A LA INNOVACION.

- Innovación significa cambio, por lo que se puede interpretar como una amenaza a la gente que se ve afectada por ella y es probable que origine su oposición.
- La creación de una clima donde pueda desarrollarse la innovación demanda:
  - La presencia del empresario estimulando su desarrollo.

- La habilidad con que el innovador (ingeniero ó técnico) presente su caso. 131
- Estrecha comunicación entre el innovador y la dirección.

g) DEDICACION Y COMPROMISO POR UNO O VARIOS INDIVIDUOS

"Las innovaciones *no* suceden, son hechas", detrás de cada innovación exitosa hay una persona o un grupo de personas, los innovadores, quienes son responsables de traducir una idea a la práctica.

Chapter 1

Introduction

Society long ago learned the value of anticipating the character, intensity, and timing of major environmental forces in social and economic activities. Forecasts of the weather, agricultural production, population growth, industrial production, markets, sociological change, government spending, economic conditions, political attitudes, and many other attributes of future conditions are regarded as essential to planning wisely or to dealing effectively with coming changes. The wisdom of trying to anticipate these things that influence the future is well proven even though forecasts are almost certain to lack perfection. Strangely, society has been very slow in coming to grips with the forecasting of technology.

WHY TECHNOLOGY IS OF INCREASING SIGNIFICANCE

Today, one of the most powerful forces in our environment—and at times by far the most important for many firms, institutions, nations, and society at large—is technology. And the power of technology for good and bad is growing. Its increasing impact stems from the following factors.

The degree of advance in the technical capability of many new devices and materials over their predecessors often is in multiples of improvement—and not a few percentage points. These gains in performance are so great that they abruptly and drastically alter the means, effects, time, or costs of doing things. Thus they disturb, for better or worse, existing practices, institutions, and human activities. For example, consider the speed of commercial computation by computer systems.[1] (See exhibit 1.1.) Notice that the degree of advance is in multiples of previous performance and not in percentage points. The same phenomenon appears in many other things—speed of transportation, power of explosives, energy storage, miniaturization of electronic circuits, the impact strength of plastics, accuracy of watches, the capabilities of hand-held calculators, etc.

The rapidity of introduction of technical successors seems to be increasing in many

[1] Data for speed of "commercial computation" computers are based on an extremely complex formula for computing "P" (operations per second) as developed and computed by Kenneth Knight in the course of his doctoral work. See chapter 6 for this formula. Short papers by Knight have appeared in "Changes in Computer Performance," *Datamation*, September, 1966, and "Evolving Computer Performance, 1963-67," *Datamation*, January, 1968. Also, see his paper in *Technological Forecasting—An Academic Inquiry*, ed. by Bright and Schoeman (Canoga Park, Calif.: Xyzyx Information Corporation, 1970). Portions of his work are provided as tables for exercises in chapter 6.

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EXHIBIT 1.1
Speed of Commercial Computer Computations

Date	*Computer*	*Operations/Second*
1944	Harvard Mark I	0.403
1946	Eniac	44.65
1951	Univac I	271.4
1953	IBM 701	615.7
1961	IBM 7074	31,650.
1962	Univac 1107	76,050.
1963	RCA 601	58,880.
1963	CDC 3600	156,375.
1964	CDC 6600	4,091,293.
1965	IBM 360/75	1,437,806.
1976	CDC Star 100	*

*This *scientific* computer was announced as available for commercial time sharing. Its "power" by Knight's formula has not been computed. However, the company said it was able to average 97.9 million operations, or results, per second due to "vector processing." The Star 100C will be offered in late 1979, offering a fourfold increase in vector-type processing, meaning that it should be able to average about 400 million results per second. The Star 100A, available in late 1977, will do *conventional* processing about 600 percent faster than the Star 100, due to improved circuitry.

fields. Therefore, each technology concept tends to have a shorter marketplace life because of prompt challenge from a new and superior technology. The phenomenon is most apparent in the extremely short market-state electronic components, but it is also shown in many other products, where a given design has a life of nearer to five years than the ten years of a decade ago.

The size of resources required often is so great that the R & D funding capacity of individual firms and even an entire industry is exhausted. The American SST is a case in point, and the British-French Concorde transport has required two nations to combine their resources. Rolls Royce and Lockheed represent two instances in which the financial demands of a single technical advance have been staggering. DuPont lost $100 million on Corfam, and RCA announced a $250 million loss on computers.

Technology as a national resource has long been recognized in technical circles. In the 1960s both society at large and governments began to recognize that they can and must marshal technological resources for national purposes other than war. Now the use of technology to improve social situations—urban conditions, health, education, environmental qualities, food supply, the general quality of life—and to explore space and the oceans has become widely accepted and demanded. Thus technology is being called upon more frequently and more severely to serve public needs. Currently, ERDA is spending hundreds of millions on new energy sources, without clear assurances of technical success.

Technology assessment has resulted from concern over the negative effects of technology on the environment and society. This concern has grown since the late 1960s. Of course, alarm about men, machines, unemployment, and skills is an old worry, going back more than two hundred years. The new development is intense concern about other effects of a technology, such as the pollution associated with a production process or product use and the delayed consequences of technology as it affects the environment years later or as it leads to new social problems. There are vigorous arguments that technology is responsible for generating wastes that contaminate the environment, destroy or harm plant and animal life, and ruin the aesthetic qualities of the countryside, the shorelines, the rivers, and all else on which our eyes rest. Even our ears are not free from the assault by the noises of technology.

These concerns brought national attention to technology assessment. In 1972 the Office of Technology Assessment was established. The office now has some ninety employees and has undertaken dozens of studies on technology as requested by Congress. The President's Council for Environmental Quality has been established, and new environmental controls have been established by the Environmental Protection Agency. Since 1969 factories have been legally closed for producing noxious fumes, noise, and stream pollution.

It is clear that society intends that technology will be held accountable for its total impact. Therefore, technology assessment is becoming a requirement of technology proposals. Assessment requires anticipation, hence, a need for technology forecasting.

WHY TECHNOLOGY FORECASTING IS NECESSARY

Since governments and firms have been making hundreds of thousands of plans for at least several hundred years without much explicit technology forecasting, why can't society get along as it has in the past? Consider what this posture means to decision making.

One implication is that *the future contains no significant technological change for the particular institution.* This may be a realistic and useful assumption for many activities in the one- to five-year time span. New technology generally requires five to fifteen years to diffuse throughout society on a significant scale; hence, an organization has time to recognize and adjust to technical progress. Economists, who traditionally work heavily with one- to three-year projections, have been able to ignore technology changes safely (in most cases) for this reason.

This assumption is not satisfactory for production activities based largely on technology changes—electronics, drugs, plastics, computers, aerospace, and energy conversion. It also is a bad policy for relatively stable industries that are suddenly inundated with new technology in their production processes, materials, competition, or distribution procedure. This is currently the case in the materials field—steel, wood, paper, and tiles—and in some service industries such as food, education, and health.

An alternative implication of not forecasting is that *anything of technical significance can be recognized and dealt with after it has materialized and been proven.* This, too, is sometimes a satisfactory approach. It has the advantage of certainty and avoidance of false trials. It also has some serious drawbacks—the loss of lead time, of patent position, and possibly of public image. Far more serious, at times, is the fact that the firm may meanwhile commit itself to products, processes, capital expenditures, and even personnel, which makes it very difficult to shift directions at a later date.

Another hazard, with potential for horrendous economic errors, lies in the response once the decision is made. First, there is the "crash" program to catch up at any price. And the price of buying in later is very high. Second, there is the timing fiasco. By the time the organization does catch up, the seller's market may be gone. The bandwagon atmosphere, coupled with the high cost of haste and bad timing, leads to painful experiences. Office copiers and computers provide cases in point. Materialization of technology as the only trigger to action is dangerous managerial policy.

The issue, therefore, is not whether any technological changes will affect the institution seriously, but whether to arrive at this conclusion by ignorance, neglect, wishful thinking, or explicit reasoning. Widespread awareness of the growing force of technology and increasing concern over its impact means that forecasting of technological development and consequences is absolutely essential. Why, then, should one not make use of the traditional forecasting procedure—the opinion of the technical expert?

DIFFICULTIES INHERENT IN EXPERT OPINION

Interaction of Technologies

The use of an expert's opinion is very logical but is becoming an increasingly dubious procedure. One reason is that the former ability of a competent technical man to assess progress in his special field is disappearing because of the growing interaction of technologies. For instance, if one wanted to forecast the future of computer technology, should his "expert" be an arithmetic logic mathematician, a solid-state physicist, a memory systems designer, a manufacturing process engineer, an electronic circuit engineer, or some other specialist? Obviously, none of these is adequate because single field knowledge is no longer capable of assessing total improvement in these technical devices. Technical progress is multidisciplined, but technical experts are not—at least to the same degree.

The obvious improvement to an individual expert is to form a committee. However, even if one assembles a group representing the appropriate technical experts, *opinion* alone is becoming less satisfactory. The reason is that much technology change is becoming less autonomous. New technology is stimulated by interactions with social conditions, political actions, economic conditions, and ecological pressures. One can hardly expect the technical experts also to be competent forecasters in all these nontechnology spheres. Consider forecasting the emergence of the SST airplane, of a new detergent, of the antiballistic missile system. Are the controlling forces to be found only from the study of technology? Exhibit 1.2 is a sketch that suggests five environments that interact with each other to influence technical progress. Man must learn how to think logically about the future impact of these interrelationships, their evolvement, and their impingement on each other.

Furthermore, there is a vast and often unappreciated distinction between forecasting technical development in the laboratory and forecasting technology in use. Technical knowledge *alone* cannot possibly provide a correct basis for predicting the timing of the emergence and impact of new technology. The delay of the support for the American SST, the demand for automobile safety, the outlawing of DDT, and the development of nonpolluting automotive power are examples of technology influenced by developments in other environments. These influences are not necessarily within the expertise of the experts in the particular field. Reasons for this rapid interaction of forces for change will be explored in chapter 3. Exercises at the end of this chapter will help the student sharpen his insight on these influences.

Value Changes

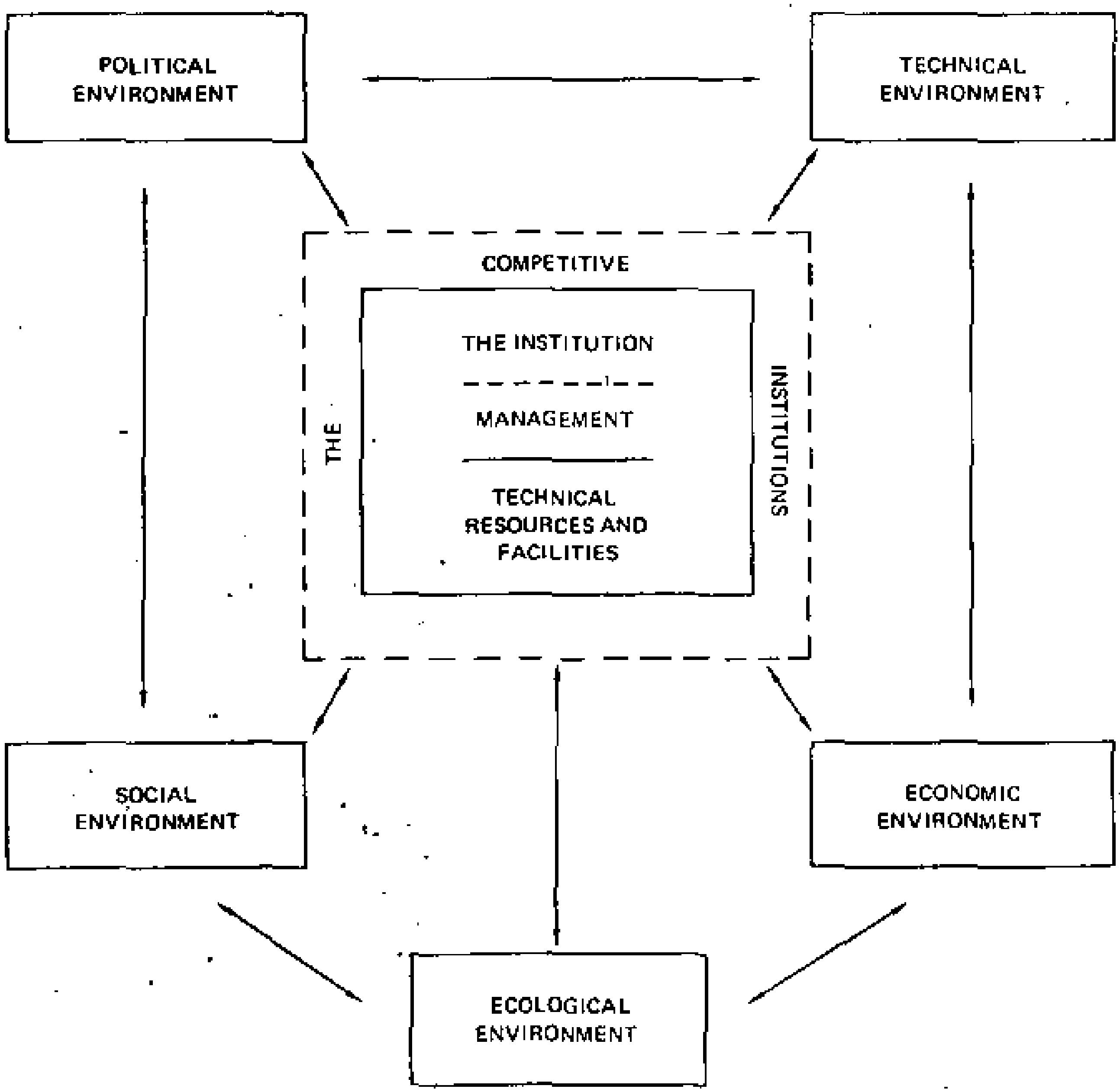
Behind these environmental relationships is another kind of change only beginning to be dimly understood. This is the changing value system in our society. Values are virtually a no-man's land to most, and one can hardly expect today's technical expert to intuitively and correctly weigh the value systems that will prevail a decade or more from now. Yet these value systems often will determine what technological choices society will support and how society will evaluate the relative merits of the products of technological effort.

Lack of Forecasting Methodology

Finally, we must recognize that methodology for technology forecasting has not been

EXHIBIT 1.2

Technology and Its Environmental Interactions



NOTE: Within each *environment* are *individuals* and *organizations*, whose *value systems* may be changing over time and perhaps in a vastly different manner than in other parts of the system. The institution also may change, as well as its leadership. Also, societal emphasis changes as exemplified by post-Sputnik *(technology)*, late 1960's *(ecology)*, mid-1970's *(social-ecological)*, late 1970's *(social-economic?)*.

taught in any engineering school or in any scientific course until, perhaps, 1969. Therefore, past forecasting by expert opinion has largely (but not always) rested upon individual knowledge, experience, belief, and intuition. As a result, many scientists, engineers, and inventors of unquestioned technical competence have produced astonishing prediction errors. It is equally true that experts have had many successes. But the significant point is that *the forecast user has no way to assess the knowledge, the rationale, the assumptions, and the range of considerations that underlie the technical opinion.* Therefore, the prediction that one gets from opinion is of highly uncertain quality, and it cannot be tested and evaluated. It is not a satisfactory basis for decisions committing major resources of an institution.

Given these difficulties, it should be clear that society badly needs something better than opinion for forecasting technology.

Learning from Past Errors

One of the most promising concepts for improving forecasts is to examine past predictions, including expert opinions, and learn from them. This was suggested by Dr. S. Colum Gilfillan, although he proposed to study past forecasts to identify reasons for success[2]. From 1969 to 1971, dozens of past forecasts were studied to find the reasons for error, with the belief that, if sources of past errors could be identified, future forecasting could be improved by avoiding these errors. A partial version appears in a *proceedings* of a conference at The University of Texas.[3] The exercises at the end of this chapter develop some of these findings. They also stress the technique of reviewing past forecasts as an aid to improving all forecasting efforts.

WHAT IS TECHNOLOGY?

Technology consists of three elements: (1) the physical things—tools, machines, and materials that mankind uses for all activities; (2) the software aspects of technology including technical processes and procedures such as heat-treating sequences, computer programs, operations research techniques, and the FAA's traffic control system for civil aviation; and (3) definitional systems that determine and describe the foregoing such as the SAE standards for motor oil, NEMA standards for electric motor insulation, and standards for screw threads. Then the definition of technology becomes troublesome. Is the social security program a technology? The welfare program? Our money system? These things are called *social* technology. Thus, this definition excludes these procedures to direct social activity and applies only to technical devices and activities.

[2] S. C. Gilfillan, "A Sociologist Looks at Technical Prediction," in *Technological Forecasting for Industry and Government*, ed. by J. R. Bright (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1968), pp. 3-35.

[3] J. R. Bright, "Some Insights from the Analysis of Past Forecasts," in *Technological Forecasting—An Academic Inquiry*, ed. by Bright and Schoeman, *op. cit.*, pp. 345-358.

Chapter 5

Intuitive Forecasting

Expert opinion is not a very satisfactory form of prediction, since the supporting data, rationale, and assumptions are not available for examination. A committee of experts presumably is superior in two ways: (1) it brings a broader range of skills, disciplines, and experience to bear, and (2) the experts supposedly challenge each other to develop reasoning and improve use of data. However, committee deliberations suffer from interpersonal relationships such as authority figures, persuasiveness, and bandwagon effects.

THE DELPHI TECHNIQUE

In the early 1960s RAND researchers Olaf Helmer, Norman Dalkey, and their colleagues introduced the Delphi technique, designed to overcome the interpersonal behavior problems of committees and to improve the use of expert opinion through polling based on three conditions: anonymity, statistical display, and feedback of reasoning.

Anonymity

The experts do not know who is on the panel or, at the very least, do not know what predictions and critiques are associated with each individual.

Statistical Display

The forecasts are structured so that respondents reply with a year of predicted occurrence (sometimes under different probabilities). Results are collated, and the median and interquartile range (IQR) are computed. Some Delphi studies now also display *extremes* as well as number of *nevers.*

Feedback of Reasoning

Summations are returned to panel members who are urged to challenge or support predictions that fall outside the IQR and to make new predictions. Arguments and new data are circulated; then counterarguments are circulated.

TYPICAL DELPHI PROCEDURE

A typical procedure might be as follows. The study director requests (or collects) initial queries in the area of interest. He consolidates and edits these queries for clarity and uniformity, then sends them to his panel of experts.

Round 1—Timing of Occurrence Requested

Each expert is requested to predict the date by which each event will occur. These predictions are returned to the director. He then tabulates and returns to each expert the group results showing the median date, the IQR (those dates embracing the middle 50 percent of the replies), the extremes, and the number of *nevers*. He may also choose to return to the experts a display of the distribution of *all* the predicted dates, as well as the statistical data.

Round 2—Conform or Explain

Each panelist reviews each of his predictions against the statistics of the group. He is expected to consider making a new prediction. If his reconsidered prediction falls outside the IQR range for that event, he provides reasons why he does not conform. The study director retabulates all statistics from the second round, appending all the reasons provided by nonconformists, and returns this summary of round 2 to all panelists.

Round 3—Conform or Provide Counterarguments

Each panelist reconsiders all nonconforming positions and the arguments appended by all other nonconformists; then he makes his new predictions. If his prediction still falls outside the new IQR, *or if he conforms but believes that arguments of certain other nonconformists are inadequate*, he provides counterarguments.

Round 4—Final Prediction

The study director recalculates, appends counterarguments, and recirculates data to obtain each panelist's concluding prediction. These predictions become the final results of the Delphi study and are usually displayed in a manner showing much of the statistical data.

DELPHI EXPERIENCES

The Delphi technique rapidly swept throughout the world. By 1976 hundreds of Delphi studies had been conducted. These ranged from little internal panels to a Japanese nationwide study involving 4,000 panelists. The comments below are based on the reactions and collective experiences of several hundred Delphi participants and study directors.

Time-Consuming Study

A thorough Delphi study takes a great deal of time to conduct. The study director must analyze and consolidate literally hundreds of replies. The first corporate Delphi study was done by TRW in 1966. TRW's twenty company panelists supplied over one thousand predictions, which were ultimately boiled down to about four hundred predictive events by the study director, Donald Pyke. Their "Probe II" in 1969 began with some twelve hundred predictions and took over three man-years of direction time.

Ambiguities, misunderstandings, and trivia must be eliminated from initial and later contributions. Smith, Kline, and French received 867 predictions on round 1 and used only 209 in round 2. Inevitably, prediction statements have to be tested, reworked, and clarified. Respondents must be briefed and rebriefed. Often, they then must be prodded into taking the time and effort to make effective statements on points of fact and opinion.

Maintaining Panelists' Support

Maintaining the panelists' continued support is difficult. Some panelists drop out when faced with evaluating 50 to 150 predictions. Others find it easier to agree to predictive dates than to provide thoughtful evaluations and concise critiques of all the pro and con arguments. Panelists' enthusiasm and interest tends to wain over the months required to complete the study.

As a result, several modifications of Delphi have emerged. Many studies have cut down the number of iteration rounds from four to two or three. Research by Norman Dalkey and others suggests that this reduction may not affect accuracy significantly. (This finding, if valid, is a disturbing critique on the basic assumption that feedback of reasoning by "experts" provides more wisdom!) One- or two-round "mini-Delphis," followed by face-to-face meetings of the panelists, are said to be useful.

A panelist might find that his self-image as an expert is rapidly eroded when confronted with pro and con arguments from many other disciplines. He may drop out with the frank admission that he is not truly competent in view of all the ramifications that come to light as arguments develop. Perhaps this view can be regarded as a plus value in favor of Delphi. Delphi studies, therefore, must be kept as short as possible, although this sacrifices breadth. Perhaps thirty to fifty predictions are an absolute limit.

Choosing the Experts

Choosing the experts becomes an issue in several ways. The study organizer literally may not know the best people in the field. Even if he does, these "best people" may be precisely the wrong people to use, at least *in toto,* since they represent orthodox thinking. The radical experimenter, the pioneer, the person with the rejected viewpoint may contribute the most rewarding and valuable knowledge input for developing insight on future changes.

One approach has been to segregate the panelists by topic areas of expertise and interest. Thus, a particular panelist stays in his field of special competence and deals only with a fraction of the total predictions. This is done by (1) prior selection or assignment of areas of interest or (2) instructing each respondent to rate his degree of expertise on each prediction and using the responses according to some weighting scheme. Note that the segregation of experts seriously erodes the other basic reason for using a group of experts since it may explicitly exclude multidisciplinary wisdom. Yet collective wisdom across disciplines is the very reason for using the group of experts.

In many industrial and government studies, internal politics may require the use of officials who are "nonexperts," or those with highly prejudiced positions or limited viewpoints. Politics may also prevent the use of certain people because of institutional structure and personal attitudes. A common fault found with many firms is the decision to conduct its Delphi study internally on the grounds of company security. While the interest in security is quite understandable, the record of science and technology dramatically refutes the validity of limiting *technological* prediction to the persons in any one organization. Technical predictions conducted under this restraint are certain to be limited. Delphi studies should seek wisdom beyond the organization.

Framing the Questions

One approach to framing questions has been to have the study director supply them. However, it is almost inevitable that he will exclude some very important predictions by panelists. Alternatively, one can describe the general purpose of the study and even limit the areas of consideration. A possible refinement is to provide a scenario or a set of assumptions about the future, so that all respondents will be using a common frame of reference. Again, the dilemma is that the chosen assumptions or scenario may eliminate the very wisdom sought.

The phrasing of questions must be done very carefully. A frequent error is to use terms such as "generally," "common practice," "widely," and "most people." Indeed, any modifier (or even a lack of modifier) that implies a totality of condition in a prediction will lead to wide variation of interpretation by respondents.

The precise meaning and degree of rigidity in technical concepts need careful handling. If a predictive statement is made about vertical takeoff and landing (VTOL) aircraft, does it or does it not include helicopters? Some technicians will argue that VTOL, by definition, implies aircraft other than helicopters. Others may see the term as embracing *any* concept for vertical lifting.

Predictive statements must be limited to one thing. Cause and effect or multi-causes and multi-effects must not be linked into one prediction. It is repeatedly shown that some panelists will reply to one aspect, others to a combination of aspects. Still others reject the whole question as being impossible to answer as stated because of the ambiguities that they see. Consider, for instance, this question:

> *By what year will the population of the U.S.A. stabilize at zero growth because of the availability of birth control devices and the attitude of women toward family size?*

Note that a respondent might feel that only one or neither of these reasons will be responsible for zero population growth. He might assume that future economic conditions will be the determining factors. He might feel that the attitude of women is by far the greatest significant factor and that birth control devices are of negligible influence. How, then, will he answer this question? Will all the respondents use the same interpretation? Indeed, exactly what was intended by the question? Was the study director concerned about zero population growth, or was he concerned about the influence of birth control devices on population growth or about the attitude of women on population growth? Or was he concerned solely about the unique combination of those two factors? The study director's only solution is to pretest carefully thought-out predictive questions.

Interpreting Final Data

What is the meaning of the final data? Many participants feel that single dates are far too absolute and what is needed is a range of dates or preferably a range of probabilities applied to given dates. Some Delphi studies are so constructed as to elicit shades of confidence and other data. See exercises IF-2 and 4 on some designs to this end.

Then there is the issue of the reality of a far-distant date. Does a precise yearly date have any real meaning after ten years or so? Is there any reason that a prediction of an event occurring in the year 2009 has any more usefulness than 2000 or 2006? If the expert can be confident about the year 2009, can he be equally confident about the year 2070? Dates of technical events and degrees of usage of technical devices might be realistically predicted for the immediate decade or so, but at some point the decade, rather than the year, is a more proper forecasting time frame.

Many Delphi results are presented and/or accepted as though they were the work of experts. In fact, they are not. They may be no more than collections of opinions of persons who have titular awareness in a field but have no expertise whatsoever on the *precise* technical-economic issues raised. The technique thus may mesmerize the forecaster and the forecast user into believing that statistical collections of uninformed opinions provide valid technological predictions. Some Delphi studies invite "interested persons" to reply, but is "interest" an adequate means of selecting experts for that study?

The stress on achieving consensus has been overdone. Consensus is not necessarily truth. One important value of the statistical display lies in providing the forecast user with a picture of the degree of unanimity and the range of opinion. This display may be extremely useful additional information to the decision maker. See exercise IF-1 on this point.

Despite these criticisms and potential problems, Delphi provides a very useful way to bring future-oriented thinking into the organization of possibilities that may otherwise be ignored. The exercises that follow will further clarify the technique and its application. It is also important to realize that Delphi can be applied to fields other than technology. Management has dozens of areas in which opinion is the basis of decision, and Delphi can be helpful in such situations. The bad experiences with Delphi should not obscure its record of helpfulness in opening up explorations of the future. Delphi, thoughtfully done, is a very useful tool.

OTHER POSSIBILITIES FOR IMPROVING EXPERT OPINION

Interest in the Delphi technique has tended to obscure the basic issue: How else might the use of expert opinion for forecasting be improved? By what techniques of inquiry can more wisdom be obtained from the minds of knowledgeable people?

The Dialectical Approach

Based on the philosophical concepts of Hegel, the dialectical approach calls for making a prediction and then proposing an extreme opposite or counterprediction. Both predictions are then exposed to the strongest possible critical argument. The only known industrial example is described by Richard O. Mason in "A Dialectical Approach to Strategic Planning," *Management Science,* April 1969. A model for a dialectical approach was proposed by Ian I. Mitroff in "A Communication Model of Dialectical Inquiring Systems—A Strategy for Strategic Planning," *Management Science,* June 1971.

A Psycho-Heuristic Approach

A psycho-heuristic concept has been suggested by Warren Duff. His idea is to have the study director make extremely rigorous and critical inquiries of experts in order to elicit sound reasoning to support their forecasts. Obviously, the director must be a technical expert himself in order to ask penetrating and comprehensive questions and to evaluate the validity of answers. This technique borders on the Delphi concept in that the experts do not confront each other. Theoretically, the study director could force the experts to deal with a far more rigorous feedback of reasoning. This is the basis of John H. Vanston's predictive analytical forecasting (PAF) technique applied to fusion power predictions, discussed in a later chapter.

Forecasting by Exclusion

It might be possible to improve prediction by systematically excluding unlikely developments. By defining "forbidden regions," one might narrow and better describe the domain of the more probable. Occasionally, this concept is applied in engineering and scientific studies, as the boundaries or limits of performance are shown. However, systematic applications to technology forecasting is not commonly practiced.

Nominal Group Technique

Andre L. Delbecq and Andy Van de Ven developed the nominal group technique (NGT) in 1968 after social-psychological studies of decision conferences.[1] It utilizes a four-step structured format in a group meeting:

1. Individuals independently and silently generate their ideas on the problem (forecast) in writing.
2. In a recorded, round robin procedure each person presents one of his ideas to the group without discussion. It is summarized in a concise phrase written on a chalkboard.
3. Then all recorded ideas are discussed by the group, emphasizing clarification and evaluation.

[1] Andre L. Delbecq and Andy Van de Ven, "Nominal Group Techniques for Involving Clients and Resource Experts in Program Planning," *Academy of Management Proceedings,* 1970, pp. 208-227.

Chapter 6

Trend Extrapolation

Economists have long used historical data to forecast various aspects of economic activity. The *Harvard ABC curves* were developed by the Committee on Economic Research prior to WW I. In the 1920s the National Bureau of Economic Research began the statistical analysis of some 487 facets of the economy, some dating in the 1850s, but most based on data collections begun after WW I. Further work in 1937 was inspired by the depression, and new series were developed while some old ones were dropped or refined. Since the mid-1950s, the computer has encouraged and made possible vastly increased and sophisticated analysis of economic trends. The use of historic trends to predict changes in economic conditions over the short- to mid-range time periods (a few months to a few years) is a strong contributor to business and government decision making.

Population studies also are largely based on the examination of historic trends, although often on much longer time spans—up to several decades and even (speculatively) a century or more. Similarly, the analysis of trends is a powerful tool in agricultural estimates and planning, weather predictions, and climatology. Trend analysis is a useful technique in examining socio-political activities. In short, trend analysis has proven its usefulness as a mode of prediction in almost every sphere of activity.

Strangely, although trend studies appear in thousands of papers and books on engineering and science, *almost nothing has been done to develop theory and data bases for technological trend analysis.* Trend analysis has not been taught as an analytical device in engineering courses, as it is in economics. With a few exceptions, scientists and engineers have not approached their own disciplines, outputs, and activities as things undergoing measurable changes subject to systematic trend analysis. Although their writings include many examples of trend analyses, technologists themselves have not developed theories and data bases for trend studies as have economists.

The first technology forecasting books in the 1960s demonstrate gropings toward a discipline for technical trend analysis. Today forecasters stand where the economists were perhaps fifty years ago. This chapter examines the rationale behind trend analysis, the arguments pro and con on its usefulness, and a number of specific technical trend analysis concepts.

Trend extrapolation (also called exploratory forecasting) rests on the assumption that technical attributes generally advance in a relatively orderly manner over time, exhibiting patterns of behavior that form fairly well-behaved trends. Therefore, one can choose appropriate parameters, develop their past time series, create various trend lines for that history, and extend them in some manner to predict a future condition or estimate the rate of change. Such projections forecast the status of the measured attributes and so identify levels of technical performance and functional capability. These projections suggest coming possibilities, potential conflicts, supporting requirements, unacceptable anomalies, and the need for actions and responses on technology-oriented devices and procedures.

THE S-CURVE

It is generally believed that these technical data time series, plotted on arithmetic scales, produce S-curves, reflecting a slow start followed by exponential growth, then a leveling off against some limit produced by nature or man. No comprehensive research has been done to prove the universality of this assumption, but almost all data so far plotted show a surprising amount of confirmation.[1] The foregoing S-curve phenomenon comment refers solely to the *achievement of technical capabilities; it does not necessarily apply to the degree of that capability used by society, which is governed by more than mere availability of technology.* This orderly and apparently exponential nature of technical progress may be explained, perhaps, by reviewing the process of technological innovation.

The Start

The new technology emerges slowly because initially few people were involved, basic scientific knowledge must be gained, and engineering obstacles need to be cleared away. There may be a lack of scientific and technical understanding, and it may take time to overcome conventional wisdom and erroneous assumptions about the phenomena involved. New scientific paradigms may have to be built, as Kuhn suggests. Funding of the research effort and lack of experimental equipment may also hold back progress. Ultimately, a promising concept is achieved and progress grows.

Exponential Growth

The advance eventually begins to accelerate exponentially because of the rapid commitment of more technical effort and funds, once understanding and proof of concept are attained. Then efforts are directed not only to advancing the key technical concept, but to refining all the facets of technological execution by applying the best of existing practice. The spur of competition often inspires rapid improvement through bold new goals and unique combinations of design concepts.

Exponential progress also results from the tendency of technicians and managers to set new goals in terms of percentage improvement over present practice. The pattern of action and response between competitors in military hardware also encourages this accelerating advance.[2] Gilfillan and Lenz have pointed out that technical progress in a given device usually is the result of accretion of dozens, if not hundreds, of refinements in the component technologies; this accretion leads to exponential gains. Knight has demonstrated this with the analysis of computer evolution. (See exercise E-9.)

The Leveling Off

Finally, the technical advances cease to accelerate and even to grow. This may be because of exhaustion of technical opportunities for further advance. Perhaps a point of diminishing returns in cost, effort, and usefulness is reached, or some basic limit in nature bars progress. At times, there are limits formally imposed by society or informally imposed by the prevailing social climate.

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[1]N. Carroll Mohn, Jr., "Application of Trend Concepts in Forecasting Typesetting Technology," *Technological Forecasting and Social Change*, Vol. 3, No. 2, 1972. Mohn's doctoral dissertation is one of the few efforts to explore the evolution of a technical parameter (typesetting speed) over centuries.

[2]Robert C. Seaman, "Action and Reaction," M.I.T. 1969 Minta Marta Lecture, *Technological Forecasting*, June 1969, pp. 17-32.

Why should this technical progress be relatively orderly? It is because change in technology, particularly technology that is employed by society, is a compromise. It reflects impacts and interactions among technological possibilities, economics, social conditions, management psychology, skills, and resources of the producing group; alternative possibilities and interests in society; and the reaction of users. This complex mix of influential factors seems to moderate great discontinuities and to encourage relatively orderly evolution. While many technical advances may appear as discontinuities at the moment, in hindsight they seem to be part of orderly change that is undergoing rapid acceleration or decline.

Many trend forecasting problems arise because forecasters seek to establish and project a trend within a small time span in the overall S-curve. Better insight on the relationship of one time span of data to the overall S-curve will help avoid some foolish projections. Awareness of the master S-curve notion will stimulate exploratory thinking about the meaning of the data. It already establishes for the forecaster three fundamental questions about a particular technology:

1. How rapidly does this technology evolve from its primitive beginnings?
2. Once established, how fast does this technology advance?
3. What will limit this technology, and how will the technology approach that limit?

PROS AND CONS OF TREND EXTRAPOLATION

Trend extrapolation has been heavily criticized by some academicians from management science and policy-planning areas, as well as by some sociologists and "futurists." Arguments are listed below with possible counterarguments following each.

1. Simplistic "eyeball" curve fitting in the manner of much TF work today is naive; therefore, it is invalid or useless.

- Naive or not, the facts are that many, if not most, technological trends have been quite orderly and a rough guide to that rate of change is helpful.
- Mathematical elegance in curve fitting is of dubious value in many instances, because of the small amount of data and lack of statistical studies of the phenomena involved. Rarely is there evidence that a particular technology evolves according to a *precise* formula and *that it will continue to evolve in that same manner.*
- Useful guidance usually comes from consideration of the approximate future condition forecasted, not from the prediction of a precise number and date.

2. Extending trend lines for several decades or centuries leads to ridiculous conclusions.

- True enough, so do not do this. Trend extrapolation loses validity over time. It is a guide to the next five, ten, and occasionally twenty years, not to the next century.

3. There is no proof that past forces will continue to support the trend, so extrapolations are intellectually and philosophically unacceptable.

- On the contrary, the burden of proof is on the critic. The past trend is historical fact. It resulted from a complex interaction of forces. It is up to the critic (and the forecaster) to demonstrate what forces will change, when they will affect the historic rate of change (the projection), and by how much.
- What reasons are there to assume that the present is a point of major discontinuity? If this cannot be established, the trend is the best guide to the near future.

4. We can be certain that future technology will be modified by new controls, technical developments, attitudes, value systems, and societal choices.

- This very plausible argument applies especially to the *technology adopted* by society but probably not as strongly as to the *achievement of new technical capabilities.* The forecaster must try to consider these impacts in establishing his projections.
- Society is fractionated. Technological activity is international, and the technological choices of one nation do not necessarily control technology elsewhere. It is by no means proven that the control of a technology in one nation seriously alters the orderly nature of technical advance, except for a few items under international control. The adoption of the SST by France, Great Britain, Russia, and perhaps China and other countries is a 1972 example that U.S.A. attitudes do not always dominate the world's technical efforts.

DEVELOPING THE TECHNOLOGICAL TREND FORECAST

Identifying Technical Attributes

The output of technical activity is improvement in capability, so the forecaster's objective is to measure that improvement. The first step is to determine the attributes of the technology that seem to be important. An *attribute* is the qualitative description of a characteristic of the technology or its performance. Speed, quality, efficiency, size, and cost are examples of simple attributes commonly used. Energy consumption, abrasion resistance, and creep strength exemplify more specialized technical attributes. Many attributes encompass complex combinations of technical factors. For instance, in exercise E-9, *computing power* is the attribute of concern and, in this case, involves more than thirty elements of the technology.

To identify the important attributes, not only must the *performance* of the technological concept be reviewed, but its *composition, production,* and *usage* may also be critical.[3] A good starting point is to explore questions such as:

- What technological attributes are being improved?
- To what attributes are current R & D programs directed?
- What is the technological means of competition?
- What attributes will be critical in the future?

This exercise usually leads to the identification of at least half a dozen attributes and more likely twice that. These attributes must be reviewed, compared, and then arranged in order of priority after considering:

- Will they be important in the future?
- Are they sufficient?
- What are their interrelationships?
- Should they be combined to reflect design trade-offs?
- Is the attribute so defined that it will apply to other technological means of providing the desired end result?

The list should be reduced as much as possible to simplify the TF effort.

Developing Parameters

Each attribute must be converted into a quantifiable measure, or technical *parameter*. For each attribute consider:

- What measures the desired attribute?
- How can that measure be quantified?
- How can the data be collected?
- Is there a leading indicator that might reflect the attribute and be easier to measure?

Parameter development is a deceptive business and requires careful thought:

- Considering the best feasible parameter, what is included and omitted by its use?

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[3]Cost, price, investment, etc., are *economic* attributes of technology. Their economic character should not deter application to technology forecasting since they describe the performance of technology in a domain of ultimate concern. Whether this is forecasting economics or forecasting technology is a pointless argument. The economists should be turned to for all the assistance they can give from their half century of dedicated effort. For instance, their concept of *leading indicators* exemplifies a principle of great usefulness to TF, as will be seen in the exercises.

- How will the organization behave if it concentrates on optimizing this parameter? (This is especially critical for technical *services* as distinct from products.)
- Will a compound parameter embody the technical progress more effectively?
- Does the parameter *truly* measure the attribute as experienced by sectors of society?
- Is the final list of parameters consistent with the organization's goals?

Lenz provides the following example based on aircraft engines.[4]

Attribute Selection

Current R & D objective—reduce engine noise.
Pertinent attribute—quietness.
Additional objectives—retain power and reduce fuel needs.
Pertinent attributes—thrust and fuel consumption.
Rank attributes—thrust is primary, with fuel consumption and quietness secondary, in that order.

Parameter Definition

Attribute—quietness; the parameter measuring it is decibels.
Parameter evaluation—decibel rating does not accurately reflect discomfort as experienced by the human sensory system.
Additional parameters—perceived noise decibels and frequency range.
Parameters for other attributes—fuel consumption by lb. fuel/lb. thrust/hr.; thrust by lb. at sea level, static.
Query on thrust parameter: If this engine is intended for high altitude reconnaissance planes, is the sea level rating still the best parameter to use?

Additional considerations must be reviewed throughout the study development. There is a temptation to concentrate on one single parameter; however, a single parameter rarely encompasses all the important attributes of a device, service, or material. For instance, speed is not the sole important factor in airplanes. Corrosion resistance, as well as tensile strength, is important in some steel construction, and people do not buy automobiles solely because of their mileage performance. The forecaster can easily become so absorbed in studying one parameter (or compound parameter) that he overlooks other attributes that are vital or interacting in his particular case.

As indicated earlier, it is important to look at parameters related to *performance, composition/construction, manufacture,* and *end uses*. For complex devices the technology should also be "decomposed" into *systems* and *subsystems*. The automobile, for instance, must be studied in at least several subsystems—engine, drive train, body, suspension, etc., and then as components of these subsystems. Parameters relating to laboratory equipment, measuring techniques, and even technical knowledge also may be useful as *leading indicators* of an aspect of the technology.

Developing the Data Bank

The weakest part of technological trend forecasting is the lack of long and consistent time series of technical data. The massive and relatively consistent data bases found in economics, population, and agricultural statistics do not exist for very many technology/performance parameters. It is almost certain that the forecaster will have to build his own historical data base. A patient search of many sources is needed. Some useful ones are listed below.

1. Technical and scientific papers published in technical journals (such as *American Machinist* or *Oil and Gas Journal*), in professional society journals (such as *IEEE Transactions*), and the proceedings of special symposia.

[4] Ralph C. Lenz, Jr., has been the major contributor to this topic. This example is drawn from his presentaton of the technology forecasting short courses conducted since 1967 by The Industrial Management Center, Inc.

2. The data files, annual statistical reports, special studies and committee records, and annual reports of trade associations (such as *Aerospace Facts and Figures*).
3. The yearly records and historical reviews of government agencies (such as the *Annual Report of the Atomic Energy Commission*).
4. Studies, reports, and program reviews and recommendations by government agencies relative to then current issues and funding requests; reports of major committees convened by the government to study major proposals and the Congressional Hearings on those proposals are often the roots of major advances in technology.
5. Consulting reports of professionals serving clients in industry and government (often filed and forgotten).
6. Internal studies made by every firm (often filed and forgotten); company internal reports can be a rich source of technical data.
7. Codes, specifications, and studies of standards associations and their special committee reports.
8. Books on the history of technical devices and processes, as well as histories of firms and biographies of individual inventors, engineers, scientists, and businessmen.
9. Summary articles and announcements in trade journals that review new developments and invariably describe the performance of new technology; also, advertisements in trade journals and in publications issued in connection with major equipment exhibitions and trade shows.
10. Theses and dissertations of doctoral students in engineering, science, and business.
11. The private collections of those intellectually curious industrial philosophers and historians who seem to exist in every field and often have remarkable data on key innovations.
12. The papers (many unpublished) and publications of historical societies that deal with technology, such as The Society for the History of Technology and The Newcomen Society.
13. Old company catalogs, which record many statistics on the then commercially available product performance.

The forecaster must use discretion or he will become absorbed in the past to the detriment of the future!

There must be an adequate historical data base, or the projection cannot relate to a trend. With too brief a data base, the forecaster is in the naive position of extrapolating from a point. This error will be found in an astonishing number of technical papers and official forecasts of government agencies.

How far back should one go for useful data? It depends on the purpose, of course, but something like two to three decades ought to serve, unless the goal is to create a total historical picture or to understand the impact of key developments over a century or so. In many cases, the forecaster is concerned only with the change brought about by an established technological development, and so would examine only data subsequent to that introduction. One guide rule sometimes offered is, "Go as far back as you intend to forecast into the future." No logic supports this rule, and it is not recommended here. Instead, think through the characteristics of the technology of interest and go back far far enough to be meaningful to the forecast problem. Wright brothers data are not useful to NASA forecasts, which deal with technologies several generations removed.

How many data points are needed? This is a compromise between time and cost of data collection, the number of data points needed to represent the major different technological changes throughout the period, and the purpose of the forecast. Three data points are too few to establish a meaningful trend line. Perhaps a dozen or so will give a *rough* idea of many trends, useful enough to illuminate future technical issues. This is particularly true if each of these dozen points is representative of major clusters of similar contemporary technology. A minimum of sixty or so points may be required for application of very sophisticated statistical techniques, such as the Box-Jenkins method. It is best to lean toward more data points, rather than fewer, because the aim is to picture the *total* past technical progress. Points that lie outside of confidence limits or intuitive feeling for the general rates of change will lead to questions. Often the exploration of these deviations is most thought-provoking and helpful.

Data must be from comparable situations. In particular, data from experimental work usually should not be intermixed with data from operationally available technology. This error appears in many technical forecasts. The rule is worth repeating: *Don't mix experimental performance with commercially available performance unthinkingly—or without identification.*

Establishing the Trend Line and Its Extrapolation

Here the forecaster faces two issues. What best represents past progress, and what mode of extrapolation is most valid for the future? Four approaches are used: intuitive extrapolation, mathematical curve fitting, pattern identification, and analogies.

Intuitive extrapolation. Intuitive extrapolation is the "eyeball" technique often applied. The forecaster sketches the apparent trend (or connects selected data points); then he develops a projection that seems sensible to him. The only rationale supporting this procedure is that the historic rate of change was a fact in the past and is probably good for some limited future period. Extrapolation of historic rate of change will be sound up to the time that forces making for trend alteration emerge *in such strength as to operate on the parameter*. The forecaster must search for these forces before fixing his projection, for they will surely emerge someday.

The historic trend extrapolation probably is erroneous for long periods, but what is "long" depends on the parameter under study. If the study deals with the laboratory accomplishment of a new capability, that time may be short because the single experimental achievement can be very sudden and substantial. However, if the parameter reflects the societal usage of a new technology, change will be much slower since society cannot develop, build, and diffuse innovation overnight. (Fusion power accomplishments exemplify this point.) Another weakness, often more than theoretical, is whether the forecaster has used a sound data bank, whether he has chosen proper data points, and whether his subjective trend line properly reflects the data distribution.

Mathematical curve fitting. The collective trend of the historical data is described mathematically, and it is assumed that extension of that trend according to the formula is valid for an indeterminate future. The rationale is based on a definable logic, and history apparently is treated with nonsubjective rigor. Unfortunately, the method has some underlying weaknesses.

One weakness is that dozens of very different curves can be fitted to most data, each giving different pictures of the future.[3] What reason is there to assume that one curve is more valid than another? The error sum of squares and the coefficient of correlation algorithms simply argue that deviations in the data are minimized by a certain equation. They do not have any influence on the future. The parameter might well obey some force not captured by the equation. Second, all the criticisms previously raised about the neglect of new forces that will eventually operate on the trend apply to this mode of extrapolation. In other words, it offers a more rigorous, explicit condensation of the past, with that as the *only* justification for its extension into the future.

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[3]Mohn, *op. cit.* See this careful curve-fitting exploration for confirmation of this point.

Pattern identification. To some, pattern identification is a slightly intellectually superior mode of curve fitting in that extrapolation is based on historic "patterns" of behavior in the phenomena that create the data. Instead of projecting a mathematical formula, the forecaster projects a historic relationship of forces operating on the data. The extrapolation is still subject to most of the criticisms above. It also can be argued that the patterns are really no more than a kind of qualitative curve fitting. Nevertheless, if the forces that create the patterns can be explained, a bit more causal logic to the extrapolation exists, as distinct from the blind mechanism of a mathematical formula.

Analogies. Projection also can be made by assuming that the technical phenomenon changes in a manner analogous to an earlier well-analyzed phenomenon. For instance, technical growth might be analogous to biological growth, and hence the Pearl-Reed formula would apply. Or, it might be assumed that a technical phenomenon is approaching a limit similar to the way a demographic, social, or natural factor approaches its limit. For example, it might be assumed that color TV will be adopted at a rate analogous to black-and-white TV. One forecast of the late 1960s assumed that electrical power in spacecraft would grow in a manner somewhat analogous to growth of electrical power in aircraft. The validity of the analogy is the weak spot, of course.

Conclusions. No matter what trend analysis technique is used, the thoughtful forecaster will be dissatisfied by its theoretical and practical imperfections. The extrapolation is mechanistic, subjective, and not causal. It is certain to be invalid eventually. It is essentially a picture of "what," not of "why." Nevertheless, using any of the above approaches or combinations thereof does lead to an estimate of a future condition based upon some amount of historical input. One of the greatest merits of trend extrapolation is that it forces a display of history in a quantified form. Often this display alone justifies the effort because of the understanding gained from seeing the past as a whole.

EXPLORING DIRECTIONS AND LIMITS OF TRENDS

After the forecaster has made a projection of the future state of a technical parameter, he must examine its validity and limits. What influential factors will modify and eventually limit that trend? To avoid inadequate consideration, the forecaster must review influential factors in each environment—technical, economic, social, political, and ecological. (See the example on tanker size in exercises E-8 and E-10.)

Interrogating the Forecast Extrapolation

Some useful questions for interrogation are listed below. While these questions seem directed at limiting the growth of the trend projection, their answers will prove to be supportive of trend extension or growth acceleration in many instances.

Technical

1. Does the projection violate known laws of science? Does it imply an approach to the borderline of a scientific limit?
2. Does the projection violate engineering limits such as presently available design and performance capabilities in materials, power, operating characteristics, etc.?
3. Does another line of technological advance eliminate or threaten the need for the projected technology?
4. If the projection seems to be scientifically and technically possible, is the supporting technology available (i.e., the production facilities, raw materials, power)?

Economic

1. Are the economic aspects of production, application, and operation of the projected technology feasible?

2. Does the technical activity command adequate economic support for the time needed to develop the technology and then as needed to put the technology into use? Will the user consider the technical device to be worth the price?

Social

1. Do changing social conditions prohibit or limit the development and application?
2. Do changing social attitudes alter the perceived desirability of the technology (e.g., attitudes toward small cars in 1976 as compared to 1956)?
3. Will new social needs alter the necessity or the usefulness of this technical advance vis-a-vis other technical support?
4. How will users react to the technology? (For example, stereo hi-fi, digital watches, and CB radio have had public receptions that confounded prior expert opinion.)

Political

1. Are the political climate, leadership, and policy-making agencies such that technology will be encouraged, halted, or altered in direction, form, or timing?
2. Does the development of the technology depend upon certain international or national political accommodations and support?
3. Do taxation, regulation, and/or legal challenges affect the economics, feasibility, or time schedule of the technology?

Ecologic

1. Does the technology forecasted require materials, generate by-products during its production, or generate by-products during use that have undesirable ecological effects? Consideration should include air, water, noise, heat, safety, and aesthetic impact.
2. Is resistance because of presumed ecological impact—whether justified or not—likely to emerge?

Testing the Projection

The above interrogation will identify some factors of uncertain timing, occurrence, and/or impact. Therefore, the projection should be tested for sensitivity to such factors. For the period under consideration, which factors can be neglected and which are critical? Which need more investigation or should be expressed as caveats along with the final forecast? (For example, automobile horsepower may follow a certain trend of reduction, but, if gas rationing is introduced, it will surely drop abruptly.)

The projection also should be tested for cross-impact. What factors will significantly impact on each other and hence on the projection. Will certain combinations of developments have a unique impact on the trend? The forecaster's final conclusion will then fix the extrapolation.

Since earlier data points scatter about the trend line, confidence limits and appropriate statistical devices can be used to improve projection. Projections usually should be thought of as a band, possibly widening over time, rather than as a narrow, precise line.

Implied in this search for limits is the suggestion that the forecaster should try to learn what lies behind the trend. Perhaps he can then be more sensitive to factors that will alter it. Note that this effort leads to the principle of creating causal models, which are discussed in a later chapter on *dynamic modeling*.

When the forecaster has done his best with the projection, he should have the courage to believe his projection valid for a reasonable future period. Reread chapter 4 to reconsider the amount of time it will take to alter the curve by introducing new technology.

Interpreting and Using the Forecast

Now that the future condition has been projected, the next task is to ask, "What does it mean to us?" The trend study has provided a probabilistic statement about the future.

Questions such as: "If it materializes what should we be doing?" "What alternative positions might exist and what do they mean to our own position?" Often the forecaster should extend the study so as to display his organization's trend vis-a-vis their competition in the same field, as well as the trend of technical alternatives that compete in function. (For example, a study of oil-base paint performance should include that industry's trend, as well as the trend of water-base paints.)

The implications of new technical capability forecasts and possible reactions now enter the sphere of management decision making. *It is absolutely essential that no one takes the forecast as a decision.* The forecast provides additional data for management, but it does not include all the considerations needed to decide on a major course of action. No matter how elegant and brilliant the TF study, it will be imperfect. It must be reconsidered in due time.

Summary

The above sequence of steps in trend analysis and projection is intended to encourage consideration of all future forces that will impact on the trend as initially extrapolated. The method demands subjective judgment as to their collective influence in the future. A logical question now is whether there might be some quantitative way to sum up these influences, giving proper weighting and timing to each one. This is precisely what the concept of trend impact analysis offers.

TREND IMPACT ANALYSIS

Background

Although technical trend extrapolation is an old and still commonly used concept, it has never enjoyed much academic development. Ralph Lenz identified the broad concepts in his 1962 Air Force monograph. The idea of *step functions* was developed by Clive Simmonds in the late 1960s and early 1970s. Alan Fusfeld proposed the *technological progress function* in 1968-69, and *substitution theory* was explored by John Fisher and Robert Pry about the same time. Edwin Mansfield had earlier developed a more rigorous treatment of substitution from the economic viewpoint. Joseph Martino extensively discussed statistical techniques applied to technological data curve fitting and extrapolation in his 1973 book. Since 1972, Lenz and Bright have developed a more systematic approach to *selecting technological attributes, designing parameters,* and then *critically exploring factors that will influence the extrapolation.* It has remained for The Futures Group to develop a new and causal-based mathematical treatment of extrapolation, which they named *trend impact analysis* (TIA). It is important to appreciate the distinction between these basic extrapolation approaches.

Mathematical curve fitting. The projection is based upon a mathematical formula that provides the "best fit" to the historic data (or other mode of change selected by the forecaster). The logic is explicit, quantitative, and easily communicated. It avoids prejudice and arbitrariness (in other than initial selection of the formula used). However, for as far in the future as the forecaster chooses to believe the extrapolation, *he is assuming that all future events will somehow offset each other so as not to invalidate the mathematical projection.* In other words, the historic rate of change, as represented by the formula condensing the data, is still valid.

Qualitative evaluation of future influences. The Lenz-Bright approach calls for subjective or mathematical trend development and extrapolation but with much more attention to subjective judgment on which data points and what portion of the S-curve should be used, as well as subjective consideration of the type of progress to be anticipated in the forecast period. However, it concurrently recognizes that *this extrapolation ultimately and assuredly will be altered by future events.* In other words, the historic data of change is not valid indefinitely. Therefore, the second step is to review possible developments in each of the five environments (as well as the internal organization) and to use subjective (and quantitative if possible) concepts to establish the final position of the extrapolation. Thus, the extrapolation is modified by causal, although qualitative, subjective reasoning.

Trend impact analysis. TIA applies a mathematical (best-fit) curve to the historic data, then quantitatively allows for the possible future events that might impact on the mathematical extrapolation. It applies specific mathematical modification of this extrapolation for each event's impact. Next, via computer, a summation of these collective impacts is prepared. Subjective judgment is applied to the computer output in establishing the final projection. The final extrapolation, there, is based on causal, but far more quantitative, analysis. However, it is still based on subjective judgment of events and impacts.

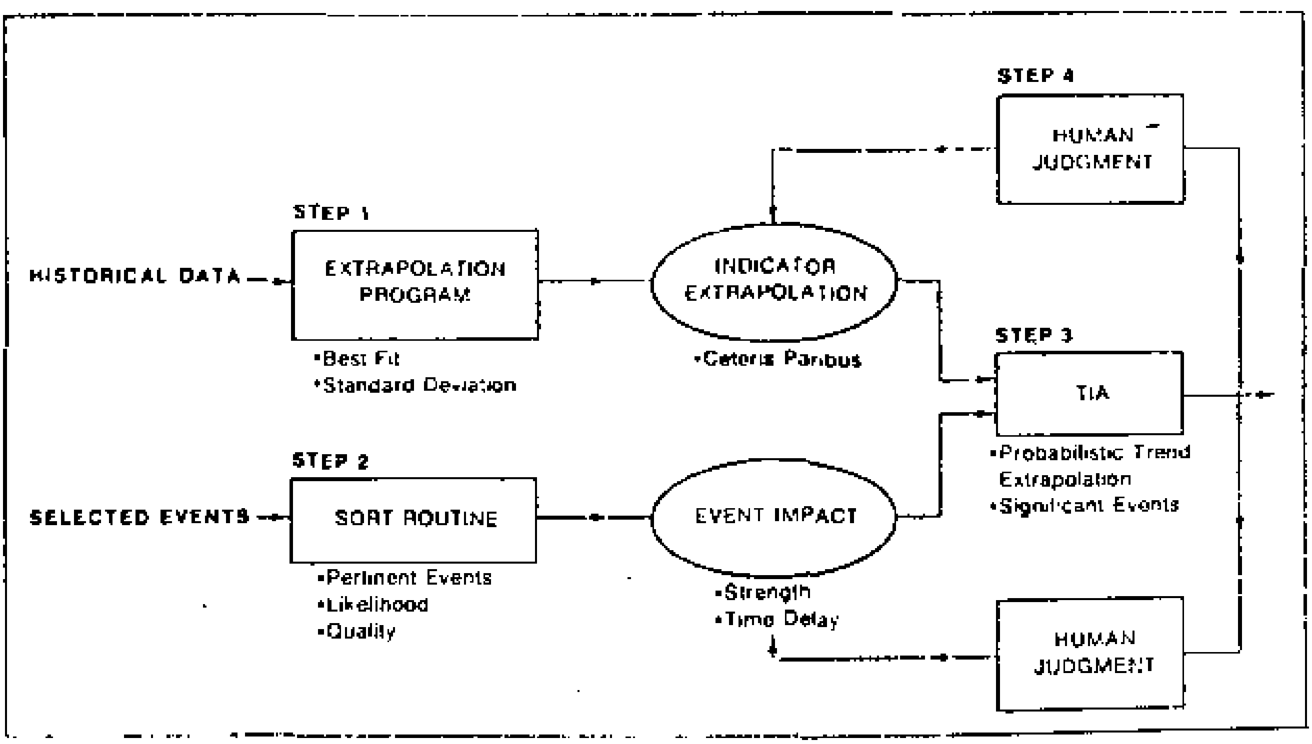
The TIA Method

The TIA concept was developed by Ted Gordon, Hal Becker, John Stover, and their colleagues at The Futures Group, an outstanding futures consulting firm in Glastonbury, Connecticut. It has been applied to several dozen techno-economic studies to date. The developers are quick to point out that the mathematical rigor is applied to a limited number of considerations, which still yields quite subjective extrapolation. TIA adds an important new dimension of quantitative analysis to trend extrapolation. The technique deserves further study and development.

The following description of TIA is presented by John Stover; the overall process is shown schematically in exhibit 6.1.

EXHIBIT 6.1

Trend Impact Analysis (TIA) Procedure



Development of an extrapolation program. The development of a surprise-free extrapolation program is step 1 in the TIA process. A computer program selects the best-fitting curve from a set of alternative equations (exhibit 6.2). This curve is then used to provide the surprise-free future extrapolation. In order to avoid unreasonable extrapolations, the program user can opt to either truncate extrapolations that fall outside upper or lower bounds or select the best-fitting curve only from among those that do not give rise to extrapolations falling outside the specified bounds. Alternatively, the user can reject the mathematical extrapolation generated by the TIA program and supply an extrapolation developed by some other curve-fitting program or one based entirely on human judgment.

Several refinements in the programming of this aspect of TIA enhance the effectiveness of the best-fit test and extrapolation procedure:

1. It is not necessary that the data cover a continuous span of time. Data in which there are gaps are fully acceptable—the program makes use of whatever data are available, taking into account any gaps, but without being stymied by them.
2. The program does not give equal weight to all data. Rather, a year may be specified (normally the present year) for which data are to be given maximum weight. As the times to which the data refer are further removed from the year which has maximum weight, the data are given less weight.* This procedure thus takes into account the possibly lower reliability of data that are more distant in the past or, more important perhaps, the lower influence on the future of developments that have occurred progressively farther in the past. The formula chosen also makes the sum of an infinite number of weights infinite, rather than convergent, so that even very distant years continue to have a finite contribution.
3. Since there is no guarantee that a mathematical extrapolation will give a good fit to the given data, the TIA program reports to the human user just how good the fit was, using the same squared correlation coefficient that determined which mathematical formula should be used. As noted earlier, where judgment or analysis indicates that a more realistic set of data should be used, they can be input directly as part of the specified data used for subsequent steps.
4. Upper and lower limits on the extrapolation may be set. In this case any curve that produces an extrapolation that exceeds these limits will be rejected. Thus the extrapolation is based on the best-fitting curve that does not exceed the specified limits.

EXHIBIT 6.2

Extrapolation Formulas Used as a Basis for Trend Impact Analysis

Equations for TIA Note: M = Slope B = Additive Constant
$V = M/Y + B$
$V = MY + B$
$V = M \, LogY + B$
$LogV = M/Y + B$
$LogV = MY + B$
$LogV = M \, LogY + B$
$LogLogV = MY + B$
$LogLogV = M \, LogY + B$
$1/LogV = M \, LogY + B$
$1/LogV = MY + B$
$1/V = M/Y + B$
$1/V = M \, LogY + B$
$1/V = MY + B$

*The weighting formula is $1/1 + |y - y_o|$, where y is a given year, and y_o is the given maximum weight.

Human judgments of event impacts. Human judgment and imagination are central to step 2 of TIA. Here, the program modifies the surprise-free extrapolation to take into account important, unprecedented future events. First, a list of such events is prepared. These events should be unprecedented, plausible, potentially powerful in impact, and verifiable in retrospect. The source of this list of events might be, typically, a literature search, a Delphi study, or a consensus among consultants. Whatever the source, the events selected comprise an inventory of potential forces that could lead to a departure from a surprise-free future.

Several judgments are made about each selected event. First, estimates are made of the probability of occurrence of each event as a function of time. Second, the impact of each event on the trend under study is estimated. Impacts can be specified in several ways; the procedure here (exhibit 6.3) involves specification of the following:

1. The time from the occurrence of the impacting event until the trend begins to respond.
2. The time from the occurrence of the impacting event until the impact on the trend is largest.
3. The magnitude of that largest impact.
4. The time from the occurrence of the impacting event until the impact reaches a final or steady-state level.
5. The magnitude of that steady-state impact.

Each of the three specified times and the impact magnitudes associated with them are taken to be completely independent. For example, the maximum impact might be positive and the steady-state impact negative, or the steady-state impact might be zero, meaning that the impact is only temporary. Finally, the maximum impact might be the same as the steady-state impact.

In addition, impacts can be specified in either relative or absolute units—i.e., they

EXHIBIT 6.3

Event Impact Estimates

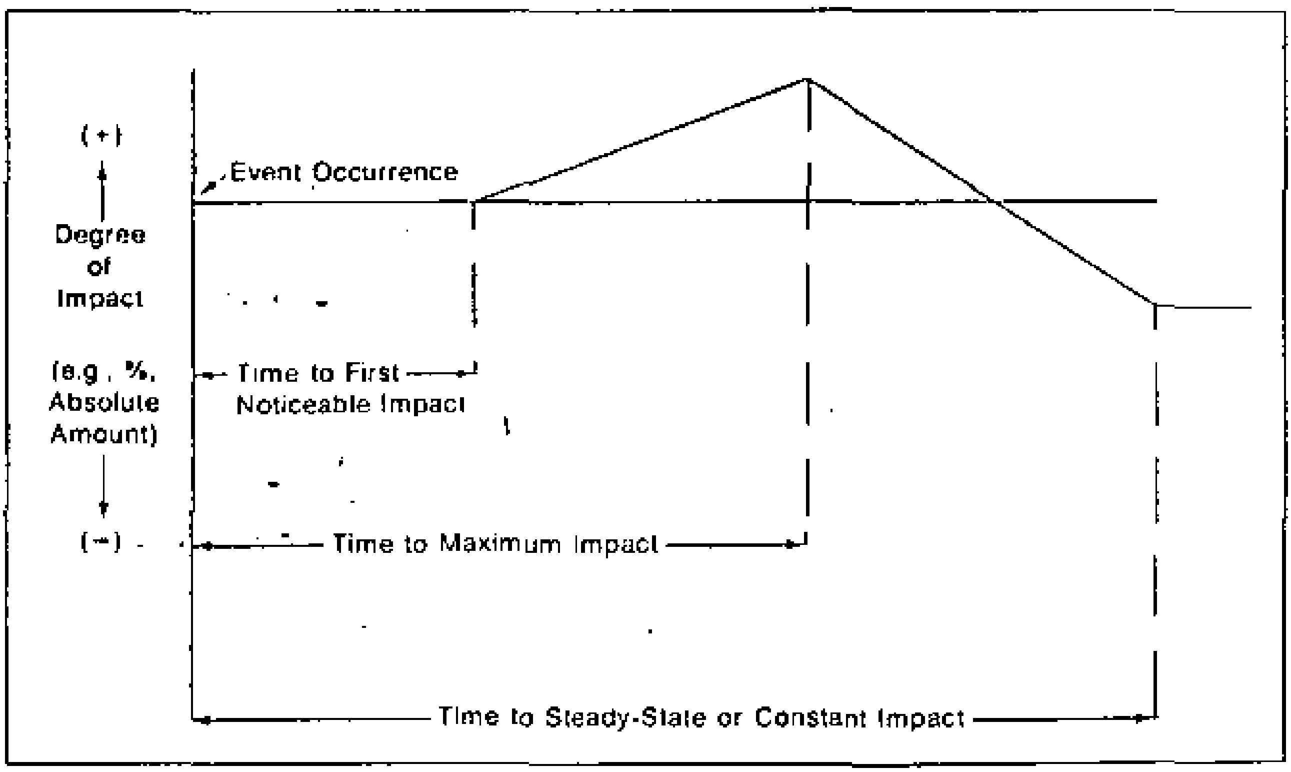


EXHIBIT 6.4

Format for Event Impacts

Index No.		Estimated Probability by Year Shown Prob	Year	Years to First Impact	Years to Maximum Impact	Maximum Impact (Percent)	Years to Steady State Impact	Steady State Impact (Percent)
021277	Single-unit drug packaging accounts for at least 50 percent of drug products sales.	99	1975	1	10	5	10	5

Estimates Provided by Experts

can be specified as percentages of the values of the trends at the time of impact, as a percentage change of that number, or in absolute units of magnitude of the trend. For example, the impact of event No. 021277 on the trend under study could be specified either as 90 percent of that number, as a 10 percent decline of that number, or as a downward shift of 12,000. The form used to record these estimates is shown in exhibit 6.4. These impacts are calculated, when sufficient information is available to do so. Otherwise, they are judgmentally determined.

Computer processing of impact on extrapolated trends. The heart of TIA is the computer which uses these judgments to calculate the expected impact of the selected events on the extrapolated trend. A closed-form procedure is used to solve this problem. The expected value, or mean, of the impact and upper and lower quartiles of the distribution of possible impacts are computed for each indicator. The expected value of the impact is computed by summing the products of the probabilities of the impacting events for each possible year times the magnitude of their impact, taking into account their specified time lags. Probabilities of events for years not specified are estimated by linear interpolation, assuming that an event has 0.00 probability at the present time. Similarly, impacts are linearly interpolated between the three specified impact magnitudes.

This approach treats the coupling among the impacts of the various events as negligible.[7] Thus, the impact estimate is produced as the sum of independent random variables. The net result is that the variance of the impact-adjusted forecast is the sum of the variance of the trend extrapolation (as measured by the square of the standard error of estimate) and the variances of the impacts of the associated events.

Thus, where p_{ye} is the likelihood that event e will occur in year y, and $a_{y_k-y,e}$ is the impact that event e would give rise to $(y_k - y)$ years after its occurrence, the expected value of the impact in year y_k would be

$$\sum_{e} \sum_{y=y_0}^{y_k} p_{ye} a_{y_k-y,e}$$

where y_0 is the present year (in this example, 1975). (See exhibit 6.5)

Typical TIA results. Use of the TIA procedure has revealed that important insights may be obtained by utilizing this form of trend extrapolation. The development of improved trend forecasts is only one of the advantages of this method. Insight into how adjustments of event probabilities and impacts vary the estimated future value of the indicator in question, in terms of both the median and

[7] This may be a very questionable assumption sometimes. One solution is to create a new "event" that combines the coupling events of concern, then to compare the resulting impact to impacts of the events treated separately.

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EXHIBIT 6.5

Expected Value of an Event Impact

Year of Event Occurrence	1975	1976	1977	1978	1979
1979	-	-	-		$P_{79} \times i_0$
1978				$P_{78} \times i_0$	$P_{78} \times i_1$
1977	-		$P_{77} \times i_0$	$P_{77} \times i_1$	$P_{77} \times i_2$
1976	-	$P_{76} \times i_0$	$P_{76} \times i_1$	$P_{76} \times i_2$	$P_{76} \times i_3$
1975	$P_{75} \times i_0$	$P_{75} \times i_1$	$P_{75} \times i_2$	$P_{75} \times i_3$	$P_{75} \times i_4$

p_x = Probability of Occurrence in Year x

i_y = Impact of Event y Years from Occurrence of the Event

$i_{total_y} = \Sigma i_{e_{1_y}} + i_{e_{2_y}} + i_{e_{i_y}}$

- Assumes Coupling Among Events and Event Impacts Is Negligible

interquartile range, can also prove to be very useful in developing an understanding of the effectiveness of policies or actions that may be available to the forecast user.

The forecast of the indicator shown in exhibit 6.6, the average cost of a prescription, is drawn from a recent report that is part of a data service (called PROSPECTS) developed at The Futures Group. The forecasts in the PROSPECTS reports are prepared using the TIA procedure and, as they represent material prepared to aid in real-world decision making and planning, should prove useful in discussing the insights obtained from using TIA.

Initial or baseline extrapolation. It should be remembered that the impacts assigned to each event describe the estimated change in the surprise-free trend caused by the occurrence of that event. In the case of the average cost of a prescription, an upper limit of $8 per prescription (in 1970 dollars) was set for the extrapolation. The extrapolation program rejected the first three curves generated because they exceeded this limit. The fourth curve remained within the limit and produced the solid-line extrapolation shown in exhibit 6.6. This, then, became the baseline to be impacted by future events.

Event impacts. The events used in this TIA are shown in exhibit 6.7. For example, the first event, the abolition of all product brand names, was judged to have a probability of .10 of occurring by 1985 and a probability of .15 of occurring by 1990. If this event does occur, it is expected that its first impact on the average cost of a prescription will begin two years after the occurrence of the event. The maximum impact will occur after five years and will be a 20 percent reduction in the average price. The steady-state impact is judged to be the same as the maximum impact.

The combination of these events, probabilities, and impacts with the baseline extrapolation is a forecast (exhibit 6.6) markedly different from the baseline extrapolation. The curve even begins to decline in 1987. The uncertainty is indicated by quartiles about 18 percent above and below the mean forecast. (The quartiles indicated the middle 50 percent of future values of the curve. Thus, 25 percent of the futures lie above the upper quartiles, 25 percent lie below the lower quartile, and 50 percent lie between the two quartiles. Quartiles are presented here; however, since the computer program calculates the standard deviation, skewness, and kurtosis for each year, any part of the range could be printed out.) This uncertainty shown by these quartiles results from the fact that many of the events that have large impacts have relatively low probabilities; thus, an uncertain situation prevails.

At this juncture, it is desirable to determine the sensitivity of these results to the individual estimates upon which they are based. For example, one might raise valid questions about the estimates of event probability, the magnitude of the impacts used, and the delay time associated with these impacts. Having prepared these data in a disaggregated fashion, it is extremely easy to vary such estimates and view the change in results. It may also be observed that intervention policies, whether they be institutional (such as lobbying, advertising, or new marketing approaches) or technological (such as increased R & D expenditures), can be viewed as a means of influencing the event probabilities or impacts.

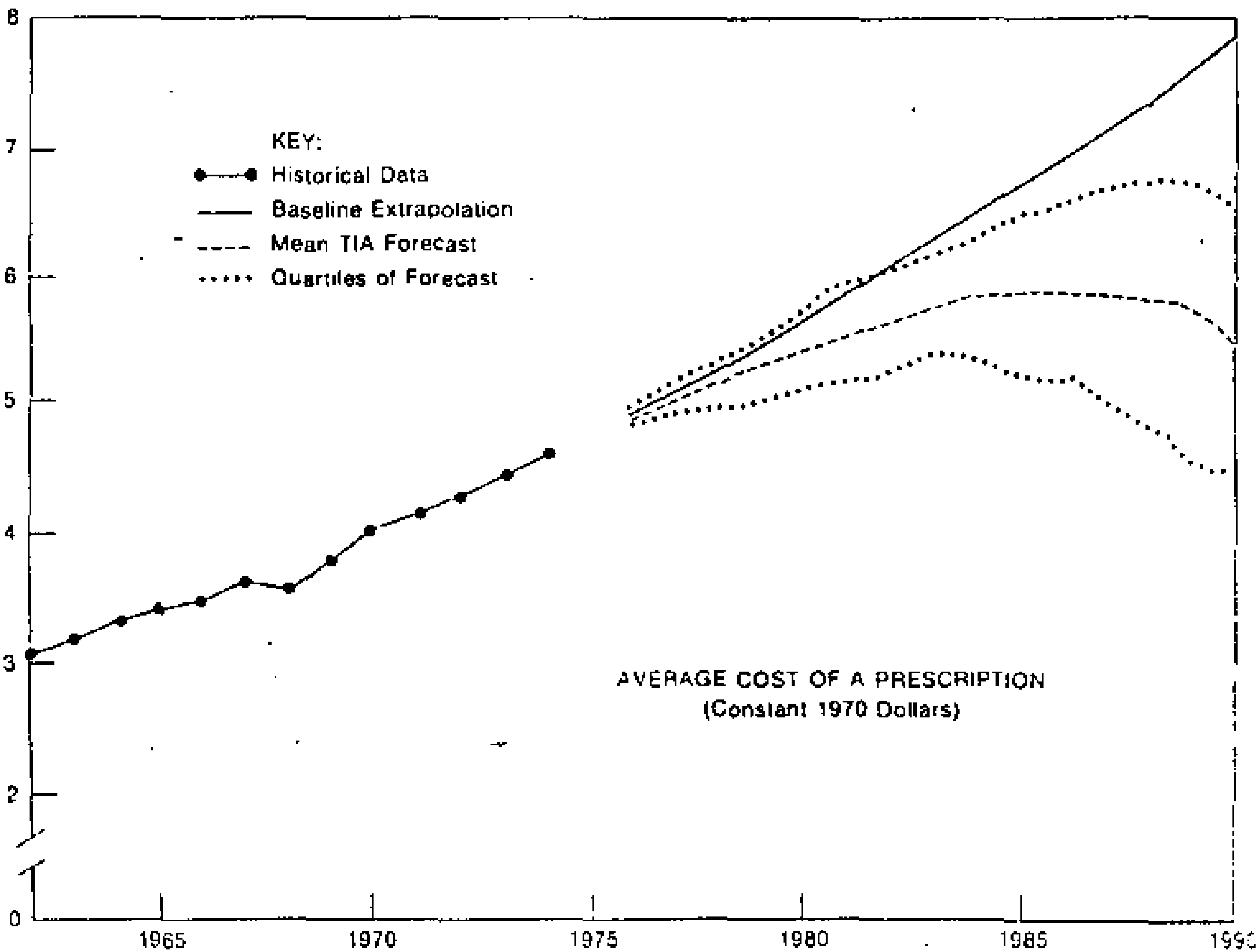
Suppose, for example, a certain pharmaceutical company was in a position to lobby for the immediate removal of restrictions on prescription advertising, or suppose an analyst thought that the removal of these restrictions was much more likely than 20 percent in 1980. In each case knowledge of the sensitivity of the forecast to the removal of advertising restrictions would be useful. This sensitivity can be tested by raising the probability of this event from .20 in 1980 to .90 in 1980. The result of this change is shown in exhibit 6.8.

This exhibit shows that the sensitivity of the forecast to an early occurrence of this event is mainly during the 1975-1985 period. During this period the forecast is reduced by about 7 percent, and the quartiles are similarly reduced. By 1990, however, when the probability of the event had already reached .60 in the first forecast, the difference is slight. The sensitivity of the forecast to each of the other events or combinations of events can be determined in a similar manner.

Thus TIA can be used, not only to improve forecasts of time series variables, but also to study the sensitivity of those forecasts to policy. Of course, any policy considered should attempt to influence as many events as possible, rather than one, as in this simple example. Realistically, corporate actions often have both beneficial and detrimental possibilities, as they may enhance both desirable and undesirable possibilities. The use of such procedures as described here, however, should make such uncertainties more clearly visible than is possible with techniques heretofore available and allow the forecaster to live more comfortably with, and even to reduce, the degree of risk in his endeavors.

EXHIBIT 6.8

A Typical Forecast Obtained Using Trend Impact Analysis (TIA)



SOURCE: R. A. Gosselin & Company, IMS America

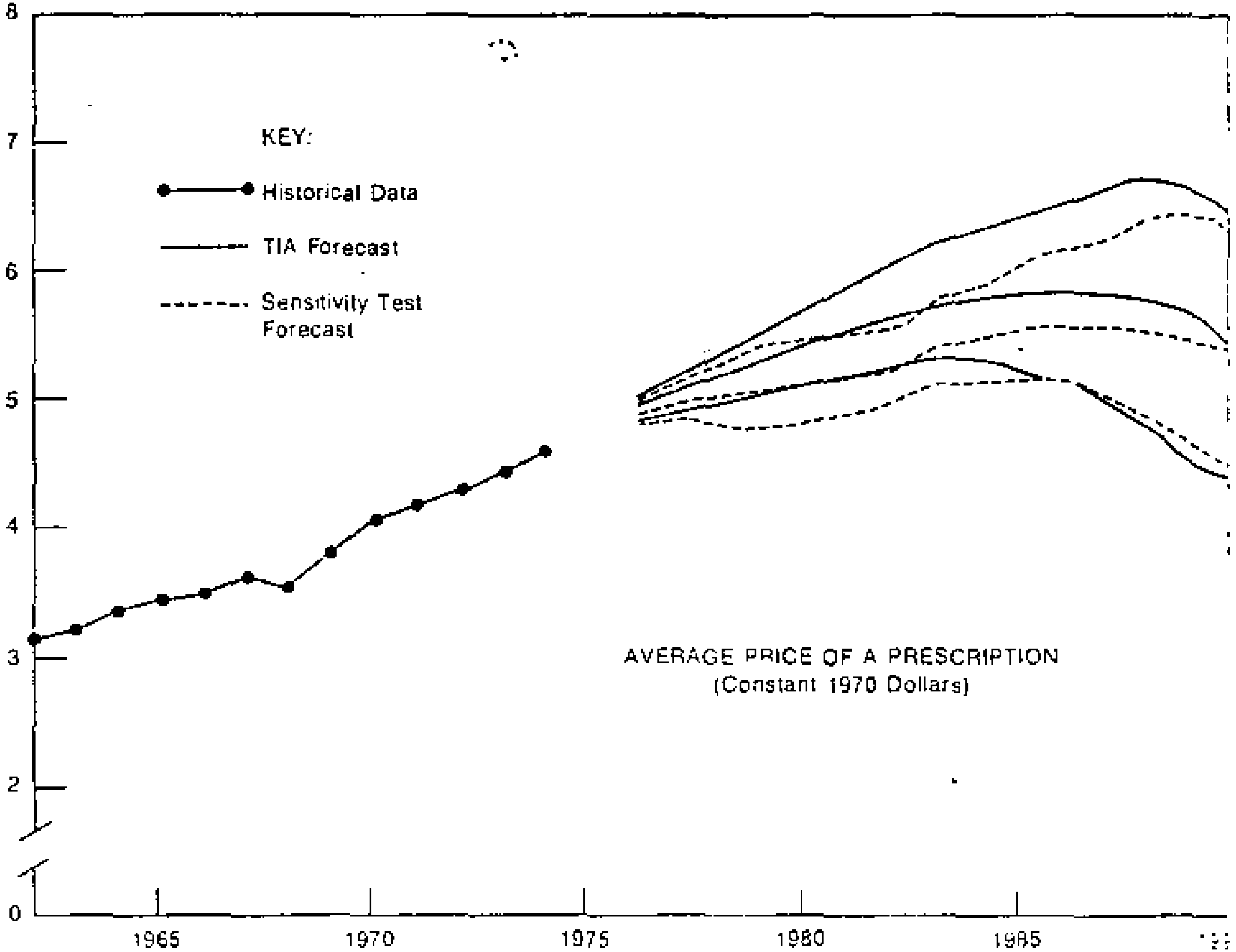
EXHIBIT 6.7

Event Used in TIA of Average Cost of a Prescription

	Event	*Estimated Probability by Years Shown*		*Years to First Impact*	*Years to Maximum Impact*	*Maximum Impact*	*Years to Steady-State Impact*	*Steady-State Impact*
1.	Abolition of all drug product brand names; standard abbreviations for generic names.	.10 .15	1985 1990	2	5	20	5	20
2.	Drug reimbursement in all federally funded health programs based on maximum allowable cost.	.75 .75	1976 1990	5	5	15	5	15
3.	Removal of all federal and state restrictions on prescription price advertising.	.20	1980	0	2	10	2	10
4.	Decrease in the average size of prescription by 20 percent.	.10	1985	0	2	10	2	10
5.	Comprehensive health care package initiated, federally run, federally subsidized.	.50	1980	2	10	10	10	10
6.	Period of patent protection reduced to five years after market introduction of product.	.40	1984	5	15	15	20	5
7.	Economic recession (similar to late 1950s).	.30 .35	1980 1990	0	2	10	3	0
8.	Federal and state legislation to allow paraprofessionals to perform more drug-dispensing duties.	.25 .50	1984 1990	5	5	5	5	5
9.	Antisubstitution laws repealed in most states.	.44	1985	1	10	5	10	5
10.	Semi-automated drug-dispensing equipment for use by pharmacists.	.50 .65	1980 1985	2	10	2	10	2
11.	Number of prescriptions per user increases 10 percent over 1973 levels.	.40 .50	1980 1990	1	10	5	10	5

EXHIBIT 6.8

Sensitivity Test of a TIA Forecast



TYPES OF TREND EXTRAPOLATIONS

Single Parameter

Hypothesis. Time series data of a technical attribute that reflects a significant aspect of the technology or its application (e.g., power, speed, cost, strength, hardness) can be plotted a trend established, and then extrapolated in some manner to predict its future state.

Potential use. The extrapolation helps to identify the likely degree of change in that attribute at future times. Implications then can be considered, and need for further investigations or actions is indicated.

Cautions. (1) A single parameter often fails to clarify the design trade-offs that are taking place between several attributes; (2) one or a few parameters are insufficient to describe all the important changes taking place in a complex technological device, such as an airplane, an oil refinery, or a computer; and (3) no trend goes on unchanged forever—the influential factors must be considered in making the extrapolation.

Compound Parameter

Hypothesis. Combinations of parameters can be designed so that the data will reflect the basic, interrelated changes in the device or service (e.g., power per unit of weight or space; computer operations per dollar). Trends of such factors reflect the technological-economic trade-offs taking place with the device or service.

Potential use. Same as previous type. They also may have more relevance to the user because they describe a total service or condition pertinent to the application of the device.

Cautions. (1) More than one compound parameter may be needed, and (2) the compound parameter may still be incomplete and may not fully reflect all the important aspects.

Leading Indicators or Precursors

Hypothesis. Time series data of a single or compound technological parameter (or other phenomenon) that seem to lead the technology in question can be used to forecast a future state (e.g., improved accuracy of measurement might lead to improved accuracy of machine tool performance).

Potential use. The rate of change in performance of the precursor and its relationship to the technology under study provide a basis for a prediction of future capability.

Cautions. Past relationship between the precursor and the subject technology may not hold for many reasons. For example, different forces may be driving the two phenomena, or certain factors may limit the one parameter but not the other (e.g., speed of military airplanes no longer relates immediately to the speed of civilian transport airplanes).

Envelope Curves

Hypothesis. A fundamental capability that society desires continues to advance by support of a succession of increasingly effective technologies. As the S-curve progress of an earlier technology begins to fall off, a new technology emerges to maintain progress of the fundamental capability. A curve approximately tangent to the tops of the S-curves describes an "envelope" of anticipated change. No definitive theory for drawing or projecting the envelope curve has been suggested, and only one piece of research has been done. (See Appendix A.)

Potential use. S-curves and their envelope curve, even though roughly drawn, suggest the coming of technological change. The S-curves display the growing inability of a given technology to support the advance predicted by the envelope curve. Examination raises questions about the decline and emergence of particular technologies and resulting market impacts.

Cautions. The fact that a given technology no longer supports the envelope curve does not mean either immediate or ultimate economic demise. Many technologies remain effective in certain sectors of society (e.g., propeller-driven planes no longer support the airplane speed curve, but they still have a viable and substantial market).

Step Functions

Hypothesis. Industries show different historical patterns of behavior in the scale and timing of technological changes that they introduced into products and facilities, especially as these factors relate to total demand. These patterns are responses to such forces as markets, prices, costs, size of investments, technological considerations, new technology, intra-industry relationships, sociopolitical restraints, and even industry tradition.

Potential use. By developing these patterns one can estimate the scale and timing of new technology introductions. Impact on the market, prices, and the supplier-customer competitive response cycle may become clearer. An individual firm could then make wiser decisions for its own timing and scale of technical facilities through profitability analyses based on various cost-price responses. The technique also is especially useful for studies of intercountry technical competition and economic competition based on the scale of technical facilities.

Cautions. (1) The existence of such patterns must first be established for the particular industry; (2) the future stability of relationships that created these patterns must be carefully considered; (3) eventually there will be limitations to the progressive increases in scale of facilities; (4) new technology and sociopolitical events can abruptly alter these patterns; and (5) automation, miniaturization, and technological "learning" may occur and so rapidly improve capacity and output as to invalidate the projected patterns.

Technological Progress Function

Hypothesis. The technological progress function assumes that a technical parameter improves with cumulative numbers of units produced in the manner exhibited by unit cost and manufacturing time in learning curve theory.[1] Where technological devices are not necessarily produced uniformly over time, the resulting curve is different from one plotting time-related data. The equation:

$$T_i = a(i)^b$$

where: T_i = technical parameter, characteristic of the ith unit;
i = cumulative unit number;
b = rate of progress, presumably dependent on environmental considerations, such as technical effort measured by rates and levels of investment and man-years; and
a = a constant.

Possible justification may lie in the fact that R & D effort often is proportional to production activity and resulting sales income on which R & D budgets are based. Also, technical progress is often the accretion of hundreds of minor improvements, which are "learned" and applied over repetitions of production.

Potential use. the function provides a basis for technology predictions against growth of technology production or usage instead of time. This basis might be far more appropriate to some technical developments.

Cautions. Same as for other trend extrapolation techniques. The assumption that technical improvement is related to cumulative production may not apply to the particular case (e.g., the advances in hand-held calculators went through abrupt discontinuity when the integrated circuit-electronic display technology was introduced).

Substitution Theory (Fisher-Pry)

Hypothesis. If a new technology begins to replace an existing technology without a major change in function, it will tend to go to

[1]Alan R. Fusfeld, "The Technological Progress Function: A New Technique for Forecasting," *Technological Forecasting*, March 1970, pp. 301-312.

completion, and the time and amount of substitution can be predicted according to a hyperbolic tangent function based on the average annual rate of displacement. The substitution formula is explained in exercise E-6. Many other possibilities are discussed in the key summary book just published.[9]

Potential use. Predictions of amount and timing of substitution of new technology provide bases for estimates of future market size, production capacity, and supporting activities as well as data for planning phase-out of old technology. Substitution rates in one field or country also might prove to be precursors of substitution rates elsewhere.

Cautions. (1) Accuracy of predictions based on the first 5 to 10 percent of displacement may be very poor; forecasts based on 20 to 25 percent displacement data seem to be quite accurate; (2) units of measurement must be carefully chosen to avoid distortion (e.g., the substitution of plastics for steel in automobiles would be badly misrepresented if weight were used as the measure); (3) it has not been explained how and why this displacement theory differs from conventional market product displacement theory; and (4) the very long time spans involved mean that the new technology will be subject to many environmental changes, including competitive technology, and presumably this reduces reliability.

Analogies

Hypothesis. A new technology may emerge in a manner, pattern, and/or rate of change analogous to some previous technology or existing natural or social phenomenon. One variation is "growth" analogy, which assumes that a technology is analogous to biological activity and "grows" toward a natural limit in the same manner. Most famous of these is the Pearl-Reed curve, named for the biologist who developed mathematical curves to describe the limits to growth of number of fruit flies in a bottle and other organic growth. For a discussion of Pearl curves, Gompertz curves, and other mathematical treatments of growth, see any text on statistical analysis. Another variation is to assume analogy to closely related prior technology (e.g., television growth will be analogous to radio growth).

Potential use. The analogy provides a pattern that may be a useful guide to a future limited condition. The very evident tapering off of growth in prior technologies, when comparing that growth to mere extrapolation of present rates of change, aids understanding of the possible behavior.

Cautions. Is the analogy really valid? Consider past socioeconomic conditions as well as different uses and needs for the future technology. Presently no theory or research suggests that technological *capability* grows in a specific manner, other than the vague S-curve phenomenon discussed earlier.

Correlation Analysis

Hypothesis. A technological device changes through a blend of many factors of performance, construction, cost, and social usage. Factors that are not actual attributes of the technology may affect the technology. Therefore, historical data on the important interrelated influences should be developed and plotted. Trial extrapolations are then made to test relationships and so to determine the most likely future state or directions. The basic notion is to search for consistency and logical relationships between trends in a field.

Potential use. By clarifying the interrelationship of elements of the technology, correlation analysis may be used to detect the way the factors will influence each other as the technology evolves. It reveals the sensitivity of technological development to future changes in each element and thus suggests the likely trade-offs.

Cautions. This is obviously a complex study that requires very careful consideration of underlying forces that cause changes in each parameter.

[9] Harold A. Linstone and Devendra Sahal (eds), *Technological Substitution* (New York: American Elsevier Publishing Co., Inc., 1976).