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The Management of Research and Development (Selected papers from a conference in Wroclaw, Poland, September 1978)

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THE MANAGEMENT OF RESEARCH AND DEVELOPMENT

Selected Papers Given at a Conference in Wroclaw, Poland, September 1978

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GENERAL INTRODUCTION

This paper is one of two IIASA Collaborative Papers containing papers presented at the Third International Conference on the Management of Research, Development and Education held at Wroclaw, Poland in September 1978. The conference was, on this occasion, jointly organized by Dr. Karol Pelc, Director of the Forecasting Research Center of the Technical University of Wroclaw and by Professor Gennady Dobrov, Deputy Director, Institute of Cybernetics, Kiev and at that time a member of the staff of the Management and Technology Area of the International Institute for Applied Systems Analysis. Formally, it was jointly sponsored by the Wroclaw Technical University and IIASA.

It is always difficult to decide what to do about conference proceedings. The greatest value of such conferences is usually the meeting between minds--the exchange of information and understanding between people from different cultures and academic backgrounds. This was particularly true at the Wroclaw conference where there was strong representation from ten countries, both East and West. It was a rare opportunity for scientists to identify potential collaborators and discover who was working in which field. Such opportunities are too few. Nevertheless, the Conference Scientific Committee felt that a number of the papers should be made available for reference in a more accessible form, and with their help, we have made a selection for issue as IIASA Collaborative Papers. A complete list of the 40 papers read at the conference are given as an Appendix to this collection--copies of individual papers can be obtained by request from the Forecasting Research Center, Technical University of Wroclaw.

The introductory paper to the conference was on 'Main Problems in the Control of Scientific and Technological Creative Activities, Application of Innovations and Education of Scientific

Staff' and was given by Professor Jan Kaczmarek, Scientific Secretary of the Polish Academy of Sciences and a member of the IIASA Council. We felt that this was of sufficient interest for a separate issue, and appears as IIASA CP-80-19. For the rest we have selected thirteen papers for issue in this volume, and have divided them into three groups.

The first group of five papers is concerned with problems of strategic decision making in the field of science and technology. The first, by Petrasek, provides a new method of classifying the tasks in a forecasting problem which should help in improving the relevance of the results to real-life decisions. Baworowski emphasizes the importance of technology forecasting in developing a producers strategy, and the importance of matching the forecasting procedure to needs at all levels. Two papers, by Schulze and Pelc, are then concerned with the analysis of factors determining national strategy for science and development. Finally, we have a paper by Dierkes and Thienen which discusses the problems of getting a satisfactory debate over science policy issues, and considers the 'Science Court'--proposed originally by Kantrowitz--as a possible solution.

The next group of papers is concerned with structural changes in science and technology and their impact on the management of interdisciplinary research. The first of these is by Albrecht and Otto who discuss, on the basis of extensive historical studies, the dangers of generalizing over the science-technology-production cycle without making clear differentation between different classes of technology, as well as other factors. Eto shows some of the problems arising from the development of new sciences--both basic and mission oriented sciences--and discusses the implications. Glowiak and Winnicki follow this theme in discussing the managerial action needed to stimulate new fields of technological expertise, such as environmental engineering. Finally, Dobrov, Randolph and Nurminski present some work undertaken at IIASA relating to technological change in agriculture, and in particular draw attention to the problems introduced by the rapidly decreasing output-input energy ratio.

The third group of papers deals with broader questions of management of R&D and of technological change. Bobryshev and Chereshkin discuss, in particular, the development of a planned management information system for research and development in the USSR. Wasniowski considers four questions related to the management of long range programs, namely: What is a long range program? What are the problems of formulation and management? Why is technology assessment needed? Why is systems analysis needed? He discusses the use of computer conferencing and the use of gaming. Ball, Miller and Pearson then give a detailed study of the development of single cell protein, and pay particular attention to the problem of matching technology to market needs. Finally, Jermakowicz and Ruszkiewicz undertake a study of the machinery industry in Poland which enable them to identify some of the major organizational factors influencing the effectiveness of the Science-Technology-Production cycle in industrial enterprises.

All the papers are presented here as given at the conference. In the interests of economy we have not attempted to edit them in any way.

We would like to take this opportunity of thanking the members of the Scientific Committee of the conference for their help with regard to the conduct of the conference and the subsequent selection of papers for publication. It was another example of successful international collaboration.

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FORECASTING OF SCIENCE AND TECHNOLOGY AS AN INSTRUMENT FOR DECISION MAKING

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From day to day the endeavour to forecast future events becomes stronger. Social effectiveness of forecasting activity, however, seems rather doubtful, especially when determining the influence of forecasting on decisions of planning and managing centres. Probably this is due to the fact that data included in forecast are often not only useless for decision making but also false and cannot be verified by the user.

A relative stagnation in preparing and using purely predictive models for forecasting can be observed to appear simultaneously with fast progress in building and pilot exploitation of various kinds of models serving for anticipation. Apart from their predictive power the latter models are characterized by the ability to reflect the problem solving process when the subject of decision prepares and realises his strategy and tactics of management 1/.

The above mentioned trends in the recent state of the art forecasting are a serious challenge to the forecasting theory with has not been fully developed, yet. Is it possible to delimit more explicitly the tasks when formulating the demand for a forecast ? Can we define more precisely an adequate method for forecasting in a certain decisive situation ex ante?

THE RELATIVISTIC CONCEPT OF FORECASTING

The classical question "how to predict the future?" makes the present forecasting methodology face the problem of finding the best predictive algorithm functioning independently of the processes of generating the future. The roots of the art predicting as a specific process of transforming existing data lay in recent concepts of forecasting. The mechanistic approach which absolutizes the value of the forecasting method is effective /though to a certain extent only/ when predicting natural equilibria and cycles using empirical sciences relevant to its understanding. It is however noneffective

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when problems of social development are to be solved. In this case the subject plays an active role in the process of creating the future. This in turn leads to the question "what does it mean to predict the future?"

When looking for the answer the reactive role of predicting in the context of decision making process demands attention. What stimulates the process of predicting is the need to anticipate the future in the process of problem solving. Thus prediction appears to be formal aspect of an informational process taking place when decision making subject anticipates in order to solve a given problem. This formal aspect cannot have an 'absolute' value in the sense of determinig the future. Its value is closely connected with the content of informational exchanges realized when the subject acquires the knowledge necessary to solve a problem in a given decision making process.

We postulate that theory of forecasting should be based on an inevitably relativistic concept which reflects information processes related to anticipating the future under given conditions of decisive situation. A forecast has a special value in relation to the degree of recognition and understanding of a given situation as well as to the degree of identification and specification of problems to be solved when the subject prepares a programme of his managing activity and to the degree of the subject's ability to manage and control a given situation.

THE PROBLEM OF STRUCTURALISATION OF TASKS FOR FORECASTING

To delimit more explixitly the tasks for forecasting, especially those for forecasting of science and technology an attempt was made to classify the tasks stemming from the analysis of complex decision making processes concomitant to planning processes when the development of national economy is oriented, programmed, managed, and controlled. Three working hypotheses were adapted for this purpose:

1 - processes of understanding a given situation can develop effectively only when an informational exchange takes place between general and particular knowledge. As a consequence understanding is combined with simultaneous formulating and solving of problems at various levels of generalizing the knowledge concerning a given situation 2/.

Structure of problem situation from the viewpoint of the need of anticipation when managing the development of the national economy

Stage of maturity of management system	Problem situations according to the level of generality employed when solving the tasks of development		
	orientation	programmation	regulation and control
identification of problems	fuzzy concepts-needs and resources of system development	fuzzy concepts-effective ways of solving the development	fuzzy concepts-output abilities of developing system
specification of problems	delimitation of preferences for goal-orientation of development	dilimitation of criterions for safequarding the effectivness of solution	dilimitation of norms for output of particular developmental activities
synthesis of model for managing	strategy of development in given limiting conditions	programming instructions for selecting effective variants of solution of development in real time	system of management and control over normalized developmental activities
application of the model	actualisation of the structure of preferences	actualisation of programming instruction by reorganisation of its project structure	actualisation of the system of management and control by adaptation of the norms for development

2 - processes of formulating and solving of problems are constantly modified due to decision process feedback consisting in using some decisions in the system of management.As a consequence the evolution of systems of management results in an organisational modification of an intellectual activity of a decision maker. Especially in processes of designing and projecting of new or improoved systems of management,certain stages occur that make processes of formulating and solving the problems more effective from the point of view of goal-orinted behaviour of a decision maker.

3 - the disponibility of various systems for human management and control is not unique.Hence their understanding is not of the same value for a given stage of problem solving process when a certain system of management is functioning.Especially the possibility of finding an algorithm for programming a certain technological system brings about the task of anticipating its future being different from the task of anticipating the future of a totally nonprogrammable system within the same system of management 3/.

Results of the adoption of the hypotheses in the case of the management of national economy are given in the table.Tasks of anticipating the future are distinguished according to three levels of generality of formulating and solving the problems of the development of national economy.The first level being the most generally valid one describes a strategy of development,the second level serves for an interchange between general and particular problems of development via its programming under definite conditions,and the third level represents the particular knowledge of developement.In the latter case problems are formulated and solved during functioning of a certain system of management and control of the development of national economy.Four stages of problem situation are distinguished according to the tasks associated with the process of preparing and realizing the system of management.The decomposition of tasks of anticipating from the point of view of the programmability of systems is not included in the table. One way of doing this was experimentally realized for the purpose of long-range planning of the developement of a given institution.For every stage of problem situation,distinguished in the table,the tasks of anticipating for institutional, organizational,and technological subsystems of a given institution were proposed according to the theory of organization 3/.When compared with the actual needs resulting from maturity of the system of management of the institution, the forecasts of individual developmental factors can be evaluated according to their relevance to that stage of problem situation at which the subsystem is interpreted for management. Thus, for instance the technological subsystem of a given institution can be managed according to a certain formalized model. At the same time the organizational subsystem of a given institution is managed intuitively. Hence in the former case the forecasts will serve presumably to meet the needs of anticipation stemming from the fourth stage of problem situation whereas in the latter case the need of identification of problems predetermins the need of anticipation and the necessity of effective objects and methods of forecasting.

The interactions betwen particular problem situations presented in the table, are formulated basing on the presumption that when a certain system of management is functioning on a pilot or full scale then close informational interactions between individual levels of generality of the process of problem formulating and solving must be attained to proserve the stability of the system. On the other hand when the problems of the development of national economy are identified and specified during the process of preparing a certain system of management, the proces of acquiring the necessary knowledge proceeds rather in isolation at particular levels of generality of understanding a given developmental situation. This presumption affects the integrity of forecasting informational systems at particular stages of problem situations and leads to the hypothesis that the endeavours to build an integrated system for forecasting when the problems of next social developement are to be identified seem rather senseless. For the same reason in order to maintain the stability of the existing system of management an integrated informational forecasting system must be created.

SOCIAL CHALLENGE TO SCIENCE AND TECHNOLOGY FORECASTING

A short review 4/ of forecasting of science and technology over the period of the last 15 years shows a variety of stimuli and needs effecting the forecasting activity. Hence there are quite a few approaches to forecasting. Each of them is quite effective when solving some tasks joined with anticipating the future but very noneffective when other tasks included in social demand of various decision centres are to be solved. These approaches concern:

1 - technology and science forecasting 5/. It explores forms and functional capabilities of various artefacts /including scientific information/ in the future,

2 - Technology assessment 6/. It explores interactions between functional subsystems of artefacts and various systems conditioning social developement in order to establish goals and preferences in science and technology policy within the framework of a certain strategy of socioeconomic developement of society,

3 - future research 1/. It explores the impact of possible ways of science and technology development on the strategy and tactics of management while solving global or local problems of the next devolopment of human society or its subsystems,

4 - planning of science and technology development 7/. It explores and creates norms for goal-oriented planning of science and technology development within the framework of the planning mechanism used to influence the socioeconomic development of society.

The older technological forecasting is applied to solve the development of certain functional subsystems of products or technologies whose description is relatively easy on the grounds of traditional informational systems.On the other hand the new models appropriate for planning the developement of big social systems have been developed recently for the needs of future research.They represent multiaspect and interdisciplinary approach to every problem that must be solved when managing the development of society.

From the point of view of the relativistic concept of forecasting it is possible to explain this historical trend /in the development of tasks for forecasting the future/ in the following way:

- a need of anticipating arose in connection with problems of the regulation and control of management systems /at the right bottom of the table/ being interpreted as relatively isolated technological subsystems of a given social organisation,
- a need of programming of social development by way of the coordination of specialized functionally effective activity within a given managed social organisation stimulates the need of anticipation to safeguard the effectiveness of reaching definite goals by the organization /the trend at the left top of the table/.As a result a more complex model for anticipating the future originates in which science and technology stands as factors of the development of many functional subsystems of the model,

- a need of anticipating arises when systematic attemps are made to improove the orientation of development of managed social organisations/at the top of the table/ whereas this need appears as early as in first stages of formulating developmental problems. A model interpretation used for anticipating the future assumes a form of gaming and learning systems whereas science and technology development represent a substantional goalforming activity when the strategy of development is modelled.

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TECHNOLOGICAL FORECASTING AND
THE PRODUCERS INNOVATIVE STRATEGY

L.J. Baworowski*

1. Policy of Production Enterprises

The main superior goal of each producer is the satisfaction of individual and social needs changing in time /satisfaction of current needs generates new ones/ and responding to the demand of other producers /means of production, semi-finished products, products for cooperation/.

The quality and modernity requirements of products are every day higher: both individual users and the branches of industry want the products to be better, more functional and more economic. In international trade there is also another factor - competition, forcing the producers to diversify the range of products, to improve their quality and functional properties.

The incentives in this respect are due to:

- increase of requirements due to improvement of the quality of life, and to information about competitive products in other countries,
- higer demand for modern, more functional, more beautiful products, which are easy to handle and economic in use,
- wide diversification of products, causing various "fashions",
- substitution of heavy materials by other, lighter and of more attractive appearance, preserving the same functional qualities.

An ever higher rate of production renewal, shortening of life cycles of products makes for an increase of a new product to old product ratio in the whole industrial output. In the years 1963-68 about 40% of turnover increment in the US in the automobile, electrotechnical and chemical industries was due to the introduction of new products 8 . In the radio engineering industry about 80% of sales was due to products that did not exist 10 years earlier /9/ . The record belongs however to electronic devices of wide use. Their development cycle is no longer than 3-4 years, and their life cycle does not exceed 4 years. The cycle invention-diffusion is becoming shorter and shorter. And thus, if for Bell it lasted 55 years, 35 years for the radio, 15 for the radar, in case of transistor it became reduced to only 5 years /3/ .

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According to Spruch /9/ "there is a general tendency to maintain systematically the high rate of production renewal". This is due to pressures exerted both by users and receivers with respect to three conditions: modernity, high quality and price. These are three major elements in enterprise policy.

2. Global Strategies of Producers

In general terms, strategy is a political tool and its task is to define the ways of achieving the goals set up by politics using allocated funds /9/ provided for this purpose. What is most important in strategy is the concentration on the superior goal to which subordinate goals of lower order are assigned. In the construction of a strategy the goals and resources should be considered in long time intervals. That is why all strategies should be based on the results of forecasting studies.

By forecasting we mean alternative assessment of a probable, possible and desired development of a given system, concerning any processes and trends of development of various phenomena or events occurring in nature, social life or the consciousness. A forecasting object must be described by means of appropriate parameters, on the basis of which and relying on scientific methods a description of its probable and possible changes in the future is made. It is a foundation for decision making.

On the basis of internal /enterprise level/ and external /branch, departments, nation, world levels/ information, forecasting activity is conducted in the following areas:

1. Investigation of needs and forecasts of their development,
2. Market research /sales, prices, product quality/ and forecasts about future changes,
3. Forecasts concerning areas of interest for producers with respect to the national or world socio-economic system,
4. Forecasts of probable development of competitive foreign markets,
5. Forecasts of technological developments in branches of interest for producers.

The decision-making process /12/ with respect to global strategies of producers occurs as follows.

- analysis of the enterprise and of its environment,
- forecasts of probable change of the environment, of possible benefits and threats /a set of alternative decisions/,

- selection of feasible and desired alternatives of production activity /a set of possible and admissible decisions/,

- development of a global strategy of the producer /a set of selected decisions/.

Usually we can have to do with two kinds of basic strategies /i.e. sets of possible and admissible decisions/ in the producer's situation characterized by a high degree of innovative dynamics, as described above. They are:

1. Offensive strategy,
2. Defensive strategy.

A defensive strategy, called also adaptive, aims at the preservation of the position of the producer. It is a strategy of adaptation and survival. We often have to do with apparent innovations /innovations on a national scale only/.

The offensive strategy tries to change to position of the producer and is characterized by a competition race and an active innovative activity as well as intensive introduction rate of R+D innovations.

3. <u>Strategies of Technological Growth</u>

The achievement of socio-economic goals of an enterprise is realized by its technical and production section. The necessity of pursuing the global strategical objectives of the enterprice requires its transmission to the language of technology.

What are the possible technological strategies / 4 / in an enterprise?

First, we can adopt an already used technology, by licence buying.

Second, we can adapt /adjust, improve/ it according to the changing needs.

Third, we can buy a new invention /patent/.

Fourth, we can develop the creative process by our own means, i.e. conduct all R+D works in order to achieve new, original technological and constructional solutions, as well as new products.

Let us look now at specific innovation levels. Assuming after Valenta / 10 / that innovation is each change in a real technological structure denoting the passage from one state to another, different state, we have also accepted his division of innovations into eight levels / 10 /:

0 - regeneration,

1 - internal adaptation,
2 - external adaptation,
3 - adjustment, a small qualitative change,
4 - a new variant - change of some functional elements,
5 - a new "generation" - change of all functional elements,
6 - a new "type" - change of operational concept of all elements,
7 - a new "species" - application of new rules.

What is the relation between the innovation levels and the technological strategy / 2 / ?

A defensive strategy refers to innovations of the third level /the first three levels are neglected since they are part of overhaul and rationalization processes/. It aims to achieve a minimum development level in a given branch. It requires, however, some degree of originality and application of various results of scientific research.

The offensive strategy can be realized exclusively / 6 / by 4-7 levels. There are three possible substrategies in this respect:

1. medium position strategy,
2. high position strategy,
3. supraposition strategy.

The first one aims at the achievement of an average world level. Parameters /quality, modernity and price/ of products, technologies and construction have to represent an average world level.

The socond one aims at the achievement of the highest world level, that is why the products' parameters must represent the level comparable with the best world products.

The third - tries to surpass the world level in a given area, and the parameters must be higher than the world standard. Table 1 presents specific strategies and innovation levels corresponding to them.

Technological and production effects are also shown in Table 1. Technological levels are accompanied by successive economic effects:

- substitution of imported products,
- beginning of the exports,
- possibility of licence selling,
- profitable export,
- profitable licence selling,
- very profitable export,
- very profitable licence selling.

Also the possibilities / 2 / for substitution /of own products/ by licence has been defined.

	1 Innovation Levels	2 Strategies	3 R+D Phases - Starting Points	4 Techn-Econ. Effects	5 Substitution through Licence Buying
0	Regeneration	Operational maintenance	-	-	-
1	Internal Adaptation	Improved functioning	Technical improvement	-	-
2	External Adaptation	Energy and material saving	Technical improvement	-	-
3	Adjustment - small qualitative change	Minimal advance-survival	Development works	Solution of structural, technological and production problems	easy
4	New alternative - change of some functional elements	Moderate progress - achievement of medium level	Development works	Substitution of imported products New products at good technological level	possible
5	New "generation" - change of all functional elements	Considerable progress-achievement ofadvanced techn. level	Applied Research	New products at a very high techn. level. Exports. Pos. of licence sell.	difficult but pos.
6	New "type" - change of operating rule in all elements	Dynamic progress - drive for a top position	Applied research	New products at world level.Profitable exp.Profit. licence selling	sometimes possible
7	New "species" - application of new laws of nature	Leader position in the world	Pure,oriented research	New products at the highest world level. Very profitable exports. Very profitable licence selling	almost impossible

Table 1

4. Strategy-Dependent Technological Forecasting

Technological forecasting is a probabilistic assessment with a high reliability level, of the future technology transfer from scientific resources through technological systems up to technological applications, socially, economically and ecologically accepted.

As far as the producer's strategy is concerned, technological forecasting has to enable a choice of his technological strategy considered as a technological system. At the first stage

- producer's strategy is determined by the centre /i.e. decisions made by political or economic authorities/,
- producer's strategy may be determined by himself or within the framework of strategy established centrally for the whole branch or group of products. It is shown in Table 2 by column "strategies sought".

As far as the three offensive strategies are concerned, the Table shows the areas and goals of technological forecasting.

One of the elements of technological forecasting is investigation of technological gap. Without entering into details / 7 / we shall only say that it is a kind of forecasting presented in Table 1 as a link between rows: "competition development" and "technological development". What we want is to define the gap described in technical parameters or technologies /methods of production/ between new products and competing products. That gap shown in form of vector of parameters does not explain everything. It must be transformed into a time lag or resource gap. Problems of competition planning discussed in / 5 / are also elements of the offensive strategy.

5. Technological Forecasting and Scientific Research Cycle

In case when the producer wants to launch a strategy based on scientific research of his own, the whole cycle of his activity is presented by Table 3. The procedure is the same for both kinds of strategies, although the defensive strategy does not inspire its own R+D activity.

A success in R+D depends on the technology transfer and interactions between changing technologies. Technological forecasting should indicate both the transfer starting by current technologies, and make a review of elements, processes, products, structures, technologies, i.e. it should reveal the function of transfer and alternative transformations of specific functions.

The goal tree is a method most widely used in forecasting since

Table 2

Strategy	Sought for	Determined			
		Offensive			Defensive
		I	II	III	
Goals of technological forecasting and auxiliary research	Identification of probable and feasible technologies and structures	Exploration of the highest level of world technology and forecast of its dynamics	Assessment of the world technological level and forecast of its dynamics	Exploration of future innovations for adoption	Identification of development trends of technological parameters of products. Exploration for diversification of products. Exploration of new applications for new products and technologies
	Assessment of future opportunities of their development	Assessment of of probabilities and orientation of breakthroughs	Assessment of new applications for new products and technologies	Forecasts of feasible adaptations of adjusted technologies	
		Exploration and assessment of technical, technological and organizational gap			

it allows for determination of strategies of scientific research. Extrapolation techniques, on the other hand, enable the identify the constraints of technology development for alternative strategies.

6. Conclusion

We have tried to present interactions between the producer's strategy and technological forecasting. Together with the needs analysis, market research and economic forecasts, technological forecasting constitutes an important element in the development of producer's strategy. We should also emphasize that the above elements of setting up the producer's strategy are necessary prerequisites of its determination.

Table 3

Producer's situation	Current markets are not sufficient	There is R+D potential	New constructions and techn. are ready	Techn.policy must be set up	Technical policy has been set up		Long-term investment planning
Strategy	Search for new feasible technological solutions - assessment of their feasibility			Assessment of probable and feasible techn. Assessment of techn. feasibility	Offensive Search for the highest techn. level	Defensive Search of technologies for adjustment	Search for tech. solutions for new investments
Goals of technological forecasting	Diversification or adjustment by new products	Application of own potential by innovations	Effective applications	Protection against possible techn. threats	Forecast of probable and feasible technologies and structures		
Methods	Brainstorming, morphology, goal-tree, tests, experiments, trend analysis, network methods		Delphi, morphology, trend analysis, intuitive methods	experts panels, Delphi, trend extrapol., brainstorming, morph.	Delphi, panels of experts, trend extrapolation		

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THE FACTORS FOR BUILDING OF STRATEGIES FOR SCIENCE AND TECHNOLOGY

Dieter Schulze*

The activities of science and technology policy may be classified in: (a) determination of directions and goals of the research, (b) building of conditions for effective realization of the research, (c) building of conditions for effective using of the results of research.[1]

Science and technology policy is inseparably connected with the building and realization of strategies for development of science and technology. Therefore we can say: building of strategies for science and technology is a main task within the field of science and technology policy.

What is the meaning of the term "strategy of science and technology"?[2] In my opinion we can determine the meaning of this term as follows:

(a) Strategies of science and technology--formulated at the level of states for instance in programs of parties, as "national goals", in declarations of governments and administrations--are tied to *general political line* of the leading class forces in the respective social system since scientific work is inseparably linked with society's overall activity and its basic objectives arise from social requirements.

(b) In the field of scientific or scientific--technological activities, too, the term "strategy" aims at *long term lines and processes* of development. Strategies have to define--in a forecasting manner and with the possible degree of precision--especially long-term goals of scientific and technological activities and also long-term effects of these activities, for instance such effects on environment.

(c) In scientific and technological strategies we cover interrelated, *complex aims* as well as the *main ways and methods* to achieve these aims.

The combination of aims and means is fundamentally for strategic orientations, because only this combination of the desirable with the realizable guarantees the practicability of these orientations. Of course the desirable must be a possible goal in the gnossological area and the realizable also includes the building or regrouping of necessary powers.

(d) In an instrumental point of view strategies of science and technology are increasingly *backed by prognosis* of future scientific-technological developments, for which in growing degree scientifically elaborated, methodologically founded prognostic documents are necessary. As a

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rule these strategies are laid down in *programs, concepts or long-term plans*, thus assuming a binding character and must be transformed in *concrete plan-directives* within the five-year, or the year-plans, the last of course under the condition of existing of a state system of planning.

From this point of view we can ask the question: which are the factors, influencing the building of strategies for science and technology? The main factors in my opinion are the social needs of a given society, the possibilities for gnoseological development by the given statement of science and technology in the world and the economic, scientific and technological resources of a given country.[3] To this list of factors we have to give some remarks.

The influence of these factors on the building of scientific-technological strategies is only realized through the interrelation of all these factors. Only the declaration of a social need cannot constitute a strategy for science, if in the given statement of scientific knowledge not exists the possibility for solving the unsolved problem. And also: if we have the gnoseological possibility for solving of a scientific problem, then we need also the economic and technological conditions for realizing of the research, and so on.

The dependence of strategies from influencing factors is threefold, the influencing factors have not only different characters in the qualitative sense, but also different dimensions in the quantity. The further gnoseological possibilities we have to analyze in a worldwide scale--on this guarantees to define the whole lot of possible strategies. The social needs depends on the character of society, which as a rule is more or less identically for groups of countries, for instance for the member countries of CMEA or for the group of developing countries. The main goals in the fields of economics, of policy and of social development are determined through the social characteristics of such groups of countries and have a very deep influence on strategies for science and technology. This we can see for instance at the important place of scientific-technological cooperation in the complex program of CMEA.[4] The concrete strategy for science and technology within a given country depends on the economic power and possibilities, the given technological level and many other factors of the concrete statement within this country.

Going out from the concrete situation in our country and looking on the main social needs of our society, on the gnoseological possibilities for development within science and technology and also on the economic and other objective conditions and possibilities in scientific-technological institutions in the country the main principles and aims for strategy in science and technology in the GDR are determined as follows:

(a) Scientific and technological progress represents the *main factor for the intensification of the reproduction process*. Scientific and technological achievements to be attained and utilized in the GDR by 1980 are to:

-- ensure 60-70 percent of the required increase in labor productivity;

-- save an annual 220-280 million working hours in industry and construction;

-- guarantee SO percent of the necessary savings of materials.[5]

(b) The raising of the social efficiency of research requires the *intensification of scientific and technological work processes*, including measures such as:

-- consolidating the technical and technological use of research and rationalizing the research processes by the wide application of electronic data processing and modern means of information;

-- deopening cooperation of institutions of academies and higher education with industry and other spheres, and with scientific institutions of the USSR and other member countries of the Council for Mutual Economic Assistance;

-- raising the professional standards of research staff;

-- applying government standards to ensure optimum solutions to recurrent operations in development, design, technology and production;

-- improving the proportions between research and development so that research results can be faster applied in production.[6]

(c) It has to be ensured that *basic research is further expanded*, since it is a source of new knowledge about law-governed interconnections in nature and society and helps to make long-term decisions on the development of the economy and of science.[7] The following main lines and priorities have been established in taking account of the GDR's concrete economic and social requirements and of the potential available:

1. Development of the energy base, the seeking of new or improved formulas for the generation, conversion, transmission and rational use of energy, including the scientific preparation of investments regarding installations for the generation or transmission of energy.

2. Extension of the raw materials base, mainly through systematic geological prospection and the increased, comprehensive utilization of domestic natural resources and by-products ensuring stable supplies of raw materials and fuels to the national economy.

3. Development and rationalization in the field of primary materials, materials and substances and of processing techniques in order to save materials and reduce the specific consumption of raw materials and other materials in production.

4. The permanent raising of the technical and technological level of production by increased research work in such fields as microelectronics, cybernetics and mechanics.

5. To lay the scientific, mathematical and technical foundations for the effective control of material and mental processes that lend themselves to computerization, and their increasing automation.

6. To preserve, promote and restore human health and physical capacity, and to ensure optimum environmental conditions. In the framework of biological and medical research it is necessary, for instance, to create conditions enabling cancer research, research into cardio-circulatory regulation and virus infections, human genetics and pharmacological research to make further progress.

7. A healthy nutrition requires more research efforts in the fields of livestock farming and veterinary medicine, but also with respect to the development of new protein foods based on plant proteins, and perhaps in the future of microbial proteins.

8. To satisfy the growing demand for fashionable consumer goods easy to wear or to maintain.[8]

(d) The realization of these aims requires a radical *improvement of management, planning and organization of scientific-technological working processes.*

In this respect it is necessary to implement, inter alia, the following series of measures:

-- To develop the planning of scientific and technical work so that it becomes the main element of economic planning, using such methods as target-program planning in conjunction with branch and regional planning;

-- To develop new forms of organization for an effective linkage between science and production, e.g., the creation of scientific-industrial associations or academic-industrial complexes (without that this form of organization are inadmissably generalized);

-- To develop forms and methods for the efficient management of interdisciplinary research;

-- To effectively organize international cooperation of the CMEA member countries in the field of research.

(e) The *international cooperation of research* is to concentrate on the following directions:

-- rational use of the resources of fuel and energy;

-- complex use of the raw material wood;

-- protection of metals against corrosion;

-- production of biomedical implements and apparatus;

-- developing of new arts of pesticides and of methods for protection of plants;

-- elaboration of effective methods for production of proteins and for raising the nutritive quality of foods;

-- developing of apparatus for cleaning of gas, including the needing implements of measurement and control.

In this strategic conception reflects in concentrated form and for the level of the state the main goals of the political and economic program for further growth and prosperity, the main economic and social needs, which may only be realized with the help of new results in research and development, the given possibilities for winning of new scientific and technological knowledge, the priorities in the fields of science and technology within the present period, the specifics and also the limitations of economic and scientific potential, as just as the needs for management and organizing in science and technology. The defined strategy on the level of the state is the result of many activities and analysis in organs of the leading party and of the state administration, especially of the state commission of planning, and of expertices and assessments of many groups of scientific specialists. This state strategy at the same time gives the basis for elaboration of certain target-programs and also for definition of strategic orientations and conceptions in scientific and technological organizations on different levels. The strategic goals were transformed into concrete goals and tasks within the five-year-plan and in the year-plans in all spheres of national economics and at all levels of organization.

From the methodological viewpoint we can define the main procedures for building of strategies in science and technology as following: analysis of scientific-technological progress, prognosis and assessments of future lines of development, comparison of variants and definition of priorities, and elaboration of target-programs for defined complex aims.

For *analysis* of scientific-technological progress we can use the following methods [9]: production functions, patent statistics [10], analysis of costs and benefits of technological change, studies of innovations, analysis of information flows [11], especially with the Science Citation Index, studies of the cycle science-technology-production [12] ('embodiment' of science and technology) in the form of histograms and in other forms.

Strategies of science and technology have to be founded on *prognosis* of scientific development, which to elaborate on a strong methodological base. Within the CMEA is worked out a methodological program of forecasting [13] and there are many uses of this program in different countries, also in a modified and improved form. [14]

The method of *technology assessment* is worked out in the United States and there are many practical experiences in using this method. [15] First steps in using this method are also done in the GDR.

The *definition of priorities* is to be found in comparison of variants of future development and depends on the national goals, the given potential within the country, and also on the internal structure of scientific problems. [16] To define priorities is a task of scientific and administrative organs on the highest level, and assumes the synthesis of all influencing factors on science and technology policy.

Going on to transformation of strategic aims into planning documents there is the famous method of *target-program-planning*, which is using in a wide dimension in Soviet Union also in other socialist countries and by cooperation within the CMEA. [17] The careful elaboration of such programs is a well condition for the realization of strategies of science and technology.

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TECHNOLOGY STRATEGY--DETERMINANT FACTORS

Karol I. Pelc*

"... We are in the midst of an intriguing debate on the merits of large-scale versus small-scale technology, centralization versus decentralization, and capital-intensive versus labour - intensive development... No group has the wisdom or foresight to plan how whole societies, not to mention all of mankind, can or should advance down any single path of development".

Frank Press: An Agenda for Technology and Policy, "Technology Review", Jan.1978, p.55

The above quotation may be considered as a stimulus for rational analysis of ways towards establishing some principles for the TECHNOLOGY STRATEGY /TS/. There are several reasons for such attempts. Most general reason may be illustrated when looking upon Technology as a main part of interface between Science and Society where technology or technological systems are considered as codified ways of deliberately manipulating the environment to achieve some material objective [1] . Multiple linkage between technology and society may be easily studied when a new concept of technology is used, based on technology representation as a combination of three elements: hardware, software and orgware [2] , where the last component corresponds to organizational and social structure being involved.

Technology has to be considered here as an object of management but one should still take into account that there is always some randomness in appearing of new technological ideas and inventions which is related to the nature of human creativity.
Managerial approach to selection of technology and orientation of its development is required at various levels of social organization

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beginning from the individual company, through large corporations, up to governmental bodies. It is also considered recently as an important part of international policy both on regional and global scale.

Technology strategy /TS/ has been studied by several authors from the standpoint of a corporation, as a part of overall corporate strategy or as a result of economic strategy chosen by the firm [3] , [4] , [5] . Governmental concern in technology strategy /TS/ was developed first in the socialist countries as a part of central planning system. During the seventies it has also grown in other countries with direct linkage to newly developing domain of technology assessment /TA/.
There are some general features of TS which may be observed as independent on the level in hierarchical structure of the management system.

The term - technology strategy /TS/ - is used here as a derivative from notions of strategy accepted by theory of management and economics[1/].

For the purpose of this paper, TS may be defined as a group of decision rules which are used to choose technologies /or technological systems/ adequate to desired long-term objectives of given economic system, in the light of major factors influencing the situation.
Formulation of TS represents a synthesis - type of task compair, for instance, to technology assessment which is analytical one. The aim is to establish a framework for creating a coherent technology mix which fits to overall strategy of development. There is no formal methods or principles of solving this problem in general, though some experience and partial solutions already exist.

1/ Examples of definitions utilized in this discipline:

Strategy - activity which specifies for a business a course of action that is designed to achieve desired long-term objectives in the light of all major external and internal factors present and future [5] ,

Strategy - group of decision rules with certain characteristics which are used to choose from an infinite number of possible product - market combinations [6] .

Let us specify questions which arise when some principles of TS formulation are to be found:

- what technology strategies /TS/ are possible?
- what are main factors determining TS?
- what combinations of determinants exist, are possible and probable?
- how to measure or assess relative values of TS determinants?
- how to use this information for TS formulation?

The subject of this paper concerns mainly the first and second problem. There are a few types of technology strategies described in literature [5] , [6] , [8] . Most significant are: offensive strategy, interstitial strategy, defensive and absorptive strategy. Main features of these strategies may be described as follows:

(1) o f f e n s i v e s t r a t e g y (S_1) :

it is assumed that given enterprise, corporation or the national industry as a whole has to play a leading role in the domain of technology under consideration; this may by accomplished by continuous conquering of "terra incognita" and effective transformation of new technological knowledge into economic and social results; it is a high risk and high potential payoff strategy which demands: an intensive fundamental research, large R+D programs, considerable skill in technological innovations and considerable reserves of resources of all kinds; this TS is a strategy of rich and already established "players", it is adopted by big economic powers and the most developped national economies;

(2) i n t e r s t i t i a l s t r a t e g y (S_2) :

it is an orientation towards gaps or interstices remaining or appearing on the technological battlefield; attempt to avoid a direct confrontation with big competitors is a main principle of this strategy which requires moderate resources but extreme flexibility, developed information systems and dynamic operations; constant analysis and mapping of technological development is necessary; this strategy is offensive only on carefully selected areas of technology, it is most suitable for medium-size "players" and for the countries with advanced technological and managerial infrastructure but with limited resources;

(3) d e f e n s i v e s t r a t e g y (S_3) :

main technological effort is oriented towards lowering the manufacturing costs of known products or systems; this strategy requires some amount of specialized development laboratories in the area of R and D as well as low labour costs in the area of manufacturing, while the expenses for research may be limited; this strategy is sometimes used by the developing countries with considerable amount of labour force and limited capability for widening of technological variety /e.g. technologies linked only with local natural resources/;

(4) a b s o r p t i v e s t r a t e g y (S_4) :

it is based on licensing and adopting of technology from outside; this strategy involves small risk and relatively small expenses on R and D, it is however usually combined with technological dependence; it is usually applied by less developed countries though in some areas of technology it is also used among partners in economic and technological cooperation; the flow of patents and technological know-how as well as the balance in this domain are indicating the relative position of partners in the cooperation; strategy S_4 may be considered as a transient one, if the receiver of licences develops simultaneously his own R and D potential and prepares a jump to strategy S_2 or S_1 .

The above categories of TS are utilized very seldom in a pure form in a wide spectrum of technologies. They are usually combined by given organization, firm or governmental body depending on the domain of technology. There are also used frequently some mixed strategies with a tendency towards shift from one to another. Formulating of TS is not a single step or definite sequence of steps but a continuous adaptive process utilizing iterative procedures.

As an example of necessity for dynamic TS formulation, one can study the problem of overpassing the technological gap by a delayed producer while this gap is changing its dimension with time.

Choice of a given type of TS depends on both: goals to be achieved and existing capabilities or situation. Assuming that goals are externally defined by policy makers or top management, we should concentrate on determinants of technology strategy resulting from the capabilities and situation of the organization, firm or national industry as a whole. Some kind of classification of situations becomes necessary.

When the national scale is considered and some selection of alternatives for development has to be done, a similar type of problem appears. For solving this problem, A. King has recently proposed an approach which started from the coarse classification of situations [9] . He has classified countries according to their natural resources and food situation versus their economic, financial and technological position. By using these two kinds of determinants and applying two extreme estimates /rich-poor/ it is easy to arrive to 4 classes /Fig.1/.

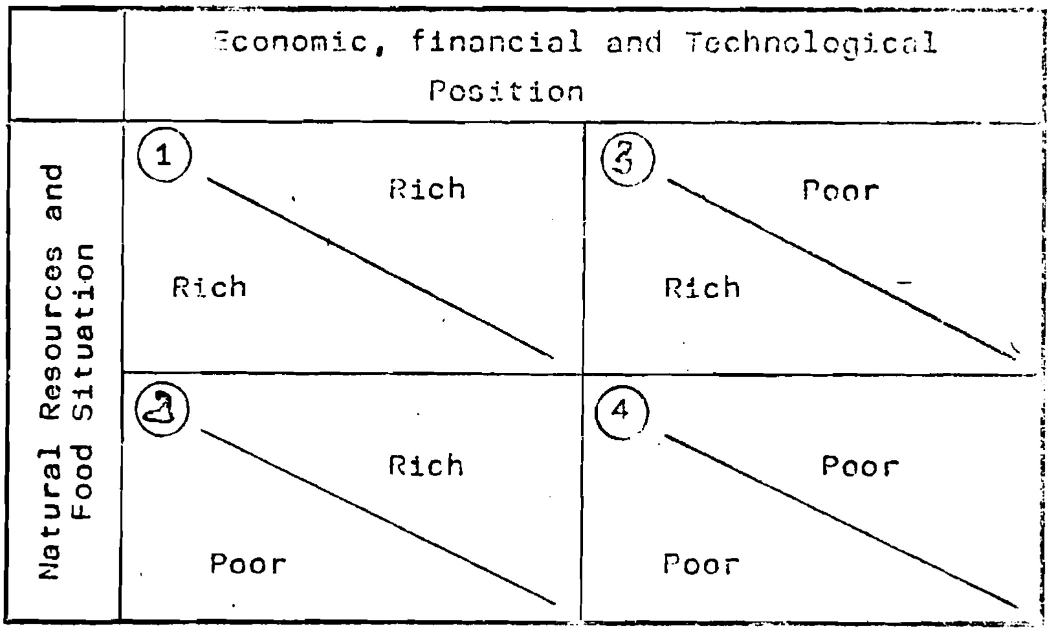

Fig.1 Example of coarse classification of situations influencing the strategy [9]

Content of these classes is following:

(1) USA, USSR, Canada, Australia, South Africa,

(2) Japan, East and West Europe,

(3) OPEC, Brazil, Iran, Saudi Arabia,

(4) most Less Developed Countries /LDC/

Simplification in this approach is not only due to inaccurate distinction and measures applied but also due to very limited amount of attributes taken into account.

For technology strategy selection a similar approach could be applied, if more detailed specification of attributes characterizing the situation of the object /enterprise, corporation, national industry etc/ would be defined[2/]. Obviously, the list

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2/ Notion "object" is used in further part of the paper as a general one for organizations or economic systems e.g., companies, industries, national economies, for which the technology strategy is formulated.

of atributes should correspond to main factors /determinants/ influencing the selection of strategy. These attributes may also be considered as state variables which in turn are resulting from previous technological changes. Classifying these factors and their subsequent measurement or estimation may become a tool for discovering the similarities among objects and their compatibility. Such observations could lead to analytical determination of strategy for further development.

First step on this way may be limited to consideration of attributes characterizing the situation of objects which are operating in one domain of technology, so that it is possible to introduce an approximate comparison of their relative situations.

In table I main groups of attributes are listed with distinction of two categories: policy independent and dependent factors. First category is more stable while the second one should be estimated both for present and future conditions.

Table I.

Groups of attributes X_k /policy independent/	Groups of attributes X_l /policy dependent/
Raw materials	Economic and financial position
minerals	Intellectual potential
other natural res.	scientific staff
land, etc.	information, systems etc. patents, know-how, etc.
Energy	Educational and cultural level
Environmental conditions	Technological infrastructure
climate	Managerial experience
water	Social structure
soil	Marked needs /or access to the market/
geography, etc.	market size
Manpower /human res./	- - - - - - - - - - - - - -
demographic data	Others
- - - - - - - - - - - - - - -	
Others	

Each of these groups contains a set of parameters or measures which should be further analyzed. In case of a simplified approach one can use qualitative estimates and comparisons of situations /e.g. introducing two - or three - levels such as: low-medium-high, etc./. Configuration of such estimates indicates the capability or need for some type of strategy /e.g. S_1, S_2 ... / in case of given object. Such qualitative representation enables an approximate localization of the object in some class /similar to that shown by A.King/.
Further studies are required on appropriate selection of data /absolute and relative measures/ and relationships for determining TS when situation is identified.

Some attempt to formal statement of the problem concerning the definition and classification of the object's situation and strategy is shown below.

Let us denote K - the class of objects under consideration and K_n - the n-th object belonging to this class being characterized by an ordered pair of vectors $\left(\bar{X}^{(k_n)}_{n;1},\ \bar{X}^{(l_n)}_{n;2}\right)$:

$$\bar{X}^{(k_n)}_{n;1} = \begin{bmatrix} X^{(1)}_{n;1} \\ X^{(1)}_{n;2} \\ \vdots \\ X^{(1)}_{n\,k_n} \end{bmatrix}, \qquad \bar{X}^{(l_n)}_{n;2} = \begin{bmatrix} X^{(2)}_{n;1} \\ X^{(2)}_{n;2} \\ \vdots \\ X^{(2)}_{n\,l_n} \end{bmatrix} \tag{1}$$

coordinates of which represent the attributes of this object. Coordinates of these vectors belong to 2 different categories of attributes. This fact may be represented as:

$$K_n \rightleftarrows \left(\bar{X}^{(k_n)}_{n,1},\ \bar{X}^{(l_n)}_{n;2}\right) \tag{2}$$

Let us define a function f by the following formula:

$$f\left(x^{(r)}_{ni}\right) = \begin{cases} 1 & \text{if attribute } x^{(r)}_{ni} \text{ satisfies the condition } W^{(r)}_{ni} \\ 0 & \text{if attribute } x^{(r)}_{ni} \text{ does not satisfy the condition } W^{(r)}_{ni} \end{cases}$$

for $r=1$, $i=1,2 \ldots k_n$ and for $r=2$, $i=1,2 \ldots l_n$

By introducing the function f we can describe an object $K_n \in K$ by an ordered pair of vectors $\left(\hat{X}^{(kn)}_{n;1}, \hat{X}^{(ln)}_{n;2}\right)$,

$$\hat{X}^{(kn)}_{n;1} = \begin{bmatrix} f(X^{(1)}_{n1}) \\ f(X^{(1)}_{n2}) \\ \vdots \\ f(X^{(1)}_{nk_n}) \end{bmatrix}, \quad \hat{X}^{(ln)}_{n;2} = \begin{bmatrix} f(X^{(2)}_{n1}) \\ f(X^{(2)}_{n2}) \\ \vdots \\ f(X^{(2)}_{nl_n}) \end{bmatrix} \tag{3}$$

and

$$K_n = \left(\hat{X}^{(kn)}_{n;1}, \hat{X}^{(ln)}_{n;2}\right) \tag{4}$$

Among objects belonging to class K we can distinguish 4 specific objects K_α, K_β, K_γ, K_δ which are defined in the following way:

$$K_\alpha = \left(\hat{X}^{(k_\alpha)}_{\alpha;1}, \hat{X}^{(l_\alpha)}_{\alpha;2}\right) \tag{5}$$

where the attribute $X^{(1)}_{\alpha i}$ does not satisfy the condition $W^{(1)}_{\alpha i}$, $i = 1,2, \ldots\ldots k_\alpha$, while the attribute $X^{(2)}_{\alpha i}$ satisfies the condition $W^{(2)}_{\alpha i}$, $i = 1,2, \ldots\ldots l_\alpha$

$$K_\beta = \left(\hat{X}^{(k_\beta)}_{\beta;1}, \hat{X}^{(l_\beta)}_{\beta;2}\right) \tag{6}$$

where the attribute $X^{(1)}_{\beta i}$ satisfies condition $W^{(1)}_{\beta i}$, $i=1,2,\ldots,k_\beta$ and the attribute $X^{(2)}_{\beta i}$ satisfies condition $W^{(2)}_{\beta i}$, $i= 1,2 \ldots\ldots l_\beta$

$$K_\gamma = \left(\hat{X}^{(k_\gamma)}_{\gamma;1}, \hat{X}^{(l_\gamma)}_{\gamma;2}\right) \tag{7}$$

where the attribute $X^{(1)}_{\gamma i}$ does not satisfy the condition $W^{(1)}_{\gamma i}$ $i = 1,2 \ldots\ldots, k_\gamma$ and the attribute $X^{(2)}_{\gamma i}$ does not satisfy the condition $W^{(2)}_{\gamma i}$, $i = 1,2 \ldots\ldots l_\gamma$

$$K_\delta = \left(\hat{X}^{(k_\delta)}_{\delta;1} \ , \ \hat{X}^{(l_\delta)}_{\delta;2} \right) \qquad (8)$$

where the attribute $x^{(1)}_{\delta i}$, satisfies the condition $W^{(1)}_{\delta i}$ $i = 1,2 \ldots\ldots, k_\delta$, while the attribute $X^{(2)}_{\delta i}$ does not satisfy the condition $W^{(2)}_{\delta i}$, $i = 1,2, \ldots\ldots, l_\delta$

One can easily observe that vectors characterizing the objects K_α, K_β, K_γ and K_δ have the form adequately:

$$\hat{X}^{(k_\alpha)}_{\alpha;1} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} , \quad \hat{X}^{(l_\alpha)}_{\alpha;2} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ \vdots \\ 1, \end{bmatrix} \qquad (9)$$

$$\hat{X}^{(k_\beta)}_{\beta;1} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} , \quad \hat{X}^{(l_\beta)}_{\beta;2} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} \qquad (10)$$

$$\hat{X}^{(k_\gamma)}_{\gamma;1} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} , \quad \hat{X}^{(l_\gamma)}_{\gamma;2} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \qquad (11)$$

$$\hat{X}^{(k_\delta)}_{\delta_i 1} = \begin{bmatrix} 1 \\ 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}, \quad \hat{X}^{(l_\delta)}_{\delta_i 2} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \qquad (12)$$

Objects K_α, K_β, K_γ, K_δ are then representing the extreme cases for which we may define corresponding extreme strategies. We denote representation on class K:

$$F : K \longrightarrow S$$

which indicates a strategy $s \in S$ for each object $k \in K$ or $F(K) = S$, so that we obtain the following correspondence: for K_α strategy S_α, $F(K_\alpha) = S_\alpha$ and for K_β, K_γ, K_δ strategies S_β, S_γ, S_δ adequately.

Conclusions:

It is possible to distinguish several types of technology strategies which are applied in the practice of enterprises, corporations and national industries. Some characteristics of these strategies are given in the paper. There is a need for analytical approach and indications for an improved technique of formulating and selection of appropriate strategy. It is suggested to structure the problem of TS formulating on basis of a classified list of main factors determining the situation of the object /enterprise, corporation, state/ from the standpoint of its relative capability. Preliminary classification of such attributes has been shown here. However, it requires further alaboration. It seems reasonable to orientate further studies of this topic towards establishment of possibly general set of dimensions which could serve as a common framework for determining the adequate technology strategies at various levels of management. An attempt to formal statement of the problem /which is also shown above could perhaps facilitate its more precise structuring.

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THE ACCEPTANCE CRISIS OF RESEARCH POLICY: DOES THE SCIENCE COURT PROVIDE A SOLUTION?

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1. POINT OF DEPARTURE : THE ACCEPTANCE CRISIS OF TECHNOLOGICAL POLICY

As little as ten years ago public research and technology policy was not a topic calculated to spark off party political and ideological discussion. From almost one end of the political spectrum to the other there was general agreement that the Federal Republic must close the technological gap that existed by comparison with other industrial nations, particularly the United States and that the state must therefore create the structural and economic prerequisites for this scientific and technical leeway to be made up as swiftly as possible.

Research and technology policy encountered its first crisis amid the discussion about the quality of life and social indicators in the early seventies, when it was confronted with the question of how its aims and plans fitted in with a broad range of goals affecting society as a whole and how both might perhaps be better coordinated. This injection of controversy into the topic of research promotion, which had until then been supported by a broad consensus, was the point of departure of a world-wide discussion on concepts and institutions for the social evaluation of new technologies (Technology assessment)[1].

The declared aim of these endeavours was "to undertake as integrated and systematic as possible an assessment and forecast of the essential (positive and negative, direct and indirect) effects on the central areas of a society (economy, environment, institutions, the general public, special groups) which occur when a technology is introduced or changed"[2]. An attempt was to be made as early as the development stage of central technological research processes to take into account as high a proportion of social aims as possible by means of continuous evaluation and, where negative effects were to be expected in the view of different affected groups, to minimize these by as farreaching a modification as possible of the technology in question.

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At the same time an effort was made by those drafting public research and technology policy to develop socially relevant criteria and lists of objectives to be used as guidelines in the general parties of technology promotion. The aim was no longer to simply close the technology gap, but to subordinate scientific and technological progress, as a resource, to the overall aim of social progress. We might cite here - in place of many other concepts - the principles for promoting industrial research drawn up by the Federal Ministry for Research and Technology [3].

Looking back from our present-day vantage-point, both strategies must be regarded as not having achieved much success - despite the intense efforts made. This applies both to the alignment of technology promotion itself on the broad range of social aims referred to under the slogan the "quality of life" and to the development of effective control mechanisms to ensure that these promotion criteria were observed. Furthermore, there was in many cases a failure to make clear to the increasing number of citizens critical of official research and technology policy that there had been a reorientation within that policy. This must be attributed, substantially, to the fact that while technology assessment institutions were intensively discussed in the Federal Republic, as in many other countries, few were ever set up and where they were - as in the case of the Office for Technology Assessment (OTA) - the necessary public exposure and the expected political effect were lacking. Nor did the new lists of objectives and criteria for research promotion bring about a basic change in policy : the large-scale projects already promoted (energy, transport, data processing) remained the prime targets for public support.

The central problem of this first crisis, the question of whether the goals set by promoting specific technologies are also, in the main, socially desirable and whether a broad consensus can be achieved regarding such goals, was thus by no means solved. Rather, it has shifted more and more to the conflict over the concrete application of these technologies, as the example of the peaceful use of nuclear energy demonstrates almost daily.

This switching of the conflict over ideas as to how our society should be organized in the medium and long term - for the controversies over research policy aims are nothing else in view of the long-term investment character of research and development - to the level of concrete utilization of technologies is not the least of the factors which have nurtured the birth of a second crisis, the substance of which is not only doubt about the goals of research policy, but in equal measure doubt about the efficiency of the decision-making bodies concerned with the problem of research promotion in parliament, government departments and special sectors of the economy. The crisis concerning aims has increasingly become a crisis concerning institutions.

There are various reasons for this :

- Although such basis and vital questions as energy growth and the quality of the environment have aroused great interest on the part of the general public and the mass media, they are not being discussed in parliament in sufficient detail and in sufficient breadth to secure a wellfounded formulation of intent and consensus. Partly bodies admittedly often deal intensively with the problems in question, but the fact that the application of new technologies is becoming more and more a matter of political controversy all too often prevents the man-in-the-street from recognizing his objectives in policy statements ; furthermore internal party discussion of this subject appears to have little influence on the work of parliament.

- Both those who provide subsidies and those who receive them rarely succeed in finding a common language with those who are openly sceptical of public support for scientific and technical innovations in a number of fields. Even though the responsibility for these failures in communication can by no means be imputed to one side only, it is nevertheless surprising how little effort is made by those groups interested in developing a subsidized project to secure broadly-based legitimation of their policy. When opposition to the introduction of new technologies is airily attributed to the "railway syndrome", a general fear of new technological developments, to justify the rigorous pursuit of a specific policy, this may - by the same token - all too easily nurture in the minds of critical citizens the suspicion that a specific decision on technological policy was not in fact motivated exclusively by objective reasons likely to promote a consensus.

- In a widely-noted article Ulrich Lohmar recently pointed out further reasons for the crisis of the institutions concerned with questions of promoting research and applying technical knowledge [4]. Lohmar complained that the decision-making structures in the competent government departments and at parliamentary level were insufficiently geared to scientific, social and economic requirements and opportunities. Furthermore, public administrative bodies and recipients of subsidies often shared the same interest in pursuing specific projects , even where these had proven unprofitable or susceptible of replacement by alternative technologies. On the other hand, the main reason why parliament was unable to perform its corrective function was because its members lacked the expert knowledge and the time to come to grips with a difficult scientific subject. Besides, a member of parliament who concerned himself intensively with questions of research planning and promotion was passing up the chance of a parliamentary career such as, for example, domestic and economic policy offered.

  Apart from this lack of parliamentary control, Lohmar saw as another reason for the inadequacy of research and technology policy the fact that scientific promotion programmes were not developed until considerations of profitability prevented industry from taking action itself. However, this principle of public subsidizing policy discouraged recipients of subsidies from making major efforts to sell their research products and encouraged them to prove that the subsidized project was unprofitable, since only then could they expect further public support.

It does not look as though parliament's inability to function in the field of research and technology policy, as described by Lohmar, can be remedied in the foreseeable future[5]. There is no sign of a change in the parliamentary career structure he mentions, nor is in-depth scientific advising of parliament and the relevant parliamentary committee to be expected : only two years ago that committee decided in the course of discussions on a possible institutionalization of technology assessment not to set up any advisory institutions to deal with this topic.

- Another reason is that socially relevant decision-making processes about the concrete utilization and application of new technologies are being switched more and more from the legislative, executive and administrative levels to the judiciary. Although this trend is by no means restricted to aspects of technology policy, these are particularly affected because, as soon as the application and further development of scientific and technical knowledge impinge upon environmental matters, they become a focal point of public discussion and controversy. Litigation is expected to settle problems, the solution of which - because of their technical complexity and their significance for the environment and for society - requires a high degree of knowledge in the fields of science, technology and social science, a requirement which in the long run even judges with a broad range of knowledge and experience at their disposal can meet only imperfectly and even then only after devoting a great deal of time to the matter, as is shown by a wealth of - in part - contradictory decisions in the past few months. There is every indication that there will be an intensification of this process by which political decision-making bodies are being bypassed - if not de jure then de facto - through increasing recourse to administrative courts. In the final analysis this trend is also undermining the part which parliament should play in relation to fundamental questions of research and technology.

If we see this trend as an essential element of the acceptance crisis of technology policy, which has spread from questions of determining goals to the institutions which make the decisions on research policy, and which has reached proportions which call for re-thinking and an active search for alternatives, then we are obliged to ask the following questions : What can be done to improve the existing decision-making structures so as to achieve a broad consensus in the field of scientific and technological developments ? And : What other institutional measures must be taken to stimulate further expert discussion on the advantages and disadvantages, i.e. in the final analysis the benefit to society as a whole, of these developments, so as to increase the likelihood of achieving a consensus ?

This article is an attempt to help find such a consensus by presenting a number of concepts on which there has been little discussion so far, evaluating their consequences and, where necessary, modifying them. Its particular aim is to broaden the discussion on the optimization of research policy decisions by the addition of a model, the Science Court. It also considers the question of whether the Science Court idea - contrary to the intentions of its first protagonists - might not be more profitably applied in problem areas which at least for the Federal Republic - are of greater urgency for politics and science than the areas of application for which the model was drawn up in the United States.

However, before the various possibilities are discussed in detail, the fact should once again be recorded that subsequent remarks are based on the view that, according to all the available information regarding possible options, a number of basic facts seem to be established already. We refer, in particular, to parliament's loss of function and the increasing importance of court decisions in the assessment of technological developments, in the light of their acceptance by various groups and sectors likely to be affected.

2. IS REVITALIZATION OF EXISTING INSTITUTIONS OR THE SETTING UP OF NEW ONES THE ANSWER ?

In the last few years a varying degree of attention has been paid to the difficulties which are currently plaguing the politico-scientific advisory system, research and technology policy and the sectoral application of scientific and technical know-how ; the number of solutions suggested has been roughly in proportion to the degree of attention paid. Thus, discussions about improved implementation of scientific information and analysis systems in the political sphere already have a certain tradition behind them, while the transfer of decision-making from the political level to the judiciary is only gradually penetrating public awareness. Apart from those proposals which aim essentially at improved integration of the findings of the social scientists into political decisions, there are three models which promise a more effective liaison between science policy advising and the decisions made on research policy with a view to overcoming the difficulties cited above :

- a more marked involvement of the propositions of independent experts in research policy decision-making (Royal Commission model) ;

- a revitalization of parliament's decision-making and control functions (Scientists' Parliament) ;

- specialization of and a change in the function of those sectors of the legal apparatus in which, increasingly, decisions are being made about the application or non-application of technological developments.

The following section describes and discusses each of these three models in the light of the abovementioned questions.

2.1. The Royal Commission model : difficult to transfer

The Royal Commission model developed in Britain attempts to improve traditional forms of consultation by setting up independent bodies of scientists, with commissions appointed by the government providing expert opinions on specific questions and problems of sectoral and research policy. The idea is that the reputation of the scientists forming these commissions and their political independence will guarantee the binding character of their opinions for the political decision-makers, although there is no legal foundation for this. Ideally, government, opposition and the general public would use the expert opinions provided by these commissions as a joint basis for discussion.

Although this model appears to be an attractive solution to the abovementioned problems, above all because of its organizational simplicity and practicability, it must be recognized that its effectiveness derives essentially from long-established British patterns of thought and action. Research policy decisions, no matter how the Commission is made up, set political signposts for which political tolerance - whether achieved ideologically or traditionally - can be expected in very few cases. Furthermore, there is no reason to expect the sections of population concerned simply to accept and endorse the scientific statements of such bodies, as the controversies of the last few years, particularly in the field of energy policy have shown. Indeed, it is far more likely that the opinions expressed by such a body, even were it made up of the most outstanding representatives of a large number of scientific disciplines, would, in the final analysis be as subject to doubt as expert opinions in general or the multiplicity of recommendations by individual groups of scientists for or against various technical developments and their application. The Royal Commission model depends for its effectiveness on an informal authority which has developed organically in Britain. If an attempt were made to apply this concept to German affairs, it would be likely to come to grief not only because of the purely consultative and non-executive nature of such a body, but also because scientific pronouncements are not accorded the necessary degree of trust by those to whom they are addressed.

2.2. The Scientists' Parliament : expert knowledge and legitimation ?

The second model, which proposes the setting up of a parliament of scientists who would publicly discuss the implications of present and future science policy, derives from an idea mooted by the Deutsche Physikalische Gesellschaft (German Physics Society) and re-floated by Lohmar in the article we quoted earlier. Lohmar's proposal aims at improvement in three areas of the research-policies relationship where there are problems :

1) an intensified control of the administration of research and technology policy and of recipients of subsidies by a more informed parliament ;

2) stepped-up public criticism and discussion causing the administration and the recipients of subsidies to provide more comprehensive and thorough explanations and justification for their decisions, and

3) better association of economic and efficiency-oriented standards as part of the control functions of, for example, the Federal Audit Office.

A critical appreciation of this proposal should first of all take account of the fact that the author himself has been mainly concerned with intensifying the discussion on improved implementation of existing scientific knowledge in specific policy decisions as a means of coping more efficiently than hitherto with the dreadful state of affairs regarding research policy. There are still no concrete proposals regarding such matters as the composition of the Scientists' Parliament, its powers and the extent to which it can be ensured that such an institution will restore the credibility of scientific and technical decisions. Furthermore, from a practical standpoint, it must be made clear, on the one hand, which internal structures of organizations and institutions are to be changed so that the latest knowledge research strategy can be brought to function in administrative and political practice, and, on the other hand, it must be made clear how such a parliament can modify the substantial shift in actual decision-making power from the legislature to the judiciary.

2.3. The Science Court : a better solution ?

The model on which the Science Court is based derives from a proposal by A. Kantrowitz in 1968 6. This focussed in particular on the problem of scientific consultation. In order to improve the integration of the present state of scientific knowledge into policy decision processes, Kantrowitz suggested the setting up of a special court for scientific and technical questions (the Science Court) to examine questions that are pressing both from a scientific but also a political point of view, as regards their scientific principles and dimensions (the construction of nuclear power stations, pollution of the ozone layer, the tolerance of the human body to chemical or biochemical noxious substances). In this connection, Kantrowitz proposes the setting up of a panel of judges composed of independent and prominent scientists, who, on the basis of their fundamental abstract knowledge and their experience should be in a position to look sufficiently objectively at problems and related factors, including those outside their own disciplines. The necessary data for an all-embracing total presentation of the phenomena to be evaluated would be obtained with the aid of scientific witnesses and lawyers who, on each individual issue, represent the various scientific positions. In a kind of cross-examination to which the witnesses would be subjected an attempt would then be made to produce the most objective picture possible of the present state of knowledge, which would then be made available in a detailed report to the decision-makers and also - in an abbreviated form - to the general public[7] as a basis for a decision.

The original concept of the Science Court as represented by Kantrowitz and later by other authors proceeds from the assumption that scientific description of facts and political evaluation with a view to the practical application of the data supplied can be separated analytically. In this sense, the final "judgment" of the Court, i.e., the report on the results of the procedure, is seen as being a determination of the factual situation, with no attempt to recommend or reject.

Without wishing to re-open the issue of value judgments, which dates back at least to Max Weber, it must be recognized that the publication of the "judgments" of the Science Court proposed by Kantrowitz will be regarded at least partially as a recommendation to take action. However, the practical usefulness of this model for assessing the consequences of technology through the use of a Science Court, limited, in the final analysis, to technical questions, stands or falls by this factor. Limiting the problems to those of a purely scientific and technical nature also produces political recommendations which, as a consequence of their self-imposed restrictions, must be regarded, however, as inadequate for the resulting formation of consensus and decision taking by political bodies and the general public, because they disregard many significant effects of new technologies on society. As has emerged from the discussion on energy, the consequences of research and sectoral policy measures for the labour market, for the quality of the environment and the quality of life and the economy are, in general, frequently regarded as being just as grave as problems connected with technical implementation or technology-induced risks.

More recent proposals concerning the Science Court advocate more and more that those aspects which are part and parcel of more broadly defined social consequences of the application of new technologies should no longer be disregarded. Therefore, considering the concept of a Court for scientific and technical questions including the broader range of tasks set, we see that there are three essentially different tasks to be performed in relation to science and politics.

Firstly, it is possible to depict the state of knowledge as regards the main lines of development in science and research policy and their necessity, together with possible alternatives to them (MODEL I) ; secondly, Science Court procedures could accompany socially significant research projects, through the taking of relevant decisions, at intervals still to be determined, on whether a specific project is still in line with existing or politically desirable development trends, or whether there is a justifiable relationship between expenditure and objective or whether it would not be possible to use alternative technologies in a more efficient, cost-saving and environmentally acceptable manner (MODEL II). In addition to these areas of application that are determined primarily by research policy, the following application of the Science Court would be possible, in a context which has hardly been touched upon up to now : if, in fact, it is correct that the evaluation and expansion of scientific and technical knowledge is influenced to an ever-increasing degree by decisions of the courts, which are only imperfectly prepared for the new tasks they have been assigned in this field, then a branch of case law relating specifically to these questions could lead to more rapid and well-founded judgments (MODEL III). Below, an attempt will be made to sketch in greater detail the three fields of application of the Science Court model, on the basis of what they are and are not capable of achieving. Because of certain common structural characteristics, MODELS II and III are summarized in a comparative fashion.

MODEL I : Medium for testing statements on the "State of the Art"

Up to now, only Kantrowitz's Science Court model, of which a brief description is given above, has been discussed in detail ; essentially the discussion has been confined to the United States. The structure is based on the following two main approaches :

- what formal arrangements are to be taken into account, to be adopted, still to be clarified, to enable the Science Court model to operate effectively in practice ?

- what advantages does the concept offer as opposed to conventional scientific consultation systems ?

Formal criteria which apply when setting up a Court for scientific and technical questions are, for example, whether it should be a permanent institution with a permanently unchanged jury, who appoints the individual judges, who decides what subjects are to be dealt with, who chooses the lawyers, who bears the costs, etc...However significant these details may be as a whole - with particular emphasis on the question of who has a right of action - they should nevertheless, in principle, be susceptible of solution once it has been decided to apply the model experimentally. This also applies to the other two variants of the Science Court concept still to be dealt with, and which, in detail, can involve a variety of similar problems to which the scope of this paper cannot extend. They can be solved only in actual practice, in a relatively long-term discussion, experimentation and learning process. Initial experiments in the United States indicate that with the aid of the Science Court procedure technological evaluation criteria can be developed, which, by virtue of their transparency and scientifically balanced approach are acceptable to the population sectors concerned[9]. However, at the present time it is, of course, still too early to make general pronouncements on this matter.

The second question as to what can be achieved with the Kantrowitz model, by comparison with existing expert opinion procedures, has already been gone into briefly above? Apparently in this way, broad factual discussion, involving the general public, of technical and scientific progress can be conducted, which contributes both to the securing of a consensus and to greater transparency of the political area in question, and its effects on the broad spectrum of overall social objectives in all aspects of life. However, the Kantrowitz model, as conceived so far, is basically limited by its own possibilities, since only scientific and technical problems are to be accepted as phenomena for examination. It would, of course, amount to a failure to appreciate the intentions of Kantrowitz and all those in favour of this version of the Science Court, if they were to be regarded as endeavouring to enrich traditional consultation systems simply through another gambit. Their deliberations are based much more on the idea of furnishing political decision-makers and the general public with only the best possible data. It is not just incidental that in this connection arguments advanced by the psychologist, Levine, are mentioned, which, based on the recognition theory concepts of critical rationalism, are aimed at securing a closer link than hitherto between research results yielded by experiments and critical discussion by a body of research workers. In this sense, the Science Court can be regarded as representing such a body of research workers on a small scale ; its discussions should reflect the present state of knowledge with regard to a particular problem area in the best way possible.

Irrespective of the assessment of the epistemological assumptions underlying this approach, it must be conceded that, for the purposes of general discussion, an overall representation of what is and is not available by way of "confirmed" knowledge for coping with a specific problem could be very useful. It is not only in the fields of economics and sociology but also in public discussion of scientific and technical questions that the lack of reliable forecasts turns political discussion into a kind of religious struggle in which the opposing forces chant to one another, with a greater or lesser degree of justification, but without being able to produce evidence based on scientific fact, either faith in progress and the ideology of growth, or economic ignorance and nostalgic glorification of nature. Although both sides try to support their line of argument by reference to confirmed facts, it can, nevertheless, not always be assumed that, as regards reactor construction, for example, safety is really the decisive ground in favour, or disposal problems the decisive reason against. Scientific witnesses who will attest to the logic and scientific foundation of one or the other standpoint are - at least in the case of such controversial subjects - legion.

The Kantrowitz model is intended to counter this virtually endless process of scientific and quasi-scientific discussion. In this connection, it is expected that the jury will succeed in distinguishing between "reliable" and "less credible" witnesses, i.e., those whose contentions are based on established facts and others who may use spurious scientific arguments to further other interests. That is why Kantrowitz insists that the panel of judges be composed of scientists not involved in the controversy, i.e., from other disciplines : the acid test of scientific progress is a plurality of theories that institutionalizes criticism and counter-criticism. The reason why sociological questions are considered by the protagonists of this original idea of the Science Court to be outside the terms of reference of the procedure is obviously not because their research results would be outside the general outline conditions for the validity of a theory - empirical backing for and provisional corroboration of the findings of the research workers : it is far more readily assumed that the plurality of theories of the social sciences will prelude the security of a consensus on the part of research workers, based, as in the case of the natural sciences, on a commonly accepted paradigm. Consequently, there is no way in which the numerically restricted jury could be representative of such a plurality of theories. This scientific self-restraint - possibly against Kantrowitz's own intentions - would have the paradoxical consequence with regard to research policy in practice, that scientifically substantiated or unsubstantiated decisions regarding the non-technical social effects of the application or non-application of technical know-how would have to be reached elsewhere then within the Science Court. This would detract considerably from the consensus securing character of an institution of this kind and call in question its overall contribution to the rationalization and clarification of research policy decisions. Albeit that historical experience which is reflected in sociological theories does not enjoy the status of the laws of the nomothetic sciences, it cannot be endlessly relativized. Epistemological purism, therefore, does not go as far as actual practice, with this Science Court model ; in actual practice, however, preference should be given to a substantiated plan of action drawn up by an economist, and based on the previous success or failure of specific economic policy instruments with boundary conditions that have not been completely clarified, rather than mere value based decisionism.

As a whole, the Kantrowitz Science Court model would appear promising insofar as its intention, with reference to research policy, is to procure confirmed data as a basis for better decisions. However, since Kantrowitz leaves many questions unanswered, such as how the present state of scientific knowledge can be more effective incorporated in political decision-making processes and how it can, to some extent, be guaranteed that decisions on the application and further development of technical knowhow will be based on scientific criteria, an extension of the range of subject matter with which the Science Court should concern itself is highly desirable.

MODELS II and III : The Science Court as an institution acting in parallel with technology evaluation

There are as yet no detailed concepts - akin to the Kantrowitz model - of the other two variants of the Science Court. The only suggestions in this respect are to be found in a number of informal papers by Raymond Bauer, and these will be gone into in this paper. However, both proposals provide for a common framework as regards the structure and decision-making powers of such a court for scientific and technical questions :

- the Science Court includes sociological implications in its decision-making criteria in so far as they are relevant to research policy questions or the application or extension of technology.
- as with the Labour Court, the independence of the jury is not defined primarily by that of each individual assessor, but rather as a whole, through the equilibrium maintained when selecting the judges and assessors. The judges themselves are appointed in accordance with criteria such as also apply in other areas which are important from the standpoint of social and legal policy ; here, analogies may be drawn, for instance, with constitutional courts, labour courts and other specialist courts.
- questions of procedure and evidence are in line with the traditional practice of the courts, that is to say that in addition to the respective parties' lawyers, the court may also call witnesses or procure expert opinions on its own motion.

The first of the two variants (MODEL II) is specially geared to the prevention of faulty plans and their retention in research and technology policy ; on the basis of developments in this area, as described above, it aims in the national research policy more closely to economic and other social criteria for the success of a project. To this end, research projects of importance from the standpoint of finance and development policy would be examined regularly by the Science Court which would check whether there were a justifiable relationship between objective and expenditure, the extent to which the same objective might be attained by other more economic means and whether the same significance attached to the objective in question as when it was first made the object of state aid.

The problem arises of the legal force of judgments of the Science Court in the abovementioned case, in so far as in this procedure it is not a question of whether the subjects under investigation are in accordance with existing laws or rules, although, of course, any risks attached to the implementation of research projects, which affect the constitutional rights of individual citizens, will, in practice, enter into the decisions of the Science Court. In principle, however, it will be a question of choosing, on the one hand, between alternative projections of objectives, and on the other hand, between alternative means for the attainment of those objectives ; projects will be evaluated in accordance with catalogues of sociopolitical objectives, and scientific, technical and economic categories. However, the political nature of the decisions made in this context also determines their status ; were they to be legally binding, Parliament, irrespective of any influence it may have on the composition of the Science Court, would be deprived of supervisory powers which it has always had in respect of research policy. Such a result would be a contradiction of the original intention when devising the Science Court model, i.e., not to deprive Parliament of decision-making powers but rather to provide the legislature and the executive with an instrument which renders possible the planning of research and technology policy in accordance with scientific, sociopolitical and economic standpoints, and prevents an administrative vacuum. In this form, the Science Court would therefore function primarily as an advisory body on research policy for Parliament ; in addition, however, it could also serve as a platform for a broad public dialogue conducted by experts on fundamental technological development trends. Such a Science Court would correspond essentially with the concept of an institution for the evaluation of technological development in the form of an independent advisory body, as proposed by one author (Meinolf Dierkes) on the occasion of a hearing by the Committee for Research and Technology of the Lower House of the German Parliament[10]. Moreover, the extent to which this Science Court model might be linked to other proposals should be investigated ; institutional dove-tailing of a Scientists' Parliament and a scientific court would, for example, be conceivable.

In contrast to this concept, which sees the function of the Science Court very much as an advisory body in the field of research policy, the third variant (MODEL III) consciously takes as its starting point the "gradual depolitization" of research policy developments by ever-increasing utilization of civil and administrative courts in the face of the increasing scientific and sociological complexity of cases. Although nobody wishes to deprive the individual citizen of his right to bring legal proceedings against the effects of the broad application of new technologies where they restrict his legally guaranteed rights, it must be conceded, on the other hand, that it becomes difficult to weigh up the pros and cons where a firmly established series of civil laws are confronted by a broad range of scientific and technical information relation to which it is often only on the basis of a high level of specialist knowledge possible to determine the extent to which particular rules are influenced at all by particular effects. In general, the task of the judge is to examine the extent to which particular rules can be applied to a particular situation. In determining the facts, as in evaluating the evidence, (the principle of the freedom to assess the evidence) criteria that are well established from every day practice are used which, although not held to have to comply with scientific validation criteria, are nevertheless expected to prove their worth in cases of controversial scientific opinions - as, for example, with regard to the disputed question of accountability. Such rules concerning apportionment and evaluation become problematic, however, when the judge can no longer rely on the principles of every day experience. This is often the case where matters of a scientific and technical nature are at issue, the different judgments relating to protection against bursting in nuclear power stations are a good example of the difficulties encountered these days by those handing down judgments in this area ; there are no rules for evaluating issues, secured through many years of judicial practice and which guarantee an inviolable relationship between the issue and experience. The dangers of placing excessive reliance on traditional case law are clear : controversial judgments reduce public confidence in research policy and legal decisions, and heighten the impression of arbitrariness.

For this reason, the Science Court model III provides for a more pronounced degree of participation on the part of scientifically and technically trained lay judges. It is not assumed that putting specialists on the panel of judges would produce more objective decisions and truths that are valid for all time ; however, there are grounds for believing that this could lead to decision-making processes that are more efficient from the point of view of time, and scientifically better balanced. However difficult agreement among scientists has been made these days by specialization, we may not conclude from this that scientific laymen - and this is what judges in the civil and administrative courts are in many instances - are in a better position to understand scientific experts more correctly than a representative of another discipline. It is precisely the practice of basic theoretical methodologies which will better promote a pertinent evaluation of scientific data rather than a scientifically "tainted" assessment model.

Many details of this model also remain unclear. However desirable, on these grounds, establishment of such specialized courts, which may be more capable of doing justice to the manifold tasks and problems of a modern industrial society with regard to science and technology than conventional judicial institutions, may appear, the social consequences of such a concept of the Science Court must equally be taken into consideration. What status should the Science Court be accorded, for example, should it be set up as a highly departmentalized institution comparable to the system of labour courts or might it not be better for the Science Court to act only at a level comparable to that of an Oberverwaltungsgericht (Higher Administrative Court), with a view to taking scientific decisions of great consequence ; who should take part as a lay judge in the proceedings of the Science Court ; to what extent should certain scientifically oriented changes in the qualifications of lawyers be encouraged : who should decide which cases should be dealt with by the traditional courts and which by the Science Court ; there are no evidently ideal solutions to all these problems. The manifold difficulties inherent in political consultations of a scientific nature, research and technology consultations and the application and further development of technical knowledge make further discussion and search for possible solutions matters of urgent necessity. All three versions of the Science Court model might well serve as a contribution to this.

Notes

1) See *inter alia*, Dierkes, M., Planung des technischen Fortschritts - Berücksichtigt "Technological Assessment" den gesellschaftlichen Bedarf, in : Umschau 75 (1975), vol. 4, p.751 et seq. and Paschen, H., Gutachten zum Problemkreis Technologie-Folgenabschätzung (Technology Assessment), commissioned by the administration of the Lower House of the German Parliament, Heidelberg 1974.

2) Dierkes, M., Staehle, K.W., Technology Assessment - Bessere Entscheidungsgrundlagen für die unternehmerische und staatliche Planung, Schrift des Battelle-Institut e.V., Frankfurt 1973, p.3.

3) Der Bundesminister für Forschung und Technologie, Bundesbericht Forschung V, Bonn 1975, p.13

4) Lohmar, U., Versäumnisse unserer Forschungspolitik : Denkanstösse zu einer Reform, in : Bild der Wissenschaft 2-1977

5) Lenzer (CDU) and Stahl (SPD), members of the Bundestag, recently spoke in similar vein during a "Dialog" broadcast by the Saarländischer Rundfunk (Saarland Radio).

6) See, in particular :
Kantrowitz, A., Proposal for an Institution for Scientific Judgment, in : Science, Vol. 156, N° 3776 (May 1968), p. 763 et seq.
Task Force of the Presidential Advisory Group on Anticipated Advances in Science and Technology : The Science Court Experiment, in : Science, Vol. 193, N° 4254 (August 1976), p. 653 et seq.

7) The need to publish the entire judgment is still a controversial matter in the USA.

8) This problem and the question of how the efficiency of the Science Court should be examined are dealt with in detail by Bauer, R., Experimenting with the Science Court : Some Preliminary Issues, unpublished. Manuscript.

9) In this connection see, for example : Bross, I., Adversary Science in Aliquippa, in : Health Physics, Vol. 26 (June) New York, Oxford 1974, pp. 581-583.

10) See Dierkes, M. Technology Assessment in der Bundesrepublik Deutschland - Eine Stellungnahme, Battelle-Information N° 19/1974.

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ANALYSIS OF CURRENTS OF INFORMATION WITHIN THE FRAMEWORK OF THE CYCLE OF SCIENCE-TECHNOLOGY-PRODUCTION

E. Albrecht*, Ch. Otto

Scientists have for long been concerned with the analysis of innovation periods. Thus GILFILLAN, LYNN, DOBROW, LISICKIN and MANSFIELD/1/ have been trying to verify the thesis that in the 20th century the innovation periods were considerably shorter than in previous centuries. In more recent times, however, more and more objections have been raised against such a thesis. Indeed, the theoretical and methodological foundations used as a point of departure for such studies were developed only insufficiently.

The above-mentioned authors, in determining the rate of the innovation process, have used the period between the discovery of a new principle of effect and its conversion into large-scale production as a criterion for their studies. In most cases these are basic innovations, i.e. those innovations necessitating the establishment of new industries. The shortening of periods sufficient for putting these innovations into practice, as was proven by above authors, will have to be attributed to various reasons, among others to the purposive and dedicated control over these processes.

In connection with the motivated formation of theoretical and methodical principles characterizing our own standpoint it is contemplated to show the problems involved in the selection of such an indicator and to point to the falsity of scientific and economic conclusions obtained as a result of the hypertrophic nature of the statement.

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Our concrete argumentation will be based on the analysis of the development of synthetic fibres carried out by us. In pursuit of this aim we proceeded from the consideration that the analysis of currents of information on the basis of "Science Citation Index" and patent literature provides the possibility of checking the conclusions derived from our theoretical model of the cycle "Science - Technology - Production".

The metamorphosis in the relationship between science and production proceeding apparently under the conditions of the scientific and technological revolution permits to recognize the following: The more complicated the processes, structures and regularities used technically and technologically in the production process are, the more urgent is the theoretical understanding to be available as the indispensable premise for controlling these phenomena in practice. This idea points to the generalizing statement that the transition from the classical factory system to fully automatic production requires not only a revolution in the sphere of technology, but even a revolution in science.

In conformity with this statement, in our view, a complete cycle of 'Science - Technology - Production' comprises the formation of new theories, the discovery of new regularities and phenomena of objective reality and their subsequent stepwise technical, technological and economic utilization, in short, the process of revolution in science and by means of science. Its major phases are: development of theories, technical implementation, economization and industrial expansion./2/

What are the methodical implications to be derived from this for determining the innovation periods?

First, it is necessary to classify innovations in terms of their theoretical premises, i.e. innovations that would require a scientific revolution should be treated as a specific class of innovations in comparison with others. Second, the discovery of a principle, or an effect, would have to be included in the development of those theories that would permit to explain these discoveries.

Nuclear energy, electronics and synthetic materials are undoubtedly innovations that contribute to characterizing the nature of the scientific and technological revolution. But in the same way as nuclear energy and electronics present themselves as the technical materialization of findings of quantum physics, synthetic materials constitute the outcome reached by the technical application of the findings of macromolecular chemistry, i.e. of new theories that have evolved only at the beginning of our century.

However, this fact is not considered in the analyses of above scientists; they give, e.g. the innovation period for polyformaldehyde with 99 years, whereas that of nylon with only 3 years./3/ Indeed, polyformaldehyde was prepared for the first time in 1859. But this year would not be correctly chosen for the calculation of the innovation period because at that time the theoretical foundations were still inadequate to be able to understand the conversion of monomers into polymers. The purposive industrial production of this high polymer has become feasible only in the middle of the 20-ies after the formulation of the theory of macromolecules.

Thus, methodologically, it would be incorrect to take the sheer discovery of a principle of effect, or the synthesis of a substance, as the starting point of a process of innovation. A new theory prompting a scientific revolution can be considered the decisive theoretical premise for a series of innovation processes.[1)]

This new theory will provide a stable and safe foundation for decades both for research and for technological development. Of course, within this process the theory will be subject to further development, and its dynamics will become obvious in the wake of interactions of global research programmes.

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1) This is not intended to assert that all innovations of our time will be directly or indirectly initiated by scientific revolutions.

This statement has become especially clear as a result of the studies on rates of quotations carried out by us[2)] for the Nobel-prize-winners for macromolecular chemistry (H. Staudinger - 1953; K. Ziegler and C. Natta - 1963 and J. P. Flory - 1974) on the basis of the "Science Citation Index". As a result of this analysis it was possible to recognize that in the process of theory evolvement in principle three various types of research programmes have to be passed through. While the first programme is concerned with the creation of the theoretical basis, the acquisition of fundamental abstract-theoretical findings providing the framework for additional research, the second programme is characterized by an intensive penetration into the microprocesses of objective reality, notably by the revelation of new structural principles, and the third programme will take account of the objective demand for a systematization of the theoretical knowledge thus accumulated. The dialectics of dynamics and stability inherent in the process of cognition becomes apparent in the succession of these research programmes. In this context there is another problem: In the literature on science of science it is sometimes maintained that the "half-life period"[3)] of scientific information would presently be 5 to 7 years, for natural sciences only 3 to 4 years[/4/].

However, this view cannot be considered to be generally applicable to any kind of scientific finding, since it is necessary to allow also for qualitative aspects when estimating the obsolescence of scientific information.

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2) When assuming that a scientific theory constitutes a system of information and that its further development will mainly proceed via certain currents of information between scientists, conceding that these currents of information will surface in the form of scientific publications, the volume of the scientific literature may serve as an indicator of these currents of information.

3) By the term "half-life period" we understand that period in which the intensity of the use of information is lowered by half.

The study carried out on the basis of "Science Citation Index" has shown that fundamental scientific ideas prompting revolutions in science and leading to the formation of a new paradigm/5/ in the course of decades will leave behind great effects in the various fields of science. This fact can be clearly proved, for instance, by the number of quotations of scientific papers by H. STAUDINGER, the founder of macromolecular chemistry.

Fig. 1 shows the number of quotations of H. STAUDINGER contained in the "Citation Index" of "SCI" of the years 1969 till 1975[4] in dependence upon the year when these publications were made. The total number of quotations within one year will thus be obtained from the sum of points recorded per each five-year period and thus forming a polygon. It is strange, however, that at present the most frequently quoted papers by H. STAUDINGER are those published in 1916 and 1926. This is the period when he laid the theoretical foundations of macromolecular chemistry that provided the scientific prerequisites for the synthesis of high polymer materials. It is worth noting that although some 50 years have since passed H. STAUDINGER belongs still to the world's 500 most quoted scientists. This can be taken from an analysis by E. GARFIELD who had ascertained for H. STAUDINGER a quotation frequency of 3,325 for the period from 1961 to 1975./6/ The average quotation frequency over these 15 years accounts thus for 221. When comparing this figure with the average quotation frequency of 201 determined by us for the years 1969 till 1975 it becomes clear that only a slight decrease had happened. This would mean that fundamental findings will retain their scientific generality over decades because of their paradigmatic character and they have the capacity to encourage productivity also among the next generation of scholars. Now let us address ourselves to another problem which plays a pivotal role in the analyses on innovation periods in a methodological respect: the determination of the terminal point of innovation processes.

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[4] The study has to be confined to this period since "SCI" has become available in the GDR only after 1969.

Here the technical implementation, sometimes also the transfer of the outcome of research into large-scale production is taken as a criterion. When e.g. for nylon three years are given as the innovation period, this would cover the period between the registration of the basis patent (1935) and the beginning of large-scale production (1938) with Du Pont.

In our view, however, the process of basis innovation is considered to be relatively terminated only with the transition to mass production. And large-scale production does not yet mean mass production.

The term 'mass production' comprises first the definition of the concrete needs of users and in the second place the territorial expansion of the new process, or new products. New products tend to cause a substitution effect. From the economic standpoint a substitution would be sensible, if the new product could be produced at a cheaper rate than the old one. Under the aspect of performance characteristics it is intended to achieve new, or comparable physical, mechanical, or chemical properties.

But the development of the different needs of users is done only step by step. While e.g. nylon was used for the production of ladies' stockings already in 1938, the production of nylon tyre-cord was started only at the beginning of the 60-ies.

A complex study, as conducted from the standpoint of our cycle model, refers to the necessity to regard the synthetic mass fibres, including also the polyamid- the polyester- and polyacryl nitril fibres, as one class of innovation processes. According to its economic nature this class has to be designated as a basis innovation.

At present all the prognostic estimates proceed from the fact that in the next few decades we have to reckon with a stable assortment in the line of chemical fibres. In recognition of this statement it is therefore required to improve the technology, i.e. to ensure a cheaper production of mass fibres, and to modify the present-day mass fibre materials with a view to extending the range of fine-type fibres.

Here we have taken a specific interest in the life cycle of basic technologies required for the production of mass fibres. When analyzing the development of a definite technology it becomes obvious that various basic processes are practicable. But once a process has been introduced it will be substituted only when the possibilities have by far been exhausted. When considered over a longer period, we obtain series of technological variants T_1 -- T_{11} -- T_{12} ...-- T_2 --- T_{21}, where the transition from one link of the series to another one is designated by the partial supplementation of a definite basic technology.

Thus e.g. for polyester fibre production three different basic technologies are known which can be schematically described as follows:

<u>Basic process No. 1</u>

DMT + EG <u>esterification</u> → DGT + methanol
↓ polycondensation
PETP

<u>Basic process No. 2</u>

TPA + EG <u>direct esterification</u> → DGT + H_2O
↓ polycondensation
PETP

<u>Basic process No. 3</u>

TPA + EO <u>ox-ethylation</u> → DGT
↓ polycondensation
PETP

This is the meaning of abbreviations used: DMT = dimethylterephthalate; EG = ethylene glycol; DGT = diglycol terephthalate; TPA = terephthalic acid; EO = ethylene oxide; PETP = polyethyleneterephthalate (= polyester).

It was of interest to us to analyze the activities of research done for the development of these technological basic processes under informational aspects. A study on the frequency of patent registration specifically conducted in the U.S., U.K., the FRG and the GDR - the major historical carriers of this development - allowed to recognize the following: The process of accumulating the scientific and technical information ranging from the registration of basis patents up to the maximum technical and technological utilization of a basic process (T_1, T_2...) comprises a period of some 25 years (cf. Fig. 2 and 3).

This process is not of an exponential type, but is rather noted for periods of differently intensive research activities. The general course of development is equal to an undulatory movement. This phenomenon to be found equally in all countries under study suggests the existence of certain regularities in the dynamics of the technical development and, in our view, should be explained as follows: In the first period of development of a technological process the research activities are centered on the collection of a as far as possibly wide range of modifiable technical solutions. On the basis of the measures to use these technical solutions industrially the research activities will be shifted in the direction of raising the rate of efficiency of the processes introduced. Especially the latter point mentioned is fast assuming specific importance under economic aspects.

Here the step-by-step improvement of a process is expressed especially by the transition from discontinuous to continuous processes, by the increase in yield, the introduction of process control as well as by the increase in the capacity of plants.

Thus e.g. the benefit of continuous processes compared with discontinuous processes in the production of polyester fibres is to be found mainly in the quality of products obtainable and in the economy.

The following table shows the results of a comparative technological and economic analysis with regard to the costs for the continuous and the discontinuous process on the basis of DMT (Basic process No. 1).

C o s t s	Total production	chemical part
Investments	93.0	71.0
Enterprise production costs	94.0	not ascertained
for processing	91.6	64.0
labour involved	92.0	55.0

Table: Costs incurring during the production of LASAN-polyester fibres according to the continuous process (in % of the costs incurring during the discontinuous process) /7/

Fig. 2 shows that the research activities designed for the partial supplementation of this first basic process for the production of polyester fibres have receded since the middle of the 60-ies and have been shifted increasingly to the basic process No. 2 already under preparation. Though this second process has been known since 1941, any processes based on terephthalic acid gain increasing importance only when it had become possible to produce terephthalic acid on a large scale and in required purity and to overcome the difficulties related to the insolubility of terephthalic acid in ethylene glycol.

The same applies to the third basic process, the most productive process which, however, involved a number of technical problems. The registration of the basic patents was done in Great Britain in 1947. But this process has been prepared for use only since 1960 and was first tested in pilot plants by the Japanese firms Teijin Ltd. and Toyoba Co.

Still in 1971 80 % of the world production of polyester fibres was done according to the basic process No. 1.

This fact shows that although society has at its disposal a stockpile of technical solutions they can be translated into practice only after fulfilling certain conditions. These conditions involve the adequate materials and technical prerequisites, but also the consequences derivable from economic goals. The specific social conditions determine also the time when a scientific and technical development has to be taken up in the individual countries and lead to the formation of peculiarities in the dynamics of the scientific-technical progress in these countries.

The outcome of studies thus obtained permit to recognize that the scientific and technical progress is characterized both by factors of dynamics and stability. Obviously basic innovations which result in a substantial change in structure of the economy are feasible only within greater intervals.

From the standpoint of scientific and technical policy important questions of decision-making arise in e.g. determining the proportions between the expenditure required for improving an introduced technology and that for the introduction of a principally new technology. When proceeding from the recognition that under present-day conditions a fundamental progress in the development of the productive forces can be achieved only as a result of a long-term strategy covering a time horizon of 30 to 40 years, it would imply that for any period of planning the research programmes will have to be formulated with different objectives, e.g. programmes for the investigation into new principles of effect, for the development of technical prototypes, for the transfer of technical prototypes as well as for the technical and technological complementation of current production.

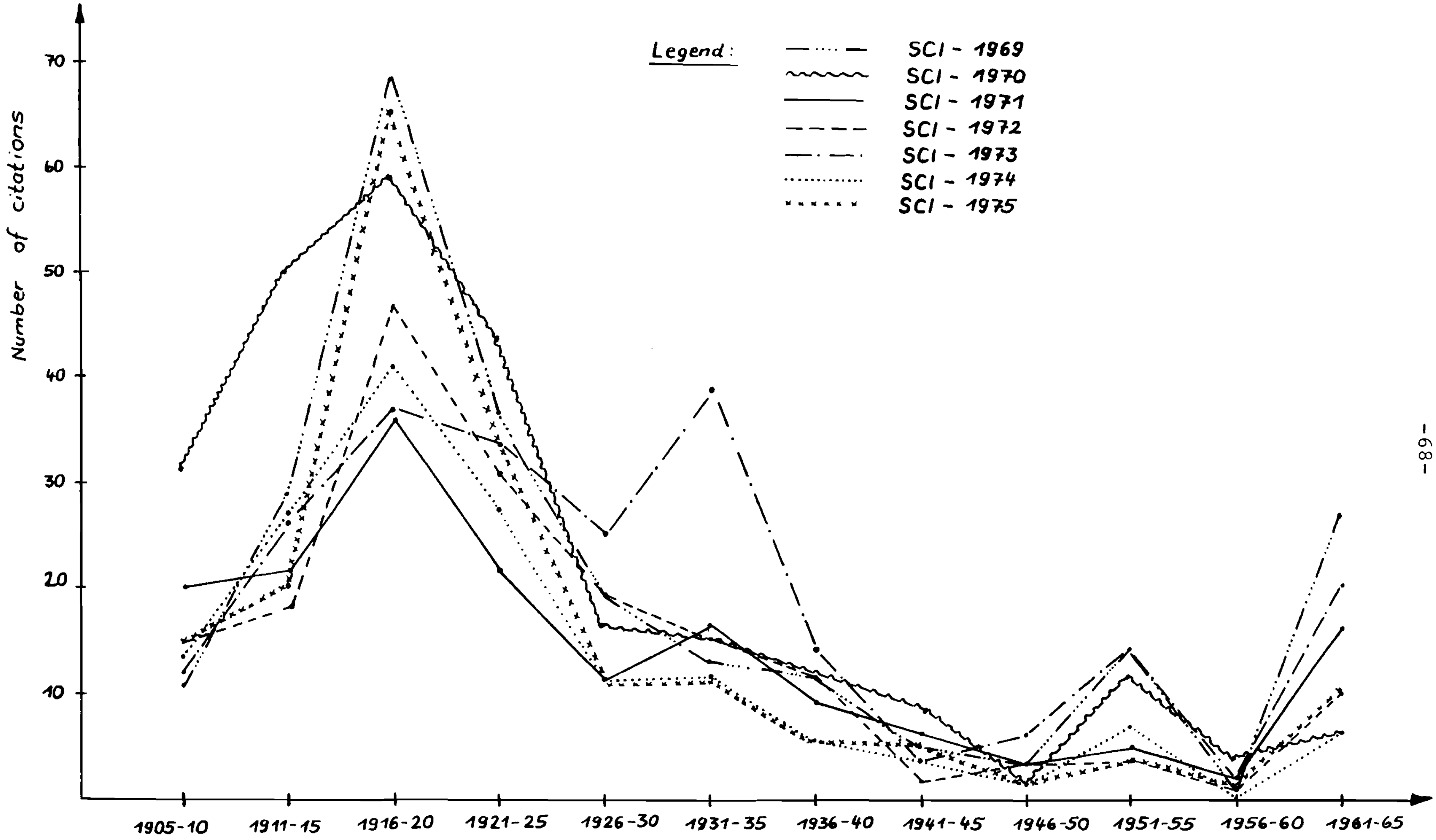
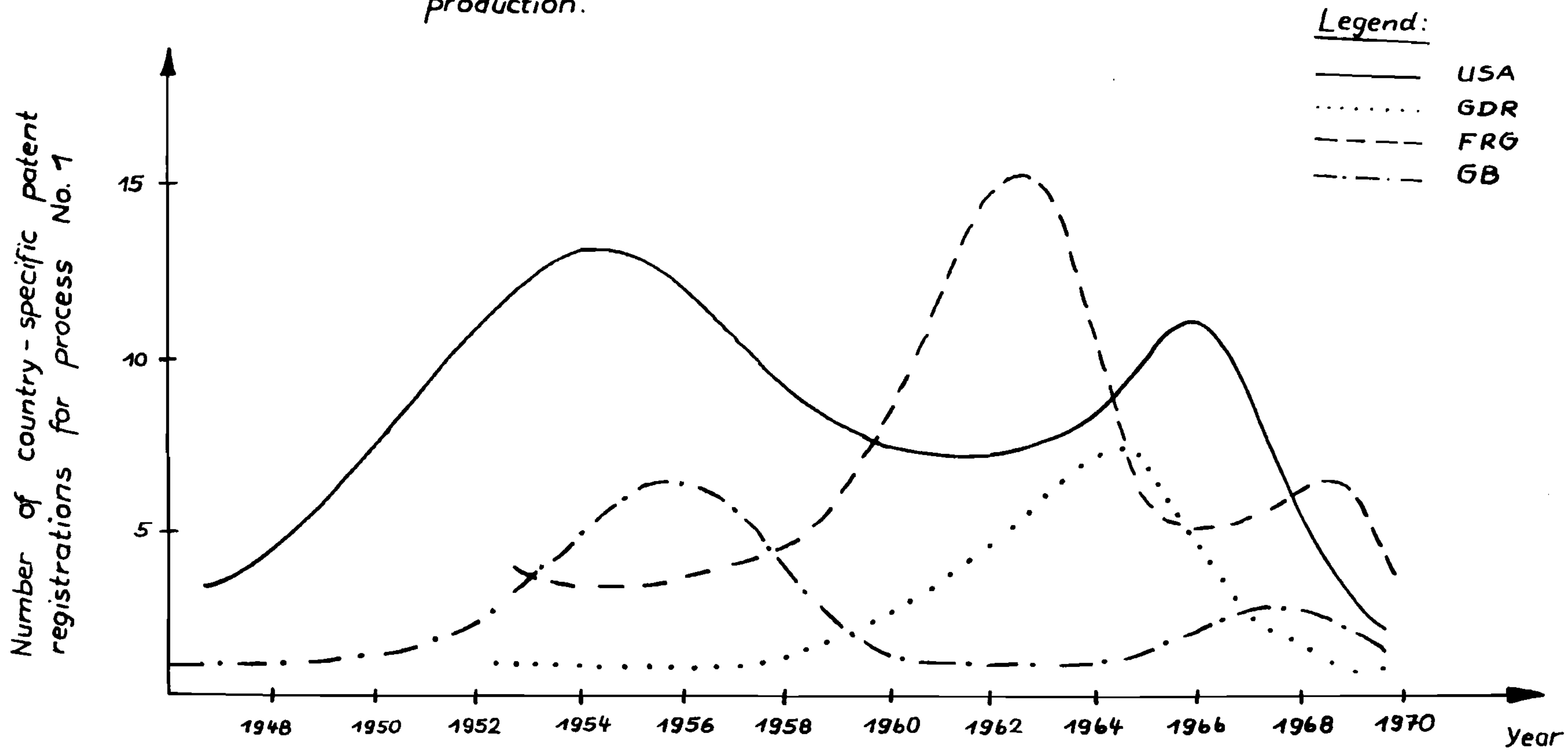


Figure1: Total citations of H. STAUDINGER from 1969 to 1975 based on data from the Science Citation Index

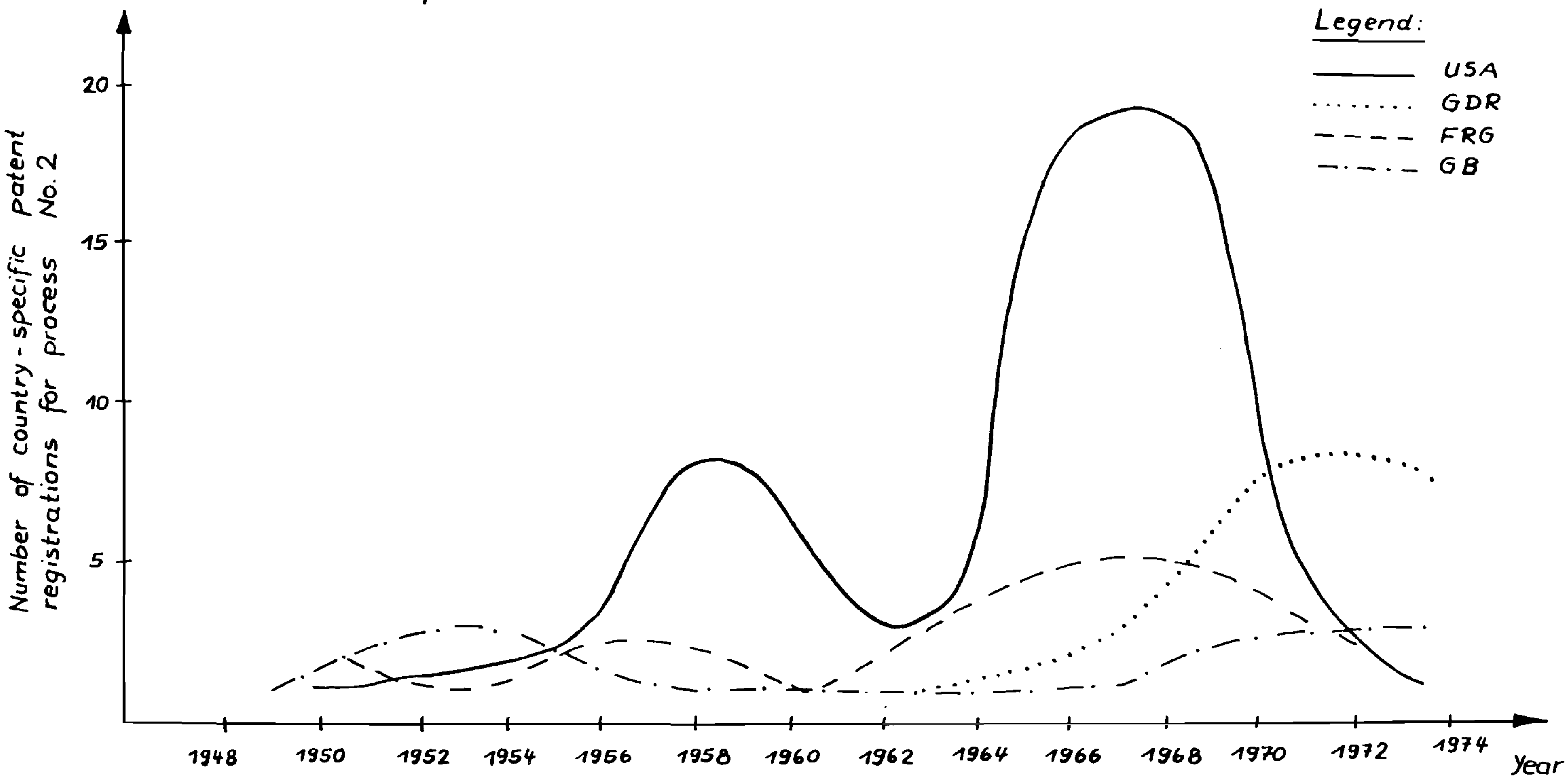
Figure 2:

Frequency of registration of patents of selected countries for the basis process No. 1 of polyester fibre production.



<u>Figure 3:</u>

Frequency of registration of patents of selected countries for the basis process No. 2 of polyester fibre production.



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MANAGEMENT OF INNOVATION IN INTERDISCIPLINARY FIELDS

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1. FOUNDATION FOR MANAGEABILITY OF TECHNOLOGICAL INNOVATION

It is often said and might be true that our basic knowledge has remained foundamentally the same in these thousands years. This leads to another statement that any breakthrough or innovation is just a combination of existing knowledges or just a transfer or application of existing knowledge from a field to another. This statement may be included in a widely accepted historical recognition that any jump in our history of knowledge is just an integration of many infinitesimal steps. This yields a possibility that technological innovation is controllable under proper management of the infinitesimal steps.

It is also widely recognized among science historians that any scientific finding can be explained as a product of efforts for solving the confronting problem which was theoretically or socially urgent at that time. This means that, independently from motivation of individual scientists, a scientific finding is target-oriented. Hence a proper target orientation is expected to guide science in an effective manner.

2. ALTERNATIVES FOR GUIDANCE IN SCIENCE AND TECHNOLOGY

This guidance has long been done for both basic and applied science by each professor or research director. One of its most successful examples is the guidance by Niels Bohr in physics. As the number of scientists increases, however, it becomes more difficult to have a proportional number of professors and directors who are eligible for the guidance. Hence a systematic guidance may be needed even in basic science. There are two alternatives for this purpose; one is informational and the other is institutional. A science information system is an alternative to assist

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a scientist to find a promising topic. The other alternative is to launch a new and appropriate field whereto young scientists are expectedly attracted. The knowledge accumulated in existing fields is to be transferred thereto and is to be reorganized therein through this flow of scientists.

3. TREND OF SCIENCE REORGANIZATION

One of the most remarkable trends in basic science is the rise of new basic sciences such as earth science and life science all over the world. Another trend is the rise of mission-oriented sciences such as environmental science and systems science. Many institutes for life science were established to promote research in this field. It goes relatively well since their establishment because it is purely the matter of science. In contrast some managerial problem arises with the mission-oriented sciences because they are involved with policy formation activities beside purely scientific activities. Hence some governmental assistance may be needed. As a matter of fact some governmental assistance or even intervention is seen in many countries; for example, space science in U.S. and policy science in Japan.

4. ORGANIZATION EFFORTS FOR NEW FIELDS

As computers came to wider use, many universities launched new departments called computer science, information science or informatics in late 1960's and early 1970's which train programmers and system engineers in computer hard- and software. With wider spread of computer applications, another type of systems analyst is demanded who can integrate knowledges in various fields for problem solving in a quantitative manner with aid of computer. This field is now named in various ways. In higher education, Tokyo Institute of Technology launched a graduate school of systems science as a new field of integrating science and technology in 1974, and the University of Tsukuba and Saitama University launched graduate schools of policy science in 1976 and 1977 respectively. In national technology planning the Science and Technology Agency, the Prime Ministers Office of Japan generated a new word "soft science" in 1971 which is a scientific method to integrate the knowledge (in particular, hardware technology and social science) for long-range planning.

Definitions of information science, systems science, policy science and soft science remain unclear yet despite some organized efforts. Judging from their activities in these past years, systems science in Tokyo Institute of Technology is not policy oriented but an integrating technology, and policy science in the University of Tsukuba neglects the role and contribution of technology in and to the further society whereas soft science of Science and Technology Agency focuses technology planning and assessment.

5. DEFINITION OF METHODS AND SCOPES OF NEW FIELDS

As universities are administratively autonomous and financially supported fully by the government, the graduate schools of systems science and policy science are not forced to define their scopes and methods. In fact the graduate school of policy science in the University of Tsukuba which started just in 1976 has made no effort for its definition yet. In contrast some faculty members of the graduate school of systems science in Tokyo Institute of Technology formed a project team with scientists outside which is trying to define systems science in terms of thesaurus of the key words (key concepts) and its other faculty members are trying to construct the general theory of systems as well as theory of general systems with scientists outside.

The Science and Technology Agency took another step for the same effort and made a contract with Institute of Future Technology for definition and promotion of soft science in 1971 - 74. The Institute sent questionaires to scientists who identify themselves as soft scientists. The result was that soft science is to solve the presently critical problems with methodological aid mainly of systems engineering, management science, computer science, ecology and life science, and behavioral science.

In 1976 the Science and Technology Agency made the second Delphi technology forecasting over five major fields (food and resources, energy, industrial technology, information and frontier). Soft science was included in the frontier field as one of its four subfields (space science, oceanic science, life science and soft science). The Delphi survey of soft science was composed of two parts. One was to locate the problems to which soft science can contribute. The other was to forecast the progress of soft science. As to the first part, urban redevelopment, environment protection, hazard protection, resource, energy and food security were denoted as the major problems to which it is expected to contribute. Whereas international crisis, domestic conflict and societal frustration were not expected solvable by soft science. As to the second part of the survey, soft science is expected to make the fastest progress in evaluation and assessment of new technology, the second in forecast of civilian opinions and of socio-psychological changes.

These prospect and idea of soft science are not implemented yet. The Science and Technology Agency is just for planning and its implementation is left to other ministries and agencies (industrial technology to Ministry of International Trade and Industry, transportation technology to Ministry of Transportation etc.). For that reason soft science remains just a concept and is left to spontaneous effort under existing education and research system.

6. PROBLEMS OF TRAINING SYSTEM IN NEW FIELDS

Education and training is not only a matter of school and university but a matter of job. There are many jobs on which young engineers are well trained and there are also many jobs which are for well trained policy scientists, systems scientists and soft scientists. However young policy scientists, systems scientists and soft scientists are seldom offered jobs on which they are well trained. Industry and governmental offices explain that they do not offer them such jobs because they have no senior staff to train them at present. Hence, in place of on the job training in industry and in governmental offices, casestudy-based instruction method may be needed at schools and universities.

In fact the graduate school of business at Harvard, Keio and some other universities take this method. However, few university professors are experienced with real problems. Hence personnel exchange between real world and academic world is needed but this is hardly acceptable to the both worlds.

The graduate school of policy science of the University of Tsukuba solved this difficulty in a peculiar way. That is a tentative oneway transfer of governmental officers. In more detail a few government officers are rotated to the University of Tsukuba and Saitama University which are national universities and whose faculty are accordingly governmental officers in title, and after a few years duty there they come back to their original offices. In such a way the first step was initiated by the government though it is hardly expected to proceed to the extensive personnel exchange system. The most critical barier for that lies in the closedness of academic world and on the side of Ministry of Education which decline to offer permanent jobs to those staff in industry and government who have no teaching experience. This problem of personnel exchange will be the key of success in new fields.

7. CHANNEL FOR INTEGRATION OF SCIENTIFIC INFORMATION

Scientific information needed in a new field comes from various existing fields. This information channel is not established yet. Computerized data bank of scientific information is a solution for that. One of its critical demerits lies in its inflexibility for possible future change. Another solution is to have an ad hoc symposium for a respective topic. It is often found in a symposium that some information which is quite common in a field is surprisingly unknown in another field. As a third solution a new interdisciplinary field is a forum where information is exchanged between various fields. Maldistribution of information is therethrough dissolved.

As interesting effort is being made in systems science and soft science to establish new vehicles for information transfer. Systems science is trying to construct a general systems theory which generalizes and systematizes methods of various fields.

If it should be successful in any sense, then it is expected to serve as a common language or as an interpreter between different fields to some extent. On the other hand soft science which defines itself sometimes as an integrator of intellect (e.g., intellectual technology by Daniel Bell, Columbia University) organizes scientists in an ad hoc manner from various fields whose extent depends on each problem and therethrough provides a forum for information exchange.

Graduate School of Policy Science at Saitama University is aiming at integration of information science, economic science, political science, sociology and socio-psychology, and policy analysis in a systematic manner. This is also expected to serve as an information forum.

8. APPLICATION ORIENTED BASIC SCIENCE

The meaning of "basic" in the word of basic science is quite unclear. Physics is undoubtedly a basic science but some of its knowledge bases no other sciences and technologies because of its triviality. Whereas basic science is never characterized by triviality though it allows triviality as its unexpected byproduct of laissez faire type research. Basic science is expected to base other sciences and technologies and is accordingly to be applicable. In this sense the concept of application oriented basic science is never contradictory but consistent to the original meaning of basic science.

Another aspect of existing basic science is its elementality or element-orientedness. The first step of research procedure in existing basic science is to decompose the problem into elements, and their recomposition thereafter is practically often forgotten. Application oriented basic science is integration oriented in contrast.

A third aspect of existing basic science is its exactness seeking property while application oriented basic science does not sacrifice its integrality for exactness.

9. TURNING POINT OF SCIENCE AND TECHNOLOGY POLICY IN POSTINDUSTRIAL SOCIETY

After the prosperity of basic science (in particular, physics and mathematics) in 1940's and the beginning of 1950's, Japanese scientific investment focused industrial technology, in particular, production process technology since the mid 1950's. This was needed to get more industrized and to catch up with the Western countries in economic standard. A byproduct of this trend is to make people free from a traditional idea of respecting of basic science only.

Now that the Japanese industry catches up with the Western one, Japanese science and technology policy faces its turning point and is trying to shift its focus from production process technology to basic science and technology. This seems not to return the traditional basic science but to proceed towards some new interdisciplinary sciehces such as information science, life science, earth science, environment science, systems science, policy science etc. These new interdisciplinary sciences may be expected to form new disciplines under which students will be trained in the future and to occupy the central role in the coming scientific reorganization or scientific revolution.

Science has originally started from application and proceeded to theoretically systematized disciplines. If the same process should be repeated in the coming scientific revolution, the science policy which preempts these emerging fields may be desirable. An important key to successful science policy may lie in this preemptive effort.

Finally it must be mentioned that development of appropriate technology for developing countries will affect technology as a whole at a global level and that its management will accordingly be a key issue for international community.

STIMULATING THE DEVELOPMENT OF NEW FIELDS OF EXPERTISE

Bohdan Glowiak*, Tomasz Winnicki*

1. INTRODUCTION

The notion of scientific discipline may be understood in many different ways. That is why we still have difficulty in precisely defining the comprehension of the term of new fields of expertise discipline.

The ever increasing rate of scientific and technological development - which is, on one hand, due to the expansive progress in basic research and, on the other hand, to the high performance demands placed by mankind upon the developed new technologies-has caused that the development itself is characterized by a certain kind of ups and downs. There exist a number of disciplines which, irrespective of some stagnation in the field they are dealing with, attract many investigators and are equipped with modern technological devices. This situation is not only attributable to the stereotype in educating scientific staff who follow their Master and Teacher, but also to the shortcomings in information on the state-of-the art and current development trends of Science in general. At the same time, in the large area of Science and Technology, there appear more and more silent zones, which then continue to increase. The bridging of gaps and flaws discovered in the field of scientific activities proceeds very slowly, if at all. This is first of all due to the shortage in manpower, as well as to some major organisational and material shortcomings. Hence, a new field of expertise may be defined as a domain of research activity which does not meet the demand either of current development or applications.

There are no rules nor regulations to definitely localize deficit domains. Nevertheless, most of them are centred on the borderline between conventional disciplines; in other words, they fall in the range of interdisciplinary relations [1].

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New fields of expertise are characterized by certain shortcomings which may practically take the form of any of the factors affecting the course of a scientific activity. It has already been mentioned that deficiency in specialized manpower is most troublesome. But there are some additional shortcomings to be indicated here; such as unsufficient connections with related or complementary disciplines, lack of methodology, want of specialized equipment or specialized periodicals which could serve as a forum for the exchange of ideas and information.

On the other hand, new fields of expertise are characterized by expansiveness, dynamic development and lack of tradition. It is commonly known that the development of new scientific disciplines is of great significance; but two motivations prevail over the remaining ones. These are the lack of a strictly defined scope of cognitive activities and the arrival of current development trends to a critical point at which the so far theoretical knowledge, equipment and methodology appear to be unsufficient for stimulating qualitative or quantitative progress,

2. SELECTION OF AREAS OF INTERESTS

A careful consideration of organisational and personal factors indicates that the selection and identification of really new and missing areas in scientific work raise most serious difficulties. This problem should therefore be discussed prior to any other.

Two information sets must be analyzed independently and next compared, to determine basic trends of the missing research domain. One of these sets includes information on current achievements in the development of Science and Technology as well as some short- and long-term forecasts. The other one contains a system of local (nationwide, regional or organisational) preferences and realisational backgrounds.

The tasks resulting from the first information set are more troublesome than the remaining ones. The flood of scientific information has caused that a great number of important and stimulating literature reports from the area of the user's interest became unavailble.

Similar constraints occur in the domain of forecasting. Predictions most often consist in a logistic extrapolation of those developmental trends which are sufficiently known and precisely defined. Only a small number of forecasts (if any) are made for new development directions. The reason for it is that they originate spontaneously and are, therefore, sometimes owing to their non-scientific value, less readily distributed.

The selection of new research problems does not raise serious difficulties. Every nationwide or regional system, as well as individual organization have more or less precisely defined short- and long-range goals. The better is the system's organization, the more precise are its long-term goals.

It is just the most precise formulation of long-term goals which decides upon the development of new disciplines. The stimulation of the development of new fields of expertise should result from two initiatives complementary to one another - that of an individual who disposes of the first set of information, and that of political and economic organizations disposing of the second set of information and capable of modelling them.

This ideal situation can be defined as a congruence between the internal goals of the scientific organization and the external goals of the sponsors.

When developing new trends and disciplines it is advisable to deal with sponsors who are responsible for the policy and strategy in national economy, because they are neither interested in formulating short-term goals nor claim for quick investigation results and applications. Thus, the optimum and necessary conditions for developing a new scientific discipline are achieved.

In this country, research is being sponsored by a system of central entertainments of various priority. These fall into the following: the several Governmental Programmes of top priority, the several dozens of Nationwide Main Problems of over-ministerial level, and the hundreds of ministerial-level problems. In addition to the precisely defined goals, any of the Programmes mentioned gives considerable freedom to develop own work and activities. These governmental scientific and technological undertakings are, at the same time, sponsors of research which can (and should) include also new fields of expertise However, the decisions of the sponsors are most frequently influenced both by the achievements and by the manpower potential of the executer of research works. And this is the crucial point deciding on the initiation of new disciplines.

Similar sponsoring systems are encountered outside of Poland. This will be best illustrated on the example of interdisciplinary approach to environmental problems practised by the Scientific Committee on Problems of the Environment SCOPE [2] which is a constituent of the International Council of Scientific Unions (ICSU). Briefly, ICSU is an interdisciplinary and international scientific organization, speaking for:

- the 18 adhering unions (for example the International Union of Geography) and the 12 scientific associates (for example the International Society of Soil Science),
- the 66 adhering national academies of science, royal societies and research councils.

From time to time, ICSU establishes scientific committees, and gives th considerable freedom to develop their own work programs within designated interdisciplinary areas.

Such was the case in 1969 when SCOPE was formed, in response to the same environmental concerns as those that led to the 1972 UN Stockholm Conference on Human Environment.

The main activities of SCOPE at the present time are contained within seven project:

- biogeochemical cycles,
- dynamic changes and evolution of ecosystems,
- environmental aspects of human settlements,
- ecotoxicology,
- simulation modelling of environmental systems,
- environmental monitoring,
- communication of environmental information and societal assessment and responce.

In the last time scientific disciplines have become more and more specialized. Yet the environmental problems facing mankind are widening, and there has been increasing recognition of the need for interdisciplinary approaches to problem solving. For example, the atmospheric CO_2-greenhouse problem is being studied by a wide spectrum of specialists who in some cases are working quite independently of each other. Some of the topics under study are:

- inventories of fossil-fuel emissions and scenarios of future outputs (engineers and economists)
- models of the world carbon cycles (modelers, meteorologists, oceanographers, marine biologists, limnologists, and plant physiologists and microbiologists)
- models of climate change (modelers, meteorologists, oceanographers, hydrologists and glaciologists)
- models of the impact of climate change on mankind (meteorologists, sociologists, economists, engineers, forestars, and agronomists).

SCOPE is acting as a focal point for the specialists, facilitating interdisciplinary dialogue but always complementing rather then competing with the activities of the ICSU unions and other scientific committees.

Such interdisciplinary dialogues are often a starting point to the creation of new disciplines. Environment Engineering as a discipline has developed within the framework of the following sciences and specializations: biology, sanitary engineering, chemistry, chemical engineering, and the like. The scope and tasks of the new discipline were formulated in 1973, at the Congress of Polish Science. According to the definition accepted, Environment Engineering is a science of methods and techniques for pollution control in the particular environmental media with the aim to ensure optimum living conditions of man and stimulate a reasonable management of natural resources.

Pollution control is a term of a wide comprehension and includes not only environmental monitoring but also the control of pollution monitoring systems; not only urban planning but also an optimization of investments and environmental projects. Pollution control develops suitable models of pollution forecasting, deals with the modelling of technological processes and is aimed at reconstituting degraded environmental elements [3].

3. STIMULATING THE DEVELOPMENT OF SPECIALIZED MANPOWER

The high requirements placed upon Environment Engineering call for a careful and reasonable training of specialists skilled in two different fields such as, for example, meteorology and atmospheric or water chemistry; economics and gas purification technology or water treatment; town planning and models of pollution diffusion. This training is aimed to bridge a gap which appears in the periphery of Science, or to support a developing discipline which, as a matter of fact, can also be a new field of expertise.

One of the most important factors affecting the development of a new discipline is the necessary and sufficient number of specialized manpower capable of performing different activities as, for example, design, teaching, technological and theoretical studies, organization and management, etc. The number of specialized staff depends on the weight and importance of the problems studied. Nevertheless, the development of specialized manpower can be controlled by organizational intervention:

(1) invitation of experts from developed scientific or industrial centres (also foreign experts - UN, UNIDO, UNESCO, WHO),

(2) training own staff in other centres (graduate and postgraduate studies, advanced education, evening school, doctoral and postdoctoral fellowships, participation in Conferences, Congresses and other scientific meetings),

(3) specialized education and training at own institute.

Situation (1) is best illustrated on the example of developing countries (Africa, Asia). This is, however, a partial solution only, since the experts are invited to resolve a given problem in a given period of time. Hence they are not interested, either, in creating a field of activity or training specialized staff. The staff are not concerned with the problem of the expert's interest and confine themselves to help him, if he needs any help. Visiting fellows invited by a university develop teaching activities alone and have no opportunity to perform advanced training of the local manpower.

Situation (2) ensures a proper development of scientific skills to selected individuals but has the disadvantage that good results are not achieved until a long period of time.

Situation (3) appears to be best and is successfully applied under Polish conditions first of all in new disciplines. However, it is advisable that the following requirements be met:

(a) precise and accurate definition of the tasks and goals to be fulfilled by the research team involved in the development of a new discipline,

(b) careful selection of individuals who will be able to adapt their investigation methods and techniques to the needs of the new discipline, and

(c) speeding-up the development (both qualitative and quantitative) of the staff indispensible in the given discipline, in order to meet social expectations.

4. ORGANIZATION AND MANAGEMENT OF RESEARCH ACTIVITIES

To prevent confusion the following definition will be used for the purpose of this discussion. Organization and management of research activities will be defined as a system of those facilities and services of a scientific natur which provide a correct performance of the research process. The system itself depends on the level of research in the full R+D cycle and, from the "chronological" point of view, can be classified in the following way:

(1) Data collecting and selection of scientific information.

(2) Access to a computer system for the storage and processing of data and investigation results.

(3) Availability of apparatus.

(4) Competent and efficient planning.

(5) Administrative service.

(6) Effective material procurement.

(7) Specialized routine service (chemical analyses, biological tests).

(8) Design facilities for various stages of the R+D cycle.

(9) Facilities for the production of laboratory- and pilot-scale apparatus.

(10) Forum for the publication of investigation results.

When developing a new discipline, it is difficult to meet all the requirements listed above. Difficulties also arise when considering any of the elements which compose the system of facilities and services. The shortcomings of the system or of its components considerably influence the effect of scientific activity. The most neuralgic are those constituents of the system which refer to the selection of scientific information, to the decisions on the feasibility of the apparatus and instrumental equipment (purchase of new devices) and to the possibilities of publishing the investigators' own results with the aim to initiate indirect (through publications) or direct dialogues (at conferences, seminars and expert meetings) with specialists in many different fields.

The stimulation of the development of a given discipline requires that careful consideration be devoted to the critical constituents of the entire R+D service system. There are also some other factors which may indirectly affect the effectiveness of scientific activities such as accomodation, number and professional skill of the staff, location of the research unit in the nationwide settlement system, available non-scientific service (e.g., transport, store-rooms, social back-up facilities), and the like. Insofar as possible those factors should also be taken into consideration.

5. ORGANIZATION AND MANAGEMENT OF RESEARCH

It is not easy to construct an optimal organization model for research activities. Hence, we may limit our considerations to the following two types of research organizations: industrial R+D centres and university institutes. We are not authorized to conclude about the activities developed at industrial R+D centres; nevertheless there is some evidence that they are more ready to accept and tolerate a "stability" of the research problems in a certain group of workers than do university institutes. The research staff of university institutes combine teaching activities with scientific work; this is the reason for which "stable" structures will become a considerable disadvantage and shortcoming in the entire system, as they lead to routine both in teaching and research, and routine inhibits any developments and advances.

The development of new disciplines requires that the organization and management of research be conducted in a highly elastic manner. At modern university centres preference is given to the separation of teaching and research activities. The Technical University of Wrocław has introduced three independent systems involving the same scientific staff but organized on different principles. These are the system of teaching teams, the system of seminars and the system of research teams.

The system of teaching teams represents several specializations and is characterized by lowest turnover. The system of seminars serves as a forum for exchange of ideas and discussion of results. The staff involved in this system also exhibit a marked tendency to "stability" which results from the stability of their specialization. The system of research teams employs a certain optimal group of workers with the aim to perform and complete a precisely defined task. After completion of the research task the staff involved may or may not be turned over.

Having these in mind it is apparent that the systems of research teams and seminars are first of all responsible for the stimulation and development of new disciplines. The first stimulating impulse to the generation of a new discipline may come not only from the Scientific Counsil of the Institute but also from the research team (as a result of their studies) or from the seminar (as a result of discussion and exchange of ideas). No matter who was the inspirator of the idea, the idea itself must be first accepted by the representatives of the three groups mentioned, and then by the authorities of the University.

CONCLUDING REMARKS

(1) Both in the development of Science and in the application of achievements some spontaneousness and irregularities are being observed, which account for serious shortcomings of certain disciplines and developmental trends.

(2) It is crucial to discover those shortcomings as soon as possible in order to establish (on the basis of the current state-of-the-art) short- and long-term forecasts of the future demand for scientific activities.

(3) Stimulating the development of missing disciplines involves multilateral activities carried out both by the research institutes and by their sponsors responsible for the policy of the national economy.

(4) The system of activities associated with the stimulation of developing disciplines includes many different projects in the social and organizational domains; em hasis should be placed first of all on staff training and education which must be carried out prior to any other activity.

(5) The shortcomings of scientific activity manifest themselves most frequently in those areas which cover interdisciplinary research; interdisciplinary domains raise serious organizational and decision problems because of the superposition of real troubles and competence controversy.

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ENERGY EFFICIENCY AS A CRITERION FOR TECHNOLOGICAL SYSTEM EVALUATION*

G. Dobrov, R. Randolph, E. Nurminski

1. INTRODUCTION

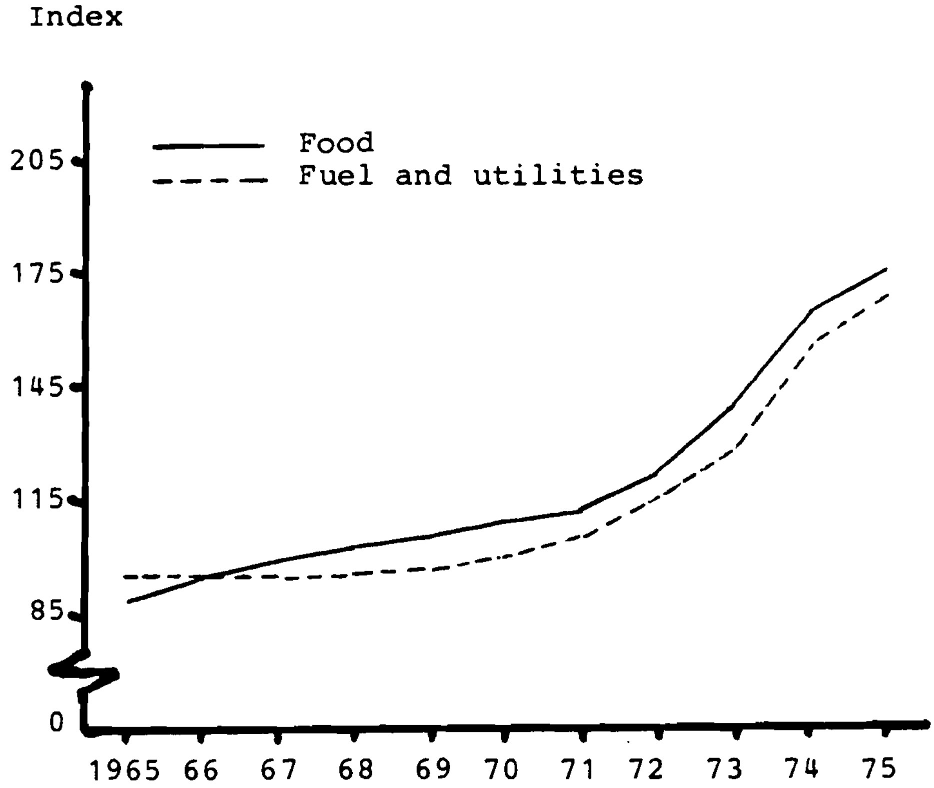
One of the main challenges facing technological policy makers today is to overcome the widening gap between two growth rates: that of the cost of new technological systems, and that of their usefulness. Successive generations of technology in many fields achieve greater output capability only at the expense of even greater (and often wasteful) resource use. The challenge then is to change the patterns of technological change, to begin selecting technological options which promote intensive utilization of resources through optimal exploitation of the technologies' inherent properties and possibilities--in short, to begin improving the efficiency of resource use.

This challenge has become increasingly urgent in recent years because of shortages and price rises for many key resources. As we see it, the world faces a "3F" crisis--a shortage of Food for people, Fertilizer ("food" for land), and Fuel ("food" for machines). These three shortages are intimately interrelated and cannot be adequately understood in isolation. Figure 1 vividly illustrates the economic contours of the problem, corresponding closely with Leonard Silk's generalization:

> The crisis stems not from a deficiency of demand but of supply, the most dramatic manifestations of which have been shortage of food and soaring food prices, and shortages of oil and soaring oil prices.[2]

Although the increasing sophistication and resource demands of modern technology play an important part in this drama, a moratorium on technological advance would not solve the problem. Much more promising is the idea of developing truly appropriate technological systems, systems which are carefully organized for maximum efficiency and which include a comprehensive set of appropriate components.

* This is a working version. An improved version will be published at a later stage as an IIASA report.



Source: [3]

Figure 1 CONSUMER PRICE INDEXES, 1965-75

As we shall see in Section 5 below, there is no dearth of proposals for technological options by which to attack the resource-efficiency problem. It is not so easy, however, to evaluate such options adequately. True, a number of sophisticated analytic techniques and algorithms have been developed for performing such evaluations, taking into account the resource criterion among others (e.g., [4]). But there can still be problems: how to measure or predict the resource-use characteristics of a given option, how best to measure output (in terms of what product characteristics), how best to deal with choice criteria other than resource efficiency (e.g., stability of output under changing conditions, technical feasibility, economic feasibility, managerial requirements, risk). Also it seldom happens that any one technological option is sufficient by itself, a proper mix of options being preferable. Even if a promising option or mix of options can be identified, the evaluation must deal somehow with the very real deterrents to adoption of an innovation which arise even when it is demonstrably superior to existing practices.[4,5] To compound matters even further, long-term evolution of technologies is clearly affected by changes in factor prices, marginal value products of factors, and elasticity of substitution, which in turn may well be affected by technological change! [6]

In view of all these complexities, we believe that improved models and methods are needed for the formation and assessment of optimal mixes of technological options, in the name of long-range effective technological policy. Static assessments based on current circumstances (e.g., energy prices, wage rates, commodity prices, regulatory policies, etc.) simply may not be valid in the long term, since even slight changes in such circumstances may abruptly reverse the relative profitability of options. [7] In short, there is an urgent need for full-scale study of the interplay between changes in technology and changes in these circumstantial variables. All of these variables are related in complex ways and it is impossible to foresee or regulate their future course without examining their dynamic interactions. For purposes of technological policy design, the thrust of such research would be to permit prospective assessment of the appropriateness of various technological options, based on forecasts of future circumstances of relevant kinds (socio-economic, scientific, etc.).

Many separate methodological contributions would be needed to make such complex analyses possible. In this paper we shall consider only one small part of the overall problem, though an important part: the need for measures by which to evaluate the long-range effectiveness of technological systems. Recognizing the gravity of the resource-efficiency crisis mentioned earlier, we propose that resource input/output efficiency be considered as one such effectiveness measure. And to facilitate aggregation of data about resources of various kinds, we propose that all such data be translated into energy terms. In order to investigate the possible value of these proposals, we shall try applying them to a particular example of an evolving technological system--that of maize production.

In short, the purpose of this paper is to explore the usefulness of energy input/output efficiency as an integrated measure of the appropriateness of technological systems, taking as an empirical example the current and future trends in agricultural technology, with maize production technology as a specific case.

2. EVIDENCE OF THE PROBLEM

2.1 The World Food-Energy Dilemma

To begin with, we must understand the agricultural energy-use problem in some detail. As we shall see, there is ample empirical evidence that increases in world food output in recent decades have been achieved primarily through even more rapid increases in the corresponding inputs of fossil energy. This type of "progress" is recognized to have a dubious future, and it is for this reason that new technologies evaluated in new ways are urgently needed.

The essence of the situation is this: since most of the world's readily usable fertile land is already under cultivation, expansion of food output by increasing harvested acreage has been possible only to a very limited extent. Therefore growth in output has depended primarily on growth in yield. This in turn has been achieved through technological changes which have involved increased application of inputs based on fossil energy (chemicals, machines, fuel, etc.).[8] As M. Slesser has aptly put it,

> . . . rising intensities of food production pay the resource cost of steeply rising intensities of energy use, and hence of total energy use.[9, p.129]

Data for the United States (Figure 2) clearly demonstrate this overall trend, which numerous authors consider to be <u>the</u> fundamental change under way in world agriculture today.[8,9,10,11]

The fact that the yield-enhancing technological changes have required ever-greater energy <u>intensity</u> is only part of the problem, however. Even more serious is the fact that they have failed to improve energy <u>efficiency</u> and indeed have allowed it to decline. In other words, agricultural production methods developed in recent decades have required an ever-higher "energy subsidy" (the amount of fossil energy inputs required to produce a unit of food energy output). Changes in agricultural technology (including genetic improvement) have <u>not</u> increased the food output obtained from a given level of energy inputs; all they have done has been to accommodate increased "throughput", allowing more energy inputs to be productively employed per unit land.

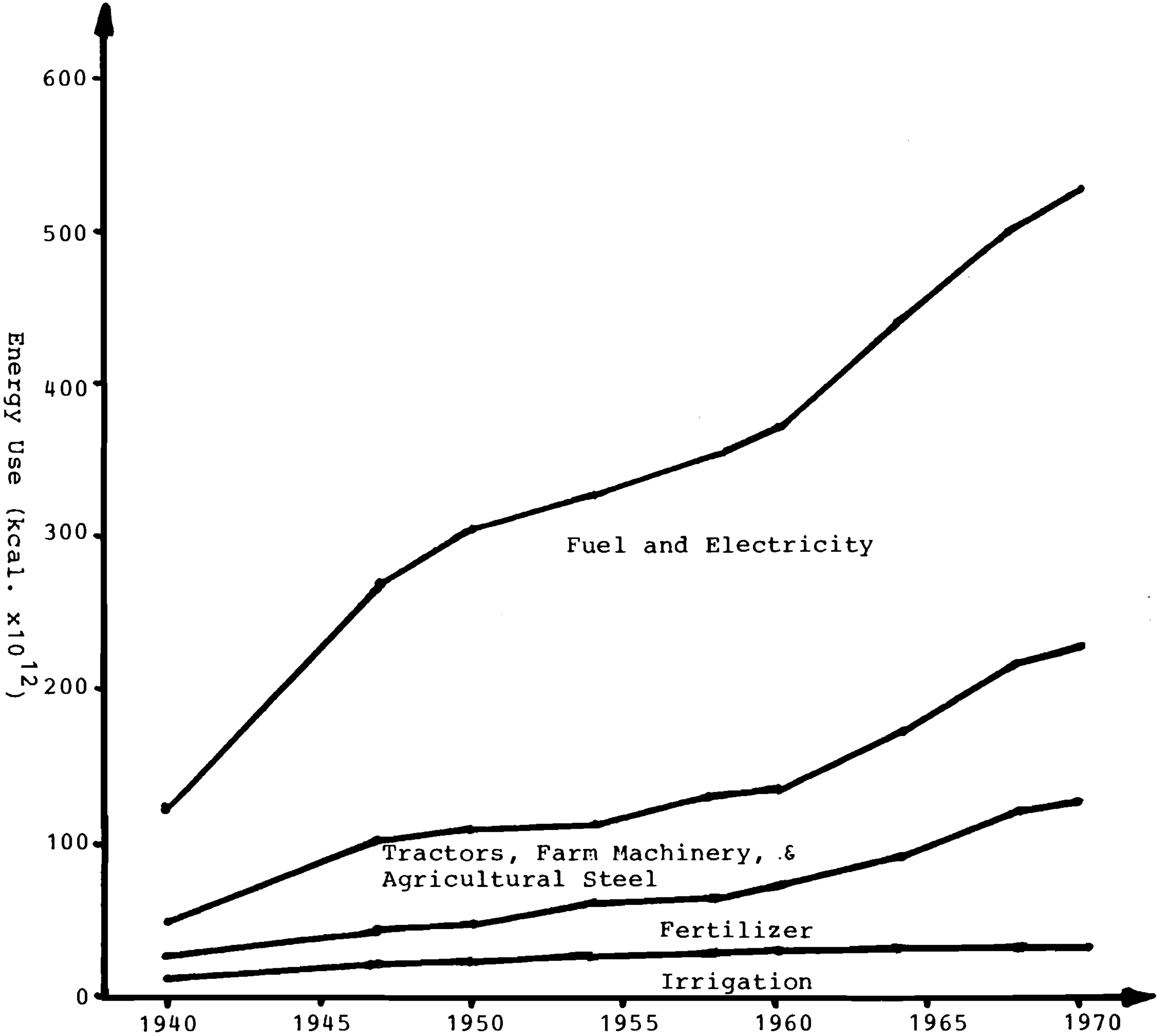


Figure 2 ENERGY USE IN UNITED STATES AGRICULTURE, 1940-70

(Derived from [11, p.309])

It can be argued of course that a high energy subsidy is not necessarily such a bad thing. This might be an acceptable situation if we view agriculture as a mechanism for converting energy from one form (e.g., oil) into another (i.e., food).[9;12, p.25] After all, one cannot eat oil. But from a global perspective, this path for agriculture has to be reassessed in the long run. For developing countries, scarcity and high cost of energy-based inputs are already a serious barrier to the use of energy-intensive technologies (indeed this is seen to be the basic flaw in the original "green revolution"). And even for developed countries, the growth of energy intensity is an ominous trend because of diminishing returns and the virtual certainty of future energy cost increases.[11;13, pp.59-62] Thus the problem of maximizing energy efficiency cannot be ignored.

As a limiting factor on agricultural output, energy is of course not the only problem today--climatic changes, environmental constraints, and water supply being equally serious in many cases. [13, pp.53ff;14] But it could be argued that the solutions to such other problems will require expenditure of energy, so that even they can be interpreted in energy terms.

2.2 The Example of Maize

About 70% of mankind's food calories originate in grain.[15, p.11] "Coarse grains" are the most important, constituting roughly 52% of all cereals. And among the coarse grains, maize is by far the most important, representing over half of total production.[13, p.31] In short, maize figures very prominently in the world food-energy output situation.

Current forecasts suggest that this general situation will persist through 1990 at least.[16] Production of grain in general and maize in particular will continue to grow more rapidly than world population, thus helping to explain the continuing growth in daily per-capita food consumption (see Table 1). Thus the long-term importance of maize seems assured.

Table 1 MAIZE PRODUCTION IN CONTEXT, 1963/65-1990

TREND	1963/65	1972/74	1990	ANNUAL GROWTH %	
				Historical	Projected
POPULATION (mil.)	3227.0	3820.0	5201.6	1.9	1.8
FOOD CONSUMPTION					
Cal/capita/day	2455	2535	2730	0.4	0.4
Kg/capita/day	1.33	1.41	1.53	0.7	0.5
GRAIN PRODUCTION (mil. tons)					
Total	1011.5	1329.6	2041.3	3.1	2.5
MAIZE	221.6	303.3	458.7	3.6	2.5

Source: Adapted from [16].

Unfortunately, current and projected trends in maize production and consumption demonstrate an imbalance among world regions in their ability to satisfy their own maize consumption needs out of domestic production (Table 2). The underlying assumption here is that in many countries maize production will not be able to increase rapidly enough to match demand, and the reason for this in turn is that growth of yields will be slower in future than in the past. And why should this be? In developed countries it will be partly because of "declining returns to yield-enhancing production inputs"[16, p.13], but in both developed and developing countries it will also be because of the resource shortages and price increases that we have already seen.

In point of fact, maize will probably not suffer from these input problems as much as some other crops will. Relative to other food groups, maize has a moderate to good level of energy efficiency. This is so because, although its level of energy intensity is extremely high when the most developed technology is used, the energy content of the mature corn plant is also extremely high. Thus the energy subsidy for maize is actually lower than that for many other commodities (0.2-0.5 calories of energy input

Table 2 MAIZE PRODUCTION AND CONSUMPTION, 1963-90, BY REGION

(million metric tons)

REGION	1963/65			1972/74			1980			1990			ANNUAL GROWTH*	
	Prod.	Cons.	Net Imp.	Prod.	Cons.	Net Imp.	Prod.	Cons.	Net Imp.	Prod.	Cons.	Net Imp.	Prod.	Cons.
North America	99.5	87.2	-12.3	137.1	109.4	-27.7	158.3	124.9	-33.4	192.2	151.5	-40.7	2.0	1.9
Latin America	28.4	25.0	-3.3	37.7	35.0	-2.7	44.8	41.7	-3.1	58.2	54.0	-4.2	2.6	2.6
Europe	38.1	51.3	13.1	55.7	78.1	22.5	68.3	96.5	28.2	94.0	128.7	34.7	3.1	3.0
Africa-Mideast	17.2	16.2	-1.0	24.6	22.9	-1.7	29.7	27.4	-2.3	38.7	36.0	-2.7	2.7	2.7
Asia	38.3	40.7	2.4	48.0	56.8	8.8	57.5	66.7	9.2	74.8	85.9	11.1	2.6	2.5
Oceania	.2	.2	-	.3	.3	-	.5	.5	-	.8	.8	-	5.9	5.9
World	221.6	220.6	-1.0	303.3	302.5	-.8	359.1	357.7	-1.4	458.7	456.9	-1.8	2.5	2.5

* Annual growth rates refer to the period between 1972/74 and 1990.

Source: Adapted from [16].

required to produce one calorie of output, depending on intensity). [11, p.312]

Nevertheless, maize production technology has suffered the same dilemma of decreasing efficiency that we have discussed above. As output of maize per hectare has risen over time, energy inputs have risen even faster. [17]

The extent to which the energy-efficiency problem afflicts maize technology is clearly illustrated by the fact that R.C. Liebenow--who is a well known expert and President of the Corn Refiners Association--considers scarcity of energy-based inputs to be one of the two main problems facing maize production today (the other problem being the risk of catastrophic loss through drought, disease, pest damage, and microbial contamination).[10] Essentially the same opinion has been expressed by Deere & Co., one of the world's leading firms in the area of maize-related engineering. As they see it, there are three main groups of factors that will shape the technology of maize production in the United States in the future, and two of these are closely related to energy efficiency: (i) "the energy situation, particularly future cost and availability of portable fuels" and (ii) "continuing efforts to increase overall efficiency of agriculture from the standpoint of cost, choice of cultural practices, yields and net income". (The third set of factors relates to pollution legislation.) [18]

3. THE "EE" PARAMETER AS A SYSTEM CRITERION

As a modest first step toward the comprehensive assessment of technological systems in light of the problems described above, we suggest that technological system options be evaluated in terms of energy input/output efficiency ("EE"). This parameter, which some authors refer to as the "energy ratio", is defined thus:

$$EE = \frac{\text{energy output}}{\text{energy input}} ,$$

where both output and input are measured in kcal. per year per hectare.

There are numerous facts which justify our in-depth interest in this criterion. For example,

- on the world scale, an estimated 25% of all fossil fuel use is for food-related purposes; (cited in [19])
- in developed countries, the food sector ranks third in general consumption of energy (after steel and petrochemicals).[20]

In other words, the level of energy efficiency in a country's agricultural sector may be expected to have a non-trivial effect on that country's overall energy balance.

Our understanding of the EE criterion and of the types of analysis to which it may lend itself becomes more complete when we reflect on the complexities of the overall agricultural "system" within which agricultural technology is developed and utilized. As we see it, agricultural production actually involves the interaction of three subsystems, three kinds of potential, three kinds of inputs (Figure 3): Economic, biological, and technological. Changes in the EE parameter over time are caused by changes both within these subsystems and in the relations between them--in particular, by changes in:

(1) the specific technological options used,

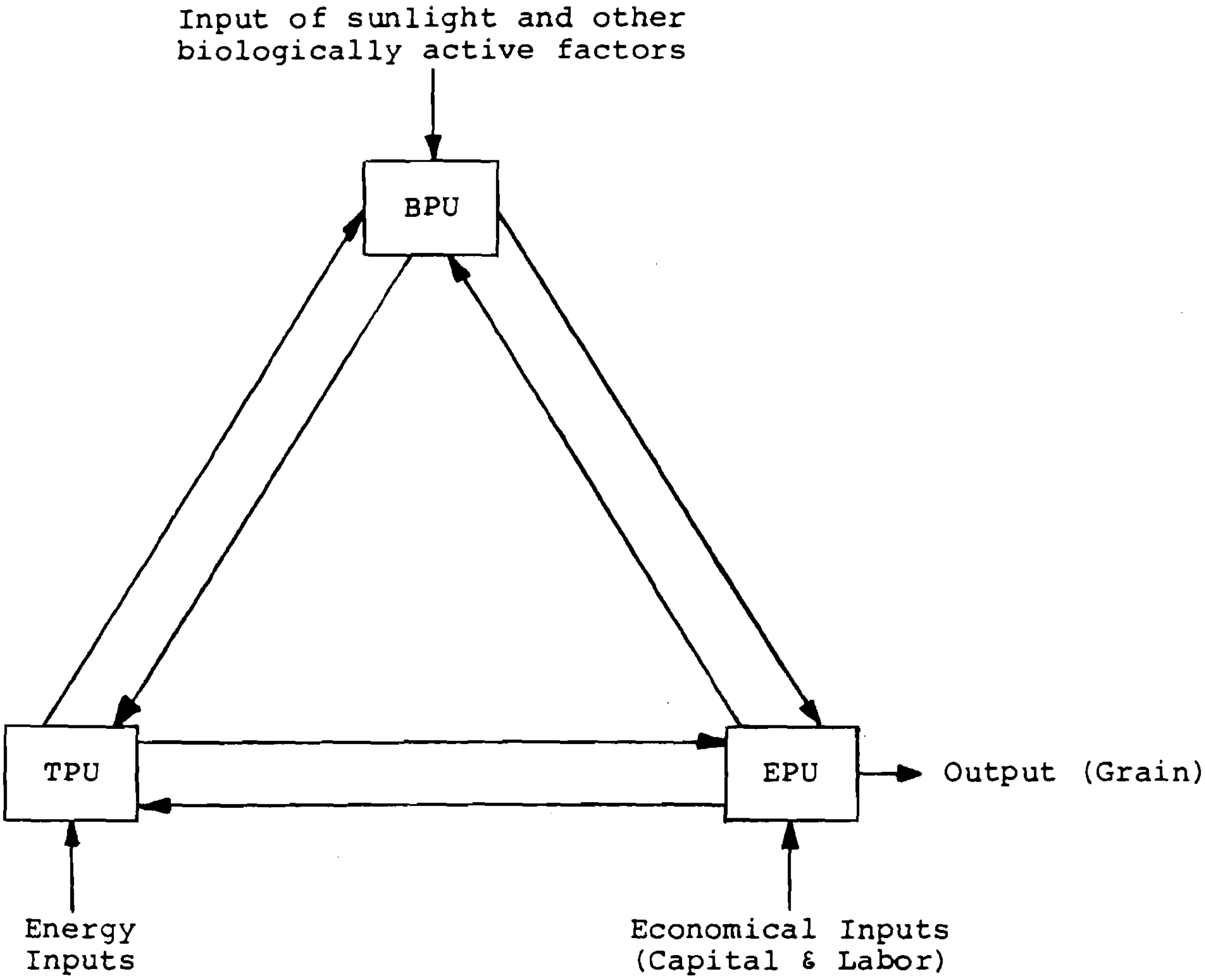
(2) the attained level of biological knowledge and its application,

(3) the levels of prices and other economic constraints,

(4) the impact of technology on biological and economic potential utilization and thus indirectly on output,

(5) changes in the cost of utilizing technological potential, as related to changes in overall system productivity, and

(6) special demands which the biological characteristics of of the commodity to be produced and also the prevalent socio-economic constraints place upon the productivity, reliability, adaptability, and energy consumption of the technological means employed.



BPU = Biological Potential Utilization,
TPU = Technological Potential Utilization,
EPU = Economic Potential Utilization

$$EE = \frac{E\ output}{E\ input} = \frac{cal^{*} \cdot ha^{-1}}{Cal \cdot ha^{-1}} = \frac{Benefit}{Cost}$$

EE = Energy Efficiency
cal* = Edible calories of food
Cal = Mix of mainly non-edible calories of energy

Figure 3 SUBSYSTEM INTERACTIONS IN THE AGRICULTURAL PRODUCTION SYSTEM

Note, by the way, that items (1)-(3) correspond respectively to the "hard" part of any production system in general, to the "soft" part (which provides the "methods of doing"), and to the "org" part related to the institutional and economical regulators of system performance. Items (4)-(6) represent interactions among the system's hard, soft, and org aspects.

Although higher EE may be useful as a guide for future policy concerning all of these system components and interactions, we must remember that efficiency alone is not a complete success measure for production systems. There are, after all, some primitive agricultural systems which have high EE but low overall output and which therefore do not provide adequately for people's food requirements. And yet even here, future policy should aim at maximizing both food production as well as efficiency of using all resources needed for it. In short, regardless of the present developmental level of the agro-technology system in question, EE is an important integrated criterion for evaluation of proposed system changes.

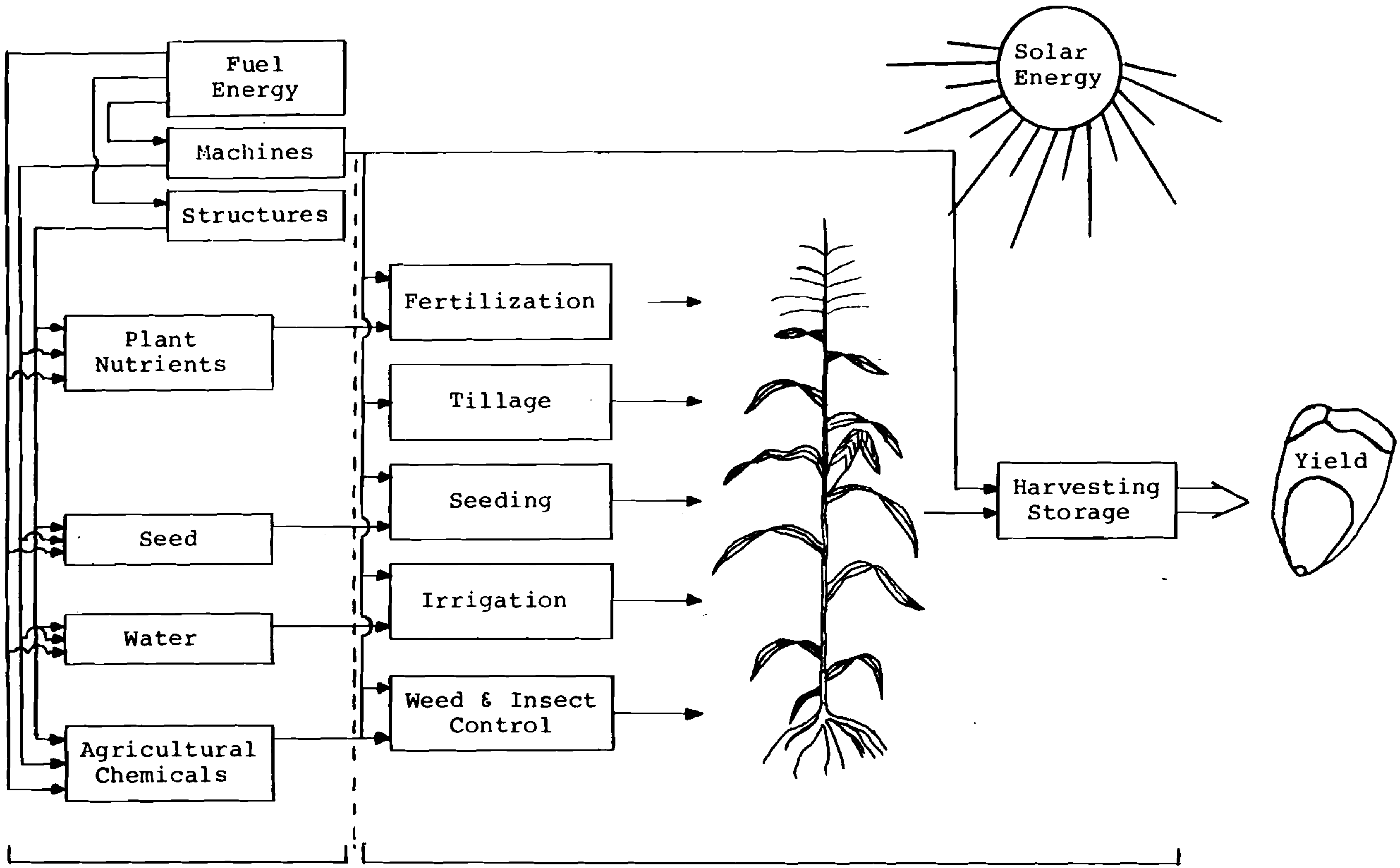
4. STRUCTURE AND DYNAMICS OF EE: THE MAIZE EXAMPLE

It has been computed that to grow an average yield on 4 ha. of maize plantation by "modern" methods takes as much energy as to build a six-passenger modern automobile ($\sim 30 \cdot 10^6$ kcal).[21] The yield of maize received from those 4 ha. (18-20 mt.) provides about $75 \cdot 10^6$ kcal of edible energy. Thus EE is about 2.5.

Let us look at the structure and flow of the energy subsidies and returns in this case. The technologically required flows of energy input are represented in Figure 4, with quantitative details shown in Table 3.

In the past 30 years, the following components in the structure of energy expenditures on maize production have grown especially rapidly:

- fertilizer--growth more than 10-fold
- irrigation--growth more than 7-fold
- transport--growth about 4-fold
- agricultural machinery--more than 2-fold.



Source: [20, p.65]

Figure 4 THE FLOW OF CULTURAL ENERGY REQUIRED BOTH ON AND OFF THE FARM TO PRODUCE RAW FOOD AND FEED COMMODITIES

Table 3 THE ENERGY STRUCTURE OF CORN PRODUCTION

(kcal $x10^3$ per hectare)

	1945	1950	1954	1959	1964	1970	1975
Labor	30.9	24.2	23.0	18.8	24.8	12.1	9.2
Machinery	444.4	617.2	740.7	864.2	1037.0	1037.0	1139.2
Gasoline	1341.6	1520.4	1699.4	1788.8	1878.2	1967.8	2100.0
Nitrogen	145.2	311.1	560.0	850.3	1202.9	2322.8	1943.0
Phosphorus	26.2	37.5	44.9	60.0	67.6	116.3	230.0
Potassium	12.8	25.9	124.4	149.1	167.9	167.9	176.0
Seeds for Planting	83.9	99.7	46.7	90.1	75.0	155.5	146.2
Irrigation	46.9	56.8	66.7	76.5	83.9	83.9	780.0
Insecticides	0	2.7	8.1	19.0	27.2	27.2	81.3
Herbicides	0	1.5	2.7	6.9	10.4	27.2	145.2
Drying	24.5	74.1	148.1	246.9	296.3	296.3	375.0
Electricity	79.0	133.3	246.9	345.7	501.2	765.4	380.0
Transportation	49.4	74.1	111.1	148.1	172.8	172.8	180.0
Total Inputs	2286.0	2978.6	3822.8	4664.4	5535.2	7152.2	7685.1
Corn Yield (output)	8461.8	9457.2	10203.9	13439.3	16923.5	20158.9	18771.1
EE	3.70	3.18	2.67	2.88	3.06	2.82	2.44

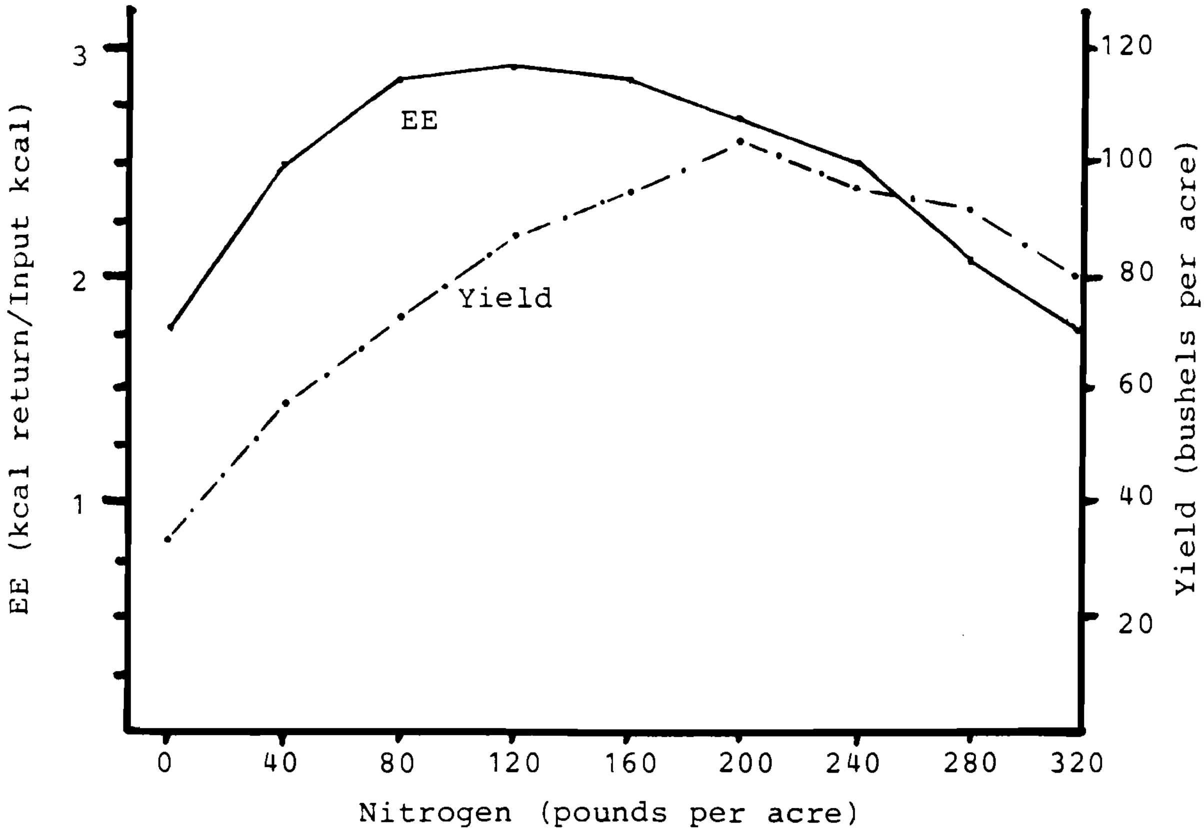
Source: 1945-70 [17]; 1975 [19].

In U.S. practice, energy inputs into maize production have grown 3.15 times while the corresponding output has grown only 2.4 times. Thus EE has declined from 3.70 to 2.44--that is, by more than 50%.

These dynamics and the underlying structure of energy inputs to maize production are a regular consequence of the agro-technological policy pursued in all these years and in all of the "advanced" maize-producing countries--the policy of "grow or go" (that is, produce of else!). By this approach, the needed growth of maize production was obtained at the expense of an even greater growth in energy expenditures. In fact, the most rapid growth has been in precisely those inputs which are most energy-intensive. Even such a notable achievement as the introduction of hybrid seed varieties was directly oriented toward biological realization of concentrated use of fertilizer and irrigation--that is, some of the most energy intensive elements of the production technology process.

In the second half of the 1970's, we have recognized not only the anxiety-provoking connections between this policy and the general growth of prices, stimulated by a fundamental revision in world prices for oil and other nonrenewable resources. It is important to emphasize also that, in addition, both research and practical experience have shown that biological possibilities for realization of concentrated energy inputs have obvious limits (see Figure 5) and can be sharply increased only on the basis of increase in the efficiency of biological processes of photosynthesis and a complex of cytological and morphological changes--i.e., all of that which can form the content of a new stage in the true "green revolution" as distinct from the "black (oil-based) revolution on green fields".

In these same years, the search for alternative scientific-technical options in maize production has been stepped up, relating not only to new agro-biological options ("software") but also to engineering options ("hardware") which allow new production processes to be carried out, and to innovations in the organizational (socio-economic) approaches to the use of these scientific-technical possibilities ("orgware").



Source: [17]

Figure 5 MAIZE YIELD AND ENERGY EFFICIENCY WITH VARYING AMOUNTS OF NITROGEN

All of this must certainly lead (and is already leading) to structural changes in the energy balance of maize production technology, which in turn will be an expression of a new generation of ideas in organized agro-technology, connected with the principle: "change and grow, or go" (i.e., improve resource efficiency or else!). In an expanded form, this principle can be formulated in the following way:

> Provide for growth in the quantity and quality of grain production by systematically improving all components of organized agro-technology and by increasing on this basis its energy efficiency and economic effectiveness in relation to both fixed and variable "subsidies" (inputs) into the technological system.

5. EE TREND ANALYSIS: PATHS INTO THE FUTURE

The future is always a continuation of the present, in the sense that necessary changes will be changes in current tendencies and future innovations will be new precisely in relation to the experience and possibilities accumulated up to now. This assertion is especially justified when we are discussing the future of complex and large-scale systems which contain smoothly evolving elements related to naturally conditioned subsystems. And the system we are studying--that of maize production--is a system of this type.

We think therefore that any attempt to understand the possible future evolution of the maize production system should begin by seeing what would happen if the same patterns of change observed today were to continue in the future. This is the "business as usual" scenario, not of course in any static sense of preserving today's technology but rather in the dynamic sense of preserving today's evolutionary trends. There can be no doubt that change of some kind will continue in the future; the question is what kind. And by projecting present trends into the future, we can establish a "base line" from which to develop hypotheses about alternative "paths into the future".

5.1 Base-Line Projections

By applying the "linearization" method to the time-series data discussed in Section 4 (Table 3), we obtain the "business as usual" projections of our data on the various forms of energy inputs used in maize production in the U.S.A. (See Figure 7.) Naturally the corresponding trends for other countries would be somewhat different, but we suspect that roughly the same general patterns would apply in most developed countries, only the time scale differing significantly.

Figure 7 shows that if present trends were to continue, then labor use in maize production would drop to about zero before the end of the next 20 years while the use of all other technological inputs would continue growing very rapidly. We see at once that this "scenario" is impossible, which reinforces our belief that qualitative alterations in the patterns of change are inevitable.

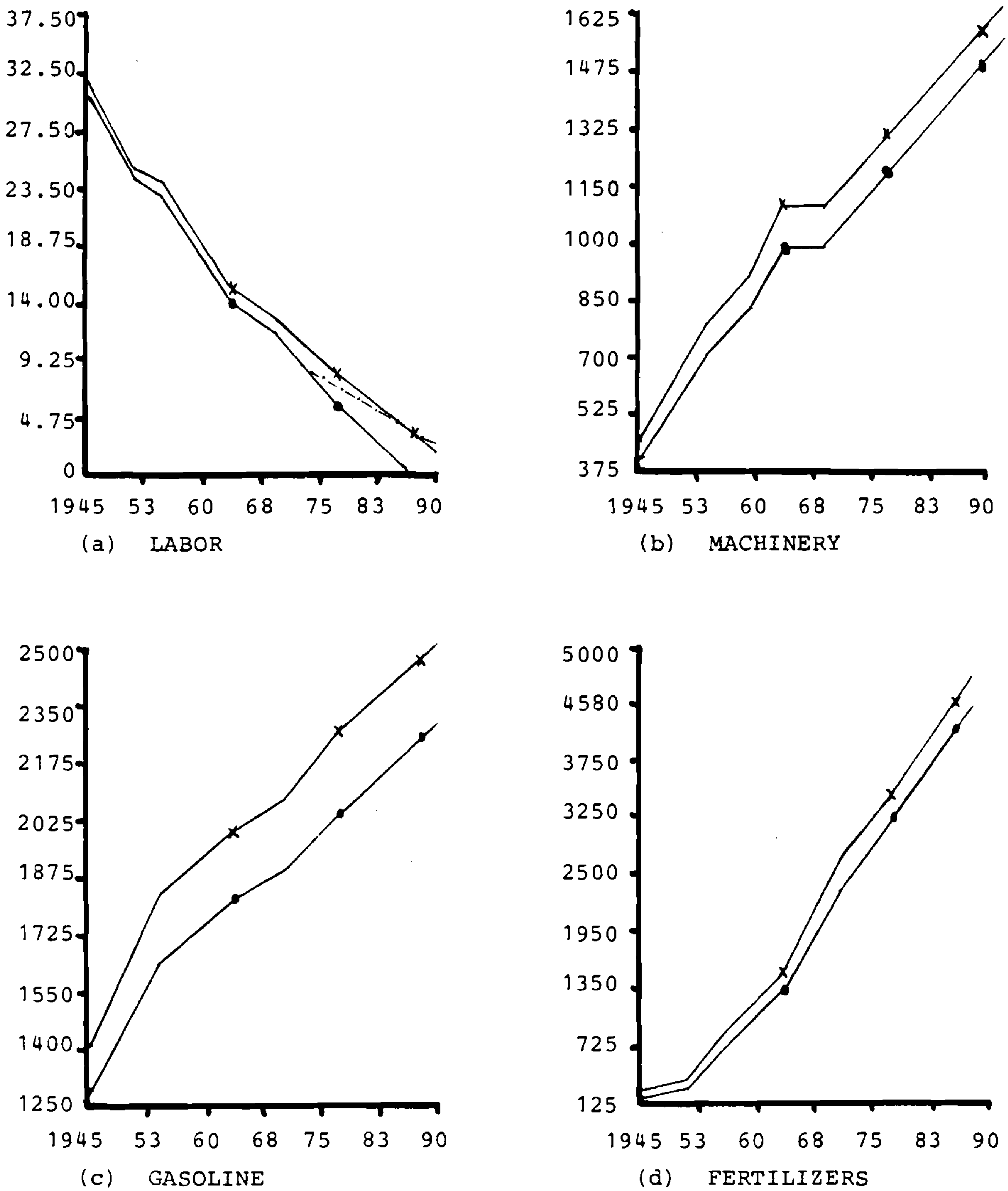


Figure 7 <u>BASE-LINE PROJECTIONS FOR SELECTED COMPONENTS OF EE</u>

Not only is the decline in labor use sure to taper off soon, but also the growth of other inputs cannot continue indefinitely at the present rates. As we have already discussed in an earlier section, resource shortages and high costs will surely call forth appropriate technological innovations--new technological options which are not only agriculturally effective but also energy efficient.

Table 4 shows our base-line projection of energy efficiency in maize production. This steadily declining trend shows quite clearly the need for alterations in the present patterns of technological change.

5.2 Technological Possibilities for Deflecting the Trends

What sort of innovations might we hope for that will improve the above-described situation? Can we visualize ways in which current trends in the various structural elements of energy efficiency could be altered for the better?

To begin with, we should note that numerous authors have suggested specific technological changes which might, in one way or another, help to solve the overall food-energy dilemma. One class of options, inspired by the idea "small is beautiful" as an alternative to the approach (popular in most developed countries) "the bigger the better", seeks to provide inexpensive ways of reducing agricultural demand for fossil energy supplies--e.g., through increased use of windmills and windmotors, water wheels and small water turbines, steam engines, motors fueled with generator gas or plant oil, etc.[7;22;23, pp.61-2] Another set of options is designed to reduce agricultural energy demand altogether

Table 4 BASE-LINE PROJECTION OF ENERGY EFFICIENCY OF MAIZE PRODUCTION TECHNOLOGY

	1945	1950	1954	1959	1964	1970	1975	1980	1985	1990
EE	3.7	3.2	2.7	2.9	3.1	2.8	2.4	2.8 - 2.1	2.7 - 1.9	2.6 - 1.8

by reducing energy intensity (e.g., by increased use of manure, crop rotations, and interplanting, instead of mineral fertilizers and other chemical treatments; "minimum tillage" to reduce fuel usage or, alternatively, increased tillage to reduce herbicide use; etc.).[4;7;24;25; and many others]. Options in this class typically involve factor substitution (e.g., labor instead of fuel) rather than true increases in efficiency (by which we mean increases in output from a given set of inputs). Finally, there is a class of options which are in fact aimed at improving energy efficiency per se. Such options include steps to optimize the efficiency of photosynthesis, maximize the use of plant energy once it has been fixed, minimize the use of wasteful infrastructures, rationalize the timing and organization of farm-related activities, etc. (e.g., [24]).

Let us now reconsider our "business as usual" projections in light of these potential innovations.

In the case of labor consumption, we have already seen that the rate of decline is sure to become more moderate. Some further savings in labor input per unit land will probably be obtained, however, through further improvement in the quality and efficiency of machinery utilization, elimination of some steps in the production process, etc. Labor use may be expected to decline more-or-less asymptotically toward a final level determined by the economic and agro-biological conditions in the given country. No absolute <u>increase</u> in labor use is likely until and unless the costs of other inputs rise substantially relative to wage rates; this we suspect is unlikely in developed countries in the immediate future, since increases in the costs of other inputs may well either cause or be caused by wage increases. And even if factor cost changes favoring increased labor use <u>were</u> to occur, the corresponding changes in farm practice would not happen overnight.

We should note, by the way, that changes in the quantity of labor input are not the only expected influence of labor on the structure of EE. Perhaps even more important are the quality and organization of work, particularly the timeliness with which various production steps are performed and technical means applied, relative to the life cycle of the maize plant.

The largest and also the most rapidly growing general category of energy use in maize production is that of fertilizers, which must therefore be seen as the first-ranking factor affecting EE. Economic constraints on the further rapid growth of this trend will stimulate a more and more active search for effective ways of replacing industrially made fertilizers with biologically made ones (through crop rotations and eventually perhaps the development of nitrogen-fixing maize plants).

Another very rapidly growing family of energy inputs is that of machinery and the fuels and electricity necessary for operating it. The "low- or no-tillage" approach can reduce this kind of energy subsidies, though of course it imposes new demands of its own (e.g., for increased herbicide use, with corresponding energy costs and pollution hazards). The demand for protection of soil against erosion gives additional stimulus for development of this option. Fuel and electricity demand will remain high, however, for purposes of irrigation, since the problem of instability in precipitation is a serious one for some important maize-growing countries.

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MANAGEMENT INFORMATION SYSTEMS FOR SCIENTIFIC AND TECHNICAL PROGRESS

D. Bobryshev, D. Chereshkin*

At present, the management of scientific research in the USSR involves a much wider implementation of a system approach both in theoretical analysis of problems as a whole, and a complex decision of applied problems in particular. The system approach to management in the field of science and technology requires to carry out research in many interconnected directions and should be based on common principles typical to socialist society. In the Soviet Union the development of management techniques and systems is tightly bound with solution of general management problems of all people's economy and being accomplished within the specialized program for further improvement of management of research, development and implementation of new technology.

The general concept of the program involves the system analysis of management problems, the development and determination of decision-making process as well as close interaction of decisions taking in the given area and those in other branches of the people's economy.

The concept is practically realized through the development of a number of mutually connected measures in accordance with main goals of research at different levels of management system hierharchy in order to provide the management of the whole "research - production - implementation" cycle of scientific and technological achievments in the people's economy.

One of main measures to improve the management in science and technology is to utilize a project management approach; by this we mean a management aimed to achieve the project final goals provided

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that local components of the final goal (concrete tasks) are to be accomplished in the defined time frames. By nature, the project management is complex and demands the use of the system approach in considering all managerial aspects, studying the interconnection of individual factors and making decisions only on the basis of factors mutual effect evaluation.

Now in the USSR the methods of the project management are widely used and we become more proficient in managing production units, for example the Bratsk-Ilimsk production complex, etc. The management methodology of scientific and technical projects is especially important at presant, therefore much attention is paid to its development. One of the most significant methodological problems is that connected with the research and development of management information systems (MIS's). To realize main principals of the project management, comprehensive information necessary for making decision at all management levels should be available. The preparation of such information, its processing and presentation in the form convinient for decision making are the main goal of the MIS.

To develop MIS's the system approach should be used which allows to consider the problem as a whole, define the interface of the given system with the others, single out primary components and again integrate a whole system.

First of all, main information system requirements should be highlighted in order to determine its parameters. The requirements depend upon data processing procedures at every stage of the project life cycle, as well as the structure of information used. The life cycle of any project can be subdivided into the following stages: goal definitions, planning and realization. The first stage involves fulfilment of poorly defined procedures, for example determination and definition of main goals, their decomposition, selection and evaluation of alternative decisions concerning achievement of goals and resources required, as well as evaluation of individual projects participants' capabilities.

The information used to fulfil these procedures is qualitatively expressed and connected with political, social, economic and ecological aspects of the discussed scientific project, analysis of fundamental scientific studies and their further evolution, feasibility of fundamental studies results and different technologies. The utilization of poorly defined information and the necessity of fulfilling special procedures for its processing justify specific requirements to MIS at the stage of goal definition. These requirements include:

- necessity of continuous data correction, use of experts' estimates, subjective estimates input;
- creation of specially organized data bank, containing real facts, descriptive materials and addresses which show where (i.e. data banks of other organizations) the necessary information is stored;
- possibility of access to the information addresses of which are stored in the MIS data bank.

To satisfy the above mentioned requirements the system must

- provide man - machine dialogue,
- provide computer - to - computer data transmission,
- have advanced and adaptive software to solve simple but specialized tasks,
- have advanced peripherals to allow access to computer for a non-professional user,
- provide rapide calculation of many variants with random change of parameter values.

It is necessary to point out that at present MIS's, which are in operation or being developed do not fully meet these requirements. However, the analysis made defines the qualitative peculiarities to be taken into account in the process of further development and improvement of the current systems.

The stage of planning for any project supposes the fulfilment of some procedures connected with drawing plans, their correlation and correction, as well as others well defined and being carried out now. Information used at this stage is usually perfectly defined and already documented. The MIS's widely used in the USSR at the present time fulfil practically all data processing procedures at the stage of planning. This stage does not impose any specific demands upon a MIS. Therefore computerized information systems find wide application in the process of planning most of scientific projects.

It is more difficult for a MIS to fulfil procedures at the project realization stage. Most of them are well known, defined and carried out by many MIS's.

The fulfilment of data processing procedures at the stages of planning and realization is rather simple in case of project management within a single branch of the people's economy but becomes more difficult when applied to interbranch scientific and technical projects. Under such conditions the procedures of interbranch coordination and interaction or, in other words, the procedures of correlation of individual participants' local goals with the project global goal are of great importance.

To accomplish these procedures it is necessary to develop a set of models, which make it possible to manage project planning and realization by coordinating local goals.

The proposed set of models (Fig. 1) includes four mutually connected models, each of which is intended to solve certain tasks concerning data processing and uses one of data base.

A data bank includes planning assignments for each participant (local goals), parameters of main operations carried out according to the program and their mutual connection, directives (global goal), parameters of participants' resources and indices of their current activity. The graph of project status mutual connection is a multigraph, which reflects the project global goal as well as time and indices ties between every participant's assignments and the global goal. The time cross-section of the multigraph is a two-dimension model of participants' interaction at a given moment of time. Thise graph is closely bound with a model of dynamic status change, which is intended to organize initial information, select indices characterizing interbranch ties and form a set of indices necessary to define management effect. The model status is corrected on the basis of the goal mutual connection characteristics, received with the help of multigraph cross-section.

A model for management of interbranch ties, using the set of indices, generates control signals for redistribution of resources among participants to correlate their goals with the project final goal. Feasibility of decisions made is verified by a simulation model which reflects the organisational structure and the associated economic mechanism. The received correcting signals are directed to the graph of project status mutual connection and the model of management thus allowing to make a new practical decision.

At present this set of models has been developed into computer programs. The use of the set of models for information systems permits to provide effective management at the stages of planning and realization of scientific and technical projects in which a great number of participants subordinated to different organizations take place.

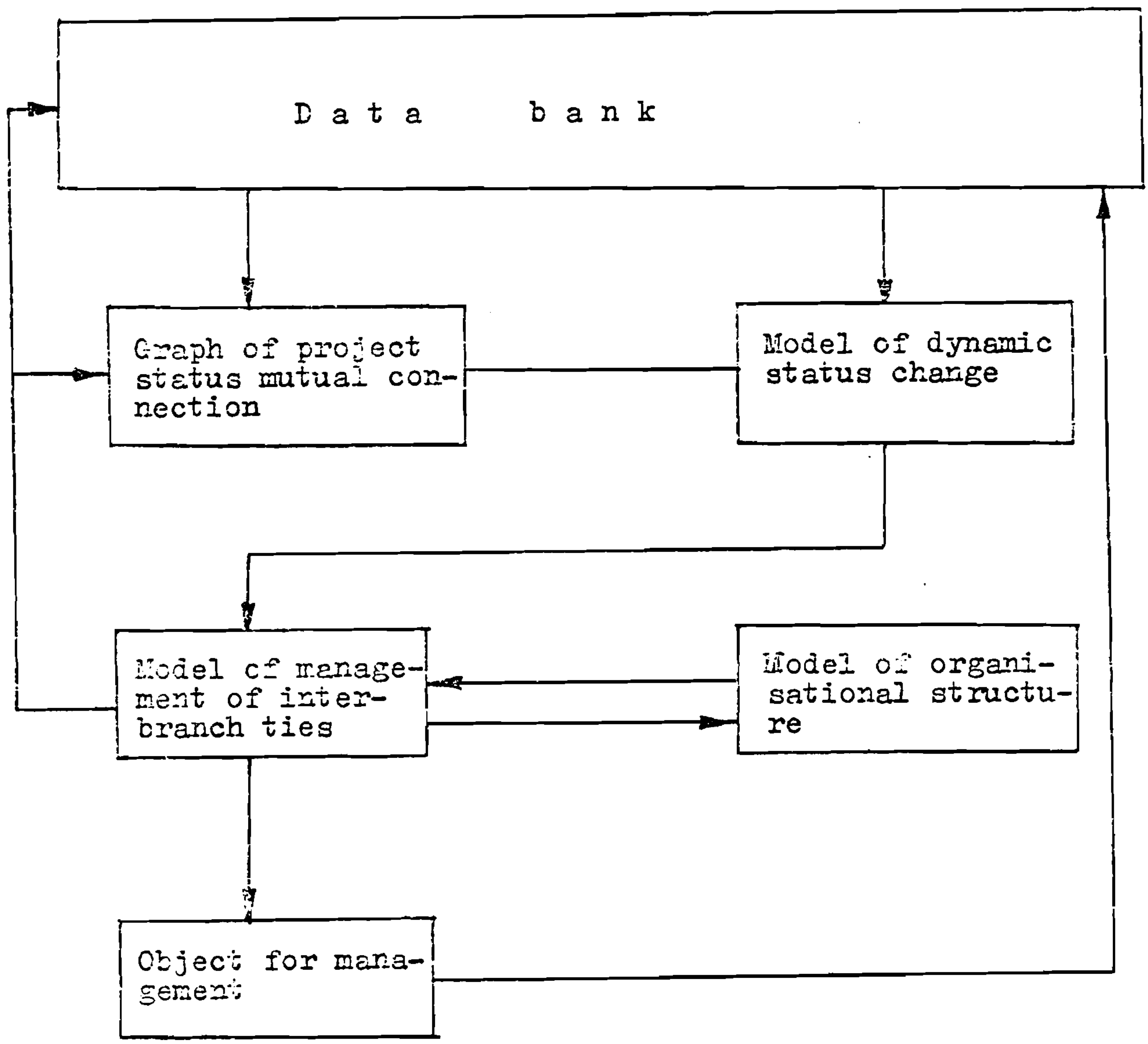

Fig. 1

LONG-RANGE GOAL-ORIENTED RESEARCH AND DEVELOPMENT PROGRAMS AS AN OBJECT FOR TECHNOLOGY ASSESSMENT AND SYSTEMS ANALYSIS

Ryszard Wasniowski*

I. WHAT IS A LONG-RANGE GOAL-ORIENTED PROGRAM?

Nowadays programs are of increasing importance. They have great potential impact on socio-economic development, but the magnitude of the resources engaged (financial, material and manpower), the high cost of failure, other possible negative consequences, together with many other problems concerned with their realization, require that the formulation, management and evaluation of programs be placed on a scientific basis.

First we must explain what the process of programming is, and how to define a program. There are many definitions in the literature, and many papers concerned with this "problematique". In our opinion a progrmaming process is a public process of choosing among plausible alternative futures and incorporates the following five procedural steps:

-- conceptualization of alternative plausible futures,
-- presentation of plausible futures to the public,
-- public debate of the alternative futures, pathways to achieve them, and possible long-range consequences,
-- public selection of a desirable future and of pathways to achieve it,
-- a monitoring process whereby the movement toward or away from the desired future can be ascertained through proper ecosystemic indicators with corrective steps taken in time to affect the outcome.

The conception and implementation of programming form an integral and most important part of the process of consciousness, rational and creative action and future development. This process may be conceived as unfolding in the interaction among four activities: (1) futures research, (2) programming, (3) planning, (4) action. A framework of this process is presented in Figure 1.

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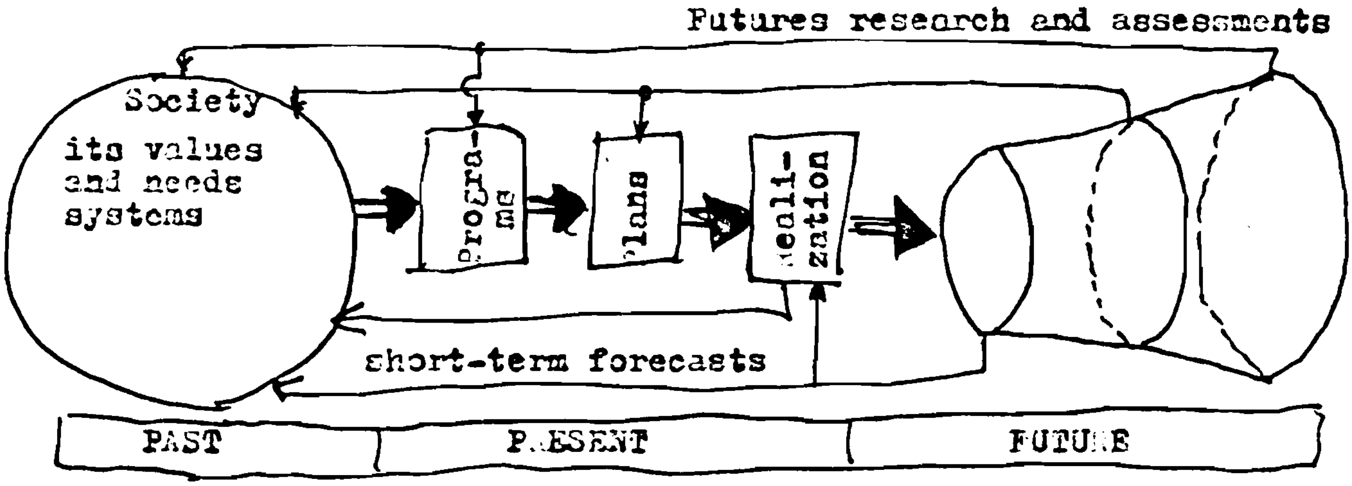

Figure 1

A programme is an end of the programming process. For the purpose of this paper we will use the following description.

By the term "long-range goal-oriented program" we shall denote an integrated complex of undertakings warranted by an adequate organizational capacity and resources, leading to the achievement, in a long-range period, of a definite concrete goal or a complex of interrelated goals. Goal-oriented programming includes a goal development phase, yet little concrete information is available on this subject in the programming literature. In our opinion, goals can be viewed as having at least two major functions for program realization: they can facilitate the systems evaluation and the system control.

As goals play such an important role, we need some techniques to formulate them. Experience has shown that there are benefits of technology forecasting helping to generate and recognize goals. We do not want to talk about TF techniques now. It was Jantsch, who, through his OECD publications gave the touchstone of status to TF including its application to goal formulation. Fig. 2 shows the process of transformation of forecasting information into programs and levels of management.

We shall distinguish the following scopes of programs:
- international cooperation programs,
- governmental programs,
- regional programs,
- corporation programs.

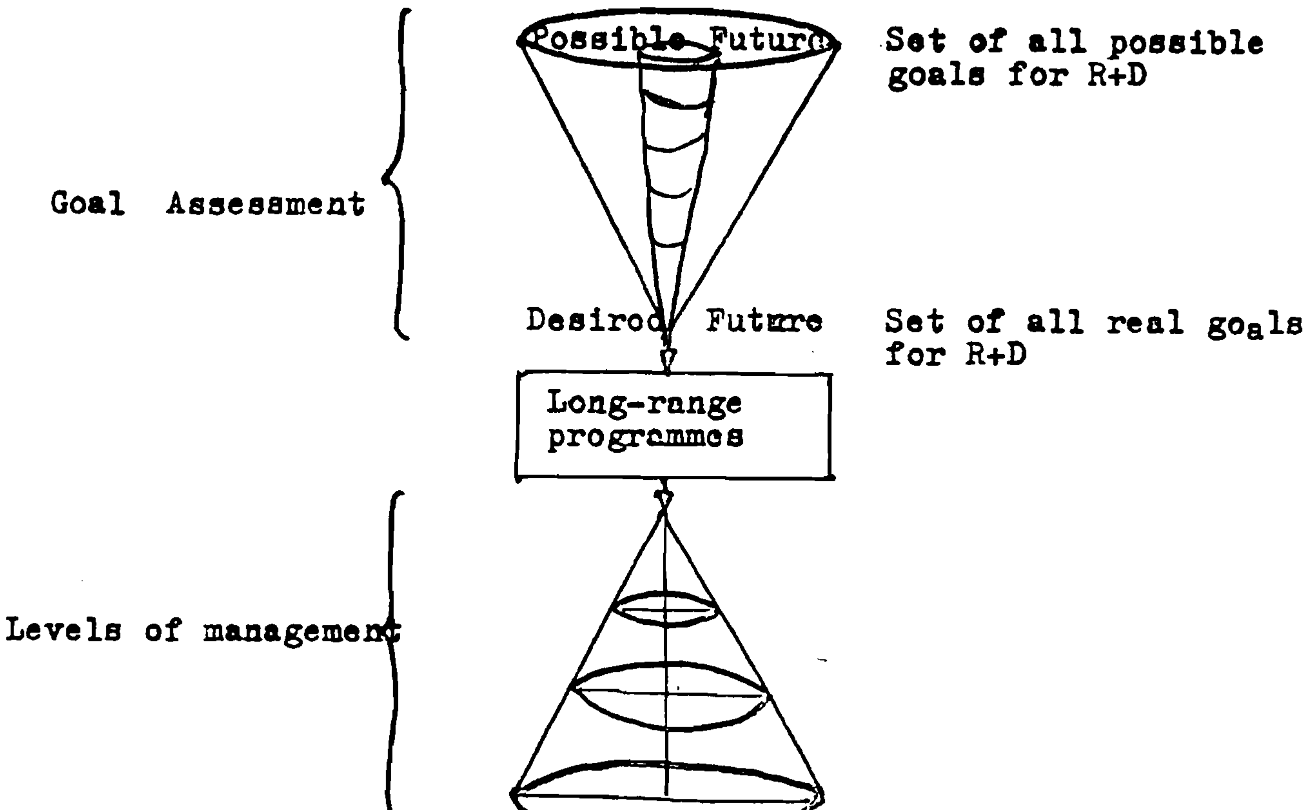

Fig.2

The problems of formulation and realization of long-range goal-oriented programs from the first group have recently come into fore in the field of international scientific and technical cooperation at the global scale and within the framework of such organizations as CMEA and EEC. Formulation of these programs is not a new phenomenon in international cooperation. In the course of the last few years many attempts have been made to develop international scientific research. They aimed at full utilization of scientific and technological innovations, the introduction and diffusion of which exceeded financial resources of a single country.

II. WHAT ARE THE PROBLEMS OF FORMULATION AND REALIZATION OF PROGRAMS?

In order to gather concrete experience on the realization of R+D programs, the author made the analysis of the following programs: 1. realized at the Technical University of Wrocław [16], 2. realized at the national level, 3. realized in the framework of international cooperation [6 , 11] .

The following problems were analysed:

- methods of goal formulation in programs,
- methods of decomposition of global goals into subgoals,
- scope and ways of utilization of forecasting information to goal setting in programs,
- interrelations between goals, methods and funds allocated for the goal achievement,
- research effectiveness evaluation methods, methods of goal assessment from the viewpoint of results obtained; range and techniques of goal updating,
- formal recommendations and real operation of programs,
- interrelations between the goals of scientific development, national, and supranational goals,
- impact of decisions made by management centres and performers on goal achievement.

Information about results of the analysis of the first group was published in [16] . Let us discuss some problems that occur at the international level, and in particular - major difficulties met by international institutions, and possible ways of surmounting them.

The analysis of national research programs allows to make the following statements:

- number of institutions dealing with research programs, number of research topics and of the staff involved in them is constantly on the increase;
- exchange of information between participants in the realization of national programs cannot be considered as satisfactory since it is being done mainly in the form of publications in scientific periodicals, by personal contacts at conferences and symposia, which results in considerable delays of the diffusion of information. This gap is widened in case of enlargement of the scope of research conducted. The ever increasing number of scientific publications complicates the search for information needed and causes unnecessary overlapping of scientific results. The attempts to organize international data banks have not been successful so far;
- works dealing with similar research problems conducted in various countries are difficult to compare since there are no common evaluation criteria of scientific achievement.

Generally, two major types of international cooperation can be distinguished:

- organization of common research undertakings /laboratories, experiments, scientific staff, etc/;
- foundation of common research coordination centres /information exchange, exchange of scientific staff, etc./.

The latter form, i.e. international coordination centres have been developing very rapidly in recent years. They are a multi-lateral form of scientific and technological cooperation enabling multiplication of benefits obtained, as compared with bi-lateral cooperation. On the basis of mutual agreements between the parties interested, coordination centres perform a function of coordinators in the process of development and realization of cooperation programs in specific disciplines selected by those parties.

Let us consider now main problems of formulation and management of programs:

1. Goals are indigenous to many programs but their function and structure is often not explicit,
2. Any R+D program has uncertain outcomes in terms of the degree of success in meeting program objectives, time and cost overruns,
3. Usually the program contains some program areas. Each area contains many subprogram areas. The number of subprograms is likely to be in the hundreds,
4. Usually it is difficult to evaluate the social value of the R+D and long range impact on the society,
5. Realization of R+D programs is highly complex. In addition there are at least two groups of people involved in decision-making researches and managers whose requirements and standpoints are different but whose needs must be met if the objective of the program is to be achieved,
6. A hard look at the literature shows that there is no adequate methodology for comprehensive evaluation including technology assessment for long-range programs,
7. Usually program is realized in cooperation with many institutions, on local, national and international levels, so problems of coordination and communication occur,
8. Factors making common research difficult are:

- different development levels of research activity,
- differences in the social systems,
- ineffective information exchange.

III. WHY IS TECHNOLOGY ASSESSMENT NEEDED?

Some years ago, the rapid growth of scientific advances and technological innovations was viewed by many people as the promise of the good life. Today, while science and technology is still recognized as the foundation of societal advance, there is a rising and vocal concern about the unanticipated social costs of various technological achievements. There is increasing public recognition that societal problems are becoming more complex and that the accellerating rate of social change is creating shock in the culture, values and norms. There is also increased recognition that some technologies have provided important new benefit to selected sectors of the society, but that these benefits have been costly to the others. Of course problems related to changes in technology are by no means identical for all countries. What is a problem now for some countries may be perceived as a desirable goal for some other countries. For example, some countries are suffering from the "success" of their industrialization and resource depletion, while other countries are striving for industrialization, having accepted the fact that industrialization means their countries will be polluted.

Increased public awareness of the accelerating rate of social change and role of technological change in generating unwanted societal side effect has provoked widespread demand for improved mechanisms to forecast, manage and control new technological initiatives. Technology forecasting and technology assessment are most promising approaches to respond to this demand.

The definition which has achieved the widest acceptance is that TA is a class of policy studies which systematically examines the effects on society that may occur when a technology is introduced, extended, or modified with special emphasis on those consequences that are unintended, indirect, or delayed..

Technology assessment is a relatively new concept which offers opportunities for improved decision-making. It has nowadays many advocates and also obstacles for its implementators.

It enables decision-making to consider systematically the known options and to arrive at conscious social choice about future technological developments - to encourage them, to discourage them, to modify them, to prepare the institutional infrastructure for them, or to block them when appropriate.

Perhaps the principal reason that TA is confused with other technology studies /e.g. alternative technologies, evaluation of research, science indicators/ is that TAs are not characterized by a unique methodology. It is rather a set of analytic tools and techniques /e.g. cross-impact analysis, dynamic modelling, factor analysis, relevance tree, scenarios, Delphi/ derived from different fields.

In practice the specified method selected for an assessment is determined by the characteristic and expected applications of the specific object to be assessed. Thus we will receive: technology-oriented, problem-oriented, program-oriented, hardware-oriented, software-oriented- orgware-oriented Technology assessments.

From the viewpoint of Technology Management System /TMS,Dobrov[5]/ program can be analyzed as a system consisting of a set of technical means - hardware, methods and procedures to use those means effectively - software, and a special organization - orgware.

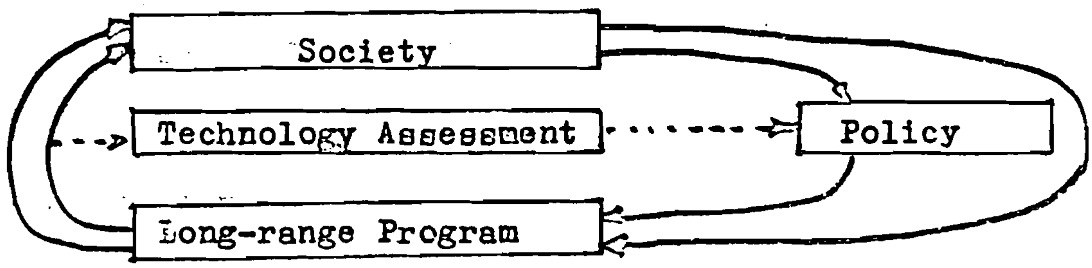

Fig. 3 /Source [2]/

In practice, program-hardware-software-orgware-oriented TA can be realized in following steps:

- definition of the program,
- identification of hardware, software and orgware as parties of interest,
- examination of impact and consequences,
- analysis of policy options.

To be effective, TA should be included to a different scope of programs, e.g. as international agreements for international programs, to state policy as for governmental programs, to regional policy for regional programs, and to corporate planning for corporate programs.

If a long-range TA program is done too soon, necessary information may not be available and results may be taken as gospel, thus stopping program development of the problem assessed. If TA is done too late, the opportunities for public policy intervention may be limited. If possible, Project TA should be performed prior to program.

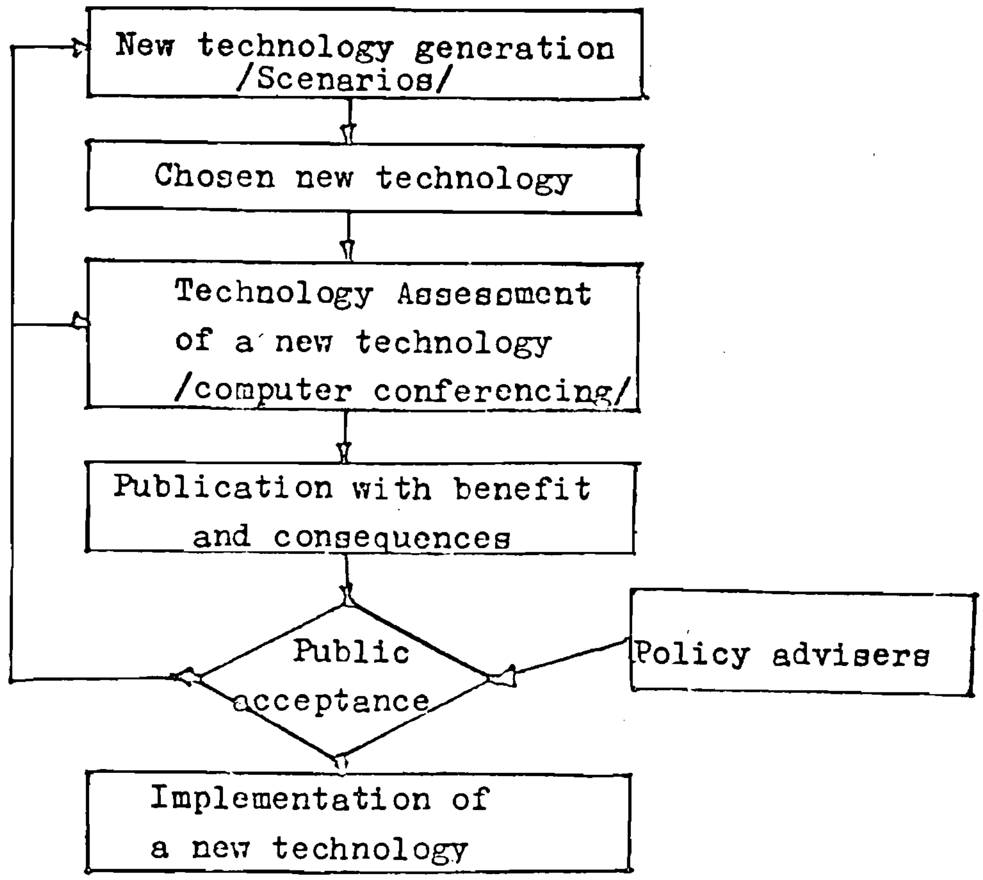

Fig. 4. A diagram illustrating activities and their sequence relationship, and control loops in the total process of TA

Currently, computer conferencing is being used as a tool for TA Computer communication is a new communications technology which will affect the efficiency and quality of decision-making process of TA within existing groups and institutions. The uniqueness of this form of communications and the convenience offered suggest that it will ultimately have significant impacts on TA development.

IV. WHY IS SYSTEMS ANALYSIS NEEDED?

Usually program contains many subprogram areas which complement and supplement each other and must be coordinated to maximize the expected degree of success in achieving the overall program objectives within given time and budget constraints. Moreover, program must be viewed as but one tier of a larger structure of overall national system. Thus the program is a subsystem in a larger system, and the program itself contains many subsystems.

The solution of complex problems connected with the field of formulation and management of research and development program requires a complex approach. Such an approach can be worked out with the help of systems analysis.

The Forecasting Research Centre at the Technical University of Wrocław conducts studies based on the systems approach and aiming at the development of methodology of program formulation. Some of the results obtained can be applied also to cooperation programs.

Since we use the systems approach, we shall start by introducing some concepts inherent to the systems theory.

The systems analysis approach to the study of a problem or a situation involves consideration of many interrelated features of the problems simultaneously rather than the study of each facet in isolation.

This approach embraces in particular: formulation of the global and local goals, exact analysis of the structures of research objects, definition of factors determining the conditions of program realization.

A general procedure of the program development including the system techniques is shown in a diagram below.

GOALS	1. Identification of global /world/ science and technology development objectives 2. Formulation of alternatives of research goals 3. Construction of goal tree 4. Setting of goal priorities 5. Acceptance of specific research objectives
PROGRAM	1. Creation of an organizational structure for preparation of a project 2. Development of program alternatives 3. Selection of international cooperation programs
PLAN	1. Coordination of programs and national plans 2. Inclusion of program elements in national plans
REALIZATION	1. Creation of centres controlling the program realization 2. Control of program realization

Diagram 1

Since the range of information is very wide, construction of a program information system can be useful here. Each of program executors should have access to the system, and should systematically transmit information about his results; he should also have access to information about scientific results of all other contributors to the system. The author's rights should be warranted in the process of information diffusion. The information centre should employ its own experts on methodology, which should enable the development of most desirable lines of research.

Formulation of complex programs requires the possession of complete information about the mechanism of the system's control and about principles of action to be adopted by the top management of the program. In practice, both these conditions are rarely satisfied. It is not always possible to build the graph of the program. Nevertheless, one should always try to delimit those program blocks where full information is available. Realization of the program can be started by this division. It is essential, however, that these subprograms facilitate the achievement of the superior goal of the whole program. In that case we have to do with evaluation goal-program methods of control. They can be called so if the ultimate goal is defined only in heuristic way, and is being successively determined in the course of program realization.

The main task, therefore, is to define where and to what extent research should be developed in order to assure the achievement of the global goal. The first step would be to determine the desired state of research in a given discipline within specific time interval. PATTERN methods are helpful in the construction of a goal tree. The second step is to determine a set of individual actions /see Diagram 2/. It follows from the diagram that in formulation of a long range program, essential role is played by computation techniques.

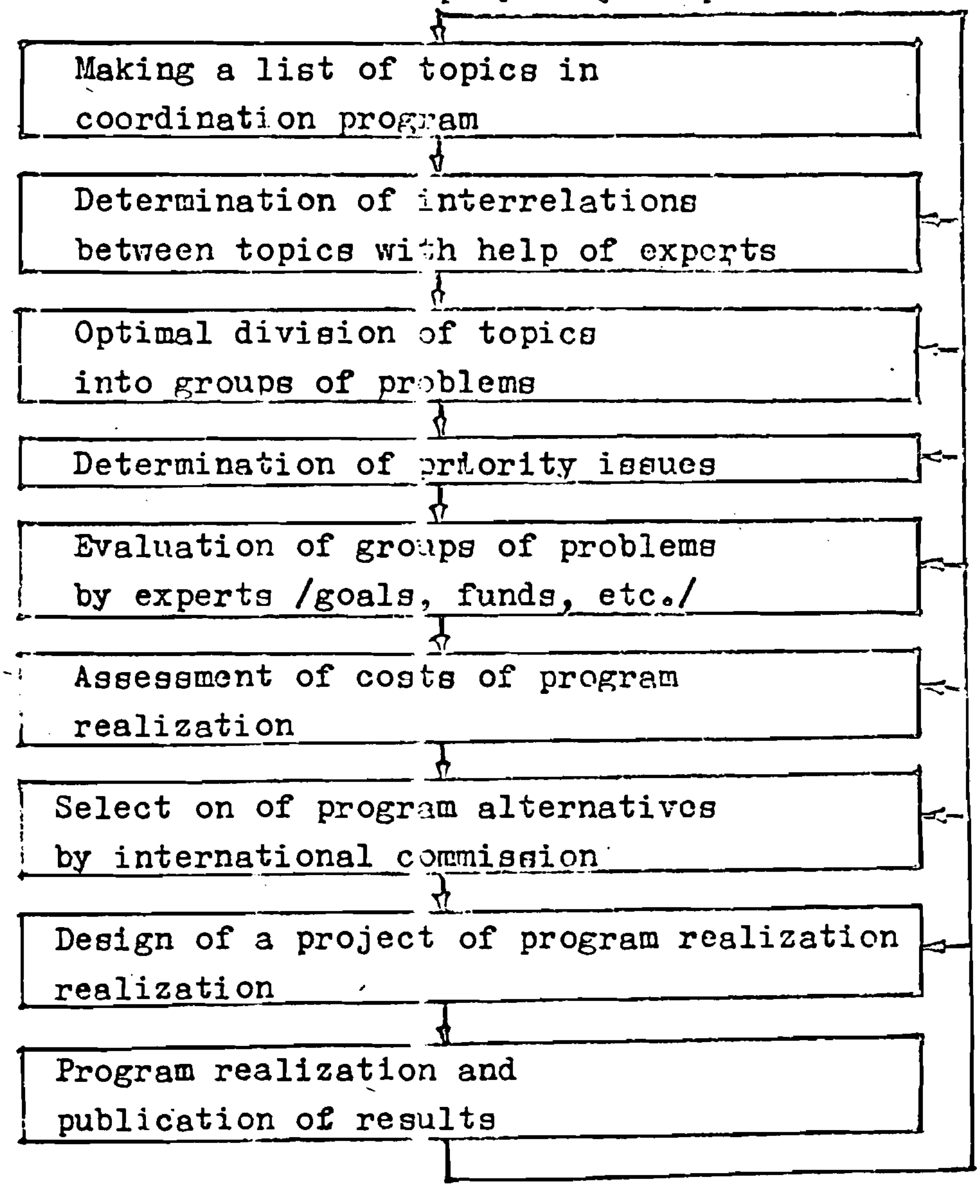

Diagram 2

The practical experience and the above discussion prove that almost every practical consideration of R+D program formulation, realization and evaluation can be illuminated by some existing system concepts and techniques. Some of such techniques have been developed and improved in FRG. We present main of them below. /Diagram 3/

	Method algorithm	Utilization	Application
1	Scenario generation	Improvement of the goal selection process	At the stage of program formulation
2	PATTERN and the like	Evaluation of variants of the program's goals	Tree of goals
3	Experts' opinions	Revelation of the experts' opinions	Definition of goals Forecasts Selection of projects Choice of performers Evaluation of goal achievement
4	Mathematical programming	Determination of optimal solutions with many variables	Selection of projects Choice of performers
5	Network analysis	Determination of minimum time and cost of programs	Programs whose duration can be assessed
6	Allocation of resources	Improvement of material and manpower resource allocation	Programs with defined realiz. network
7	Planning of experiments	Optimization of experimentation procedures	Programs requiring experiments
8	Optimization	Optimal decision-making	Programs that can be evaluated quantitatively

Diagram 3.

In the author's opinion, from the standpoint of long-range R+D programming, there is a greater need of devoting our efforts to the integration of existing system techniques than to further investigation of particular techniques.

This process can be realized with the help of computer conferencing, among other methods. Computer conferencing differs much from other available communication forms such as face-to-face conversation, letters, and telephone, that it may ba termed a new communication media [12].

Computerized conferencing most simply involves a group of people to comunicating by typing into and reading from computer terminals, rather than by speaking and listening. Such conferences may be asynchronous, this meaning that the participants are actually on the system participating in the discussion of times of their own choosing, with the computer supplying each participant with everything new that has occurred each time he or she sings on. Thus such conferences may stretch over days, weeks or even months.

One of the major research efforts in the computer conferencing is a large scale field experiment. This involves the development of an operational computer conferencing system for invisible colleges of scientific who are currently doing research in the same special area.

It is a multi-goal system. The most important of these goals are: goal of scientific development, goal of development of research programs, and the goal of development of specific scientific teams . Since those goals are not necessarily concommittant, a problem of their harmonization and coordination arises in order to enable effective operation of the whole system. Optimal performance of the system can be achieved, therefore, only by means of goal coordination [3].

Gaming and active systems theory [3] may serve here as a tool for such a coordination

A general scheme of computer conferencing is presented in Fig.5.

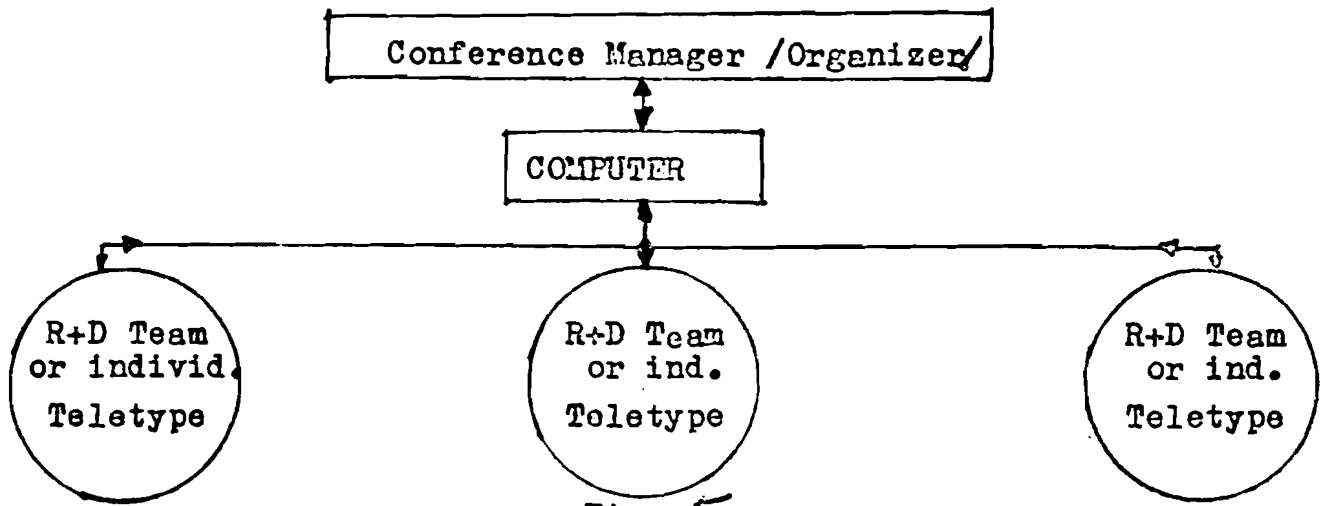

Fig. 5

The author views in computer conferencing two possible roles in group decision-making. The simpler role is that of opinion manager in the sense of keeping track of all individual and/or group decisions and, perhaps, of reminding the participants in these decisions if they make contradictory statements later in the discussion. On a more sophisticated level, the computer could serve as a quest expert which could include assessing of data bases, making predictions, and construction of simulation models. There are also some drawbacks in using a computer, but it should not annoy the participants in a long-range program, since practically each recommendation of the computer is controlled by the experts in a given discipline and in the systems analysis. A close cooperation of man-machine type, realized in the framework of a long-range program development creates the possibility of feed-back for reinforcement and warrants the successful realization of the program.

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MATCHING TECHNOLOGICAL OPPORTUNITIES AND MARKET NEEDS

Derrick F. Ball*, Denise Miller*, Alan W. Pearson

Introduction The literature both academic and popular contains many papers all of which have argued, that at various times new technologies were going to make major penetrations, often on the basis that they had characteristics which would satisfy important market needs - both on the grounds of providing personal satisfaction and also by filling gaps which could not be met adequately by existing technologies. Important examples include synthetic tobacco (1), accelerated freeze drying for food products (2), poromerics and synthetic leathers (3), and high fructose syrups (4). In all these situations the large market penetration forecasted has not occurred, yet in many cases people are still saying that the market or need still exists. The reasons for this difference between actuality and expectations are not always easy to identify but some general features do seem to be common. Examples of these are: the new technology is not good enough, the costs are too high, the marketing is inadequate, and the old technology improves. In most cases large amounts of time, effort and money have been spent, big companies have been involved and these companies have been forced to withdraw from the area through lack of success. This suggests that some apparently obvious market needs are not easily met by technological innovation. This is well illustrated by the case study presented in this paper which clearly shows how changes can occur over time which influence the success or failure of a particular technological approach. It also indicates that it is useful to pay particular attention to market segmentation at the outset of any significant new technological venture.

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In this paper the case of single cell protein (SCP) is considered and the extent to which the technology matches the needs is examined. Particular aspects discussed include the process technology, the energy requirements and certain social and political aspects relating to acceptance of single cell protein.

The world food shortage has been with us for many years and one of its most serious components is protein deficiency. Proteins consist of a special combination of amino acids - the building blocks of life. These can be derived in the diet, either from animals as in more affluent societies or from vegetables as in poorer countries.

In 1959 a division of the British Petroleum (BP) in France found the means by which yeasts could be grown on oil by-products in a commercial process and then harvested for their protein. The idea was not entirely new as it had been tried as an animal feed supplement in Germany in the 1914-18 war and by other countries including the USSR during the 1939-45 war. However neither the technology nor the product were satisfactory and it was not until the breakthrough by BP that SCP became possible. Since then there has been an ever increasing interest world-wide.

Process Technology Single cell protein can be harvested from four types of organisms i.e. algae, bacteria, fungi and yeasts. Specific strains have the property of being able to utilise unused carbon compounds as food sources ranging from agricultural waste to sewage, oil etc. Not only can this be used to give added value to unwanted by-products but the process has the advantage of a very high mass doubling time under optimum conditions, is independent of sun, weather, soil and water and the final product differs from normal crops in that it is of constant quality and the volume of production can be carefully controlled.

The essential features of process technology are the design of an efficient reactor, the determination and control of optimum operating temperatures and pressures, the separation of the products of reaction, the economical use of energy, the avoidance of hazard and the appropriate choice of construction materials. However biochemical reactors differ from traditional chemical reactors in a number of ways. These include the complexity of the reaction mixture, the increase in the mass of the micro-organisms, the ability of the micro-organisms to synthesise their own catalysts, the mild conditions of temperature and pH, difficulties in maintaining stability, restriction to aqueous phase, and low concentrations of both substrate and products.

Large scale production of SCP is a relatively new technology. The main features are shown in Figure 1. In protein fermentation processes the essential elements for the growth of micro-organisms include carbon, hydrogen, oxygen, nitrogen, phosphorus, magnesium, potassium and sulphur plus certain trace elements. These are provided in the fermentor where it is essential to supply sufficient oxygen for the organism to grow and from which the carbon dioxide must be expelled.

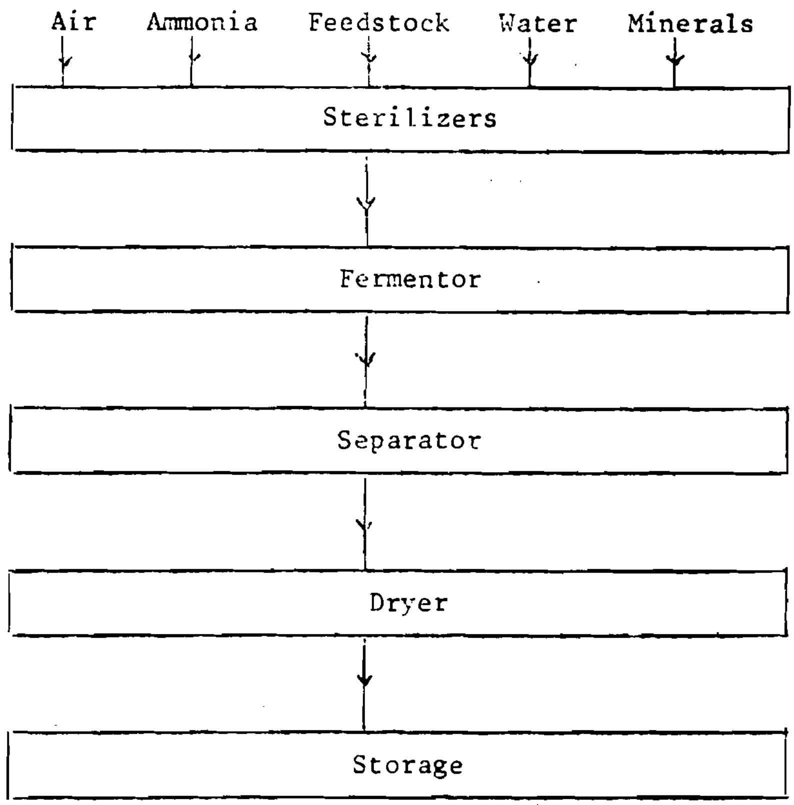

Figure 1 SCP production

On a laboratory scale it is relatively simple to supply the micro-organisms with the necessary nutrients including the oxygen, and to remove the carbon dioxide produced. However on a large scale considerable difficulties are encountered. As oxygen is only sparingly soluble in an aqueous medium a method of replenishing the oxygen supply must be devised. The solubility of oxygen in an aqueous solution is, in fact, so low that if the oxygen supply is cut off the dissolved oxygen would be exhausted within a few seconds. Accordingly for aerobic cell growth the fermentor is usually designed to maximise the rate at which oxygen is transferred into solution and to try to minimise the power requirement for achieving this.

The earliest large scale fermentors consisted of large cylindrical tanks with air introduced at the base. This design was soon modified by the use of impellers to increase the rate of mixing and to disperse the gas phase. When air is sparged (blown) into the base of an aeration tower at low gas velocities the bubbles rise freely at their terminal rise velocities. The velocity of the gas phase with respect to the fermentor wall is then simply the bubble rise velocity. Upon increasing the air flow rate the velocity of the gas phase remains the same and the void fraction increases linearly with the air flow rate. Initially, therefore, the oxygen transfer coefficient is a direct function of the air flow rate. Once the void fraction reaches about 0.1 the spacing of the bubbles becomes close enough to bring about an upward flow of the liquid as the bubbles ascend the column. This is because bubbles ascending the column tend to push the liquid in an upward direction. Since there is no nett flow of the liquid phase through the column a recirculating liquid flow pattern results with the maximum upward velocity at the centre of the column and the maximum downward velocity near the wall. This tends to concentrate the gas phase moving upwards at the centre of the column where coalescence of the gas bubbles is induced. Furthermore the recirculating liquid flow pattern causes the gas phase to ascend the column more rapidly. The nett result is a tailing off of oxygen transfer coefficient at void fractions greater than 0.1. At high void fractions coalescence in the gas phase leads to the formation of large bubbles. The outcome is that high gas velocities rarely create high interfacial areas for oxygen transfer.

The above considerations have led to a number of novel fermentor designs aimed at increasing oxygen transfer rate and/or decreasing the power requirement for agitation and aeration.

The airlift fermentor consists of an outer column with an inner cylinder called the draft tube. For normal flow, air is sparged into the base of the draft tube which leads to a recirculating flow pattern. As the sparged air flow rate is increased the liquid flow rate in the circulation loop increases and bubbles entrained above the draft tube are carried down the outside by the flowing liquid. The result of this is that oxygen transfer takes place throughout the whole system.

An alternative to increasing the agitation is to increase the oxygen pressure, although this increased pressure tends to impede the evolution of carbon dioxide. However this problem is overcome in the ICI pressure cycle fermentor shown in Figure 2. This consists of a tall bubble column the height of which allows significant hydrostatic pressure at the base. As a result the absorption of oxygen from the air supply is promoted by the high pressure in the lower regions of the column and the desorption of carbon dioxide is aided by the low pressure in the upper regions.

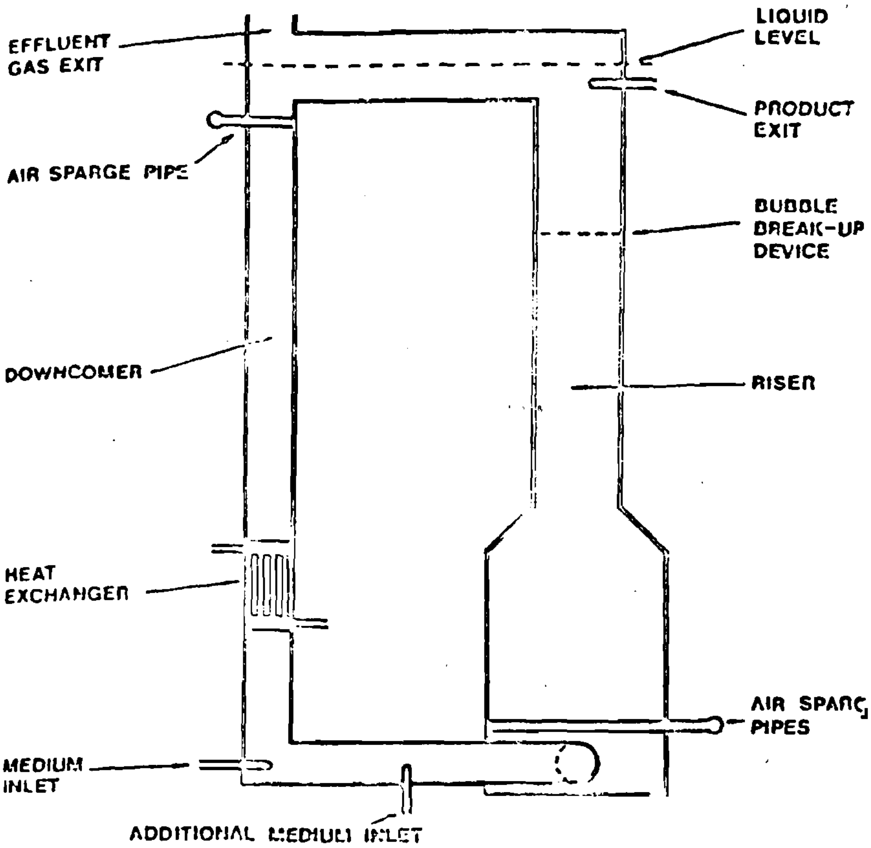

Figure 2. The ICI pressure cycle fermentor

In fermentation processes it is essential that the system is continuously cooled otherwise the temperature rises to an unacceptable level. At high production rates a considerable amount of low grade heat is produced. This arises from the heat produced in the chemical reaction itself, the mechanical generation of heat during agitation and the heat generated in compressing the air fed into the reactor. The amount of heat generated is too high for the use of jacketed vessels or internal cooling coils and it is therefore normal to use an external cooling circuit. This can involve plate heat exchangers, or refrigeration systems with pumps capable of handling an aerated aqueous medium. An effective way of developing the technology would be to increase the operating temperature in the fermentor by say 10°C. This would have a significant effect on the cooling problem and may avoid the use of refrigerated systems in warmer climates.

In addition to the fermentor itself there are other items of equipment. Both the gaseous and liquid feeds need sterilisation. Gas sterilising filters are commercially available but because they consist of a multitude of individual filter elements fitted onto a base plate there is some doubt about their suitability for this application because of the large numbers of joints involved. Accordingly BP have designed a single unit which utilises glass fibre filtration and which overcomes the disadvantages of the conventional gas sterilising filter. Conventional heat sterilisation can be used for the large flows of liquid feed. By the use of heat exchangers and steam heating, sterilisation is achieved by holding the feed flow at the required temperature for several minutes.

The final product should be in the form of a dry stable powder. Since the fermentor broth has a dry cell weight of from 1-5% the removal of up to 99 kg of water per kg of product is required. In addition any unreacted feedstock must be removed. This latter can be particularly troublesome when the feedstock is in a separate phase (e.g. oil). The single cell protein has a density only a little greater than the aqueous medium in which it grows. The sedimentation rate under gravity is therefore slow but separation can be achieved by centrifuging. This is preferable to filtration since it is not easy to maintain the high standards of cleanliness required with filters. Following mechanical reduction of the water content down to about 20% the remaining moisture is removed in dryers or evaporators.

The industrial production of SCP requires a lot of energy, and in a world where energy considerations are of increasing concern the high energy requirement of SCP may limit its use as food. The energy requirements for SCP production have been calculated by Lewis (5). He uses the concept of Gross Energy Requirement (GER) which is the amount of energy source of sources which are sequestered by the process of making a good or service (6). This is usually expressed in mega joules per kilogram (MJ/kg). The GER from SCP production from six different substrates is shown in Table 1. The high GER's when hydrocarbon or hydrocarbon derivatives are used as substrates are due to the large GER's of the substrates themselves. This may limit the use of hydrocarbons and constitute a reason for concentrating on processes based on carbohydrates or wastes which are much less energy intensive.

Actual energy breakdowns are discussed by Lainé et al (7). Excepting the chemical energy of the feedstock the major energy inputs are the power needed to drive compressors and the fuel for the dryers. Power for fermentor agitators is a smaller proportion of total energy requirements. It is possible that energy savings could be made by the use of improved technology. This could involve improved reactor design, the use of chemical biocides instead of steam for sterilisation, operating at a higher temperature to reduce refrigeration requirements and the use of additives to reduce the energy needed in centrifugal separation. It is difficult to envisage economies at the drying stage but it is possible that lower grade energy such as solar radiation could constitute some of the input.

Lewis (5) also presents data on the land and labour requirement for SCP production. In terms of land usage the large scale production of SCP from hydrocarbon or hydrocarbon derivatives is over three degrees of magnitude more economical than production from carbohydrates where crops have to be grown as raw material prior to processing. A similar disparity occurs in labour usage where large scale SCP production from petroleum and derivatives uses only one seventh of the labour per unit weight of product when compared with a smaller plant using waste materials.

However from an energy point of view the most attractive substrates remain the carbohydrates. This points to an increased utilisation of genuine wastes and a greater use of molasses even to the extent of growing more sugar cane. The GER for beef is 61 MJ/kg and therefore for all but one of the processes in Table 1 it is energetically unsound to manufacture protein for feeding to animals to be consumed by man. These considerations together with a soya meal price of about £79/tonne bring into question whether for the third world more conventional agriculture will prove to be a better solution. The major advantage is low land usage arising from the very fast production rates and also substantial economy of scale in labour costs.

For production of SCP from paraffins or gas oils the plant size will be determined by the size of the refinery and feedstock availability. The appropriate scale index of 0.8 gives significant but modest economies of scale. The relatively high value presumably reflects the extent to which heat transfer operations contribute to the capital cost.

In some countries the individual items of equipment are close to the maximum unit size for a relatively small plant. The result of this is that for larger plant replication of units is required with economy of scale limited to savings on land and structures. For the largest plants, in particular, the effect of interruptions in electric power supply should be considered.

It is noteworthy that a major sugar company is pushing the concept of village level SCP systems to handle distributed agricultural wastes. This uses systems constructed of plastic employing cheap local labour and operating at about 3 tonnes/day.

Problems of nutrition - animals vs humans In the early days of SCP work, up to the early 70s, it was always hoped, and almost assumed, that SCP should be directed for human use and to help the third world in particular. However more recent experience has shown that there are far less digestive problems with animals than man, let alone any sociological, political or acceptance problems.

The first thing that must be done is to find out if the SCP is toxicologically safe and nutritionally adequate. So far all the tests on animals have proved satisfactory. Often these tests included comparisons with other protein supplements such as soya, fish meal, etc. and again there were no adverse effects. Long-term feeding tests on Toprina (SCP from oil) have shown the absence of any carcinogens and this is currently being widely used. At present the levels of SCP in an animal's feed are set by government regulations in most countries, but the experimental evidence shows that these could be increased without any ill effects.

There are three directions that could be taken to increase the use of SCP in animal feed. First is to just extend the current levels; second is to use genetic engineering on existing strains of SCP to modify characteristics to make them even more suitable to particular livestock; third, breed selected livestock which respond best to being fed the existing SCP.

Feeding SCP to man has run into a lot more problems, mainly physiological. The initial constraint is even more stringent tests for toxicology etc., especially if the substrate is biological waste from animals or from crude oil. The most important obstacle so far has been the range of gastrointestinal complaints in feeding studies. Some people seem particularly sensitive to SCP and get violent reactions even when it is removed from their diet and then re-introduced.

The other problem is that blood uric acid can be elevated causing in some people gout or stones. This does not happen in animals as their digestive pathways are different.

The quality of SCP source does vary. Bacteria, at present, seem the least viable source for humans due to protein quality and digestibility. Yeast, particularly Torula yeast, gives few pathophysiologic reactions although extensive data on petroleum grown species is not yet available Other fungi may well be a more promising prospect. When considering feeding SCP to man the other important constituents of food must be considered particularly minerals, vitamins etc. The future, then, seems to be directed at SCP for enriching of food rather than a food on its own. Many people are digestively sensitive to a number of common foods, that we already accept widely and would not think of banning because a small percentage of the population couldn't eat them.

Some ways of incorporating SCP into human foods There are already a number of 'new proteins' being used in human food, e.g. Texturised Vegetable Protein (TVP), and it is felt that acceptance of SCP will depend largely on their acceptance. The most efficient way to utilise SCP would be to use it directly in human food, but people do not eat on the basis of need and nutrient alone, therefore there are a number of ways in which SCP can be incorporated into food, either as a major or minor component. It has three major pluses: First, for nutrients, second for flavour or colouring, third for its functional properties such as a surface active agent; other surface properties, as a structure orientating agent in thermosetting, extrusion or spinning; to affect structure orientation to use it as a major ingredient (coagulation, rheological properties, spinnability); or as a filler. All these indicate that SCP can be made into attractive food for the human consumer, extrusion and as a filler being the most economically sound, but it is acceptance by the consumer that is paramount.

Marketing SCP and its competition There are two main markets at which human SCP can be aimed. These are in developed countries, and low income countries. Marketing for animal feedstuff is much more basic and relies on government regulations and price, while for humans presentation is also very important.

Price will be a very important factor, especially for institutional food such as in schools and hospitals - possibly as a meat extender like soya. However a more attractive name seems necessary for more sophisticated markets, and even with government approval marketing would be very hard as the source of the protein sounds so unattractive. Typical examples of the force of the consumer are Japan and Finland. In Japan they have forced the closure of the industry with scare talk of carcinogens as the substrate was hydrocarbon. In Finland the reverse happened, as there was an acute protein shortage for animal feed and the government wanted to minimise imports.

With low income countries the major problem is adapting technologies to existing tastes and dietary patterns, as well as to a low income. Often the planner's approach to cure malnutrition ignores the human aspect. Most of these problems have already been documented with the introduction of other 'new proteins' To summarise this part, SCP must have an image of safety, government backing and good mass media communications before it can even begin to succeed.

There are a number of other unconventional protein sources. These are:

a) Soybean protein concentrates
b) TVP (textured vegetable protein)
c) Rapeseed cake
d) Fish protein concentrate (FPC)

e) Cottonseed oil

f) Whey concentrate, etc.

However, the most important of these are soya, and fish meal. Soya can be affected by the weather and fish meal was recently scarce due to the non-arrival of the anchovies off Chile which makes the idea of an independent protein source attractive. But SCP must be economically competitive, which at present it is not (i.e. about twice the price of soya).

All that has been written so far is a very brief survey of the area. More details on all aspects are available.

Just to bring things right up-to-date:

a) ICI have their plant running at Billingham

b) BP are still arguing with the Italian Government over their pilot plant and their new commercial plant which has still not been turned on

c) BP are collaborating with the Venezuelian Government to build a plant there

d) Amoco has got permission in the USA to add SCP to certain human foods (3% to 10%)

e) USSR is producing 300,000 tons a year and is planning to increase by another 500,000 tons per year

f) Rumania is producing 60,000 tons a year.

<u>Some comparisons with other 'novel proteins'</u> There are basically two main categories of novel proteins. These are:

a) Processing conventional food sources

e.g. FPC (fish protein concentrate)
Desalted soya meal and flour
Soya protein concentrate
Soya protein isolate
Residues from other vegetable oils

b) Making use either of plant material not previously exploited for use in human food, or growing microbes on substrates which can provide a cheap carbon source.

Soya is the most widely used and this is the most direct competition for SCP, although fish meal and the other vegetable oils together are about 40% of the current market.

Soya is processed into three main forms. The oil which is about 20% is used in margarine and cooking fat, - the meal, protein isolate and concentrate can be made into textured forms (TVP) and the isolate can also be spun (like Courtaulds' KESP).

There are no real figures as to the actual human consumption but there are a number of products on the market at the moment. The first was Crosse & Blackwell with Mince Savour, then Cadbury's Soya Choice, and Danoxa meatless varieties made with Courtaulds' KESP. Brooke Bond Oxo have also recently launched Soya Mince.

In the UK British Arkady are the largest manufacturers of TVP, with British Soya Products, Spillers and Courtaulds also involved. There are also plants in Holland, France, Germany and Sweden in Europe, and also in the USA.

So far, soya cannot be grown in Britain and our nearest equivalent is the field bean used by Courtaulds. By far the largest soya grower is the USA, with Brazil expanding fast and China static. The price is around £160, compared with approximately £300 per tonne for SCP.

When it comes to market SCP for human consumption, provided any toxicological and digestive problems can be overcome, most people believe it will depend on the fortunes of soya and provided that is a success then SCP should have a chance.

Conclusion This brief presentation of a more detailed analysis of the area of single cell protein illustrates a number of features which are commonly encountered in studies of technological innovation. In particular it shows

1) that the identification of general market needs e.g. food shortage or protein deficiency, does not necessarily lead to the acceptance of new technology which has a potential for meeting this need. In this case it is argued that the need has not been correctly identified because it does not take into account factors of a social or political nature which have a considerable effect on the acceptance of change of any sort.

2) long research and development times which in this area are almost inevitable can result in changes in many factors which affect the degree of utilisation, and success rate, of new technology. In this case the increase in energy costs has had a significant effect on the viability of at least one route and may, in fact, have an important influence on the likely future success of other routes currently being pursued. In addition as is so often the case improvements in the present means of meeting the needs are considerable, for example in yields and varieties of protein from natural sources.

3) that the needs, and the way they might be met, must be very carefully identified and assessed in terms of the characteristics of the particular market and environmental situations. For example the availability and cost of particular raw material sources, of energy sources and of markets must be carefully considered. Analysis, in the case considered here, indicates that there are a variety of starting points and of ways of using the final product.

The conclusion one can draw is that there is not a general market need but a variety of more specific ones and that there is scope for a variety of processes, utilising a variety of starting materials and being used in different ways. This offers a lot of opportunities for technological innovation but success is not likely to be achieved unless careful attention is given to more specifically identifying the needs and the comparative advantages of different approaches in different situations.

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Table 1 GERs and production costs of SCP production processes

Organism(s)	Substrate	Estimated GER/kg actual protein (MJ)	Manufacturing costs £/tonne 1974
Bacteria - pseudomonads	Methane	165	118*
Bacteria - pseudomonads	Methanol	145	150*
Bacteria - pseudomonads	Ethanol	145	
Yeast - Candida sp.	Methanol	190	
Yeast - Candida sp.	Gas oil	190	
Yeast - Candida sp.	n-Paraffins	185	176*
Yeast - Candida sp.	Ethanol	190	
Yeast - Candida sp.	Molasses	75	233*
Yeast - Candida sp.	Distilling industry waste	155	
Moulds - Aspergillus niger	Solid agricultural waste	80	72**
Moulds - Aspergillus niger	Agricultural process effluent	30	62**

* labour excluded

** labour included

ORGANIZATIONAL ASPECTS OF INTEGRATING THE SCIENCE-TECHNOLOGY-PRODUCTION CYCLE IN ENTERPRISES*

Wladyslaw Jermakowicz**, Jerzy Ruszkiewicz**

I. Introduction

The Science-Technology-Production (S-T-P) cycle is concerned with the process of the introduction of innovation in the microeconomy. The S-T-P cycle in factories, industrial associations and other enterprises has three main stages:

1. Research and creation of new ideas, preparation of technical and economical conditions of a new product. (Science)
2. Preparation of technical specifications and prototypes. (Technology)
3. Introduction of successful prototype and initiation of mass production. (Production)

The research team at the Warsaw Technical University conducted an investigation of the form of the cycle and the factors and recruiting events influencing the integration of processes within this cycle. Twenty new products which have been introduced into full scale production in the machinery industry during 1970 - 1977 in Poland were examined. These 20 products were selected as being the best or most successful during this period. Research methodology consisted of interviews with four persons responsible for each product introduction. These persons were: the director of the factory which introduced the product and three key persons involved in the project, i.e., the inventor, the head of the R & D department (or project team, task force, etc.)

* Based on research prepared for the Machinery Ministry in Poland by a research team comprising W. Jermakowicz, J. Oseka, O. Rzepka, J. Wipijewski, and headed by J. Ruszkiewicz.

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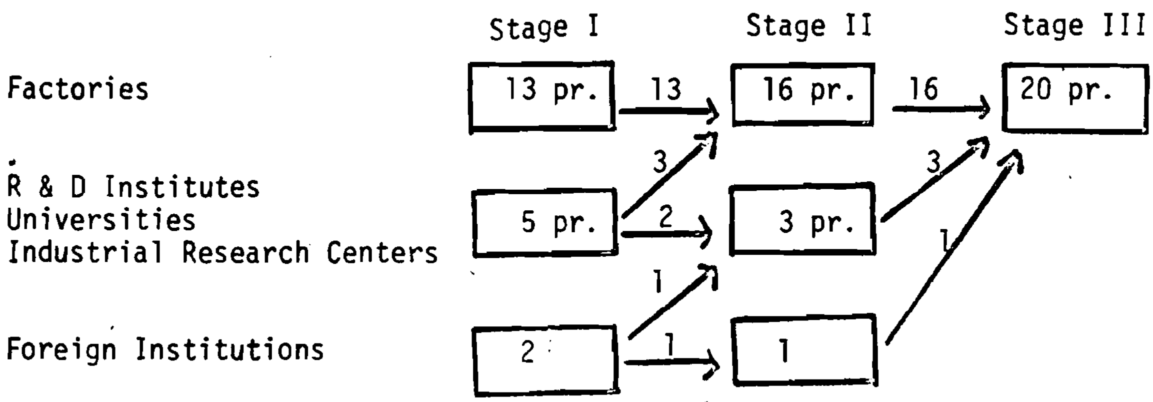
or the head of the production department directly responsible for the introduction of the new product.

This study identified the stages and functions in the cycle of new product introductions. Research was aimed at identifying the factors inhibiting effective implementation and methods to reduce these barriers.

The stages of the S-T-P cycle of these new products are applicable in various environments. They have been realized in different settings and institutions: in factories, in R & D institutes, in universities, in industrial research centers, and in foreign institutions. The relationships between the stages of the S-T-P cycle of the 20 products and the place where they were conducted is shown in Figure 1.

Figure 1



The differentiation of the S-T-P cycle and the segmentation of the organizations responsible for the realization of these different stages causes many barriers towards achieving the successful introduction of new products.

I. The factors causing difficulties in implementation of new products.

Research has shown that long introduction times of new products are a result of difficulties experienced in the integration within all the stages of the S-T-P cycle.

a. In those cases where the same individual (key person) is responsible for all stages of the cycle there is a marked reduction in the time needed to introduce new products. More time is required, on the other hand, where there are many head people involved.

b. The difficulties with introduction of new products markedly rise together with each successive accomplishment and are highest in the third stage. Therefore, the most unfavorable situation is when the next stage is conducted by a new person who did not participate in the previous stage.

c. The time of implementing a new product also depends on the position of the person within the organizational structure. The higher their position, the quicker new products are introduced.

d. The results of the study show that the informal status of the key person is usually higher than his formal position and status in the organization. This is usually due to the fact that the key person enjoys high authority as far as the decisions about a specific new product. Higher informal authority in the organization leads to a shorter time in the fulfillment of a new product.

e. Management of factories and institutes which introduce new products choose and promote those individuals who have a high formal position. These are usually those who are the key persons managing the new products. Inventors of new ideas are very rarely promoted.

f. The key persons usually have a limited amount of discretionary authority in comparison to their responsibility and tasks. This follows the necessity of coordinating the activities between project leaders and managers of enterprises which decreases the effectiveness of management of the new product.

g. The competence in organizations depended much more on the formal position within the organization and less on the function which the key person had to fulfill in the organization in respect to the new product.

h. The investigation shows that independence of the key person in decisions over equipment, technology, resources, and monitoring of products is very limited by the constant interference from superior levels. These interferences usually have a negative influence on the quality of new products and/or on the time required for introduction.

i. The most common organizational structure for the realization of new products is one where existing structures and teams are retained and the new tasks for product development are allocated to these teams. As a result of this, there is resistance against all new tasks and duties. Rarely are task forces established for solving of definite problems. However, in those situations these special task forces are very successful.

j. In those cases where task forces were used the members were chosen on the basis of prior knowledge and previous preferred experience with them, not because of their creativity, originality and independence in thinking. As a result, reliable solutions were achieved with a low degree of originality and innovativeness.

k. The most popular planning techniques implemented in the process of fulfilling innovative ideas is the GANTT'S graphic schedule. Very seldom are network techniques (PERT or GERT) used and only in those cases where the main resistance is against the additional tasks.

l. In no cases were creative techniques like brain storming, synectic, etc., implemented.

m. The dominant leadership style is the task oriented style. The main functions of team leaders (key persons) are: allocation of tasks for definite workers, monitoring of work process, and control of results. The leaders are not interested in consideration. The orders are given usually orally and formalistically.

III. The main suggestions of improvement of organization of S-T-P cycles in industrial enterprises. Analysis of questionnaries taken by persons responsible for new product development and introduction yielded the following results:

1. To interpret all the stages of the S-T-P cycle:

   a. The main concern with the new product in all stages should be conducted in the same organizational units. (85% answer)

   b. The construction, technological, and R & D units should be united in one large universal organization. (85%) Many difficulties arise due to the fact that testing stations for prototype units are independent subunits within the construction office. Serious problems develop between on line mass production while prototypes of the new product were very successful.

   c. Task forces should be established with a leader (key person) who would be responsible for all stages of S-T-P cycle. This leader should have authority competences toward the other department heads (sales, production, equipment) in respect to the new products. These competences should be increased, the higher the priority of a new product.

d. The process of introducing a new product should be so organized that feedback would exist between construction tasks and the testing units.

2. Some factors necessary for increasing the independence of individuals participating in the process of designing new products are:

   a. To provide a key person (product leader) with a number of main personnel competencies which are necessary in management of a new product. The competencies should be as follow:

      (a) selection of workers to the task force

      (b) rewarding and punishing persons in task force

      (c) promotion of subordinates in respect to position in the organization and their salary

      (d) having at their disposal the financial means in respect to that product or project

   b. To provide a key person with decision-making competencies concerning:

      (a) beginning and ending tasks

      (b) establishing stages for fulfilment of tasks and in the realization of the product, etc.

3. According to the respondents there should be increased flexibility in fulfilling of all stages of cycle. To accomplish this purpose the following should be implemented:

   a. Prepare firm product introduction schedule and, on the other hand, be flexible enough so as to make some changes during the new product introduction cycle.

   b. Allocate the R & D tasks to different units so that they will be able to accept the additional tasks, e.g., new project or product or new research necessary for achievement of this new product.

4. To eliminate or reduce bureaucratic barriers in fulfillment of new products the following suggestions were given:
   a. Eliminate fictitious reports about progress in works and the inflated degrees of participation by different team members. Most written reports about innovative activity are a fiction due to the fact that this type of activity is irregular and capricious, the solutions are being found by leaps and jumps which are difficult to predict and plan. Increasing the confidence of key person is the best method of control in this type of activity.
   b. Reduce the circulation of technological documentation. Permit the beginning of the next successive stage of a product's introduction on the basis of a general sketch and outline, not with large amounts of paperwork.
5. Increasing the cooperation between the departments partaking in the creation of new solutions can be achieved by:
   a. Increasing standardization of elements of products made, e.g., increasing influence of normalization on design process.
   b. Increasing foreign currency limits for the purpose of fulfillment of new products.
   c. Increasing economic pressure, e.g., introducing competitive economic system which would force the elements of organizational system to cooperate with other enterprises and other departments in the system and to increase the quality of products.
   c. Improving the rewards for introduction of new advanced products which would increase the interest of all enterprises and units in participating in the introduction of new products.

6. There are many difficulties in the sphere of existing economic systems. The elimination of these barriers should, according to the respondents, be achieved by implementing the following:

   a. The elimination of piece-work salary system in departments introducing the new product. The drawbacks of the piece-work system are:

      (a) low quality of introduced products

      (b) lack of interest and engagement in fulfillment of a new product.

   The centers participating in the introduction of new products should have their own highly skilled and qualified personnel paid under a monthly or annual salary system. (40%)

   b. Increasing salaries of technical staff which work in the R & D sphere in comparison to the staff working in the production sphere in the enterprise. This would eliminate the high absenteeism and turnover of this staff and eliminate the lack of interest in realization of the innovatory projects. (30%)

   c. Establishing a proper ratio between planned regular production and irregular innovative activity. The economic system prefers the production activity due to the fact that this type of activity is repeated, regular, disciplined, can be planned and results are easily measured and the risk connected with production activity is relatively low. (25%)

   d. Assigning a foreign-currency fund for realization of new products. Such types of funds exist in industry for the purpose of purchasing foreign licenses for advanced products or production processes. There are a few cases where the management of an enterprise has applied for and received foreign currency for a license and instead of acquiring this they introduced their own new product. In these few cases the foreign-currency fund was necessary to purchase imported raw materials or components to introduce this new product. It is normally easier to receive foreign currency for a new license than for a domestically developed original product (10% cases)

The research on the system of introduction of the new products has permitted identification of some organizational factors influencing the effectiveness of the S-T-P cycle in industrial enterprises. This study has also gathered some suggestions on how to interpret the activities in the framework of this cycle. This paper can be considered as a short summary of the research and as a short introduction to the factors influencing interpretation and efficiency in the course of S-T-P cycle experienced by industrial enterprises.

APPENDIX: LIST OF REMAINING PAPERS PRESENTED AT THE CONFERENCE ON 'MANAGEMENT OF RESEARCH, DEVELOPMENT AND EDUCATION' WROCLAW, POLAND, SEPTEMBER 1978.

Archangelsky, V.N. The Regional Aspect of Governing the Development of Science and Technology in the Conditions of Developed Socialism.

Benev, B., Djagarov, L., Stefanov, G. A New Approach for Raising the Effectivity of Science and Technology and Application of the Scientific and Technological Achievements.

Beran, V. Project Decision Analysis.

Darvas, G., Vas-Zoltan, P. Recent Trends in National Science and Technology Policies in the European Region.

Däumichen, K. Some Aspects of Research and Education Management in Universities.

di Roccaferrera, G.M.F. Behavioral Aspect of Managerial Decision Making Under Multiple Goals.

Dobrov, G., Randolph, R., Rauch, W. Informational Networks for International Team Research.

Dobrov, G., McManus, M., Straszak, A. Management of Technological Innovations Toward Systems-Integrated Organized Technology.

Dzagarov, L. Hierarchical Model of Resource Allocation for Complex Research Projects.

Hayward, G., Masterson, J., Sarrafi, M. Technological Innovations in the Milling and Baking Industries.

Jermakowicz, W. Some Remarks on the Future Development of the Management System of R&D and Educational Activity in Technical Universities in Poland.

Kalaidjieva, M.A., Kostov, K.H. Hierarchical Structures in Innovation Process Management.

Kazimierczak J. Game Interpretation of the Forecasting in a Cybernetic System

Kwasnicki, W. A Stochastic Model of Evolutionary Processes.

Kwasnicka, H. Use of Models of Population Dynamics for Technological Forecasting.

Magott, J., Markowska, U. Generalization Principle in Management.

Malcherczyk, W. The Application of Parametric Automaton to Forecasting Purposes at Controlled System Structure Changes.

Markowska, U. Formal Model of Forecasting Game Rules.

Medvedev, A.G. Model of Technological Change and Its Application in Comprehensive Planning.

Mikiewicz, J. An Example of Application of the Statistical Selection Method of the Best Objects.

Mosoni, J. Some Problems of Science Policy in India, Sri Lanka, the Philippines and Thailand.

Nikodem, R., Szczepanik, R. Forecasting of Computers Development with Application of Extensive Game.

Pelc, K.I. Technology Assessment as an Element of Technology Management System.

Schlutow, G. Forecasting in Basic Research as a Process of Developing Science Policy in Socialist Countries.

Shankle, J.E. Transition Considerations in Conversion to Future Computing Facilities.

Sloninski, J., Charlampowicz, J. Problems of Effectiveness of Scientific Researches (On the Example of Technical Universities.

Zeman, M. Stimulative Function of Complex Models in Research and Education.

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