ELECTROTECHNOLOGY: MANAGEMENT OF AN AMALGAMATION (FIRM) AND ADOPTION OF INNOVATIONS

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PREFACE

D. Levchuk and E. Vyshinskaya of the All-Union Research Institute in Moscow prepared this paper for the case study on electrotechnology, which is being undertaken by the Innovation Management Task. Its main purpose it to outline some major problems related to the management of innovation in the field of electrotechnology, especially those encountered at the level of the firm. The problems and possible tasks for the case study described in the paper are of an economic and managerial rather than technical nature, in accordance with the spirit of IIASA research, especially in the Management and Technology Area.

This paper is intended to provide support for the selection of problems for the case study that would be of mutual interest to Eastern and Western countries.

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Management and Technology Area

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CHAPTER 1

1. THE ROLE OF ELECTROTECHNOLOGY IN THE NATIONAL ECONOMY

Electrotechnology is a mature basic branch of machine-building. It has well developed relationships with the sectors of the national economy that are intrinsically interwined within the public production structure. In the last decades, however, its progress has been characterized by a number of factors that help single out electrotechnology from among other traditional machine-building industries by its more distinct trends of modern industrial development. This refers first of all to its relatively high and stable rate of development, which is directly connected with increased industrial power consumption as well as a higher living standard in industrially developed countries and a subsequent increase in power consumption for domestic purposes. (For example, in the Federal Republic of Germany in the period from 1967 to 1979, the amount of generated power increased by 5.5 percent annually and reached 349 billion kwh. as opposed to 185 billion kwh. in 1967, an increase of almost 90 percent. In the USA total power generation increased by 61 percent between 1967 and 1977; in Japan, by 116 percent.

Thus the growth rate of electrotechnology (though considerably lower than that of newer branches, such as computing equipment, instrument making, etc.) far exceeds the growth rates of other traditional basic branches in machine-building and (in some countries) in the industrial production as a whole. For example, in the USSR in the last two decades the annual growth rate of electrotechnology has been 10 percent higher than the average growth rate of all other industries. In the period between 1960 and 1980, the average annual increase in the volume of

production in all manufacturing industry was 6.2 percent, while in electrotechnology alone it was 8.7 percent (entire machine-building--6.6 percent). Between 1970 and 1979 industrial output in France grew by 31 percent (machine-building--41 percent), while in electrotechnology it increased by 88 percent. The industry's share in the total sale of products shows similar increases: in France it grew from 9.0 to 12.9 percent, while in Japan (over the same period) it changed from 9.5 percent to 12 percent.

The relatively high and stable growth rates of electrotechnology do not mean that little attention was given to factors of intensive development. Indeed, the transition of this branch of industry to an intensive development course was effected faster than in the majority of other basic machine-building branches of industry. This trend was also reflected in higher labor productivity,* wider utilization of advanced technology and computers,** shorter service life of equipment, and faster rates of new product development.***

The specific features of electrotechnology as an object of investigation are: the concentration of production, on the one hand, and on the other, the fact that electrotechnology's involvement in international systems of industrial specialization and integration is greater than in other branches of manufacturing industry. Suffice it to say that seven countries (USA, Japan, the FRG, France, Great Britain, Italy, and Canada) account for 90 percent of the total electrotechnology output of the capitalist world.

Electrotechnology features quick development of such new forms of concentration as diversification and combination. In 1970-1975 the share of electrotechnology in the export of machines and equipment increased from 4.6 to 9.9 in the FRG, from 3.9 to 11.6 in France, and from 3.9 to 9.4 percent in Great Britain. However, its main advantages as an object of investigation are: its close relationship with R & D in other industries, its direct participation in the delivery of equipment for the mechanizing and automating of production processes as well as wide spread mechanization and electrification of domestic work. Hence the profound and fast innovative processes in this industry and their major role in the implementation of the major goals of any country's social and economic development. This explains the great significance of effective management of innovation processes in electrotechnology.

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*From 1975 to 1978 electrotechnology output per worker in thousands of dollars increased from 42.2 to 52.2 percent in the USA, from 28.4 to 36.7 percent in France, from 23.3 to 36.7 percent in the Federal Republic of Germany, from 17.8 to 35.2 percent in Japan, and from 13.6 to 19.2 percent in Great Britain.

**In 1975 Japan's electrotechnology sector used 1687 units of computing equipment. In the entire machine-building sector the corresponding figure was 704 units, in the metal-working industry--532 units.

***For example, in the USSR more than 11 percentof products and equipment are substituted by new ones.

1.1 Research Needs

Investigation of major trends in electrotechnology development for the next 10 to 20 years; definition of key factors and their influence on the rates and proportions of development.

CHAPTER 2

2. INNOVATION POTENTIAL OF ELECTROTECHNOLOGY AND ITS DEVELOPMENT FACTORS

In its entire history of about 100 years, the electrotechnology industry has preserved many of its traditional general principles of design and production. For instance, mass production in this field is based on the principle of transforming mechanical energy into electrical energy, and subsequently electrical energy into mechanical and thermal energy just as it was early in this century. The principles of transmission and storage of electric power have also remained practically unchanged. The basic power resources (fuels, hydraulic power resources, conventional building materials) still dominate in the electric grid.

At the same time, new trends have appeared in the last two decades that in the foreseeable future may bring about substantial changes in the design and operation of products and production processes. The timely effort of industrial organizations will undoubtedly be required for optimal resource allocation, definition of appropriate R & D strategy, and the adaptation of the industrial engineering and management system. The government, for its part, should create an environment favorable to the development and adoption of innovations of a qualitatively different level. These trends are connected

The recent trends are connected first with applied research conducted on a broad scale and aimed at the utilization of new principles of transforming mechanical energy into electrical energy (gas dynamics, piezoelectricity, photoelectricity, etc.). They are are also aimed at changing the structure of the fuel balance in the next 20 years, shifting towards nuclear and solar energy, as well as wind energy. As a

consequence, new problems are arising related to the transmission of energy over long distances and its storage. New and broad vistas are opening up for technological options following almost conclusively promising discoveries in solid-state physics, electrodynamics, gas dynamics, and biophysics, and the deep penetration of electronics, computers, and new construction materials into the sphere of electrotechnology.

In this connection the next decade will witness electrotechnology facing serious problems caused by not only the above-mentioned factors but also by a new level of constraints regarding the natural environment and constantly growing social needs, from the viewpoint of both the end user and attitudes towards the conditions and character of work.

The scale and rates of innovative processes in electrotechnology are related not only to pending qualitative changes in production technology and processes as well as in social conditions and the management of nature. They are also determined by the continuous accumulation of quantitative changes in the parameters of production and products of the industry. These include greater power of the plants and units manufactured by the industry (e.g., generators of over 1 million kwh.), the fast stepping up of the installed power of electric power stations (between 1967 and 1976 this indicator increased by 90 percent in the USA, by 138 percent in Japan, and by 80 percent in the FRG), and the introduction of new materials.

The scale and magnitude of innovative processes in electrotechnology are reflected in the amount of resources allocated for R & D as well as in the degree of its concentration. For example, in the mid 1970s two US branches of industry--aeronautics and electrotechnology--spent about 50 percent of their total R & D allocations on industry. In 1975 private industrial companies' allocations for R & D amounted to 23.5 billion dollars (54 percent of which was appropriated by 4 leading concerns).

The role of innovative processes in electrotechnology and their scope and rates define the research needs.

2.1 Research Needs

Investigation of major trends of development in electrotechnology; assessment of their influence on the industrial engineering and management. Study of some specific innovations at the main stages of their evolution. Definition of their influence on the production pattern, its scale and magnitude. Indentification of the decision forms and techniques with respect to specific innovations. Formulation of resource allocation policy. Selection of administrative and economic methods of management.

CHAPTER 3

3. APPLIED RESEARCH IN ELECTROTECHNOLOGY: METHODOLOGICAL PROBLEMS

3.1 Object of Investigation

The developing innovative processes form a system where various spheres of activity (research, production, business) come into play. These depend on the orientation of the innovation: development of a new product or process, acquisition of new knowledge in organization, higher labor skill, etc. This calls for an analysis of the innovation

- in combination with current activity aimed at increasing production forces; and
- within the framework of the organizational entity (research, design, and production organizations) where the process occurs and higher level management bodies (ministries, corporations, regional and state administrative bodies).

In this context a large-scale electrotechnological firm (or a production amalgamation) is a primary (lower) level in the organizational hierarchy of innovation activity. It is the basic economic unit within which the majority of innovative changes occur and to which one can trace all the relationships between innovation and operational management, the R & D progress, and the development of the organizational forms and techniques.*

*In the Soviet Union the basic economic unit in electrotechnology (as in any other manufacturing industry) is the production amalgamation incorporating research, design, production, service and other economic organizations (an average production amalgamation incor-

The selection of a large-scale business entity engaged in electrotechnology as the object of investigation seems quite appropriate, as it provides a good basis for identifying problems common to various economic systems and for making a comparative analysis.

3.2 Common Ground

In planning joint applied research of large-scale electrotechnological amalgamations functioning in different economic systems, one may expect problems to arise. Difficulties may crop up during comparative studies, in the identification of similar problems, in the comparison of their causes, and in the search for universal answers or solutions to R & D problems.

In modeling engineering and economic systems, scientists all over the world have developed more or less universal formal tools. They construct models that can be adapted to different economic realities. We have no such tools, however, for the description of management systems or economic mechanisms. Nevertheless, in the joint applied research there can be two similar groups of objectives:

1. Description and analysis of the R & D and related problems in an amalgamation, identification of management "bottlenecks" and their causes;
2. Iterative identification of problems and "bottlenecks" by means of comparison and the attainment of generalized results bearing a universal character.

It should be pointed out that in the definition of the conceptual framework for the applied research, one can be guided by one of the two diametrically opposed but equally valid points of view. The first is to proceed from the possibility of a common (universal) approach to or an understanding of the R & D management, as well as the orientation toward obtaining comparable results and conclusions that may considerably enrich each party's practical application by adding the experience of a country with a different economic system. The other point of view is to base the study on the different mechanisms for the functioning of planned and market economies.

We are in favor of the first point of view. To our mind, in spite of the differences in the socioeconomic modes of functioning, there are features in R & D management that are more or less independent of any socioeconomic environment and therefore can serve as a basis for the elaboration of a single approach and methodology.

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porates 4 organizations). Amalgamations account for more than 50 percent of the country's total output of manufactured goods. The Leningrad production amalgamation Electrosila is a typical one by its structure, scale, spheres of activity, organization of economic links, the relationships with the management bodies of the branch, region and the state. To respond to the new tasks, organizational restructuring is effected whenever necessary. This means that new production and economic organizations are formed, and certain changes are made in the management mechanism both inside the amalgamation and outside (ministerial, regional and national levels). Such forms as project management and management of goal-oriented programs are employed.

Achievement of the first group of objectives will go beyond mere practical value. It will extend the boundaries of the existing experience in a specific area and gain a better understanding of various aspects.

Achieving the second group of objectives, we will enrich ourselves in possible approaches to the analysis of problems and their alternative solutions which will naturally raise our theoretical and practical knowledge to a qualitatively higher level.

We would like to point out 3 main principles that should underline the case study:

- the objects of investigation should bear similarity in essential parameters;
- they should be characterized by the similarity of the environment influencing the function of an industrial entity; and
- a single methodology for structurization of the objects of investigation and of the factors influencing the development, as well as of the problem area, should be employed.

Though there is always a certain scepticism regarding the usefulness of such case studies, we find a firm ground for optimism by reason of the following:

1. the positive experience of the TVA/Bratsk-Ilim complex case study;
2. similarity of amalgamations and firms with regard to industrial engineering, technology, processes and their products, as well as the management organization and techniques; and
3. in any socioeconomic environment the technological changes that determine the main directions of product or process development are governed by general and objective factors. These are the technical and economic needs to be satisfied by electrotechnology (greater utility of the product, increased power of the equipment including increased power per unit of weight cost reduction, including the lower cost per conventional unit signifying the product utility, greater reliability, minimization of manual operations, etc.).

Technological change in this industry follows similar paths in different countries, the organizaional form being very important. The management organization shares many common elements but there are also diversities. However, the similarity of R & D principles in general, and innovations in particular, permits a multi-criteria analysis of the problems, the identification of general trends and a focusing of attention on the most difficult problems.

The frame of reference includes the following similar components:

- major goals of the R & D policy at the sectoral level (with possible differences in priorities).*
- state involvement at the sectoral level; interaction of different spheres of activity: government and business;

- multi-level hierarchic organization of enterprises, corporations and ministries;
- similarity of problems in organizational development (at a level of the firm, corporation, branch of industry);
- similarity of economic mechanisms implementing the R & D policy;
- similarity of position and role of large-scale production and economic units in innovation implementation and the influence of innovation on their development;
- influence of end users in market and planned economies and the different way this occurs; and
- possibility of identification of similar units and modes of their functioning in innovation management at all levels of an amalgamation (firm), ministry, corporation and state. This implies performance of the basic functions of management (planning, organization, etc.), existence of direct and indirect ways of influence (with possibly different proportions and interrelationships).

The underlying logic is that the state, in the person of its administrative bodies (which may differ in status and functions), takes an active part both in the formulation of R & D policy and in its implementation. This can be seen, for example, in the centralized distribution and control of that part of the national income that goes to the budget for R & D needs. In this way the state compels industry to tackle specific assignment that are in line with its R & D policy. In the USA, for example, about one-third of R & D in industry is financed by the government; for a number of industries the figure is even higher. A high degree of centralization in resource allocation for R & D in industry can be found in a number of western countries and also in the CMEA countries.

When we speak of similarities in the economic mechanisms for implementating R & D policy, we imply similarity in such categories as prices, taxes, credit, finances (minding, however, different modes and scales of their influence). In the same way we can identify other essential variables that determine innovation management and critical problems related to it.

*We are referring here to a more detailed analysis of R & D policy and goals in the field of industrial production, indicating their priorities for various countries as described in the working paper by H.D. Haustein "Innovation and Industrial Strategy", May 1981, WP-81-65.

3.3 The Research Needs

How can innovation management mechanisms at all hierarchical levels be sufficiently described if one proceeds from the totality of similar elements? What are their boundaries and relationships in countries with differing economic systems? What are the criteria by which the innovation management system and its "bottlenecks" can be assessed? For example, the criterion of an innovation management system's adequacy should reflect all the organizational and economic parameters from the top down to the bottom of the hierarchy.

CHAPTER 4

4. R & D PROBLEMS AND SELECTION ENVIRONMENT

In order to identify the most often encountered problems in innovation development and management, we apply an analytical technique that allows structuralization of the problems and their aggregation by the principle of multi-dimensional cause-and-effect relationships between the elements of the system under investigation. The identification and description of these elements are done by means of conventional tools. As to the appraisal of the relationships between the elements and the influence of various factors, a special study is required. As a point of departure for this kind of analysis we used the following structure (see Figure 1).

The impetus for R & D is the discrepancy between the desired and the actual state of things (from the viewpoint of an amalgamation). As a rule, the desired state of a system is understood as its goals. Hence the convenience of formulating the problems in terms of the goals. By analyzing the degree to which they have been achieved one may describe the innovation management systems as well as their "bottlenecks" and classify them by their relevance to different aspects of the management process, etc.

The major problems to be analyzed were selected by expert judgment and with the help of the existing literature on R & D management as well as the materials of the innovation conference that took place at IIASA in June 1981.

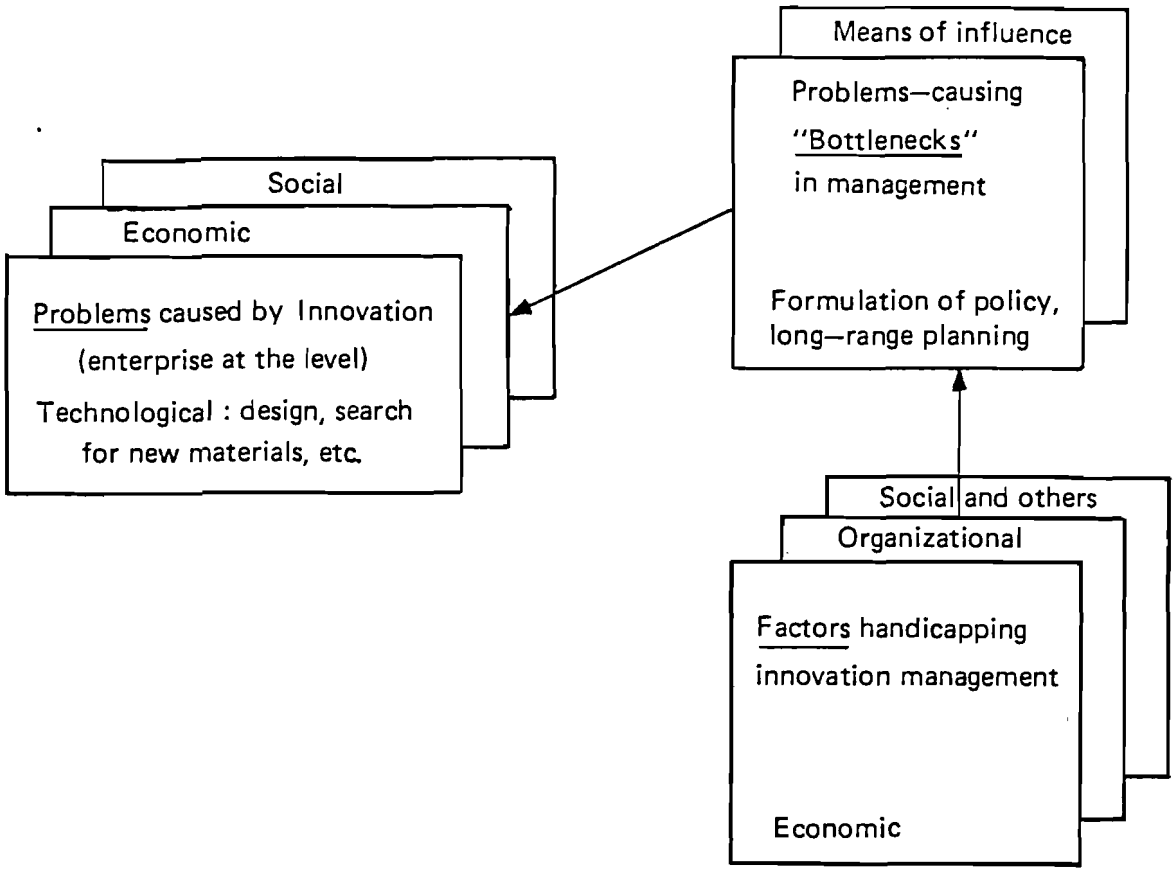


Figure 1. Structure of an approach to R & D problems.

The problems facing the enterprise in its innovative activities include the following:

- development of competitive products and processes that meet both customer requirements and international standards in the shortest possible time;
- promotion of new products;
- maintenance of an optimal balance between normal and innovative activity in an amalgamation;
- provision of the proper engineering base for innovations;
- resource constraints on R & D;
- labor supply and demand training; elimination of manual labor; changes in social needs and attitudes toward work; and
- growing imperative for improved environmental standards.

The analysis of the cause of these problems with the focus on those brought about by bottlenecks in management should employ structuralization of all the factors and of the object of investigation (here the management). As a result of structuralization certain elements are identified and their links investigated so that the goals of the research project

may be formulated.

Each of the above problems is determined by various factors that might fall under "selection environment". We have attempted to divide them into two major groups and to isolate the factors pertaining to management.

Management may be presented as in Figure 2.

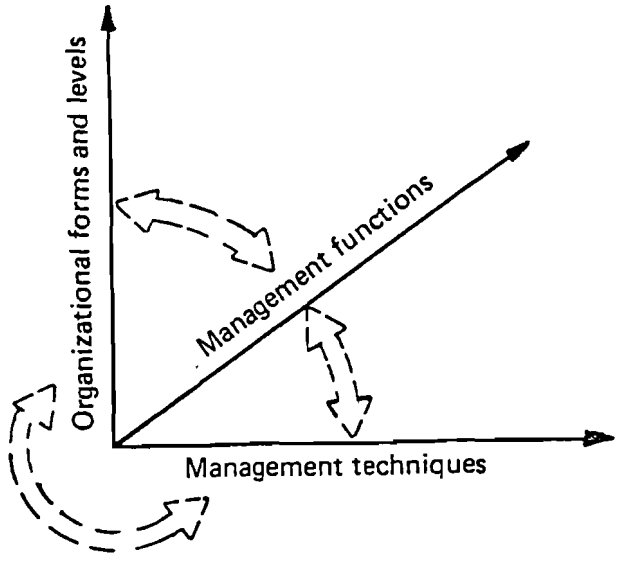
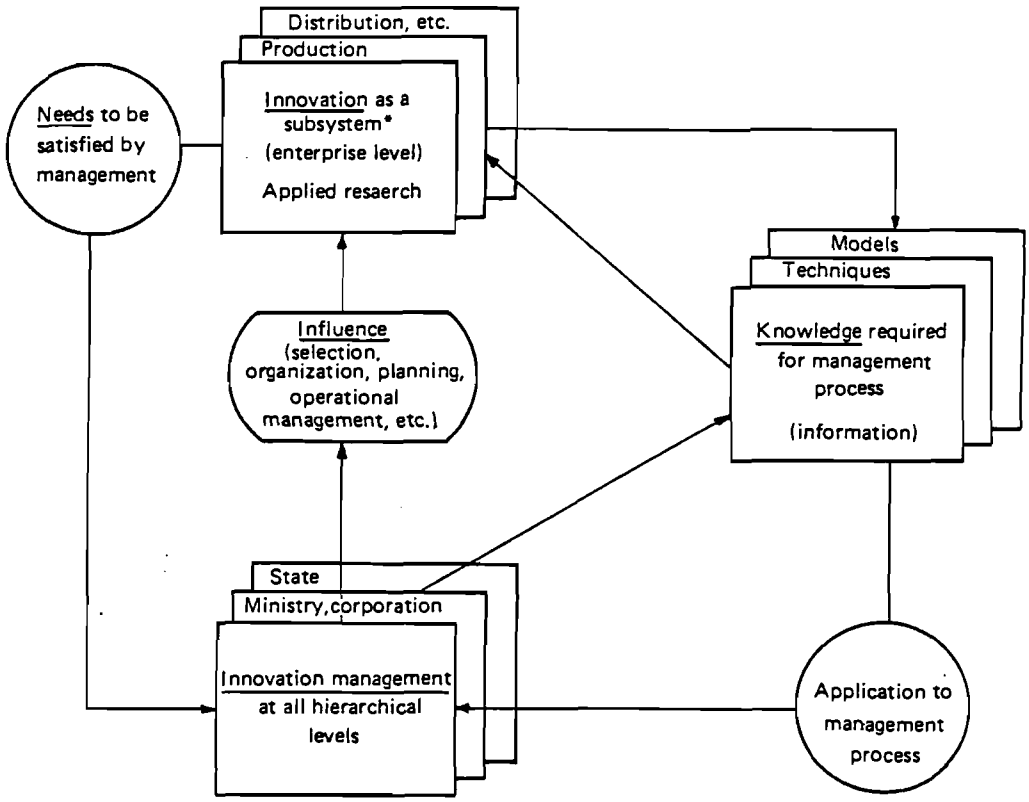


Figure 2. The interrelationships between management functions techniques and organizational forms and levels.

Under the organizational forms and levels in the management hierarchy we imply an amalgamation on the first level and a governmental body (corporation) on the second. Management techniques include the totality of administrative and non-administrative means of exercising direct influence, as well as the system of economic incentives and social motivation. In Figure 3 the subsystem (innovation process) is interrelated with management at all its levels.



*This structurization of innovations as a subsystem by types and stages was proposed at IIASA (Haustein, Harman).

Figure 3. The management of innovation as a subsystem of the entire management system.

The relationships represented in Figures 1, 2, and 3 can be aggregated as in Figure 4.

Figure 5 illustrates the principle we used in the structuralization of problems by means of a multi-dimensional "tree". The selected input parameters and the evaluated "selection environment" help define the management "bottlenecks" that bring about the existing problems. The figure can serve as a basis for the choice of tasks for a case study.

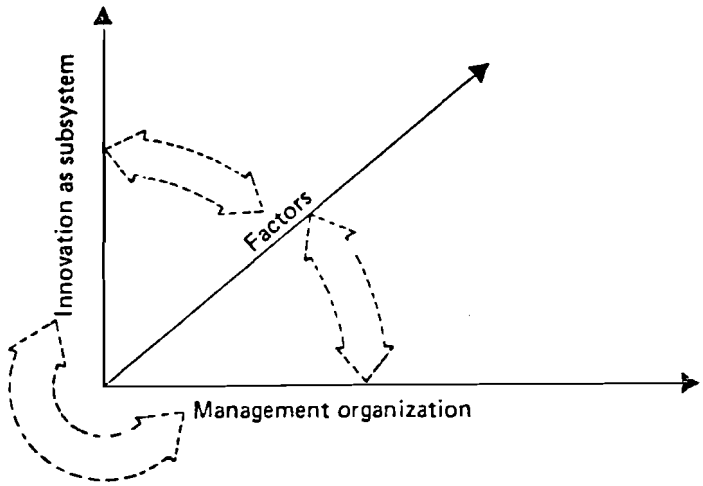


Figure 4. The interrelationships between innovation as a subsystem, management organization, and the factors involved.

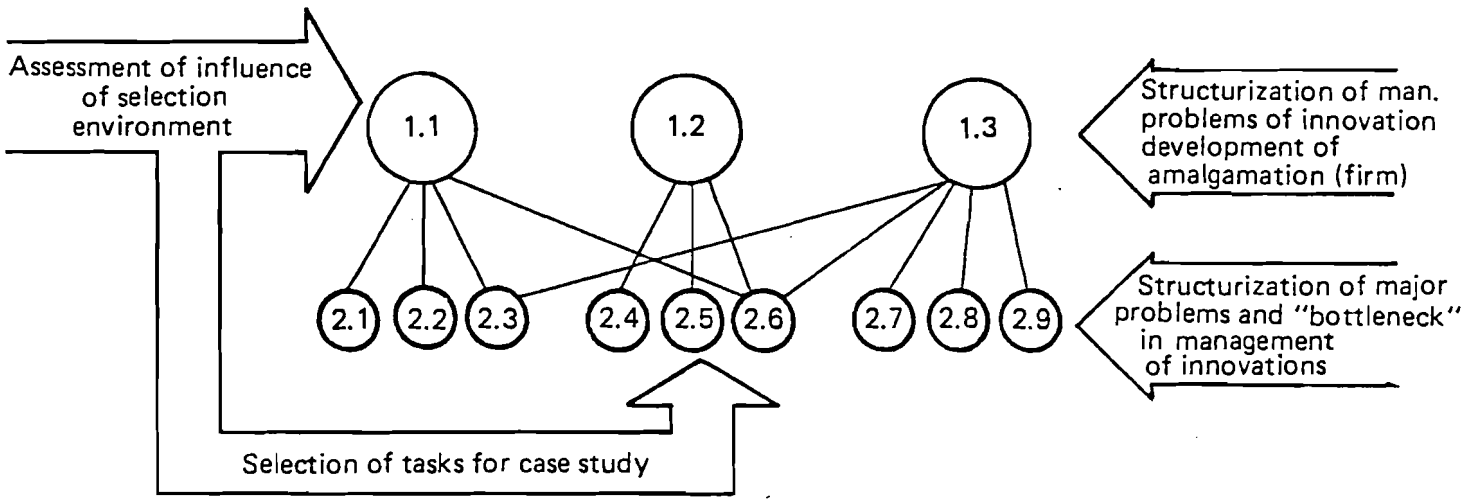


Figure 5. A "multi-national tree" for structuring problems of innovation management.

4.1 The Research Needs

Identification of major R & D problems at an amalgamation and their structurization; definition of the interrelationship and interdependence between the management system's various elements from the position of its balanced integrity; management effectiveness and its dependence on the mix of organizational forms, functions and techniques of management; appraisal of the impact of the selection environment on the innovative processes in an amalgamation (firm); development of the identification methodology of innovation management "bottlenecks".

CHAPTER 5

5. THE EXISTING PROBLEMS AND POSSIBLE TASKS FOR A CASE STUDY

On the basis of studies conducted in the USSR, the USA, and other countries, as well as the paper "Innovation Management: Toward Methodological Guidelines for International Collaboration" (Harman 1981) presented at the Workshop on Innovation Management, we can delineate the following problems and corresponding tasks of a case study

1. An analysis of the basic technological and economic parameters of specific innovations as subsystems (e.g., manufacture of powerful generators and electric machines, using the principle of superconductivity, etc.) and the requirements to be satisfied by the research-development-production cycle and its management organization include the following tasks:
   - delineation of major trends in technological changes in electrotechnology;
   - influence of innovations on the engineering and organizational aspects of the production process, research, and development;
   - rational balance between R & D and the current production activity of an amalgamation;
   - formulation of the tasks facing management with respect to specific innovations (given the uncertainty of information at different stages of the innovation process);

- interdependence between innovations on the one hand, and labor working conditions and incentives on the other.

2. The formulation of the amalgamation's R & D goals in the context of long-range planning may be disaggregated into the following tasks:
   - mechanisms of resource allocation for innovative activity and its dependence on specific features of the innovation cycle;
   - coordination of the amalgamation's R & D goals with higher level management (industry, corporation) and state (or regional) management bodies; assessment of these levels' influence on goal formulation;
   - assessment of the influence of uncertainty and risk on the mechanism of R & D policy formualtion and long-range planning (their organization, the balance between directive, motivating and limiting factors);
   - investigation of the adequacy of models and techniques used in formulating R & D policy and long-term planning, as well as their impact on organizational forms and management mechanisms.
3. Improvement of management organization and management techniques in rapidly innovating amalgamations necessitate the following:
   - studying the levels of concentration, diversification, size and structure of an amalgamation; primary (basic) organizational forms;
   - development of secondary (adaptive) organizational structures, including goal-oriented programs, cooperation by contract with other enterprises and organizations, establishment of new organizations, etc.;
   - improvement of an amalgamation's organizational design with respect to R & D development;
   - studying the relationship between planning and incentive mechanisms; providing motivation for managers and their staff as well as for professional specialists to implement innovations; and
   - development of multi-attribute evaluation techniques for assessing the effectiveness of changes in management organization.
4. The relationship of the organizational structure to the economic mechanisms that implement R & D policy should be analyzed as an environment promoting or inhibiting effective innovative activity through:
   - development of structural models of the organizational structure and economic mechanism of innovation management at an amalgamation with respect to the multi-level system of economic management (for countries with different economic systems);

- development of scenarios for description and analysis of the funtioning of different models;
- assessment of the influence of other external factors (specific features of innovations, end users, economic and social needs, etc.) on the "bottlenecks" of management;
- calculation of an innovation's efficiency for the amalgamation with account taken of implications of its diffusion and implementation.

CHAPTER 6

6. CONCLUSIONS

The content and wording of the proposals mentioned in this paper may be modified after discussion and final selection but their basic structure and interrelationships give shape to the principal guidelines for the case study:

1. The case study can best be implemented in two stages: pre-project and project proper. Each of the two stages implies unity of form, substance, and research methodology. As is known from similar experiences, it is not always possible to achieve the degree of precision desired in formulating the research tasks, elaborating the relevant methodology, and providing for the required integration of the results. Therefore the first stage should allow the research tasks, methodology, and organizational pattern to "ferment" and evolve against the background of the existing concept of a case study, its methodological guidelines, and the preliminary program. Thus at the pre-project stage, the final version of the core tasks as well as the methodology including comparative techniques should "ripen". Simultaneously a pilot study that will explore the feasibility of the goals should provide the requisite input information for the project itself.
2. Research should be centered around the core tasks, of which there may be several. Four core tasks are suggested. Structuring the project around the core tasks will allow research to focus on individual problems, will allow specialized NMO research

institutions to become involved, and will help to build up an appropriate research and methodological potential. The implementation of research by specific tasks and at the same time by the project as a whole requires both *intra- task integration* and, possibly, *integration within the entire project.* The integration process is to be accompanied by a comparative analysis within each core task.

The application of this guideline can be enhanced if one of the tasks bears an integrative character and embraces all the other tasks. In our case this role belong to the fourth task. Through these tasks, and possibly through others, there can be bridges to other studies within INNOVNET and at IIASA.

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