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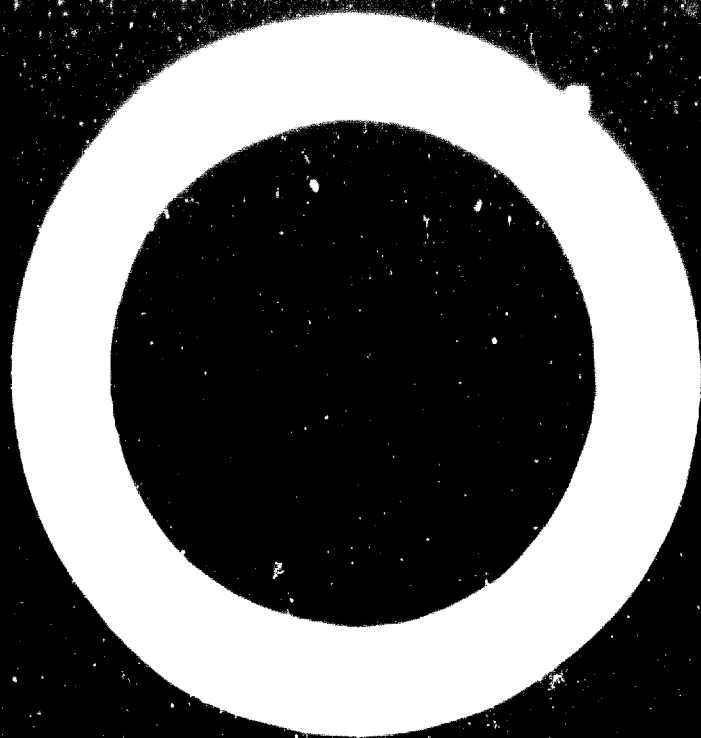
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Problems and Prospects*

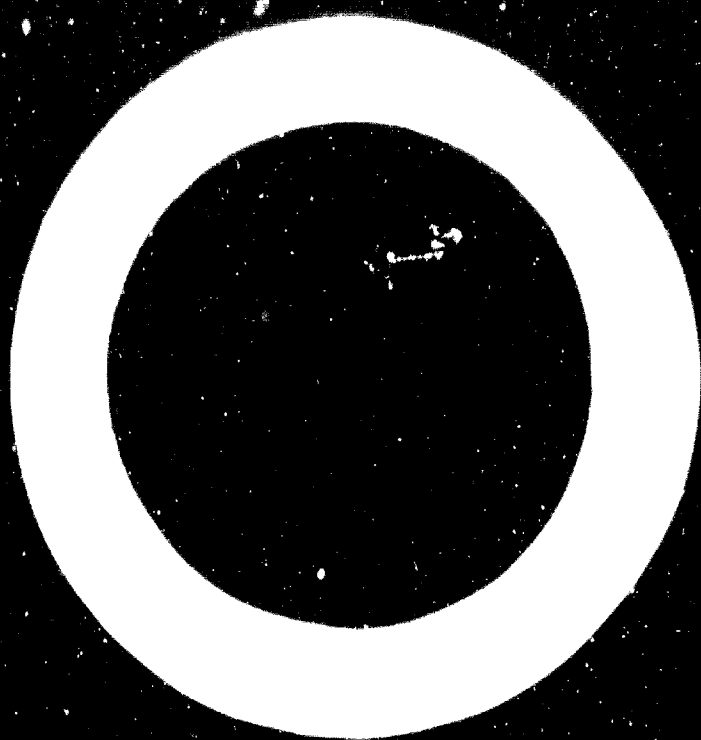
**INDUSTRIAL  
RESEARCH**

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**UNITED NATIONS**





# INDUSTRIAL RESEARCH



UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION  
VIENNA

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UNIDO MONOGRAPHS ON INDUSTRIAL DEVELOPMENT

*Industrialization of Developing Countries:  
Problems and Prospects*

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MONOGRAPH NO. 10

# INDUSTRIAL RESEARCH

Based on the Proceedings of the International  
Symposium on Industrial Development  
(Athens, November-December 1967)



UNITED NATIONS

New York, 1969

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## *Foreword*

**The International Symposium on Industrial Development, convened by UNIDO in Athens in 1967, was the first major international meeting devoted exclusively to the problems of industrialization of the developing countries. It followed a series of regional symposia on problems of industrialization held in Cairo, Manila and Santiago in 1965—1966 under the sponsorship of UNIDO and the United Nations regional economic commissions, and a similar symposium held in Kuwait in 1966 under the sponsorship of UNIDO and the Government of Kuwait.**

The Athens Symposium was attended by some 600 delegates from 78 countries and by representatives of various United Nations bodies, international organizations and other interested institutions in the public and private sectors. It provided a forum for discussion and exchange of views on the problems and prospects of the developing countries which are engaged in promoting accelerated industrial development.

The Symposium devoted special attention to possibilities for international action and for co-operative efforts among the developing countries themselves, and explored the scope, means and channels for such efforts.

Studies and papers on a wide range of problems relating to industrialization were presented to the Symposium—by the UNIDO secretariat and by participating Governments, international organizations and observers. An official report, adopted at the Symposium, has been published by UNIDO.<sup>1</sup> Based on this documentation and the discussions in the meeting, the present series of monographs is devoted to the 21 main issues which comprised the agenda of the Symposium. Each monograph includes a chapter on the issues presented, the discussion of the issues,

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<sup>1</sup> *Report of the International Symposium on Industrial Development, Athens 1967* (ID/11) (United Nations publication, Sales No.: 69.II.B.7).

and the recommendations approved by the Symposium. Some of the monographs deal with specific industrial sectors; some with matters of general industrial policy; and others with various aspects of international economic co-operation. An effort has been made to make the monographs comprehensive and self-contained, while the various economic, technological and institutional aspects of the subject matter are treated within the context of the conditions generally prevailing in the developing countries.

Since economic, technological and institutional aspects are described with particular reference to the needs of the developing countries, it is felt that the monographs will make a distinct contribution in their respective areas. They are intended as a source of general information and reference for persons and institutions in developing countries concerned with problems of industrialization, and particularly with problems and issues of international co-operation in the field of industrialization. With this in view it was considered that an unduly detailed technical presentation should be avoided while at the same time enough substantive material should be offered to be of value to the prospective reader. For a more elaborate treatment of the subject, the reader is referred to the selected list of documents and publications annexed to each monograph.

The annexes also contain information on the areas in which UNIDO can provide technical assistance to the developing countries on request; a selected list of major UNIDO projects in the respective fields; and a list of meetings recently organized by the United Nations.

It is hoped that the monographs will be particularly useful to Governments in connexion with the technical assistance activities of UNIDO and other United Nations bodies in the field of industrial development.

This monograph has been prepared by the secretariat of UNIDO on the basis of material provided by H. A. Havemann, Director of the Research Institute for International Technical Co-operation of the Technische Hochschule, Aachen, Federal Republic of Germany, as consultant to UNIDO. Mr. Havemann was assisted in preparation of the material by Messrs. U. Kuffner and A. Byertz.

## CONTENTS

	<b>Page</b>
<b>INTRODUCTION</b> .....	<b>1</b>
<b>Chapter 1</b>	
<b>REVIEW OF THE PRESENT SITUATION</b> .....	<b>7</b>
The general tasks of industrial research institutes in developing countries .....	<b>8</b>
The need for research within developing countries .....	<b>9</b>
Priorities for research at different stages of development .....	<b>12</b>
<b>Chapter 2</b>	
<b>FIELDS OF INDUSTRIAL RESEARCH AND DEVELOPMENT</b> .....	<b>14</b>
Surveys of natural resources .....	<b>14</b>
From adaptation and modification to research and development ....	<b>18</b>
Research and development .....	<b>20</b>
Standardization .....	<b>21</b>
Technical services .....	<b>22</b>
Industrial economic studies .....	<b>24</b>
Assistance to Government on policy matters .....	<b>25</b>
<b>Chapter 3</b>	
<b>ORGANIZATION OF INDUSTRIAL RESEARCH</b> .....	<b>27</b>
The institutional framework .....	<b>27</b>
Organizational structure .....	<b>34</b>
Staffing policies .....	<b>37</b>
<b>Chapter 4</b>	
<b>FINANCING AND FUNCTIONING OF AN INDUSTRIAL RESEARCH INSTITUTE</b>	<b>43</b>
General financing .....	<b>43</b>
Budgeting and financial administration .....	<b>45</b>
In-house and contract research projects .....	<b>48</b>
The research institute and its industrial clientele .....	<b>51</b>

## Chapter 5

<b>THE INTERNATIONAL SYMPOSIUM ON INDUSTRIAL DEVELOPMENT: ISSUES, DISCUSSION AND RECOMMENDATIONS</b> .....	<b>54</b>
<b>The issues</b> .....	<b>54</b>
<b>The discussion</b> .....	<b>58</b>
<b>Recommendations approved</b> .....	<b>61</b>

## Chapter 6

<b>UNITED NATIONS AND OTHER INTERNATIONAL ACTION TO PROMOTE INDUSTRIAL RESEARCH</b> .....	<b>63</b>
<b>Activities of the United Nations Centre for Industrial Development</b> .	<b>63</b>
<b>Activities of UNIDO</b> .....	<b>65</b>
<b>Bilateral aid programmes</b> .....	<b>67</b>

## Annexes

<b>ANNEX 1 UNIDO ASSISTANCE IN INDUSTRIAL RESEARCH</b> .....	<b>68</b>
A. Areas in which UNIDO can provide assistance .....	<b>68</b>
B. Selected major technical assistance projects .....	<b>68</b>
<b>ANNEX 2 MEETINGS, SEMINARS AND WORKING GROUPS ORGANIZED BY UNIDO OR BY THE UNITED NATIONS PRIOR TO THE INCEP- TION OF UNIDO</b> .....	<b>71</b>
<b>ANNEX 3 SELECTED LIST OF DOCUMENTS AND PUBLICATIONS ON IN- DUSTRIAL RESEARCH</b> .....	<b>72</b>

## ABBREVIATIONS

<b>CID</b>	<b>Centre for Industrial Development</b>
<b>ECA</b>	<b>Economic Commission for Africa</b>
<b>ECAFE</b>	<b>Economic Commission for Asia and the Far East</b>
<b>ECLA</b>	<b>Economic Commission for Latin America</b>
<b>FAO</b>	<b>Food and Agriculture Organization of the United Nations</b>
<b>ILO</b>	<b>International Labour Organisation</b>
<b>OECD</b>	<b>Organisation for Economic Co-operation and Development</b>
<b>UNESCO</b>	<b>United Nations Educational, Scientific and Cultural Organization</b>
<b>UNIDO</b>	<b>United Nations Industrial Development Organization</b>

## INTRODUCTION

**Economic and social conditions differ greatly in various parts of the world. As a general rule, it may be said that they correspond closely to the degree of industrialization achieved. The progress of industrialization may be based on abundant raw materials or on high productivity. The inhabitants of all industrialized areas appear to share a capacity for technological innovation which, in its broadest sense, is the essential precondition for general economic growth, and continue to make progress by means of research and development.**

It is well known that the share of the developing countries in world trade is much smaller than that of the industrialized countries. The plea for a larger share is rightly voiced by the representatives of the less industrialized countries, who emphasize the need for the liberalization of trade. Although this would be an important step forward, it would not in itself be sufficient to solve the world problem of the gap between highly industrialized countries and those intent on improving their over-all economic position by the introduction of science and technology. While in the past developing countries have exported mainly raw materials, in more recent times the structure of demand in industrialized countries has undergone a significant change, and this has affected the trade of the developing countries.

Modern technological developments have brought with them trends towards the use of highly specialized materials, which are no longer derived from the commodities developing countries have traditionally exported. A further change has been the growing demand in world markets for complex machinery, which requires highly sophisticated technology to produce. Lastly, industrialized countries, by means of increasingly efficient technology, have improved the utilization of their own resources. They now require products processed to meet exacting specifications or processed in a manner that is possible only through technically complex operations. The outcome of all these trends is that trade between industrialized countries has steadily grown. It would seem, therefore, that only a far-reaching change in the structure of production

and in the goods of the developing countries can improve their position in the world market. It is clear that long-term technological evolution is urgently required.

Furthermore, the social conditions in developing countries call for energetic measures to raise living standards. The improvements in agriculture and the increase in food production have been slow because of the enormous problems to be solved. Steps should be taken to accelerate industrial development in those countries where as yet little progress has been made. This should be done in such a way that the available potential is utilized to the utmost. Developing countries must introduce industrial research in order to ensure long-term technological development, since research in science and technology is the instrument to which the industrialized world owes its progress.

Developing countries must turn to science and technology in order to become partners of industrialized countries, and to improve their general economic situation. Since the cultural, economic and social conditions of the developing countries are so different from those of the industrialized countries, technology can be introduced successfully only if it is adapted to local conditions.

The evolution of technology based on local research will bring about a world division of labour and areas of activity with complementary technologies similar to the division of labour that has been achieved within industrialized countries and that is now taking shape in the larger context of international economic co-operation among industrialized countries. This long term goal of world co-operation, which will benefit the developing countries, can be achieved only by technological research carried out by the developing countries within their own territories and, in the long run, by their own citizens.

In this monograph an attempt is made to give the developing countries some guidance on the areas in which they should concentrate their research and development activities. Advice is offered on the most suitable forms of organization of these activities.

*Chapter 1* points out that research and development activities are the prerequisite for economic growth and that developing countries must organize facilities for them. Before an industrial research institute is established, its exact functions must be determined. In general terms, they will be to promote the adoption of available technical processes and products, to provide consulting services to existing industries and to disseminate information on economic and technological subjects. Recently,

much work has been done by specialized institutes in advanced countries on the problems of developing countries. There are, however, obvious advantages in working on the spot, with full knowledge of local conditions, although the benefits of international collaboration should be retained. The relative importance to be attached to the various types of research and development work depends upon the stage of industrial development the country has reached.

*Chapter 2* discusses the surveys of natural resources that must be undertaken to assess the potential of a country and to determine the most economic manner of exploiting it. This task should be undertaken by the industrial research institute.

In the early stage of industrial development, the main requirement is for development research, especially research in adaptation and modification. Developing countries are obliged in the first instance to accept imported production techniques and processes; they should therefore concentrate on determining what changes are required in order to adapt available technologies to local conditions. Developing countries, intent on industrial growth, should at a later date extend their efforts to the fields of applied and fundamental research.

The chapter also discusses the various technical services the industrial research institute should offer to industry if no other specialized consultant institutes are available. Such services might include the provision of testing facilities, quality control, consultation on problems of selecting equipment or introduction of modern techniques of production planning and process control.

After technical research and service departments have been established, the industrial research institute will have to extend its activities to economic research, including market surveys or pre-investment, productivity and management studies. General economic problems that are the responsibility of government agencies might be worked out in co-operation with the economists of the institute in view of their expertise in the field of industrial development.

Close co-operation with the Government will enable the institute to offer useful advice on labour questions, location of industry and protective tariffs. In general, the industrial research institute may suggest industrialization policies, including export promotion schemes or subsidies. It can also be instrumental in arranging international industrial partnerships so that local industry can keep pace with general technological development.

*Chapter 3* reviews the various ways of organizing industrial research: as an institute within a university, as a government department, as an activity of an industrial association, or as a private, non-profit organization.

In the early stages of industrialization in developing countries, universities should carry out fundamental research, while applied and development research appears to be best handled by government institutes. Owing to the need for government financing of research and development, special government research institutes should be set up to conduct research and development of general interest to the public. For many industries it is often difficult initially to undertake, or even see the advantages of, research and development activities.

Experience has shown that civil service methods are not suited to the special interests and requirements of an industrial research institute. A board of management appointed by the Government should supervise the activities of government industrial research institutes. A director should then be appointed to be responsible for financial administration and budgeting and to report to the board of management. He should be able to run the institute on the lines of an industrial enterprise. The qualifications of the scientific personnel of the industrial research institute should be determined by the tasks to which they will be assigned. These will be initially in the field of practical research and development. Industrial experience is desirable, and salaries should be similar to those paid in industry.

*Chapter 4* deals with the financing and functioning of an industrial research institute. Adequate funds must be available to finance both capital and current expenditure. The financial administration of the institute should be businesslike.

The cost of research projects can be roughly calculated by estimating the probable time the research personnel will need to carry out the project and by taking into account the costs of materials and processing. Provision must also be made for the overhead of the institute, which is likely to be considerable. For pilot-plant work, special financing by the Government will be necessary.

When drawing up long-term plans for the industrial research institute, the board of management has to decide on the relative number of in-house and contract research projects. The latter will guarantee that the activities of the institute will be those urgently needed to ensure short-term technological advances, while in-house projects will enable the

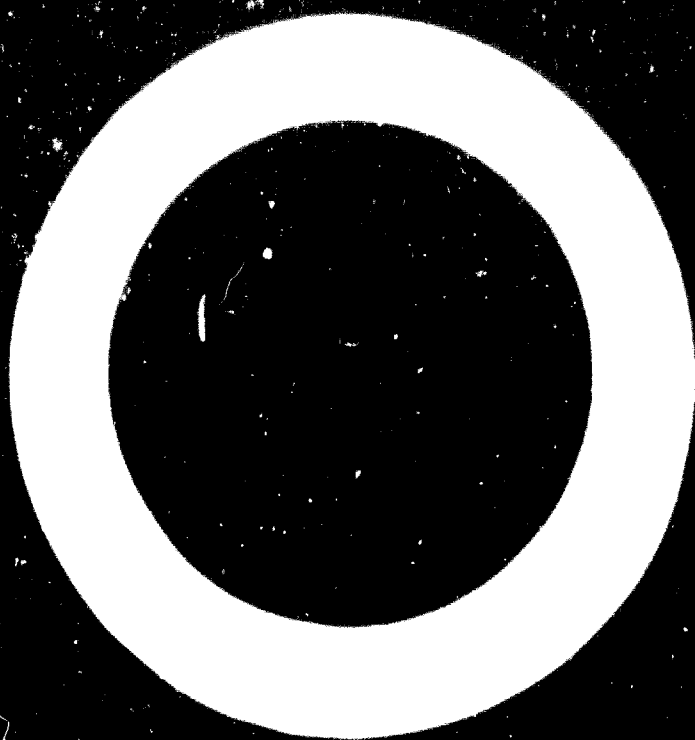


scientific personnel to follow technological ideas that they consider promising in the long run. Feasibility and practicability must be the main criteria for both types of projects. The management of the institute should reject unsound projects and be prepared to terminate work on those in progress if the results appear discouraging.

Industrial research institutes must sell their services to the community. Various promotional activities will be useful, but since the best advertisement is success, everything possible has to be done to conclude research and development projects successfully. Regular contact with clients is needed to ensure that research projects are carried out in accordance with the clients' interests and not exclusively for scientific purposes.

*Chapter 5* gives an account of the International Symposium on Industrial Development held in Athens in 1967—the issues, the discussion and the recommendations approved regarding industrial research in developing countries.

*Chapter 6* reviews United Nations action and bilateral action for the promotion of industrial research.



## REVIEW OF THE PRESENT SITUATION

Industrialization is recognized as an essential element in the economic growth of developing countries. There has already been considerable economic progress in these countries, but owing to the population explosion, the *per capita* income still remains at a depressingly low level compared with that of industrialized countries. Developing countries must therefore concentrate on the most important means of stimulating and maintaining accelerated industrial growth. Research and development work constitutes one of the most important prerequisites for industrial growth. According to some authorities, the high economic growth rates in developed countries since 1950 are explained to a considerable extent by increased expenditure on research and development. In highly industrialized countries, an annual expenditure of 2 to 3 per cent of the gross national product (GNP) is considered necessary to keep the economy competitive internationally.

Even a considerable outlay on research and development is, however, no guarantee of rapid industrial growth. In the United Kingdom, for example, over 2 per cent of the GNP has been spent on research and development for many years, but the over all economic growth rate is the lowest in Western Europe.<sup>1</sup> This may be ascribed to the low investment in new production processes. Considerable expenditure on research and development is justified only if the findings of research are promptly applied in industry.

The organization of research and development activities in the developed countries cannot be directly imitated by developing countries, for these countries cannot afford to spend a great deal of money on research and development and do not normally have enough qualified experts and scientists available. The question for the developing countries is what constitutes the optimum expenditure in relation to the technical facilities already available.

<sup>1</sup> B. R. Williams, p. 64; for full reference see annex 3 under "Other sources".

## THE GENERAL TASKS OF INDUSTRIAL RESEARCH INSTITUTES IN DEVELOPING COUNTRIES

The aim of research and development and industrial research institutes in developing countries must be to lead the way to industrialization; the first step should be to overcome the technological shortcomings, i.e., to promote the transfer of existing technical processes and products. The research activities of institutes in highly industrialized countries, in contrast, are primarily concerned with the development of new products and technologies.

In developing countries the two main objectives of research should be to smooth away difficulties in the path of industrial development and to assess potential industrial expansion. Before an industrial research institute is established, a study has to be made to determine what activities will be required of it. Such a study will assess conditions in existing industries and indicate how the growth of these industries is limited by economic, technical, social or organizational problems.

This study will outline the tasks to be undertaken by the industrial research institute. The institute should establish consulting services for existing industry that would provide relevant information on economic production or technological processes. It should offer facilities for tests and quality control and advice on suppliers, patents and licences. It should also give assistance to industrial enterprises on problems relating to their labour force and technical personnel and to their organization and management.

The industrial research institute must also identify elements in the infrastructure and in the supply of inputs that hamper individual enterprises. This type of activity is not usually associated with research and development, but the situation in most developing countries demands that the institute should so extend its scope. In addition, it must carry out the essential task of convincing a generally "non-research-minded" industry of the necessity for research and development and for accepting technological change. By introducing new sources of raw materials, new production and organizational methods and opening up new markets, the industrial research institute assumes what has been defined as an entrepreneurial function.<sup>2</sup>

One significant feature of developing countries is the lack of almost all the prerequisites for organizing and making use of research and

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<sup>2</sup> J. Schumpeter, p. 66; for full reference see annex 3 under "Other sources".

development. It will not be easy to find qualified personnel, to provide adequate funds to establish the institutional framework, to organize research institutes or to build up the scientific infrastructure (libraries, laboratories, publications, professional associations, facilities for meetings and discussions etc.). Yet it seems that none of these is the main inhibiting factor; the primary lack appears to be the absence of economic stimulation.

### THE NEED FOR RESEARCH WITHIN DEVELOPING COUNTRIES

Within the last decade research and development activities have expanded rapidly in the developed countries. Some of the most recent developments have been taking place in the fields of data processing, documentation and retrieval of information, systems analysis, problem-solving capacity, operational research, automation and computer technology. The interests of the managerial and scientific communities of the industrialized countries have widened, and the concept of a global economic strategy is now a subject of much discussion, especially in view of the world population explosion. The special problems of developing countries have been studied, and experts and scientists from the developed countries have proposed various measures to solve them.

Despite the progress achieved by research institutes in the developed countries that specialize in the problems of the developing countries, it has become increasingly evident that research and development relating to these problems must be carried out in the developing countries. The advantage of working on the spot has led to co-operation between these specialized research institutes in the developed countries and existing institutes in developing countries as well as to the establishment of new research facilities in the latter countries.

The most obvious reason for conducting research on the spot is to obtain direct access to the object of research, to the environment of the country and to the areas or industry under investigation. Research institutes in developed countries may send experts to the developing countries to gather the information needed for their studies, or they may set up laboratories to simulate local conditions, but they may still overlook certain relevant details, such as atmospheric conditions. Scientists in institutes in developing countries are adjusted to the environment; they have direct access to the object of their research and can test their findings under local conditions.

Conducting research in developing countries for particular industries

has the great advantage of establishing direct links between the research institutes and their clients. Researchers can collect the required information directly, identify and investigate the most urgent problems of local industry, have their proposals tested and possibly improve on them. For its part, management can explain its difficulties directly to experts.

The local research institute may not have the reputation of a high-level foreign institute, but it is in a position to assist industry with many problems—problems that are perhaps elementary in the early stages of industrialization—and thereby establish its own reputation. In this way, a research consciousness can be created, and contact with the industry will automatically produce a “feedback”, which ensures that research activities undertaken at the institute will be focused on the needs of the industry.

Industrial research institutes in developing countries may initially need the assistance, know-how and professional guidance of foreign institutes or international organizations. For example, a research institute in an industrialized country may train personnel for its counterpart in a developing country. This arrangement offers the advantage of an international partnership between institutes working in the same field of technological research, while the local institute remains in touch with the problems of fledgling industrial enterprises.

The activities of a well-organized industrial research institute will directly aid the flow of technological knowledge from developed to developing countries. The presence of experts who are familiar with technological advances and know the problems of local industry will ensure that the transfer of technology is correctly oriented and proceeds as rapidly as possible.

In summary, an industrial research institute established within a developing country will benefit that country more than an external institute for the following reasons:

It will be familiar with the environment and can therefore more easily assess development trends realistically in relation to local resources, technology, social and cultural traditions, the climate etc;

It will have direct contact with its clients, so that it will be familiar with the methods of production and the existing market conditions and will know how far the results of research and development may be directly applied; it will also have opportunities to influence local industrialists and to encourage them to participate in research and development work;

It will be able to facilitate the transfer of technology by disseminating information on technological development and new techniques, by helping to choose technologies suitable for local industries and by adapting foreign products and processes to local conditions;

It may provide staff for local research institutes and industry by training scientists, professional technical personnel and technicians;

It may be able to assist the Government in planning realistic macro- and micro-industrial measures; it may also exercise, on behalf of local industry, a certain influence as regards export promotion and import licensing.

Although these are good reasons for establishing industrial research institutes in developing countries, it should be recognized that these institutes will be subject to certain limitations. For financial reasons, the industrial research institute must concentrate on the fields of research dictated by the requirements of the country concerned. Even within these fields it must concentrate on the most urgent and promising subjects because of limited funds and the obvious need, especially at the beginning, to win the confidence of local industry.

In some cases the research facilities available may not be adequate for the type of research required; it is then necessary to consider carefully whether it would be more economical to provide the necessary facilities because a large volume of work is expected in the future or to hand over the project to a foreign research institute. Regional co-operation to provide a research centre where topics of common interest or those beyond the facilities or means of a single country could be tackled would be the ideal solution (see chapter 3). It may in any case be necessary to collaborate at a regional level in order to ensure a market of the requisite size for an industrial product. In this way, economies of scale may play an important part with respect to both research and the volume of production.

Interaction between scientific research and industrial application is one of the preconditions for industrial development.

The steady flow of research and development findings to industry is characteristic of highly industrialized countries. However, at an earlier stage of economic development, research and development work that would not be of a sufficiently high level for industrialized countries may satisfy local industrial needs. The level of research activities should be determined by local circumstances.

### PRIORITIES FOR RESEARCH AT DIFFERENT STAGES OF DEVELOPMENT

It is important for a developing country that is planning to establish an industrial research institute to choose activities to be carried on that are appropriate to the stage of the country's industrial development.

To accelerate economic progress at an early stage of industrial development, it is more advantageous to take over products and technological processes from industrialized countries than to develop them independently. Priority should be given to research and development activities that speed up the introduction of products and processes already well tried elsewhere, and that may be modified, if necessary, to suit local conditions.

Later on, emphasis will shift to applied and basic research because more advanced technologies will have to be developed. The structure and requirements of more advanced industries will bring about the extension of research activities to fields of particular interest to local industry. Resources of manpower, capital etc. can be used efficiently only if a proper balance is maintained between the branches of research and development (basic research, applied research and development) according to the needs of the country.

Analysis of research and development activities in the United Kingdom and the United States, for example, shows that the breakdown is as follows:

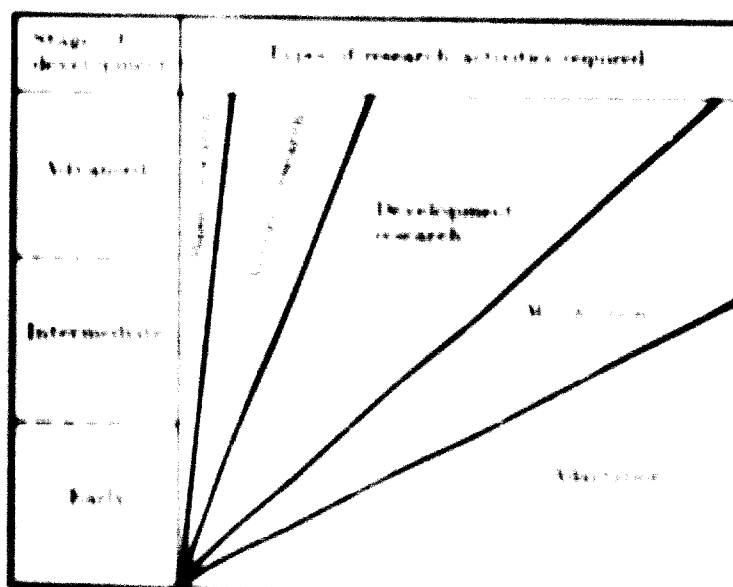
Basic research:	12 to 18 per cent.
Applied research:	22 to 26 per cent.
Development research:	61 to 65 per cent. <sup>3</sup>

On the assumption that what has actually occurred in leading industrialized countries since 1950 represents the optimum distribution of available funds, roughly one seventh should be spent on basic research, less than one quarter on applied research and about two thirds on development research.

On the basis of these data, figure 1 shows the relative importance of different types of research in relation to the stage of development in a hypothetical case. The vertical axis represents the stage of development of a country or industrial sector, while the horizontal axis shows various research and development activities as parts of the total. The five types of research activities will be defined in chapter 2.

<sup>3</sup> OECD (1967), table III, p. 59; for full reference see annex 3 under "Other sources".





**Figure 1.** *Relative importance of types of research activities at various stages of development in a hypothetical case*

To determine the stage of development of a country, it is necessary to ascertain how many scientists and engineers are working in research and development and in industry and how qualified they are, the standard of the research facilities, and the quality and quantity of the means of production.

It is very difficult to determine the precise stage of development. The most commonly used index, the *per capita* GNP, may be taken as a basis for the rough classification of countries. Countries with a *per capita* GNP of under US\$75 are at the earliest stage of development, those with a GNP of up to \$1,000 are at an intermediate stage, while those with a GNP of over \$1,000 may be described as developed countries.

## **FIELDS OF INDUSTRIAL RESEARCH AND DEVELOPMENT**

**Governments of developing countries are confronted with the problem of creating the institutional framework for research and of harmonizing its objectives with the national science policy. Developed countries may be in a position to finance fundamental research generously even though it does not appear to be of any immediate practical value, but developing countries must give priority to research projects that will have the most beneficial effect on the national welfare within the shortest possible time.**

In the following sections an analysis is made of the main fields of industrial research that are important for developing countries. However, the difficult task of identifying the most urgently needed research and development projects must remain the responsibility of the government agencies concerned and of the research institute.

### **SURVEYS OF NATURAL RESOURCES**

**The efficient utilization of material resources is of basic importance for the development of a country. One of the most urgent tasks of research is to investigate natural resources. Two methods can be applied:**

**The descriptive method, i.e. a description of the natural resources, raw materials, minerals, agricultural potential and resources of energy, their location, quantity and quality.**

**The functional method, i.e. the analysis and appraisal of how the resources may be utilized.<sup>4</sup>**

Both methods should be used. With the aid of geological and other surveys, government agencies will be able to draft development plans based on resources known to exist. However, the most detailed description of resources is not sufficient for working out development plans. The

<sup>4</sup> E. W. Zimmerman, for full reference see annex 3 under "Other sources".

resources must be appraised and feasibility studies on their utilization conducted if adequate information for planning is to be provided.

Recent discoveries of oil and natural gas fields have changed the entire economic perspective of a number of countries. There may, however, be many obstacles to the economic exploitation of these resources; for example, pipelines may have to be built through desolate or mountainous areas, or ports and storage facilities constructed. Only a thorough investigation of all the relevant factors can indicate the most economic way of using natural resources.

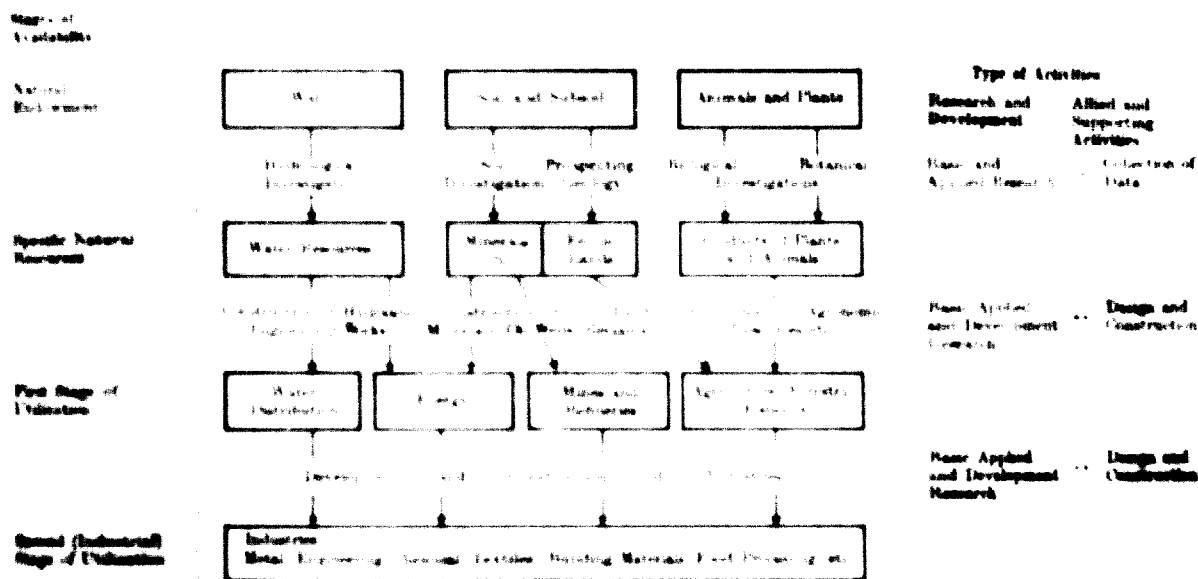


Figure 2. Natural resources and their uses in industry

Natural resources may be defined as all the elements of the physical environment that are actually or potentially useful to human beings.<sup>6</sup> A schematic description of natural resources together with their possible development and utilization is shown in figure 2.

Since the agricultural sector is dominant in the developing countries, soil analysis and surveys of animals and plants must be carried out to ensure that these resources are used to the best advantage. Hydrological surveys have enabled many countries to make full use of their water resources for the production of electric energy, for consumption and for irrigation.

Thorough large scale geological studies are a precondition for establishing a number of industries. Most of the earth's mineral resources have in the past been discovered accidentally. Prospectors were searching for

<sup>6</sup> *Science and Technology for Development, Vol. II, Natural Resources*, p. 9; for full reference see annex 3 and 4 "United Nations".

gold and silver in a haphazard way until a few decades ago, and individuals still continue to do so. It would be a serious mistake to leave the vital task of exploring mineral wealth to private enterprise of this sort except in places where the systematic survey and exploration of larger areas cannot be performed by experts.

An adequate survey is one that describes natural resources and analyses the possibilities for their use. The industrial research institute should carry out such surveys; in many cases, however, it will not be equipped to do so without the assistance of foreign experts or specialized companies.

One of the first steps in this field of research may be to establish a hydrological department to record and evaluate the precipitation and run-off of water. Plans for reservoirs, dams or other hydraulic engineering works must be based on records extending over a number of years. The failure of many such works can be attributed to lack of data about the actual hydrological conditions.

Although the lack or high cost of experts may make it impossible to set up a geological department in a newly established research institute, one of the first in-house projects should be to compile a catalogue of all available information.

### **Geological prospecting: an example of its importance**

The experience of the Byelorussian Soviet Socialist Republic (BSSR) provides an excellent example of the importance of geological prospecting.

In the 1920s, only shallow prospecting for minerals was carried out in the BSSR because the technical facilities at that time were limited. After the first Geological Research Institute had been established in Byelorussia and modern equipment introduced, prospecting at greater depths became possible, and geological survey work expanded considerably. From the early 1940s on, large deposits of salts, coal and mineral ores were discovered. In 1964, the first oil gusher was drilled, revealing the tremendous petroleum potential of the area.

The earlier idea that the mineral resources of Byelorussia were not large was radically changed within a short space of time. Exploration made possible by modern geological equipment revealed that the resources were substantial. The increase in geological prospecting in Byelorussia can be seen from the following percentages, using 1938 as the base year:

1938	1940	1945	1961	1966
100	157	200	307	1,500

In 1966, the authorities spent 4.7 per cent of the total appropriation for industrial production on geological prospecting. As a result of extensive prospecting, known mineral reserves are growing faster than is the industrial demand for them.

### Agriculture

Research in the agricultural sector covers a wide range of subjects. Because of the great variety of soils in all countries, the first step in a survey is to analyse the soil and determine which crops are the most suitable for a particular country. The development of virgin lands must be preceded by a detailed analysis of the potential of the area, or the estimated cost of development (cost of constructing highways and resettling people) may increase sharply because the need for irrigation or drainage, soil conservation, or the use of fertilizer was not foreseen.

Land already in use may be better suited to crops other than those traditionally grown. The recent introduction of Mexican wheat and a new sort of rice, "IRRI-8", in West Pakistan has proved very successful. After many years of importing cereals, Pakistan will probably now become a food-exporting country. From the point of view of agricultural development plans, the importance of analysing the soil, evaluating its potential and improving agricultural techniques cannot be overestimated. At the same time local plants and traditional crops should be studied to determine their best use.

Animal resources and animal products must also be surveyed, especially since the economic utilization of animals has been traditionally neglected in some countries. Surveys of animal resources should be more closely linked with the various objectives of development plans than surveys of other natural resources, since the social implications of research in this field may be more far reaching.

### Surveys of marine resources

Some countries have not seriously considered the exploitation of their marine resources. Yet these resources may be of great potential value. The development of fisheries in Peru may serve as an example of

what can be achieved in this area. In the mid 1950s, the total catch of Peru was about 100,000 metric tons; in 1967, it amounted to 10 million metric tons. Peru thereby moved from an unlisted position to occupy first place among fishing countries.

To utilize marine resources, however, facilities for processing and deep-freezing and for packing and storing the fish will be required. When the quality and extent of natural resources are being investigated, attention must be given to the commodity to be manufactured from them. Quality control will be needed to produce an article that can be sold in world markets and thereby earn foreign exchange.

#### FROM ADAPTATION AND MODIFICATION TO RESEARCH AND DEVELOPMENT

When developing countries begin research activities, they will generally find it advisable to collaborate with research institutions in industrialized countries. They will start by using conventional technology and importing industrial goods that do not require any changes, then progress through the intermediate stages of adaptation and modification until they reach the stage of research and development proper.

#### Adaptation

The first stage in indigenous technological development is one of adaptation of imported technologies to the particular circumstances of the developing country. The essential elements of imported production processes, however, remain unchanged. Technological adaptation would, for example, include the adjustment of modern agricultural tools to the properties of local soils and to traditional crops. The manufacture of these tools or even village arts and crafts could be upgraded by introducing modern machinery or the use of energy.

Further adjustments might be dictated by the availability of cheap labour; capital-intensive operations might be replaced by labour-intensive processes. An effort might be made to replace imported parts that are relatively simple to manufacture by parts produced within the country. Thus, an increasing number of imported parts used in assembly plants, for example, could be replaced by indigenous products.

A thorough examination should be made of domestically produced raw materials to see whether they might be used in modern or traditional

**processes.** This applies in particular to local building materials, which **are** usually much cheaper for the construction industry than newer **materials.** Many countries can refine and concentrate ores, which were in the past exported directly as mined, however, the technological requirements should be carefully investigated. Processed raw materials yield a higher return than those that are unprocessed and at the same time allow local manufacturers to make use of the mineral resources of **their own country.**

The first stage of indigenous industrial research, therefore, is characterized by the introduction of research facilities and the corresponding entrepreneurial activity. The goal for research at this stage is to bridge the wide gap between importing fully manufactured goods and exporting **raw** materials or other basic commodities, such as agricultural products. **Between** these two extremes there is ample scope for adapting imported **technologies** (which in most cases have been the result of engineering developments in the industrialized countries) to local conditions.

It must be admitted that at this stage one cannot speak of "research" in the true sense of the word, but even the simple process of **technological** adaptation raises many problems that must be solved. **Problem-solving** lays the basis for further advance, personnel gain a thorough understanding of up to date technical processes, equipment and production techniques. The economic advantages of adaptation can be seen, **and** this provides an incentive to establish technological and industrial **research** proper.

The fact that it is possible to adapt an industrial product to local conditions does not justify indifference to the need for modifying production techniques. Here the size of the market makes it necessary to evolve **a** process that can be used economically for a smaller output. The industrial research institute should try to maximize the production of one **manufacturing** cycle by obtaining the co-operation of small companies and **adapting** techniques to achieve economies of scale even though the volume of **sales** is small. Through such activities the industrial research institute can play an important part in industrial development and export policies.

### **Modification**

As its second **stage,** indigenous industrial research carries still further the process of **adjusting** imported technologies to the technological, social and economic conditions of a country. This stage is described

as "modification"; in industrialized countries it might be regarded as development research.

A steelmaking process developed in Mexico may be taken as an example of "modification". In conventional steelmaking processes coal is used to reduce iron ore. In the case of Mexico, coal would have to be imported at considerable cost, and locally made steel could not compete with imported steel. But Mexico has large supplies of natural gas. A new technological process was therefore evolved, using natural gas to reduce iron ore to sponge iron. The next step in steelmaking was carried out in electric furnaces using natural gas in gas turbines to produce the electricity needed.

Such a modification of an imported process entails much greater research effort than adaptation. Although modifications should normally not alter the basic technological conception, some original thought is required. Besides being worth-while fields for indigenous research, the adaptation, and even more the modification, of conventional technologies provide an opportunity for individuals to learn the scientific approach to concrete problems and also the art of research management—the art of guiding personnel to engage in research and to achieve results within a reasonable time.

Only limited funds are needed at this stage for equipment, housing and personnel, and the outlines of the organization structure can easily be changed as future circumstances require.

### RESEARCH AND DEVELOPMENT

While at an early stage of industrial growth the emphasis should be on "adaptation" and "modification" of products and processes, at a later stage the development of new products and processes becomes essential. At this stage fundamental and applied research have to be brought into the picture. The academic disciplines of mathematics, physics, chemistry, biology and geology form the basis for the techniques by which natural resources are developed. Consequently, progress in these disciplines is a prerequisite for economic and industrial development.

Research and development activities have to be directed in the most efficient way that the financial and scientific resources of a country permit. If the allocation of funds for fundamental research, applied research and development has not been wisely made, financial resources and scientific



work will be wasted. Naturally, the distribution of funds for research should be determined in relation to the economy as a whole. Certain economic sectors may require heavy investment in fundamental or applied research, whereas others require investment in development research or modification of foreign technologies or products.

The development of industry in Japan shows how a country deliberately took over technological knowledge from industrialized countries; this enabled Japan first to assimilate foreign technologies, then to substitute its own products and processes for those of other countries, until it reached—and in a number of spheres even surpassed—the technological level of the western industrialized countries.

This example shows once again that research and development in developing countries is a “learning process”, a progression from less complex to more complicated tasks. This procedure may seem unduly slow, but it is necessary for husbanding the limited resources. It offers the advantage that during this period industry can form close links with the industrial research institute. An important factor in the learning process is a partnership of the research institute with research institutes or industrial sectors in developed countries. Institutes may also enter into academic partnerships with universities, especially those concerned with technology and development research.

#### STANDARDIZATION<sup>6</sup>

One of the most important methods of securing efficiency and economy in industry is to introduce standards.

The activities of an industrial research institute in a developing country can hardly cover the whole field of standardization. However, the vital role played by standardization in the future development of industry requires the institute to undertake certain functions in this field until a specialized standardization institute has been established. A government decision to introduce a system of international weights and measures may depend on the work of the research staff. There are, moreover, standardization problems that are bound up with the work of the industrial research institute. For example, standards can be introduced to ensure the quality and reliability of local industrial production. If

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<sup>6</sup> Standardization and quality control are the subject of Monograph 12 in this series.

goods are to be exported to countries where special circumstances, such as climatic conditions or lack of maintenance facilities, make it unlikely that conventional goods will give satisfaction, the institute might devise special performance standards. If standards of this sort were made compulsory for exports, these exports would soon gain a foothold in markets where goods from industrialized countries, owing to the inflexibility of large-scale production, do not meet special requirements.

Standardization is also important in the manufacture of accurate instruments. Here the industrial research institute might go beyond mere calibration tests and evolve standards designed for application under special circumstances (e.g. tropical conditions).

The economics of standardization should also be taken into account. Although the cost of production and distribution increases with the number of types produced, the adaptation loss, i.e. the loss arising because the "standard" product is not ideally adapted to the demand, decreases with an increasing number of types. By balancing these two factors the optimum, or minimum, total cost can be determined.

#### TECHNICAL SERVICES

The industrial research institute can influence productivity in two ways: by introducing modern methods of management and by promoting technological innovation.

With respect to modernizing management, the institute must take the particular circumstances of the company and of the country into account. It may be necessary to suggest to the Government that management training schemes be introduced. The institute should initiate the organization of industrial associations, which would cooperate with chambers of commerce.

With respect to innovation, the industrial research institute can undertake many activities that will promote new ideas. It can assist industries in introducing technical changes, such as mechanization and the installation of new machinery. It is in a good position to do this, since it has access to relevant information, contacts with advanced industrial establishments and qualified personnel.

Although the provision of technical services is not one of the conventional functions of a research institute, such services are so important

to smaller and less developed industries that they should be made available by the industrial research institute as extension services when no other institutions providing such services exist.

Technical services that may be offered to individual companies include facilities for performance testing and quality control. As already mentioned, effective quality control is very important in building up export trade.

Production planning and control are also tremendously important to industry in developing and industrialized countries alike. The high cost of technical progress is usually regarded as a barrier for many industries in developing countries, but this argument does not apply to the wide range of planning and control techniques that do not require much capital expenditure. Experts from industrial research institutes can assist industries to increase the output of existing equipment by programming the use of plant and labour and planning product design according to the needs of the market. To put such plans into effect, a system of controls has to be introduced extending from quality to budgetary controls.

It would be wrong to assume that industrialists will spontaneously come to the industrial research institute for help. On the contrary, institute staff will have to go to industrial establishments, analyse their difficulties and offer assistance in solving their problems. In this way, the activities of the industrial research institute will be focused on the urgent problems of industry.

The institute's technical services to industry will usually be concerned first of all with solving specific problems; yet these services must also meet the urgent need for general technical assistance, including information on technical subjects, such as the availability of specialized equipment, advice on selecting the most appropriate machinery, or drafting of specifications.

In view of the size of investment involved, it will be necessary to make a careful study of new capital-saving and labour-saving production methods before recommending any. In particular, the institute must oppose the introduction of machinery merely because it is "modern"; modern machinery may well result in higher production costs. The trend in industrialized countries is to produce and employ labour saving machinery, but this type of machinery may not be best suited to industries in many developing countries; it is important to choose equipment after all relevant factors have been considered. For certain industrial processes

second-hand equipment may be as efficient as new machinery—and it is certainly much cheaper.

Since industries at an early stage of development lack capital, trained personnel and sophisticated equipment, the industrial research institute may in some cases purchase equipment—a computer, for example—that is generally needed but is too expensive for individual enterprises.

Through the close contacts resulting from the provision of technical services to industry, the industrial research institute will be in a good position to select for its own investigations projects in development research or in applied or even basic research that are related to the needs of the country.

#### INDUSTRIAL ECONOMIC STUDIES

Technical services to a growing industry must necessarily take economic factors into account. Hence, feasibility studies on the use of natural resources, on the most economic adaptation and modification of products and processes or on the optimum degree of standardization are essential. The staff of the industrial research institute must keep in mind that the limited resources of an industrial establishment or those of the national economy must be used in the most economic way.

The international trend in research is to create specialized institutions for economic research, and the institute should probably establish an economics department after it has organized its technical research and service departments.

Economic studies for industrial investors or individual establishments include market surveys, studies on marketing problems, pre-investment studies, surveys of various industrial sectors and studies on their special economic problems, and productivity and management studies. Some subjects require an interdisciplinary team of economists and technicians.

Economic studies of particular interest to individual industrial establishments may be subdivided into studies on managerial problems and studies on general economic problems.

Managerial problems are clearly the province of the economics department of the research institute. Industrialists in developing countries often do not have sufficient knowledge and personnel to tackle such problems. Owing to increasing specialization in different branches of economics, it may be necessary to employ specialists in statistics,

accounting, administration, marketing, financing, input-output analysis etc. While the technical experts should carefully consider the economic implications of their work, the economists should understand the main technical problems of the industries they serve. This is best secured by close co-operation between technical staff and the economists.

The task of the economic expert, serving as an adviser, is to assist management to attain the goals of efficiency, profitability and growth. He must be able to offer relevant information and consulting services; economic research projects should be as important to the research institute as technical research projects.

Production efficiency is often related to the availability and training of labour. Problems in this field go beyond the range of any one department of the institute, and interdisciplinary teams will be needed.

#### ASSISTANCE TO GOVERNMENT ON POLICY MATTERS

The industrial research institute may play an important part in formulating the Government's over-all industrial plan. As described earlier, the institute will collect the basic information about the country's industrial potential. Similarly, it will undertake location studies and consider the infrastructure necessary for industrialization. It must harmonize its plans with the national plan drawn up by the government planning authority and with the existing industrial structure. In this connexion, the industrial research institute may advise on industrialization policies, including regional development policies.

Another group of problems concerns the training, housing and social needs of the industrial labour force. The requirements of upper and middle management and other white collar workers must also be assessed so that they can be met in the present and in the future. Here, the Government may need advice on education, redeployment, social services etc.

The industrial research institute should also concern itself with government action to promote industry. It could serve as intermediary in the licensing of essential imports and spare parts, in pursuance of an agreed industrial development policy. It might also assist in promoting exports. The Government may set targets for exports, but their attainment will depend on individual action by industrial enterprises guided by the technical and economic advice of the institute.

When a new industrial sector needs protection against imports, the

**institute might suggest protective measures, pointing out their implications to the Government, which can then take appropriate action. The institute should encourage a fair amount of competition from imports so as to keep the price and quality of local goods competitive. Finally, the industrial research institute should arrange, in consultation with the Government, trade partnerships, which ensure that national manufactures are of the standard to suit foreign markets.**

The institute might suggest to the Government measures of **tax relief** in the appropriate sectors of the economy or the granting of **bonuses for successful exports**, particularly when new technical developments have to be put into operation rapidly. Small firms can be encouraged to **accept the services of the institute**, if the Government pays part of the cost. The general aim will be the gradual replacement of imported goods and machinery by local products in order to save foreign exchange.

Lastly, the industrial research institute might advise the Government on economic matters of national importance, suggesting, for example, how a balance might be struck between national economic interests and those of the individual company. The institute can occupy a key position between industry and Government, interpreting the actions of one side to the other, and it can influence both sides to move in the direction of long-term progress.

## ORGANIZATION OF INDUSTRIAL RESEARCH

**Industrial research must be organized within the institutional framework and economic structure of a country. It is necessary to decide what will be the relationship of the research and development institute to existing institutions such as universities or technical institutes with respect to personnel and financing. It is also necessary to determine the relationship of the institute to industry, international organizations and various government agencies. As regards the internal organization of a research institute, the question is whether the organizational forms of similar institutes in developed countries can be copied or whether the special conditions of developing countries make a different organizational structure necessary. Since conditions greatly differ from one developing country to another, it is not possible to draw up generally applicable guidelines, but experience has shown that there are certain basic similarities in the way research institutes are organized and function.**

The success or failure of an industrial research institute depends mainly on its initial organization, although this first phase accounts for only a fraction of the total expenditure.

### THE INSTITUTIONAL FRAMEWORK

The relative importance of the various types of research and development discussed in the preceding chapter determines not only the objectives of the research institution but also its institutional framework. Thus, an industrial research institute may be organized:

Within a university or as a semi-autonomous body linked to a university;

As an integral part of a government department or as a semi-autonomous institution linked to a governmental agency;

As a technical arm of an industrial establishment or an industrial association;

As an incorporated, private, non-profit organization.

### University research institutes

At the turn of the century, the research laboratories of universities in industrialized countries appeared to be the ideal place for conducting basic and applied research because the necessary installations and qualified personnel were available, young research workers could be trained, and use could be made of the administrative organization of the university. Doubts have recently arisen, however, as to whether a university institute is in fact the right place to carry out research and development. University scientists are usually interested in academic careers, which are often not oriented towards applied research. Research installations at universities have been designed for teaching purposes and may not be adequate for industrial research and development.

Applied technological research must be approached differently from basic research. Scientists engaged in basic research and teaching can carry on their work largely free from considerations of time, whereas those engaged in applied research have to show results within a given period. Moreover, in the initial stage of industrial development, research activities should be concentrated on finding solutions to practical problems, and these may not be of particular interest to the research worker. During this phase a research institute has to offer a great variety of services to industry and cannot limit its own research and development to a few specialized subjects.

Industrialists have to be convinced that research is necessary and of benefit to them, if not highly profitable. The best means of doing this is to offer solutions to their most urgent problems as quickly as possible. Experience has shown that it is precisely these problems that university scientists often consider uninteresting.

For practical and psychological reasons a research project should be assigned to a university institute only if scientists there are specializing in the particular field of research, or if the particular piece of research can be considered basic research. Basic research should always be carried out at the university because it is here that young scientists receive their fundamental training, are exposed to high standards, and are taught modern methods of research.

Through the special documentation and information it provides, basic research lays the groundwork for industrial research, and the transition from the early stages of adaptation and modification to indigenous research can be accelerated.



At a later stage, research at universities can be extended to applied research. In many industrialized countries, for example, autonomous research institutes linked to universities make it possible for scientists to avail themselves of university facilities without being hampered in their research by their duties as teachers, although they may occasionally lecture on their special research subject. If an industrial research institute is to be linked to a university, the autonomous status of the institute must be guaranteed and the two bodies sufficiently separated for the work of the institute to remain clearly industry-oriented.

### Government research institutes

The development of natural resources and the acceleration of industrialization are in the interest of the community as a whole and should accordingly be given public support. During the initial stage of industrial development the Government will have to support, finance and often organize research and development institutes. The main reason for this is the absence of other institutions capable of undertaking this research. Not many industries or industrial associations in developing countries are able to carry out research and development in their own laboratories. This would be true even if the costs were to be borne by the Government. Experience in industrialized countries suggests that the Government must finance industrial research in industry; otherwise it would not be carried on at all or only very slowly. Industrial establishments or associations may be in a position to undertake research even at a very early phase of development, but the commercial interests of such establishments will undoubtedly cause them to choose fields of research closely connected with their particular branch of industry.

In contrast to this, government industrial research institutes can be required to conduct research and development in fields of direct public interest. At the same time, depending on their specialization, they can also serve existing or planned industries. The work of such institutes may not at first make much impact because industrialists, who are usually not research-minded, may fail to respond. However, the appropriate organizational form and the education of public opinion can gradually overcome these initial difficulties. Although basic research may be better undertaken by universities, some types of research projects appear to be tackled best by government institutes.

One of the principal shortcomings of government research institutes is that they lack direct contact with industry. Furthermore, the

Government may often exert influence over its institutes or even curtail their activities for political reasons. The main advantage of government institutes, however, is that they are able to adjust their work to the development programme of the entire country. The Government can also by virtue of its own research effort acquire a strong economic position in areas where the country's potential is most promising. Government research institutes should determine their objectives within a frame of reference broader than the national context and concern themselves with the international division of research and with international trade as well as with over-all, long-range, domestic planning. International co-operation is further discussed in chapter 6.

As the resources of enterprises increase and the general economic level of the country rises, some of the initial functions of the institute may be taken over by industrial establishments or associations of industries. The research institute must then switch its area of activities accordingly, reverting to more fundamental research as its clients become less dependent on it for assistance.

### **Research within individual industrial enterprises**

In the industrialized countries, the great majority of research and development projects are carried out in the research laboratories of private industry. But even in industrialized countries, where non-governmental facilities exist, the Government gives industrial research activities a large measure of financial support. According to an investigation made by the Organisation for Economic Co-operation and Development (OECD), the Governments of Canada, France, the United Kingdom and the United States provide about 60 per cent of all expenditure on research and development.<sup>7</sup> About a third of these public funds are used to finance research and development conducted in the laboratories of industrial undertakings. (The subject of finance is further discussed in chapter 4.)

The main advantages of research and development undertaken by industrial enterprises are the following:

The research and development will be oriented towards practical problems and the actual needs of the industry;

The research findings are certain to be put to commercial use rapidly;

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<sup>7</sup> OECD (1968), chapter A, II, p. 11; for full reference see annex 2 under "Other sources".

If the enterprise is manufacturing products under foreign licences, company-owned research and development facilities will enable it to make use of foreign know-how after adapting it to local conditions; Successful research and development give the enterprise an advantage over its competitors and increases profitability.

It remains doubtful, however, that these advantages can be realized at an early stage of industrial development, for enterprises are generally small, are not able to carry out research and development and do not recognize the need for it. This situation must be changed before research can be conducted within industry, whether it is financed by Government or by industry.

There is also the question of how to make the best possible use of the limited resources available. Since the over-all growth of a developing country must be accelerated and funds are scarce, research and development findings should be at the disposal of all industrial enterprises. This would generate healthy competition and should serve to demonstrate the profitability of technological innovation. It can hardly be achieved if one of the companies is favoured by having government support for its own research and development. When research is carried out within private industrial enterprises duplication cannot be avoided if similar research is done by several enterprises. The consequent waste of financial resources cannot be justified at an early stage of industrial development, even supposing that the personnel and equipment for research were readily available.

### **Research by industrial associations**

The idea of pooling the research and development efforts of a number of industrial enterprises within a given sector was first put into practice in the United Kingdom and was later adopted by many European countries, including Belgium, the Federal Republic of Germany and France.

Very few research and development activities are carried out by industrial associations in the United States, but large contract research institutions working for private enterprises have been established. A limited degree of pooling is thus achieved, since the basic research equipment in these consulting organizations is used to a far greater extent than would be possible in a single company.

The research centres of industrial associations have usually been established through the initiative of the enterprises concerned, often with

the support of the Government. Their function is to conduct research and development relevant to the whole industrial sector and to make available to the members of the association the techniques and processes discovered. Collective research is especially appropriate for small and medium-sized enterprises, which are usually unable to run their own research and development sections although advances in technology compel them to make use of the most up-to-date processes in order to stay competitive.

The advantage of this type of collective research may be summarized as follows:

The benefits of research are available even to economically weak members of the association;

Staff and financial resources are used to best economic advantage;

The exchange of technical information is facilitated;

Research-mindedness is widely promoted, as a large number of small enterprises are served;

A store of knowledge is built up on which members of the association can draw;

Related basic or long-range applied research may also be undertaken.

In many respects the position of developing countries closely resembles that of an industrial sector consisting mainly of small and medium units. Just as co-operation within the sector brings obvious benefits, so the pooling of the available resources of developing countries for research, with government support, appears to be the most promising method of achieving results.

When an organization carries out research and development work for a number of clients, it is difficult to decide who should benefit from the results, particularly if one participant—the Government for example—contributes a substantial amount towards the costs and is not in a position to make direct use of the service. When a developing country has reached the stage in which it can benefit from research conducted by industrial associations it would be well advised to consult experienced institutes regarding the most suitable legal framework for sharing the benefits.

### **Research by non-profit organizations**

In the industrialized countries non-profit organizations specialize in particular fields of research according to the wishes of their founders; they sometimes fill a gap and sometimes duplicate the work of others.

Government support to non-profit foundations is not a solution to the problem of establishing industry-oriented research because these organizations tend to specialize in fields of their own choosing. Moreover, few companies in developing countries have the resources and are prepared to use them to found a non-profit research organization.

In developing countries where non-profit organizations do exist, they should be supported to the extent to which their research effort fills a gap left by other institutions. Excellent work has been done by some research foundations established by large industrial enterprises, such as the Indian Institute of Science in Bangalore, which was founded by the Tata family.

### **Multipurpose and unipurpose research institutes**

There are many different types of research institutes. Those carrying out research in a number of scientific fields are called "multipurpose" institutes. Specialist institutes concentrating on one scientific discipline or institutes devoted to the development of a particular product or process based on the use of several disciplines are described as "unipurpose" or "convergent". Institutes drawing on scientific disciplines and social sciences (such as economics or sociology), and giving advice on subjects such as management and marketing are called "comprehensive".

There is no clear trend towards using one type of institute in preference to another. Both private and government institutes are inclined to extend their activities, and a special science department within a multipurpose institute may become so large and important that it may be advisable to set it up as a specialist institute. Some private organizations establish independent departments to perform particular functions, while others follow the interdisciplinary approach. Although there is no single solution to the problem, it may be pointed out that the interdisciplinary approach is becoming increasingly popular even within specialist institutes.

Although multipurpose and comprehensive institutes, which can use the multidisciplinary team system, may offer considerable advantages to developing countries, the creation of specialist or unipurpose institutes can be justified or may be more appropriate in particular cases, e.g. a rubber research institute in a country whose economy depends mainly on rubber. In such cases the cost of providing a separate institute, with research and development facilities and scientific and administrative personnel, will have to be weighed against the advantage of concentrating on the special needs of a particular industrial sector.

Some developing countries that depend mainly on one commodity have established specialist institutes, such as the Coconut Research Institute and the Rubber Research Institute of Ceylon. However, the stimulation of industrial development and the effective support of a growing industry appear to be best achieved by a multipurpose or comprehensive institute.

### ORGANIZATIONAL STRUCTURE

The question of the autonomy of industrial research institutes in developing countries is particularly important, since the Government usually meets all the costs in the early stages of industrialization. There is, therefore, a danger that the methods of working adopted by these institutes—particularly in the case of government institutes—will be influenced by civil service practices shown by experience to be inappropriate. It is suggested that a board of management exercise supervisory control over an industrial research institute.

#### **Board of management (research and development board)**

The Government should appoint for each institute a research and development board, which should occupy an intermediate position between the Government and the institute concerned. The board would be responsible for the following functions:

- Defining the areas of research and development;
- Directing long-range planning;
- Providing over-all support for the institute;
- Formulating personnel policy;
- Exercising budgetary control;
- Arranging for research and development results to be utilized;
- Acting as spokesman for the institute to the Government.

In addition to performing these functions, the boards of several such institutes should co-ordinate their work. Representatives of the various boards should meet to decide upon over-all research policies.

The composition of the board is determined by its functions. An adequate number of government representatives must be included to represent the interests of the Government. In addition, representatives of various sectors of national life should be appointed. The majority of

these representatives should come from sectors directly or indirectly affected by the activities of the institute. The presence of a significant number of successful industrialists and entrepreneurs on the board is particularly important to ensure co-operation between the institute and industry. There should also be members concerned with the over-all economy, such as a representative of the Development Bank or other financial institutions. Persons representing trade interests, in particular those concerned with world trade, should be appointed. Representatives of appropriate international organizations with economic and technical interests, such as the United Nations economic commission for the region, the United Nations Development Programme, the United Nations Industrial Development Organization, or others should also be included. In this way the Government could be advised on the appropriate steps to secure international financing, for example, to cover pre-investment costs. To deal with specific questions the board should co-opt experts of international standing.

The board should receive funds from the Government and/or from the clients for whom the institute carries out projects. The chairman of the board, who should be appointed by the Minister of Industry, should be prominent in the economic or academic life of the country. In consultation with the Government, he should appoint the members of the board, a number of whom will be chosen to serve on the executive committee.

### **Executive committee**

The executive committee should guide the day-to-day activities of the research institute. It may directly advise and assist the institute's director and project managers. Members of the executive committee should therefore have practical experience in research and development. To prevent research from becoming too closely associated with the personal interests of committee members, their term of service, a term of perhaps three years, should be staggered, with one third of the members being replaced each year. In this way, continuity in the guidance of the institute would be coupled with the introduction of new ideas.

Except in the case of government representatives, appointments should be made in a personal capacity. To prevent the chairman from exerting an overly strong influence on the committee for a long period, he could be required to step down after one year and serve as vice-chairman the following year. In this way continuity in leadership would

be provided. The principles outlined here for the committee might also be applied to the board as a whole.

In the early days of the institute the committee will probably have to meet at least once a month. Later, about three to four meetings a year will probably suffice. The executive committee should present a yearly report on research and development activities to the board of management, which in its turn should present a report on the institute to the Government. Members of the executive committee should receive a fee for their services.

### **Internal organization**

The objectives and management of a research institute determine its internal organization. In principle a research institute may be organized by departments or according to projects. Organization by departments is appropriate if the tasks of the institute are limited, at least to begin with, while organization according to projects should be adopted if research projects call for a number of scientific disciplines. In this case scientists of various disciplines form a team to carry out the projects.

As already stated in chapter 2, the main task of an industrial research institute in a country at an early stage of industrialization is to provide consulting and information services to industry in order to stimulate innovation. Consequently, the institute will initially display some features of a multipurpose information centre. There will be a technical service division including senior technical men to cover physics, chemistry, biology, engineering and industrial economics. Once they have received requests for technical work from industry or set up research programmes directly related to local industrial problems, additional technical staff may be recruited. There may also be a task force to handle public relations. A small, flexible structure of this sort is to be recommended when an industrial research institute is set up; the most suitable organizational form may then be determined as the institute develops.

### **Evaluation**

The board of management and the executive committee should devote considerable effort to a regular evaluation of all aspects of the institute's work. This would include an assessment of the scientific and practical performance of the technical departments and their personnel, the functioning of the administration and the public image of the institute.



It is often debated whether a special team should be appointed to make the evaluation or whether regular staff members should do it: a special team would probably produce a more objective report but it would also cost more.

A possible solution is to appoint at infrequent intervals a "reviewing committee" with the express task of evaluating the institute. To assure objectivity, individuals of international standing should be appointed—drawn chiefly perhaps from the international academic and industrial research world and from international organizations. This committee should consider objectives in relation to actual performance rather than future trends and aims; for this, intimate knowledge of local economic and industrial conditions is not necessary. The "reviewing committee" should discuss its findings with the board of management and submit a detailed report to the Government.

### STAFFING POLICIES

The board of management should pay particular attention to staffing policies, beginning with the appointment of a director.

#### Director

The successful development of a newly founded industrial research institute depends mainly on the director. Initially he is the only person responsible for the direction of all functions of the institute: he is simultaneously director of research, director of the institute and administrative officer. These tasks will have to be delegated to assistant directors as the institute is gradually built up, although the director will remain the chief assessor of priorities relating to projects, staff, money and facilities.

The director's personal qualifications as a scientist must be high and his experience broad and, if possible, international. He should be a man of such scientific stature that he will inspire and stimulate his research staff rather than engage in research himself, especially if he is the head of a large establishment. At the same time he must be a good administrator. It requires considerable ability to organize research and development, formulate personnel policy and make decisions about investments, budgeting, accounting etc. The leadership qualities of the director are of great importance to an industrial research institute in a

developing country, since he will have to set the tone for his research workers and break down the psychological barriers he will encounter in industrialists who are not research-minded. He must represent the interests of the institute before the executive committee, the board of management, and if necessary, before members of the Government.

It has been said that man, money, masonry and material are the preconditions for successful research and development, but that only man can give value to the other three factors. This applies especially in the case of the director. He should be appointed by the board of management in consultation with the Government.

### **Staff**

The success of an institute depends upon the quality and ability of its staff. The qualifications of scientific personnel, however, should be related to the problems to be solved; they must in this case be determined according to the stage of industrial development of a country or an industrial sector. In most developing countries about 70 per cent of the institute staff will have to concentrate mainly on solving practical problems, many of which can be regarded as scientific only with some reservation; these problems consequently do not require highly qualified scientists to deal with them. The "less scientific" problems have nevertheless to be tackled by highly qualified experts, with a bent towards solving practical industrial problems. This is one of the reasons why highly qualified scientists, educated according to the standards of industrialized countries, often do not stay in developing countries.

All decisions regarding recruitment, salaries, the independent status of research workers and the training of junior staff must take this situation into account. The professional technical staff in particular must have higher professional qualifications than the employees of the enterprises that are to be served by the industrial research institute. If this is the case, the human prerequisite for fruitful co-operation between the institute and its clients is fulfilled.

### **Qualifications**

In larger institutes, the director, whose special qualifications have been emphasized above, should be supported by assistant directors, who must have similar professional and personal qualifications. The qualifications

of the institute's staff must be determined according to their tasks, which will vary from project to project. Generally, the staff will work mainly on technical services, modifications of products and processes etc. The following categories of staff will be required:

Professional scientific staff;

Professional technical staff;

Technical assistants;

Technicians;

Secretarial and clerical assistants.

Professional scientific staff carry out or direct the investigations of the institute under the general guidance of the director. In a unipurpose institute concentrating on a single technical field or industrial sector, the qualifications and knowledge of professional scientific staff will be determined by the specialized requirements of this field.

Additional personal qualities will be required for scientists working in a multipurpose institute, which handles a number of scientific subjects or problems from various industrial sectors. For these scientists, the ability to work efficiently in a team is an essential qualification.

The majority of scientific workers in a multipurpose institute should have a broad knowledge of the sciences underlying technology, namely, physics, chemistry, thermodynamics etc. This is preferable to practical experience, which may be contributed by other members of a research team set up to tackle a complex research project.

The scientific members of the team that sets up the first industrial research institute in a country or region should also be good team workers. Furthermore, they should be experienced negotiators who are able to persuade potential clients that research and development activities are essential for industrial progress.

Professional scientific staff should have an open-minded approach to new conceptions, such as information systems, systems analysis and operational research or the use of computers for decision-making and administrative purposes—methods that local industrialists are not likely to use or even know about. Scientists must make a special effort to keep abreast of the newest developments in management as well as technology in order to be able to judge whether they would be suited to the country concerned. It is the scientists who build up the reputation of the institute with the Government and with the country whose development depends on them.

Later on, besides professional knowledge and creativity, scientific professional staff should show qualities of leadership because they have to direct subordinate assistants, technicians and secretaries. Finally, since they must explain their findings to industry, they must have the ability to communicate clearly facts and functions that may well be complex. Professional staff should be graduates with a bent towards applied rather than basic research; an analytical approach is more useful in research of this kind than is scientific creativity.

Professional technical staff, who are in no way less important than the scientific staff, should deal with the more practical industrial problems. Their sphere of activity will be production technology, design and construction, testing and repair work, workshop technology etc. Here, practical experience counts far more than a capacity to solve scientific problems. Professional technical staff may also be called upon to solve labour problems, arising, for example, in the workshop or foundry. Since the technical staff members are employed in a research institute, they should be able to appreciate the complexities of the scientific approach and have some idea of the difficulties confronting their colleagues, the scientists.

The technical assistants and technicians carry out the practical work of research and development. They must have the requisite manual and practical qualifications and an adequate theoretical knowledge of the characteristics of the machines and materials they are called upon to investigate, test or handle. Technical assistants and technicians are usually trained in technical or vocational schools, but they may also receive on-the-job training in the research institute.

Experts in other areas—for example, in economics and perhaps the social sciences—require qualifications similar to those needed to fill comparable positions elsewhere. Secretarial and clerical assistants require the same qualifications as their counterparts in industry.

### **Recruitment of staff**

The lack of scientific and technical personnel in developing countries is even more serious than in developed countries. The main reasons for this shortage are insufficient educational facilities, the general tendency of qualified staff, even scientists, to prefer administrative positions, and the conviction that work in an industrial research institute in a developing country must by its very nature prove unsatisfying to a highly qualified

scientist. Many scientists prefer well-paid positions in institutes in industrialized countries, since they are better equipped and offer more challenging scientific problems than institutes in developing countries.

Another reason for shortage of staff is that in developing countries research institutes have sometimes been set up in rather large numbers with the best of intentions but without due consideration of the availability of scientific personnel. For example, the Indian Council of Scientific and Industrial Research (CSIR) had established 29 government laboratories and institutes by 1963, but 30 per cent of the posts for scientists and technicians remained unfilled.

During the first phase of an institute's existence, it will often be necessary to employ experts from developed countries. They should be employed for a limited period, during which time local personnel should be trained to work as counterparts, so that they can gradually assume the functions of the foreign experts. Such experts can be recruited through the good offices of international organizations, particularly the United Nations, or with the help of foreign Governments.

As institutes succeed in making industry and government departments research-minded and acquire a national reputation, they should find it less difficult to attract qualified scientists. A reputation is acquired by the dissemination of institute publications, by close contacts with university and other training and education institutions and, more particularly, by successful work.

In developing countries where a number of research and development institutes exist and where a relatively large number of qualified scientists are graduated from the universities every year, there is the problem of how the existing vacancies can best be filled. In India, for example, CSIR advertises vacancies in newspapers and scientific and technical journals. The selection of candidates is made by selection committees consisting of scientists and technologists from the universities and industrial research institutes and of officials from the government departments concerned.

### **Salaries**

The salaries of research and development personnel should depend on the qualifications of the individuals and on the economic and social conditions of the country. Scientists with the highest qualifications are the ones that are most likely to find well-paid positions in industrialized countries. There is, moreover, international competition among research

institutes for outstanding scientists, and government institutes in industrialized countries experience a similar drain to industry-owned research institutes and laboratories, where salaries are higher.

In general, salary scales should be similar to those in industry. However, many young scientists in developing countries prefer the administrative branch of the civil service because salaries are higher than in the scientific grades, there are better chances of promotion, and administrators obtain a number of privileges.

Salaries must therefore be sufficiently high to attract and retain highly qualified scientific personnel. Scientists should also be assured of reasonable prospects of promotion, in addition to fringe benefits, insurance schemes and retirement pensions equal to those they would receive in other sectors of the economy.

## **FINANCING AND FUNCTIONING OF AN INDUSTRIAL RESEARCH INSTITUTE**

This chapter deals with various financial aspects of organizing an industrial research institute, from long-term backing to arrangements for the sale of licences. It also discusses the organization of the work programme of the institute in terms of in-house and contract research projects and the relations of the institute with its industrial clients.

### **GENERAL FINANCING**

#### **Headings of expenditure**

After the decision has been made to set up an industrial research institute, long-term financial backing must be secured. Although the amount of money required depends on the scale of research and the fields in which it is conducted, it is difficult to work out a detailed budget in advance because the development of an industrial research institute is a dynamic process that depends on a large number of variables, most of which cannot be determined beforehand.

The first step requiring financing is the establishment of a planning body to do the preparatory work for the project. This body determines the physical layout of the buildings, their location and size and their detailed design, and supervises the construction and assembly of laboratories and equipment. This work can be done only if the over-all objective of the research establishment has been determined on the basis of detailed planning studies that have taken into account the existing industries and their needs, the material and industrial potential of the country and other relevant factors.

The initial layout determines the capital expenditure required during the first phase of establishing the institute. This expenditure covers the cost of land and basic buildings, common facilities for research work—such as libraries and computers—and requirements for roads, power supply, water and communications and facilities for staff amenities.

Financing is next required to meet current expenditure. Funds must also be set aside for the replacement and renewal of laboratory equipment as dictated by advances in science and technology, and for the training of the scientific staff to keep them abreast of new developments, both at home and abroad. Financial provision should be made for new laboratories, for which the need may arise after the initial scope of the research institute has been determined. Expansion of this sort will cover new industries and their research requirements, but it should also make possible investigations and preparatory work to identify other promising industrial activities, which may earlier have been entirely unforeseen for the country. Finally, considerable funds may be required to develop processes from a laboratory scale to industrial production, or at least to the scale of pilot plants. Such activity needs special financing for which government funds are often available; if not, some special provision should be made for financing this activity.

It is essential that the authorities concerned understand the financial implications of an industrial research institute from the outset. To gain a rough estimate of the costs involved, the experience of other developing countries that have set up similar institutes may be drawn upon. In this connexion, the assistance of international organizations working in the field will be especially helpful. It is important to determine the minimum number of research workers and the minimum equipment necessary to conduct research and development satisfactorily.

As regards personnel, a "critical mass", which is related directly to the work to be done, can be determined. In the United States, for example, the "critical mass" of personnel for research laboratories to develop nuclear power plants is considered to be 500.<sup>8</sup> On the other hand, in a research and development institute of an industrial association working on paint research and providing a consulting service to the industry, two chemists, two laboratory assistants and two technical assistants are considered sufficient.

#### Sources of funds

Research and development institutes in developing countries will have to be financed mainly by the Government. A survey made by the United Nations in the countries covered by the Economic Commission for Asia and the Far East (ECAFE) showed that research institutes and

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<sup>8</sup> Hoffmann, p. 65; for full reference see annex 3 under "Other sources".



laboratories (except institutes carrying out only basic scientific research) were financed almost exclusively by the Government.<sup>9</sup> In most cases research and development institutes in developing countries will only gradually be able to cover a part of their expenses by the income they earn on contract research. In fact, if within ten years of their establishment, they manage to cover by research fees 35 to 45 per cent of their current expenses, it is considered to be a sign of healthy growth.

Funds may also be obtained from industrial enterprises and associations, private sponsors, Governments of developed countries or international organizations, but in comparison with the contribution of the Government, the amounts obtained from these sources will usually be small. Even research and development institutes of industrial associations will need government support in the early stages. In India, for example, the Government pays one fifth to one half of the running expenses of research associations. However, the members of the association should be encouraged to assume increasingly the financing of such institutes.

A special kind of financing has been devised for institutes concentrating on the development of one product or only a very few products. A tax is levied on the export of these products, the proceeds of which are used for the research institutes. The Government of Ceylon has adopted this method of financing in the case of tea, rubber and coconut. This method may stimulate the institute to make greater efforts to improve the quality of export goods, since an expansion in exports will indirectly increase its income.

## BUDGETING AND FINANCIAL ADMINISTRATION

### Budgeting

The director of the industrial research institute, in collaboration with the executive committee, should present to the board of management a quarterly or yearly budget. Regular and careful budgeting makes it easier to plan the research and development work of the institute in relation to the income foreseen and inspires confidence among the backers of the institute, ensuring the long-term continuity of research and development. The budget should not, however, cover such a long period that estimates are merely guesses.

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<sup>9</sup> For full reference, see annex 3 under "Economic Commission for Asia and the Far East".

It is useful to differentiate between recurring expenses and capital expenditure. Two separate budgets should be drawn up because this will make it easier to regulate income and expenses and to compare estimates with actual expenditure.

The *capital budget* should show capital requirements, rent and/or buildings, and the contingency fund. Under the heading of capital requirements, the estimated costs of equipment required during the budget period should be given (together with a short description), while under the contingency fund the long-term equipment requirements should be listed.

The *current budget* should show costs under the following headings:

Professional salaries;

Non-professional wages and salaries;

Materials and supplies, including utilities, supplies of technical materials for the laboratory, books, periodicals and library supplies;

Travel on project work and for technical meetings;

Building and maintenance;

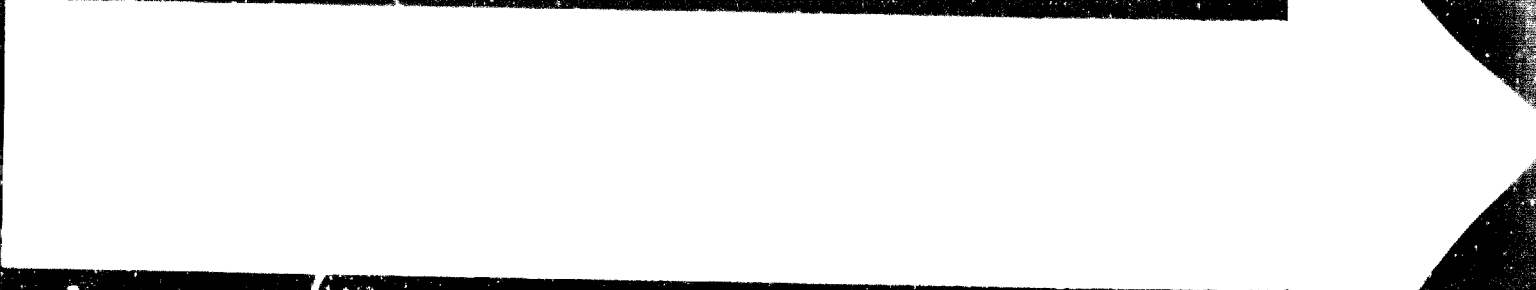
Purchasing services.

In its financial administration the institute should be conducted like an industrial enterprise. A certain amount of money—the working capital—should be at the disposal of the board of management. Working capital may be used to bridge gaps in the running expenses and to meet unforeseen demands.

### **Cost of research**

Estimates of costs should be made for in-house projects as well as for contract research. When the costs of basic research are being estimated, the risk of a failure should be carefully examined; experienced scientists should be called upon to estimate the costs of adaptation, modification and development projects.

Cost estimates should be based on the length of time it is assumed research personnel will need to carry out the project. If certain staff members are to be employed exclusively on the project it is an easy matter to calculate the costs of their salaries and wages during the project period. Experience has shown that 150 to 200 per cent added to the amount estimated for salaries and wages will be sufficient to cover the fixed costs of the institute. Variable costs, which include the use of materials and

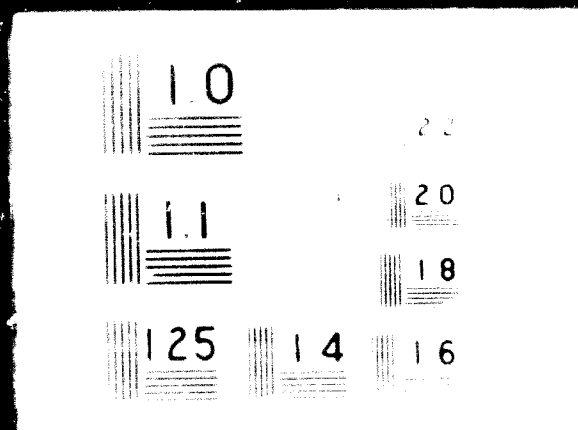


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power in tests, the hiring of external advisers or lecturers, or extra travelling and living expenses must be estimated separately.

In multipurpose institutes, research personnel will usually be working on a number of projects simultaneously, especially if the institute is mainly concerned with adaptation, modification and testing. These projects may be in-house or contractual. It has been estimated that professional technical personnel usually devote about two-thirds of their time to project work. The remainder is taken up with administrative matters. The overhead of the institute should be calculated accordingly.

In the early days of the institute, industrial enterprises will have to be persuaded that it will be profitable for them to employ the services of the institute. It must be made clear that research and development carried out by the institute will not cost more than similar activities conducted by industry. In fact, the cost per man year of technical personnel will tend to be much the same in both cases.

### **Financial administration**

The financial administration often acquires a disproportionate influence over research and personnel owing to its central position. Subject to the existing regulations, it should identify itself and its decisions with the objectives of the research establishment. Research is basically unpredictable; if it were not, it would not need to be done. This has to be taken into account when the financial affairs of an industrial research institute are being dealt with.

### **Ownership of the results of research**

In view of the financial support given to industrial research institutes by the Government, it is necessary to decide who owns the rights to research findings and inventions. It is generally stated in research contracts that if the research leads to results that should be patented, the patent rights belong to the client. Institute staff should therefore be required to sign contracts in which they agree to assign to the institute any patent arising from their work, although some payments may be made to inventors. The protection and licensing of patents arising from government-financed research and development work has to be so organized that research findings can be put to use quickly and economically.

**At the same time, private industry should be encouraged to invest in research and development.**

In most countries the rights of inventors of new technical products or processes are defined by patent laws. As a general rule, only the inventor owns the right to exploit the invention and to license the patent to a third party for a certain period. A decision has to be made as to whether inventions that have been developed in the course of in house projects in government research institutes are owned by the Government or by the inventor and under what conditions they should be commercially exploited. The best solution appears to be that inventions by employees of the institute remain the property of the institute. This would provide a source of income, which might reduce the amount of financial support required from the Government. In any case, the Government should retain the right to inform other institutes about the research findings. This has been the practice of the Department of Scientific and Industrial Research (DSIR) in the United Kingdom since 1934. The Canadian Government, through the National Research Council, provides funds on a shared basis for research by industry on approved projects. It covers the cost of the scientific staff, while the equipment etc. is provided by industry; the research results become the property of the firm concerned. This procedure appears to be advisable only if the industrial enterprise is sufficiently large to exploit the invention properly.

The conditions placed on the use of inventions made through government-financed research and development must be adapted to local circumstances. The Government often has to provide funds for developing the inventions or discoveries in addition to stimulating and financing research and development. Inventions that have reached the production stage in the pilot plant of an institute should be accessible to as many users as possible. The terms of the agreement for exclusive licences should contain some guarantee of a minimum royalty, payable to the institute, to ensure that the invention is actually used.

#### **IN-HOUSE AND CONTRACT RESEARCH PROJECTS**

In drawing up a long-term programme for the research institute, the board of management has to decide on the number of in-house research projects as against contract projects to be undertaken. Contract projects will usually predominate, as the institute is intended to serve industry

directly. To determine the correct balance between them, the advantages of both types should be analysed.

### **In-house projects**

Research projects that can be freely selected by the management of the institute can best be directed towards the general needs of the country or a particular industry. It is, however, possible that the choice of these projects may be influenced by the personal interests of the scientists concerned, although the board of management can intervene to prevent this at an early stage.

Since contract research is usually concerned with day-to-day problems, the institute should select as in-house projects subjects that are in harmony with the Government's long-range plans for industrial development. Thus, a close contact should be maintained with the authorities responsible for economic and industrial planning.

In-house projects should not be focused on limited goals but should be oriented towards areas suitable for future research and development where it might be possible to do specialized work. The projects may be selected with a view to their possible commercial application. In this case it will be necessary to give adequate notice to the industry concerned, so that the process of innovation can be started at an early date. It may be necessary to set up new industries for this purpose, either with government backing or with foreign capital.

In-house projects should reflect clearly the main objectives of the institute; they provide more scope for the institute to demonstrate its abilities than does contract research. The projects should be carried out in the same businesslike way as contract work (i.e. with project manager, project reports, cost control etc.). A few carefully controlled and evaluated projects will produce better results than a number of casually organized ones. The institute should avoid selecting projects that have been undertaken elsewhere or are likely to be given to the institute as future contract work. It is therefore advisable, before undertaking any project—whether in-house or contractual—to make extensive inquiries about previous work in the field. If considerable information on the subject is available elsewhere, either at home or abroad, it is probably better to buy advice than to repeat work that has already been done. In this case the possibility of acquiring a licence should be considered, since the need for adaptation or modification may still provide problems for the research institute to solve.



Experience obtained through contract research may lead to a valuable in-house project. Contract work deals with urgent everyday problems. In-house projects provide an opportunity to follow up the issues underlying the problems. Thus, a fruitful relationship can be established between the two types of research, which will enable the institute on occasion to propose new technological processes based, for example, on the use of particular raw materials or other natural resources available in the country; a certain variety of plant may lend itself to industrial use in a process evolved by the institute. At this point sponsors must be found to carry the project forward to the stage of pilot plant production and commercial application. Economic criteria have to be considered, such as financial feasibility, potential markets, volume of sales etc. Patent rights have to be investigated. Even at this stage the Government has to offer incentives so that local industry can take over production with a minimum of risk.

Contract research should not be allowed to grow at the expense of in-house projects. Since there is a limited amount of time and money available for contract research, the personnel and equipment earmarked for in-house projects may have to be protected against encroachment by contractual undertakings.

### **Contract research projects**

Research done at the request of industries or other clients has the following advantages: it is of immediate value, since it deals with existing problems; it helps to build up the reputation of the institute; and it provides a source of income.

Furthermore, the effect of close co-operation between the institute and industry should not be underestimated; it prevents the institute from losing contact with general economic trends and requirements. The institute should beware of thinking and acting only in terms of scientific achievements unrelated to everyday needs.

Investigations requested by clients must be carefully analysed to see whether the scientific staff members are sufficiently qualified to solve the problems involved. This is especially important in the initial phase of the operation of the institute because the reputation of the institute will rise or fall with the quality of its work. It may also be advisable to discourage projects that appear to have a poor chance of success and to propose to clients a modest exploratory programme instead. In this way

failures can be avoided, and satisfactory preparatory investigations may lead later to other investigations or research work.

Before a contract is drawn up, certain factors in addition to personnel have to be checked. It must be determined, for example, whether it is necessary to purchase equipment. If so, it must be decided whether the client should and could pay for it. If the equipment needed for a particular investigation can be used for a range of projects, it should be purchased out of the funds of the institute provided for the acquisition of new equipment. The general scientific and technical feasibility of projects must also be assessed in relation to the situation of the country as a whole. Finally, economic factors should be considered in cases where national or sometimes even international attitudes are important.

Larger institutes may adopt a policy of selecting research projects that when taken together cover a new scientific or technical field fairly completely. This policy, for example, is followed by the Stanford Research Institute in the United States. However, it requires the participation of a number of clients because usually no single enterprise can finance the entire service. Possibly an industrial association could undertake research in this manner.

### **THE RESEARCH INSTITUTE AND ITS INDUSTRIAL CLIENTELE**

In previous chapters it has been emphasized that an industrial research institute should endeavour to stimulate industry to become research-minded, especially in the early stages of industrialization.

#### **Acquiring industrial enterprises as clients**

Before an industrial research institute starts to function, the kind of services needed must be analysed. The board of management must undertake a systematic review of the range of operations, the specialities and the sizes of enterprises, the industrial sectors to which they belong and the attitude of management, in order to offer the type of services required and to find out which clients are most likely to be attracted.

The members of the board of management will no doubt help to establish the first contacts. Since board members are likely to be leaders in industry and public affairs, the first contacts will usually be made with

larger industrial enterprises. Although it might be expected that industrial research institutes would mainly assist smaller industrial establishments, which cannot afford to run their own research departments, the main clients are in fact usually medium-sized and larger companies. However, in many cases the institute may be able to encourage a group of small enterprises to tackle problems common to all of them or approach them through an industrial association.

### Promotional activities

Information must be made available on the activities and achievements of the industrial research institute. Written information usually takes the form of brochures about the institute, papers on research projects and periodical publications or bulletins. However, a direct approach to clients is usually more successful. Visits to potential clients should be arranged, and the research staff should participate in meetings of industrial associations. Symposia or special meetings may also be organized by the institute itself.

### Contacts with clients

An institute engaged in contract work must respect the interests of its client, and all the research results must be at his disposal. In carrying out contract research, the institute staff acts as an extension of the organization of the client. The basis of the relationship between institute and client is the research contract: by its terms the obligations of the client are usually limited to financial responsibility and the provision of information, but the institute must specify correctly the programme research, define its responsibilities, guarantee the confidential treatment of information supplied by the client and state clearly the publication and patent rights.<sup>10</sup> Any special legislation in force in the country must, of course, be observed in all aspects of the institute-client relationship.

Regular contacts between the client and the institute staff—usually in monthly meetings—will ensure that the research project is carried out in the interests of the client and not just for purely scientific interest.

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<sup>10</sup> More detailed information is given in the *Manual on the Management of Industrial Research Institutes in Developing Countries*; for full reference see annex 3 under "Centre for Industrial Development".

There will be cases where the results are disappointing. Even unsuccessful results, however, may be quite valuable to the client if they prevent him from undertaking a project that would eventually have led to financial losses.

Industrial enterprises should participate in establishing pilot plants built on the basis of the research and development work of the institute. Pilot-plant work is essential to bridge the gap between laboratory work, which is perhaps already being done on the scale of semi-production, and full-scale production. Costs for pilot-plant work are high, and it is recommended that if the pilot-plant investigations prove successful, the board of management and the client who is prepared to make use of the process approach the Government for assistance under the special arrangements mentioned earlier in this chapter. In such cases a major economic issue is involved, and an agreement must be reached with the government departments responsible for the strategic aspects of over-all planning. If these negotiations are successful, the industrial research institute should undertake only to administer the pilot project and not to operate it. Otherwise it might overtax its resources to the detriment of other work in progress.

Success is the best advertisement for the industrial research institute. Everything must be done to ensure the successful conclusion of research and development projects, and efforts should continue as the projects move forward to the production stage. The institute can thereby demonstrate its ability to assist an enterprise at all stages of development.

**THE INTERNATIONAL SYMPOSIUM  
ON INDUSTRIAL DEVELOPMENT:  
ISSUES, DISCUSSION AND RECOMMENDATIONS**

The issues, the discussion and the recommendations approved by the Symposium are presented in this chapter.

**THE ISSUES<sup>11</sup>**

The growth of industrial activity in developing countries and the recognition of industrialization as the strategic element in economic growth have brought with them the need to establish and strengthen certain industrial services designed to cater to and expedite the industrialization process. Industrial research and development are considered to be among those important services. Research is an essential instrument in developing the human and material resources of a nation.

The following issues are suggested for discussion:

- Levels and fields of research most appropriate for developing countries;
- Organizational arrangements for research institutes;
- In-house initiated research projects versus contractual activities and services;
- Sources of financial support for research institutes;
- Personnel policies of research institutes.

**Levels and fields of research most appropriate for developing countries**

The four generally accepted levels of research are:

- Fundamental research;
- Oriented basic research;
- Applied research;
- Developmental research.

<sup>11</sup> UNIDO, *Issues for Discussion: Industrial Research, 1967* (ID/CONF. 1/A. 20) (mimeo.).

The developing countries, because of a general shortage of highly specialized scientific personnel, will probably decide in general to confine their research activities, at least for the time being, to applied and developmental research, devoting their effort and resources to the adaptation and application of known technologies. Such investment in applied research could really be considered as an investment in industry itself, since such research is closely related to practical requirements and national development goals.

Industrial research and development activities in developing countries are not restricted to technological or scientific problems but cover practically all fields that are important to the development and growth of industries. These could include:

Systematic survey, assessment, development and utilization of local natural resources and raw materials, including the adaptation of these raw materials to non-conventional or new uses.

Improvement or adaptation of production techniques and technical development of processes for local conditions, including the pilot plant level;

Provision of various services for industry, such as testing, quality control, selection of machinery, specifications and general technical assistance;

Assistance in standardization activities, either by assuming direct responsibility or by actively participating in the work of a separate Standards Institute;

Industrial economic studies, such as market surveys, comparison of the economics of different processes, investigations connected with pre-investment studies, surveys and statistics of various industrial sectors; and, generally, all matters concerned with the establishment of new industries;

Management and productivity studies, including when indicated, operations research, aimed at strengthening production and increasing it, improving organization, rationalizing management and similar matters.

#### **Organizational arrangements for research institutes**

Industrial research institutes can be established under any of the following arrangements:

As a semi-autonomous body linked to a university or a government agency;

As an integral part of a State body;

As an incorporated non-profit, private institution;

As a technical arm of an industrial association.

Under any of these arrangements, the question arises as to the degree of autonomy which the research arm should have. One argument for control by the parent body is the greater ease in planning the institute's work programme within a larger framework, such as the national development programme. Another is the greater availability of the facilities and resources of the research organization for national priority programmes. Greater autonomy, on the other hand, has the advantage of avoiding rigid regulations and possible political intervention in the operations of the institute. Greater initiative of the institute staff in generating useful research projects and added flexibility of the institute's operations are also among the advantages of an autonomous body. In addition, the economic and industrial enterprises of the country are likely to have a greater interest and participation in an autonomous establishment.

#### **In-house initiated research projects versus contractual activities and services**

The discussion in the Symposium may deal with the problem as to what projects an institute should undertake and what should be its investigation activity. Should priority be given to projects selected and initiated by the institute itself, or should it devote its efforts primarily to services and projects requested by industry, government and other clients?

The advantages of the first alternative are, among others:

The likelihood that internally generated projects will be in line with long-range national plans for industrial development;

The encouragement to imaginative thinking on the part of the staff through the possibility of pursuing promising self-initiated projects.

On the other hand, catering primarily to requests from industries and other clients has the following advantages:

Services are more directly effective when they are aimed at finding immediate solutions to existing problems;

Services which help to solve specific current problems bring recognition to the organization,

Contract services could provide significant income, thereby strengthening the position of the institute.

It appears that, in the last analysis, while it is necessary for an industrial research and development institute to supply services requested by clients on a contractual basis, it should also assume a leading role in selecting and initiating research projects and activities related on a longer-term basis to industrial development. Collaboration with economic and industrial planning authorities will help to ensure their being properly integrated into over-all development goals.

### **Sources of financial support for research institutes**

In the establishment of an industrial research and development institute, outside financial support is generally essential during the formative years. Such support might come from the original sponsors of the institute, such as manufacturers' associations and chambers of commerce, in the form of grants and donations from industrial enterprises or individuals, or through assistance in kind (equipment, books etc.) and in manpower (experts and fellowships) from the United Nations agencies and by developed countries. However, the Government should be responsible for providing such financial support on a regular basis.

Until potential users become conscious of the importance of the research and development institute and until the reluctance to use and pay for the services of such institutes is overcome, the major financing burden falls upon the Government. As the institute becomes better established and increasingly recognized as the centre for services in fields crucial to industry, it will be able to help cover operating costs through earned income. Experience has shown that the attainment of 35 to 45 per cent self-sufficiency in about 10 years is a sign of healthy growth of such an institute in a developing country. However, income should not be considered as the only criterion for success, since the sponsors might tend to utilize the services of the institute without compensation.

In order to ensure the successful operation of an institute, the Government should take measures to make funds available in a regular manner independent of budgetary delays. The preparation of a "rolling budget" and the drawing up of a yearly budget against, say, a quinquennial forecast, is one of these measures.

### **Personnel policies of research institutes**

The productivity and efficiency of the industrial research and development institute depends largely on its success in recruiting and keeping able professional staff. It is necessary that the personnel engaged in research and development be rewarded on a scale that will enable the institute to engage and retain the best professionals to be found and ensure devotion to their work. Liberal personnel policies should also be applied, as they encourage team-work and tend to create a stimulating working atmosphere. In this connexion, the administrative policies should be such as to be considered by the scientists, technologists and professionals as rewarding efficiency in terms of effort/result ratio. Minimization of administrative interference in professional work is therefore vital. Possibility for advancement, based not only on seniority but on merit, suitable fringe benefits, and an inspiring atmosphere are among the factors that encourage young



and promising staff to make their association with an institute a lifetime career. The creation of a stimulating and rewarding professional atmosphere will help reduce, and hopefully stop, the drain of trained technical and professional manpower from the developing to the developed countries.

### THE DISCUSSION<sup>12</sup>

#### **Levels and fields of research most appropriate for developing countries**

The discussion stressed the importance of institutional research in developing countries. Its services should be as closely related as possible to practical requirements of industrial development.

The view was expressed that planning research is needed as an integral part of the over-all development programme allowing for better distribution and utilization of resources.

The general consensus was that, trained manpower and financial resources in developing countries being limited, the research projects should be carefully studied as to their cost-benefit relations. Therefore, the fields of research to be covered should cater to the most immediate needs of those countries and should be concentrated in the fields of applied, developmental and adaptive research. This should not prevent countries from going as far as they can justifiably go in basic research.

Depending on the stage of industrialization as well as on the socio-economic conditions, it was felt that research institutes should concentrate on carrying out one or several of the following activities:

Investigations and development of raw materials and natural resources with a view to their better utilization and the discovery of new uses for them;

Adaptation of foreign technology to suit local conditions including the establishment of pilot plants as an intermediate step between discoveries in the laboratory and their actual commercialization;

Co-operation with individual industrial enterprises for supplying the services that may be required to solve and identify problems, including quality control, management services and productivity studies, trouble shooting and general technical assistance;

<sup>12</sup> *Report of the International Symposium on Industrial Development, Athens 1967* (ID/11) (United Nations publication, Sales No. 69.II.B.7).

Promotion and assistance in standardization activities both at the national and the company level;

Industrial economic studies, such as market surveys, techno-economic feasibility studies, surveys and statistics of industrial sectors;

Training at the technician and craft level.

It was noted that when a specific natural resource or raw material of national interest exists, fundamental research into the nature of this material may be required.

### **Organizational arrangements for research institutes**

It was the consensus of the Symposium that the conditions of a country should determine the arrangement under which a research institute is established. Some participants pointed out the desirability of establishing suitable research and development functions within large industrial enterprises, thereby clearly identifying the fields of work and the possibility of direct application of results and findings. In this connexion, the possibility of co-operative research within industry as well as between industry and institute was raised.

The majority agreed that, whatever the organizational arrangements, a research institute should enjoy a reasonable degree of administrative autonomy. One suggestion was made that a committee be set up with as broad a base as possible to advise and assist the institute in the formulation of research policy and reviewing of programmes.

The opinion was expressed that, owing to the desirability of co-ordinating regional research efforts, the establishment of industrial research institutes on a regional basis may prove to be of great advantage to a region.

### **In-house initiated research projects versus contractual activities and services**

Many participants stressed the necessity of close contacts with industry so that results of research can be applied. Consequently, the importance of supplying services on a contractual basis was recognized as one of the major roles of a research institute. However, a balance between such activities and long-range research projects and investigations, in

line with national goals of industrial development, should be established. Such a balance is a matter to be determined in each case.

It was the consensus of the Symposium that in supplying services to industry special care should be given to the needs and requirements of small-scale and medium-sized industrial enterprises. In this connexion the technologies best suited to withstand competition while being labour-intensive should be carefully investigated.

#### **Sources of financial support for research institutes**

It was generally recognized that the Government or other national sponsoring bodies have a leading role to play in the financing of research in developing countries. The assistance provided by United Nations and bilateral aid programmes, both in kind (equipment, books) and in manpower (experts, fellowships), could greatly contribute to lightening the initial financial burden of developing countries. Some of the participants from developed countries expressed their readiness to supply a variety of technical assistance to research institutes in developing countries. One recommended that institutes have the goal of becoming self-supporting as soon as possible. In addition to the income derived from specific contracts, income should be derived from royalties as a result of the self-initiated research programmes. It was pointed out that this would have the meritorious effect of assuring the most fruitful programme of work.

#### **Personnel policies**

It was generally recognized that since the success of a research institute depended to a large extent on the quality of its professional staff members, they should be remunerated on a scale that could balance the attraction from private industrial enterprises. The case was cited of a country which had been successful in rehiring researchers who had left the country through adopting higher salary scales and providing a more stimulating professional atmosphere. The need for a sustained training programme for professional personnel was stressed in order to increase and update their skills. It was suggested that increased availability of research workers in developing countries could be achieved if they and the industrialized countries could agree on measures to limit the long-term employment in industrialized countries of trained scientists and technologists from developing countries.

RECOMMENDATIONS APPROVED<sup>13</sup>

In view of the necessity of co-ordinating the industrial research activity of a country with its over-all industrial development goals, Governments of developing countries are urged to define clearly their research aims, requirements and programmes, both in terms of objectives and co-ordination in the use of scarce resources for research, and to incorporate them in their over-all economic national development schemes.

Taking into account that in developing countries there is not always sufficient interest in the services of industrial research institutes, it is recommended that Governments of developing countries try to create "research consciousness" in order to accelerate the full utilization of institutes' services.

It is recommended that UNIDO should attach high priority to fostering industrial research projects and activities designed to:

Investigate all possible new uses for local raw materials;

Adapt existing technology to the prevailing conditions (human, capital and natural) in the developing countries;

Devise, wherever possible, linkages between products and stages of processing as a basis for viable industrial complexes.

Recognizing that the supply of experienced industrial technologists capable of adapting laboratory research findings to a pilot plant scale and to commercial production is extremely limited in developing countries, it is recommended that the necessary steps be undertaken by UNIDO in co-operation with the appropriate organizations and institutions to promote the establishment of training facilities designed to adapt existing technological skills to the needs of the developing countries. Such steps should include the establishment of regional and international study and training programmes, emphasizing plant visits and field work.

Because of the vital need for exchange of information and experience, it is recommended that UNIDO be invited to consider the question of establishment of an international association of industrial research institutes with the objective of facilitating co-operation in the exchange of experiences, know-how and professional expertise.

To attain better utilization of available experience and resources it is recommended that UNIDO, in co-operation with competent national,

<sup>13</sup> From the Report of the International Symposium on Industrial Development, Athens 1967 (ID/11) (United Nations publication, Sales No.: 69.II.B.7).

regional and interregional organizations, should promote international collaboration between research institutes and organizations in developed and developing countries as well as regional and interregional co-operation and co-ordination of activities between developing countries. Such collaboration could be instrumental in overcoming the institutional and technical obstacle to the transfer of technology.

## **UNITED NATIONS AND OTHER INTERNATIONAL ACTION TO PROMOTE INDUSTRIAL RESEARCH**

### **ACTIVITIES OF THE UNITED NATIONS CENTRE FOR INDUSTRIAL DEVELOPMENT**

Before the inception of UNIDO, its predecessor, the Centre for Industrial Development (CID) included industrial research among its activities. An Interregional Seminar on Industrial Research and Development Institutes in Developing Countries, held in Beirut in 1964, was attended by representatives of 25 developing countries from Africa, Asia and Latin America, eight expert consultants and nine observers from developed countries, and representatives of the International Labour Organisation (ILO), the Food and Agriculture Organization (FAO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). The concept and objectives of industrial research institutes, their industrial extension services and organizational problems were discussed in depth. Recommendations and conclusions of the seminar helped to clarify the area of activities most needed for developing countries. The proceedings were published in two volumes.<sup>14</sup>

In the course of the deliberations it became clear that of the many problems faced by such institutes in developing countries the problem of management was of paramount importance. A recommendation was adopted to prepare a manual which might help to improve managerial efficiency in industrial research institutes. With the assistance of an expert group of nine leading experts and twelve honorary correspondents, a manual on the management of industrial research institutions in developing countries was published.<sup>15</sup>

At the same time, CID undertook field work in conjunction with various United Nations assistance programmes. Experts were placed with government agencies to advise on policies and measures to promote

<sup>14</sup> For full reference see annex 3 under "Centre for Industrial Development".

industrial research or with existing research institutes to advise the directors on the management of these establishments. Experts in specific technological fields were assigned to institutes in order to improve technological efficiency in a specific field and to provide on-the-job training for their counterparts on the staff. Fellowships were also awarded to members of the institute staff for training abroad.

CID also assisted in the establishment of two research institutes: a national institute in Paraguay and a regional institute located in Guatemala, to serve the countries of Central America. In both cases, industrial research and the provision of industrial services to Governments and industry were the main objectives; standardization was also an important activity. CID also gave assistance in the technical operation of industrial research institutes in Israel, the Sudan and Thailand.

In all cases, laboratories for testing, quality control, technological investigations and services to clients were supplied together with a team of international experts. Fellowships were also awarded.

The terms of reference of these institutes of industrial research differed according to the conditions of the countries in which they were established—the special requirements and the level of development. They all performed some or all of the following functions:

Collecting and disseminating industrial and economic information about new technological developments;

Undertaking testing in connexion with quality control programmes of interest to the country;

Undertaking economic investigations with a view to establishing new industrial ventures;

Undertaking applied research in connexion with locally available natural resources to improve their utilization and find uses for by-products;

Providing engineering and trouble-shooting services to industry;

Undertaking sectoral studies of industry to assist governmental agencies in their development plans.

One of the last tasks of CID was to collaborate with the regional economic commissions in making a review of the current position of industrial research in developing countries for discussion at the International Symposium in Athens.

## ACTIVITIES OF UNIDO

UNIDO has continued the field work of CID. Experts in research management or industrial research in specific fields such as specialized testing, food, metals, packaging, textiles, marketing and others, have been or will be sent to Argentina, Bulgaria, Chile, Colombia, the Democratic Republic of the Congo, Hungary, Indonesia, Iran, Israel, Libya, Pakistan, Singapore, the Sudan, and Trinidad and Tobago. Industrial research institutes have either started or are being planned with assistance from UNIDO in Brazil, Libya, Malaysia, Mauritius, and Trinidad and Tobago.

In order to exchange experiences on the performance of industrial research institutes and to compare results achieved, a "Workshop of Managers of Industrial Research Institutes in Developing Countries" was organized in Athens in July 1967 with twenty representatives from countries of Africa, Asia and Latin America and eight experts. The papers prepared for this meeting are being published by UNIDO under the Symbol ID/30.

Wherever possible, regional co-operation in industrial research is fostered to ensure better utilization of available resources and avoid duplication. UNIDO is currently investigating the possibility of establishing a research institute for coconut research to serve the countries of Asia and the Far East and make the results of its investigations available to those countries interested in this important raw material.

In order to facilitate co-operation between industrial research establishments of developed and developing countries as well as regional and interregional co-ordination of activities among developing countries, UNIDO convened an expert group in Vienna in May 1969 to study a proposition for the creation of a world association of industrial and technological research organizations. The aims of the association would be to increase research consciousness, to foster co-ordination and co-operation, to establish a centralized clearing-house for information to facilitate exchanges of experience in research management, to foster exchanges of researchers, to identify training opportunities and to be instrumental in arranging contract research. A draft constitution has been circulated to organizations undertaking or promoting industrial research, and it is anticipated that the meeting of founding members will be held at the end of 1970. Support from the United Nations regional economic commissions will be enlisted for the Association, as they will be asked to play a vital role in regional co-ordination.

Recognizing the role of industrial research in economic development,



the United Nations regional economic commissions have established Advisory Councils for Industrial Research to identify regional problems in this field and recommend proper action. Meetings are also organized at a regional level to bring together persons responsible for establishing research policy and directors of industrial research institutes. UNIDO, which co-operates closely with the regional economic commissions on these matters has a regional adviser on industrial research attached to ECAFE in Bangkok, Thailand, and another attached to ECLA in Santiago, Chile.

United Nations interest in industrial research is shown by the activities of the Unit of Science and Technology of the United Nations Department of Economic and Social Affairs, which works closely with UNIDO, FAO, UNESCO, and other United Nations agencies as well as with the regional economic commissions. The Unit keeps under constant review the progress achieved in the utilization of science and technology for development in Africa, Asia and the Far East and Latin America. It regularly organizes regional and interregional symposia to report on the measures undertaken in various countries and the results achieved. It has recently been engaged, with the co-operation of UNIDO, FAO and UNESCO in a cost/benefit analysis of research and development. Research on the production of protein from hydrocarbons was given particular attention in the last regional symposium organized in co-operation with ECAFE.

UNESCO for its part has been very active in the formation of future research workers by giving special attention to the science and engineering curricula at universities of developing countries and to improving the basic technical training of young scientists. It has published two reference volumes on the subject, one in collaboration with ECA<sup>15</sup>, the other in collaboration with ECAFE<sup>16</sup>.

UNESCO also undertakes important field work on basic research and technology and has made valuable contributions to developing countries by assisting them to define the broad lines of their national research policies. It has also provided direct technical assistance to individual countries, including Brazil, Malaysia, Pakistan, the Philippines, and Thailand.

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<sup>15</sup> UNESCO, *Scientific Research in Africa: National Policies, Research Institutions*, Paris, 1967 (B. 2115).

<sup>16</sup> UNESCO, *Research Facilities in Science and Technology in Asia, a preliminary survey*, Paris, 1968 (SC/VS/192).

FAO is interested in research in the areas under its competence and collaborates with UNESCO and UNIDO in supplying professional assistance in specific fields of research such as paper and cellulose. It has assisted a number of countries in establishing research institutes dealing with food products, including grains, bread and others.

#### BILATERAL AID PROGRAMMES

Much assistance in the field of industrial research is being supplied under bilateral aid programmes, either for the initial establishment of industrial research institutes or for the strengthening of existing ones. Denmark, the Federal Republic of Germany, France, Sweden, the United Kingdom, the Union of Soviet Socialist Republics and the United States, for example, have supplied assistance on research management, ceramics, food, metal and engineering industries. An important contribution is made through the fellowships or other training opportunities they provide to nationals from developing countries.

## **Annex 1**

### **UNIDO ASSISTANCE IN INDUSTRIAL RESEARCH**

#### **A. AREAS RELATING TO INDUSTRIAL RESEARCH IN WHICH UNIDO IS IN A POSITION TO PROVIDE TECHNICAL ASSISTANCE**

- Identification of national requirements in research and development;
- Reorganization, streamlining and improvement of efficiency of existing research establishments and their links with industry;
- Supervision of in-house and on-the-job training programmes for the staff of research establishments;
- Phasing and financing the operation of research institutes by specifying the framework and scope of activities, preparation of a work programme and the supply of equipment, experts and library and reference materials;
- Provision of fellowships for the training of national staff members in the field of industrial research and related fields in specialized organizations in developed countries, as well as visits between personnel of such institutes;
- Meetings, seminars and working groups on a regional and inter-regional basis to discuss problems and issues in the field of research and development and the various experiences of participating countries;
- Preparation, publication and dissemination of manuals and training material related to research and development;
- Dissemination of information related to general research and development problems and/or needed information for a particular country on a specific problem through the planned UNIDO clearing-house.

#### **B. SELECTED MAJOR TECHNICAL ASSISTANCE PROJECTS**

The projects listed below relate to the activities of the United Nations Industrial Development Organization since its establishment in 1967. The list excludes projects carried out under the predecessor organizations of UNIDO (the former Division of Industrial Development up to 1962 and the Centre for

Industrial Development up to 1967). Since the projects are listed for illustrative purposes, the names of countries have been omitted. The respective programmes under which the projects are implemented are shown as

SIS	Special Industrial Services of UNIDO
UNDP/TA	United Nations Development Programme, Technical Assistance Component
UNDP/SF	United Nations Development Programme, Special Fund Component
RP	Regular Programme

**(1) Projects implemented or under implementation by UNIDO in areas related to industrial research**

**AFRICA**

**Adviser on industrial research policies (UNDP/TA)**  
**Industrial research chemist (UNDP/TA)**  
**Industrial Research Institute (UNDP/SF)**  
**Industrial Development and Research Centre (UNDP/SF)**

**THE AMERICAS**

**Expert in organization of industrial research (SIS)**  
**Adviser on efficiency of industrial research (UNDP/TA)**  
**Institute for Technological Research (UNDP/SF)**  
**Industrial Research Institute (UNDP/SF)**  
**Regional Research Institute for Industry (UNDP/SF)**  
**Regional adviser on industrial research (RP)**

**ASIA AND THE FAR EAST**

**Applied industrial research adviser (SIS)**  
**Industrial research advisers in four countries (UNDP/TA)**  
**Technological Research Institute (UNDP/SF)**  
**Regional adviser on industrial research (RP)**

**EUROPE AND THE MIDDLE EAST**

**Expert in packing media research (SIS)**

- (2) *Projects in preparation or under discussion with governments in areas related to industrial research*

**AFRICA**

**Adviser on industrial research (NIS)**  
**Industrial research chemist (UNDP/TA)**  
**Industrial Research and Development Centre (UNDP/SP)**  
**Industrial Research and Promotion Centre (UNDP/SP)**

**ASIA AND THE FAR EAST**

**Industrial research and development expert (NIS)**  
**Reports on industrial research in two countries (NIS)**  
**National Institute for Scientific and Industrial Research (UNDP/SP)**

## Annex 2

### MEETINGS, SEMINARS AND WORKING GROUPS ORGANIZED BY UNIDO OR BY THE UNITED NATIONS PRIOR TO THE INCEPTION OF UNIDO

	<i>Location</i>	<i>Date</i>
<b>Interregional Seminar on Industrial Research and Development Institutes in Developing Countries</b>	<b>Beirut</b>	<b>November-December 1964</b>
<b>Interregional Workshop of Managers of Industrial Research Institutes in Developing Countries</b>	<b>Athens</b>	<b>July 1967</b>
<b>Expert Group Meeting on the International Association of Industrial Research Organizations</b>	<b>Vienna</b>	<b>May 1969</b>
<b>Meeting on the Evaluation of Effectiveness of Industrial Research Institutes</b>	<b>Vienna</b>	<i>Proposed date</i> <b>1970</b>

### Annex 3

## SELECTED LIST OF DOCUMENTS AND PUBLICATIONS ON INDUSTRIAL RESEARCH<sup>1</sup>

### UNITED NATIONS

*Science and Technology for Development. Vol. II. Natural Resources* (Sales No. 63.I.22).

### CENTRE FOR INDUSTRIAL DEVELOPMENT (PREDECESSOR OF UNIDO)

*Proceedings of the Interregional Seminar on Industrial Research and Development Institutes in Developing Countries, Beirut, Lebanon, 30 November—11 December 1964* (ST/TAO/SER. C/77 Vol. I and II) (mimeo.).

*Manual on the Management of Industrial Research Institutes in Developing Countries* (ST/CID/6) (Sales No.: 66.II.B.3.). [The manual contains an exhaustive bibliography on industrial research.]

### UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

*Application of Science and Technology to Development: Arrangements for the Transfer of Operative Technology to Developing Countries. Progress Report, presented by the United Nations Department of Economic and Social Affairs, 1967* (ID/CONF. 1/53) (mimeo.).

*The Organization of Industrial Research in Developing Countries, 1967* (ID/CONF. 1/B. 14) (mimeo.).

*Progressive Industrial Technology for Developing Countries, presented by ILO, 1967* (ID/CONF. 1/B. 17) (mimeo.).

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<sup>1</sup> Symbols and Sales Numbers of United Nations documents and publications are given in parentheses after the titles.

Practice of Industrial Research and Development, presented by the Government of the Netherlands, 1967 (ID/CONF. 1/G. 1) (mimeo.).

Quality Control and Standardization as Conditions of Industrial Growth, presented by the Government of the Netherlands, 1967 (ID/CONF. 1/G. 4) (mimeo.).

Research and Development in Yugoslav Industry, presented by the Government of Yugoslavia, 1967 (ID/CONF. 1/G. 18) (mimeo.).

Science and Industrial Development, presented by the Government of the USSR, 1967 (ID/CONF. 1/G. 37) (mimeo.). [In Russian, summary in English, French and Spanish.]

Influence of the Technical Research Revolution on the Development of the Extractive Industry in Asia and Africa, presented by the Government of the USSR, 1967 (ID/CONF. 1/G. 42) (mimeo.). [In Russian, summary in English, French and Spanish.]

United Kingdom Contributions to Technological Development in Developing Countries, presented by the Government of the United Kingdom, 1967 (ID/CONF. 1/G. 74) (mimeo.).

*Report of the Symposium on Industrial Development in Africa, Cairo, 27 January—10 February 1966* (ID/CONF. 1/R.R. 1).

*Report of the Asian Conference on Industrialization, Manila, the Philippines, 6—20 December 1965* (ID/CONF. 1/R.R. 2).

*Report of the Symposium on Industrial Development in Latin America, Santiago, Chile, 14—25 March 1966* (ID/CONF. 1/R.R. 3).

*Report of the Symposium on Industrial Development in Arab Countries, Kuwait, 1—10 March 1966* (ID/CONF. 1/R.R. 4).

Technological Research and Industrial Extension in Canada, by R. E. McBurney, 1967 (ID/CONF. 2/8) (mimeo.).

The *Industrial Research and Development News* is published quarterly with the purpose of reviewing and disseminating information on the organization and programmes of industrial research and activities conducive to industrial development in developing countries as well as a forum for the exchange of technological and industrial experience.

#### ECONOMIC COMMISSION FOR ASIA AND THE FAR EAST

**Directory of Institutes of Industrial Research and Technology in the Countries of the ECAFE Region, January 1966** (mimeo.).



## OTHER SOURCES

Hoffmann, de F., „Forschung in der amerikanischen Industrie“, in R. Courant *et al.*, Eds., *Forschung und Industrie in den USA — ihre internationale Verflechtung*, Westdeutscher Verlag, Köln/Opladen, 1962.

OECD, *International Statistical Year for Research and Development Vol. I: The Overall Level and Structure of R and D Efforts in OECD Member Countries*, Paris, 1967.

OECD, *Gaps in Technology between Member Countries: General Report*, Paris 1968.

Schumpeter, J., *The Theory of Economic Development*, Harvard University Press, Cambridge, Mass., 1955.

Williams, B. R., *Technology, Investment and Growth*, Chapman and Hall, London, 1967.

Zimmermann, E. W., *World Resources and Industries*, rev. ed., Harper, New York, 1951.

See also bibliography contained in United Nations, *Manual on the Management of Industrial Research Institutes in Developing Countries*, pp. 99—122 (ST/CID/6) (Sales No.: 66.II.B.3).





**UNIDO MONOGRAPHS ON INDUSTRIALIZATION OF DEVELOPING COUNTRIES:  
PROBLEMS AND PROSPECTS**

- |  |   |
|--|---|
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| No. 2. Construction industry               | No. 12. Standardisation                         |
| No. 3. Building materials industry         | No. 13. Industrial information                  |
| No. 4. Engineering industry                | No. 14. Manpower for industry                   |
| No. 5. Iron and steel industry             | No. 15. Administrative machinery                |
| No. 6. Fertilizer industry                 | No. 16. Domestic and external financing         |
| No. 7. Textile industry                    | No. 17. Industrial planning                     |
| No. 8. Chemical industry                   | No. 18. Regional co-operation in industry       |
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