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# THE REVITALIZATION OF INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTES IN DEVELOPING COUNTRIES*

## GUIDELINES FOR UNIDO

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* The views expressed in this document are those of the author and do not necessarily reflect the views of the Secretariat of UNIDO. This document has not been edited.

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# TABLE OF CONTENTS

# INTRODUCTION

Many developing countries have established Industrial Technology Research Institutes (ITRIs) during the last thirty years, with the purpose of supporting the technological development of enterprises in different industrial branches, by facilitating their access to industrial know-how and technology, and by providing them with research and development and a broad range of technological services.

Most of these institutes were established in the sixties and early seventies, on the lines of institutions existing in industrial countries, and were often set up as national government research organizations with a wide sectoral coverage.

Twenty or thirty years later many of them are facing a host of problems. They are far from fulfilling their original aims, and have not related closely to industry. Their income has fallen as governments have cut down on expenditure, with negative consequences on efficiency as salaries and other items of expenditure were reduced. Their capabilities and their organizational characteristics are increasingly out of step with the requirements of the new situation faced by their countries in the 1990s, principally the strong pace of technological advance on account of new technologies, and the opening up of the economy with the need to enhance competitiveness in order to produce for an outside market.

Strong misgivings about the relevance and performance of these institutions are increasingly being voiced in government and industrial circles of developing countries. There is concern about the need to restructure and reorient existing ITRIs so that they may become effective instruments of development.

This paper examines the problems being faced by ITRIs in developing countries and what can be done to revitalize them, by helping them to become more effective, assisting their transition to the new environment of the nineties, and consolidating their sustainability.

The literature on these issues is not abundant, and this has motivated UNIDO and IDRC to jointly sponsor a research project which included case studies of a number of ITRIs in Latin America, using a common methodological approach. The "ITRI Project" also included two additional case studies in two OECD countries, New Zealand and Canada, for contrasting purposes. The case studies were made in the second part of 1992 and the results were discussed at meetings in February and July 1993. Annex 1 presents a description of this project.

The results of the ITRI Project were the main empirical sources of the present paper. Additional empirical sources were interviews carried out by the present author on ITRIs of other regions of the world, and some essays on ITRIs which were of particular interest.

We have divided the present paper into four chapters. The first one presents the problematique of ITRIs, reviewing the main issues they face today. The second chapter deals with the ways in which an ITRI may be revitalized, and how to organize a project for that purpose. The third chapter includes a series of suggestions to UNIDO on activities it can carry out in this field. The fourth chapter is a "Casebook", with summaries prepared by the present author of the case studies and other papers of direct relevance. A total of 21 "cases" are included, presenting a wide diversity of specific situations as well as some themes that are shared by many ITRIs.

The subject is broad and complex, and would deserve more time and effort than has been available at this time. While we are conscious of these limitations, we hope nevertheless that the present paper will be useful to UNIDO and its member countries.

# CHAPTER 1

# THE PROBLEMATIQUE: ITRIS IN A CHANGING CONTEXT

## 1.1 NEW CHALLENGES FOR DEVELOPING COUNTRIES

### Overview

During the last decade we have witnessed the emergence of a new global order as a result of major changes in the political, social, economic and technological spheres. Some of the main features of the new situation are:

- the consolidation of a new technological and developmental paradigm, with production processes increasingly science-based and technology-intensive, and a much higher rate of technological change than in the 60s and 70s;

- a growing importance of trade in a highly interdependent world with expanding globalized production systems, calling for special efforts by developing countries to compete in the world markets if they are to avoid further marginalization;

- a strong trend towards the opening up and deregulation of the economy, and in particular the abandonment by most developing countries of the import-substitution strategies that predominated until the early 80s;

- the shrinking role of the state, with a reduction in government expenditure and widespread privatization of public services and public enterprises;

- a renewed interest in direct foreign investment, now seen as a key source of capital, technology, market access and management knowhow, in contrast to the negative attitudes in previous years;

- an increasing concern about the environment, which is now considered as a new dimension of development, particularly after the 1992 UNCED Conference in Rio de Janeiro.

This new context is having significant consequences for most developing countries. The position of knowledge as a critical factor of production has been strongly reinforced. With the acceleration of technological development, the changes in the shape of markets and the comparative advantage of nations, and the deeper integration of the world economy, the technological gap between rich and poor countries is increasing further and the fears of a destiny of marginalization for the poor countries are becoming more widespread.

Many developing countries have made profound changes in their economic policies, often prompted by their large foreign debts. Governments following different political orientations have attempted to liberalize trade, reduce budget deficits, curtail state spending and the economic activities of the state, and privatize public sector enterprises. They have done away with most controls on flows of technology and foreign investment, and are actively seeking to enhance those flows.

These countries are increasingly aware that they will need to restructure and revitalize their productive system, obtain access to new technologies, and promote a deep process of technological innovation aimed at increasing the capability of their enterprises to participate in global markets that are subjected to dynamic change. There is also an increasing understanding that development objectives should include considerations of equity and of ecologically sustainable development.

**Trends in technology**

The rate of innovation in the world has accelerated dramatically in the past ten years, particularly in the "new technologies" of microelectronics, biotechnology, new materials, robotics and other. This follows scientific advances in solid state physics, genetic engineering, material sciences, computer sciences, and other disciplines where dynamic work is being conducted. There have also been significant improvements in scientific instruments and analytic techniques. From the demand side innovation has been driven by intense competition for expanding markets in the world, which have stimulated a strong increase in R&D, design and engineering work, education, and specialized training.

New technologies have often a "generic"nature that makes them applicable to different sectors and activities. Here the prime example is information technology, which finds wide use in manufacturing, telecommunications and service activities, and is transforming the workplace and the way people work. The increasing use of automation - through numerically controlled machine tools, computer assisted design, and automated banking, to give but a few examples - has sharply diminished the advantages of cheap labour as a factor in competitiveness, and increased the need for specialized skills in the factory and in administration.

The new production techniques allow more product diversification, permit higher quality, make for faster processing, and signify shorter life cycles of products. In many cases materials and energy inputs are lowered. New materials are increasingly replacing traditional materials, continuing and exacerbating previous trends, and this has an unfavourable impact on the exports of some developing countries. The substitution of synthetic for natural rubber and of synthetic fibers for jute is being continued by that of optical fibre for copper, carbon fibre composites for steel, ceramics for metal parts, and so on.

The organization of production has suffered striking changes with the introduction of practices such as total quality control, just-in-time supply of components, and other approaches, which are being integrated into a new type of production system. What is now called "lean manufacturing" permits substantial savings in most inputs - materials, energy, labour, capital - in

comparison with the previous mass-production methods. Lean manufacturing was developed in Japan and is today making inroads in other industrial countries.

A distinguished Japanese industrialist (R. Hara, President of Seiko Instruments) suggested recently at a UNIDO meeting that "there are no sunset industries", since the new hard and soft technologies are allowing the rejuvenation of industrial activities which had looked increasingly outdated in many countries, such as textiles and steelmaking.

An important aspect of the new manufacturing approach is that the efficiency of a firm increasingly depends on the industrial system within which it is embedded; this leads to a very different approach to the improvement of competitiveness, which is no longer solely related to the efforts of an individual firm.

## Impact on competitiveness

The results of these advances has often been a sharp reduction in production costs, as has been evident in electronic components and products such as chips, software, and personal computers, where price reductions have been continuous and have meant frequent restructuring of the industry.

Competitiveness not only depends on costs. Important aspects underlying competitiveness are, according to Dahlman (1993), "the ability to acquire, use, diffuse and develop technology to reduce production costs, improve product quality, and innovate through new products and services; and flexibility in the human and institutional infrastructure to adapt to rapidly changing conditions". Other aspects mentioned by the same author are: "quality, short delivery time, after sales service, responsiveness to product design, innovativeness in product design, product differentiation, aggressive marketing, efficient distribution".

Some of these aspects relate to the environment in which the enterprise operates, and which it cannot control. This is the case of the efficiency with which inputs and services are provided, the quality of the physical infrastructure, the availability of qualified human resources, an adequate macroeconomic environment regarding inflation, exchange rate and other parameters, and a good institutional infrastructure. The latter will include technology support institutions, with activities in research and development, metrology, standards and quality control, testing, technology and market information, and technological services. A developing country is at a disadvantage here, since its firms have to carry out their activities in a milieu which is far less favourable than that of an industrial country.

## Policy implications for developing countries

Technology trends, together with the new characteristics of international competition, have many implications for developing economies.

Greater international competition presents a threat to production for domestic markets. A developing country should develop its capabilities to produce efficiently and export its outputs, which will require it to reduce costs and upgrade technology. Low income countries may find it difficult to contnue

enjoying competitiveness based on very low wages , as their higher wage competitors become successful in lowering the man-hours needed for production. Technological change can be a threat if a country is not able to use the new opportunities; hence, it is important to lay out strategies to do so.

A recent observer points out that countries with large domestic markets like India " have tended to be inward-looking and continued protection and lack of competition in the past have only reinforced this unfortunate tendency... (they) will have to learn to compete both domestically and internationally... the new challenge will be that of producing and exporting goods and services of consistent quality at competitive prices... product choice, quality, design, content, packaging and marketing will determine the competitiveness" (Mashelkar, 1993).

Low income developing countries are at a disadvantage in not having a good technical and entrepreneurial basis for such purposes. Dahlman points out that countries further up the scale of development that want to move into more complex manufacturing have a number of options: use of more automation to deal with rising labour costs (policy employed in Singapore and Korea), products with large production runs (such as cement and bicycles in Korea), specialty niche products (clothing and footwear in Hong Kong), technology intensive products (such as electronics in Taiwan).

There are obstacles to this. First, the increasing protectionism in the industrial countries; this may be countered by diversifying export markets, attracting foreign firms to produce in the country and export to their home countries, and other means. Second, the increasing difficulty in the access to knowhow and its acquisition; industrial countries are increasingly stressing the protection of industrial and intellectual property and showing less inclination to transfer knowledge through licensing, foreign direct investment and other means. Third, Eastern European countries have become an important destination for foreign investment.

The more dynamic developing countries, like Korea and Taiwan, have found it necessary to increase their R&D efforts, participate in strategic alliances with firms from industrial countries with the purpose of sharing in high technology fields, and invest in high technology firms, in Silicon Valley principally. In the case of the Latin American countries, which are not yet regarded as serious a threat as the newly industrializing economies in the Pacific, a critical issue is how to attract more foreign firms to set up operations locally so that the country may benefit from the incorporation of technology and from the access to intra-firm exchanges. However, these countries should also augment their technological capabilities if they are to make the best use of the opportunities opening up as foreign investment increases.

If it is to compete successfully, a country should be concerned with four key technology-related areas, according to Dahlman:

(a) *Acquiring foreign technology efficiently.* Experience has shown the high returns of a "technological follower strategy" (Japan, Korea). Assistance to the private sector in the search, acquisition and assimilation of technology is being given in different countries.

(b) *Using and diffusing technology effectively*. This allows firms to improve their economic performance, and has sometimes been neglected as attention was overly focused on R&D and innovation. A variety of institutions and networks can help firms to learn about market and technology trends and to apply existing technology. Among them may be mentioned institutions in industrial technology, quality, standards, information, training and extension, and sub-contracting networks.

(c) *Improving and developing technology*. An important source of increased productivity is the accumulation of minor, incremental changes as experience is gained and R&D work is performed in enterprises. This contribution may be more important than that of R&D institutions in the public sector.

(d) *Investing in human capital*, in which technology is principally embodied. Experience shows that a good educational system and efficient job-related training programmes become necessary, to provide the foundation for technology related work, and to upgrade skills in line with changes in economic activity and the technological state of the art.

Two more points are made by this author. First, since there is a rapidly increasing stock of technology available internationally, most developing countries could profit more by "becoming very good at acquiring foreign technology that is relevant for their conditions, and using and diffusing technology efficiently, rather than by trying to develop their own technology". Secondly, while there is an important role for government in developing the basic technological and human capital infrastructure, most of the action relevant for international competitiveness has to take place at the level of the firm rather than in public R&D laboratories.

In the opinion of the present author, it is hardly possible to follow these suggestion in many developing countries in which locally owned industrial firms tend to be small and technologically backward. If industrial technology in such countries is to be advanced, there seems to be a clear role for industrial technology research institutes. In some low income countries (African countries come to mind) it would be difficult to think of an alternative.

## 1.2 PROBLEMS BEING FACED BY INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTES IN DEVELOPING COUNTRIES

Developing countries have built up significant scientific and technological capabilities during the past two or three decades, in university research departments, basic and applied research institutes, industrial and agricultural research organizations, and other components of the "science and technology infrastructure". Many such countries have invested heavily in this infrastructure, and built up cadres of well trained scientists and technicians. These resources should be employed efficiently in support of national goals.

The impact of these institutions on development and on the quality of life, however, has in general been limited, while foreign technology has continued to be introduced for all modern activities. The "supply push" approach, which assumes that making good science and technology will automatically produce

positive results for the economy and the society, has turned out to be ineffective in developing countries. In most cases the scientific and technological institutions so laboriously created are not properly connected to the potential users in the productive sectors, and the pursuit of scientific results has become an end in itself, rather than a means to support development and improve the quality of life. Such shortcomings are causing increasing concern, particularly in the case of research institutions that have been create to service industry.

Industrial technology research institutes, ITRIs, are prominent actors in the scientific and technological infrastructure. They have been defined as "multi-purpose or multi-functional technological institutes which (a) provide services (functional activities), either to a group of industrial sectors (multi-branch) or a single sector (mono-branch), and (b) possess a major R&D component" (UNIDO, 1979).

A good number of ITRIs were established by developing countries in the sixties and early seventies, with the objective of supporting the technological development of industry across a wide range of sectors, and facilitating access to industrial know-how and technology. They were based on organizational models existing in industrialized countries at that time, such as the Battelle Institute and Denver Research Institute in the US, and the Department of Scientific and Industrial Research in the U.K. The United Nations system, particularly UNIDO, had a significant role in supporting the creation of many of them. The present number of ITRIs in developing countries can be counted in the hundreds.

In many cases ITRIs have been created in the public sector. In other cases they have been set up as private research centres, joint public-private ventures or university-based institutes. Many ITRIs have played an important role in the development of industry in their own countries, and continue to provide valuable services to it, in areas such as quality control and certification of export products. But, increasingly, questions are being asked about the effectiveness of these institutions in terms of their real contribution to industrial development. In many cases they are held to be too academic and not sufficiently interested in working for the needs of the productive sector.

Referring mainly to the public sector institutes, Oldham (1992) points out that:

> "During the 1960s and 70s developing countries were encouraged to replicate the models of both Eastern and Western countries, and a large number of industrial research organizations were established throughout the world. They had one characteristic in common. They were largely independent from industry. In the late 1980s and 90s the models have turned out to be inappropriate even within their own countries. They are even less appropriate for those developing countries that adopted them. But, regardless of their origins, the role of State funded technology institutions is being questioned in almost all countries. Many have already been transformed and have been required to work more closely with the private sector. It is an appropriate time to take stock of the transformation process, and to assess its implications for developing countries." (Oldham, 1992)

These concerns are being increasingly expressed by policy-makers, industrial leaders and research managers, as it becomes evident that old-style industrial technology research institutes are no longer appropriate and that a different type of institution is required to attend to the needs of present day industrialization in the developing countries.

On recent visits by the present author to some developing countries, it was found that authorities in government and industry were seriously concerned about the need to restructure their institutes. This is exemplified by the statement of authorities in a Latin American country, which regarded the main national ITRI as "needing a radical restructuring to enable it to backstop the industrialization process, in a new phase in which the economy has been opened up, and the emphasis is no longer on protection, but on productivity and competitiveness".

Similar feelings have been voiced in other developing countries, where authorities are concerned with the need to do something about their research institutes, which they feel are not carrying out an efficient job in support of industry. The issue is also of concern to Eastern European countries, where applied research institutions are now facing a sudden decrease in state funding. The cases of Colombia, Guyana and Peru should also be mentioned. In each of these countries the main national industrial technology institute has recently closed down, in the face of changing economic conditions and a lack of interest of government and industry in further extending support to it.

The World Association of Technological and Industrial Research Associations, WAITRO, celebrated in October 1992 a seminar on "R&D Strategies for the 1990s" which was attended by a number of ITRI Directors. A central issue which surfaced repeatedly was how to make ITRIs more efficient, more attuned to the needs of industry in the nineties, and more self-supporting. Some of the participants were very critical of the way ITRIs are organized and managed in many developing countries, feeling that an overwhelming proportion of the activities do not have significant impacts on industry and the industrialization process. There was general agreement on the urgent necessity of restructuring, reorienting and even privatizing ITRIs.

There are interesting examples of ITRI restructuring in some OECD countries, where changes in the international environment had brought about similar problems. In Australia the Commonwealth Scientific Industrial Research Organization (CSIRO) was questioned in the early 80s as to whether it provided "value for money" in terms of its contribution to the Australian economy. A study was made and as a consequence a new Act was adopted by Parliament in 1986, reorganizing CSIRO into a number of institutes with clear missions and targets for cost sharing with the private sector. Similarly, the Department of Scientific and Industrial Research of New Zealand and other "science providers" in the public sector were restructured in 1991/92 and have now been replaced by ten Crown Research Institutes with greater independence, higher management flexibility, and the power to borrow and to engage in joint ventures with the private sector. In Canada new approaches are emerging for the organization of industrial technology research, such as the "consortium approach" of bringing together centres of excellence that operate in a given sector or technological area.

**Some key issues**

ITRIs in the developing countries are now facing a number of interrelated issues, which we may tentatively place under the following headings:

(a) *Relative failure to fulfill their original objective of assisting the technological development of industry.*

Many ITRIs have tended to put emphasis on topics of their own choice in their R&D activities, and have not had much success in the commercial application of research results. By not focusing closely on industry, they run the risk of becoming largely irrelevant to the development needs of industrial enterprises. This risk is reinforced by their lag to master new technological fields that are becoming increasingly important for industrial enterprises.

(b) *A changed milieu with different requirements*

The changing technical, economic and policy environment of the nineties makes life difficult for traditional ITRIs attuned to import substitution industrialization. As economies open up there is need to compete in globalized markets, and industry requires assistance to enhance its competitiveness. The new milieu would seem to require a different type of institution, more flexible and better able to help industrial firms facing a new set of challenges.

(c) *Need to update capabilities and develop new skills*

In order to cope with the new technological realities and the resulting requirements of industry, ITRIs find that they need to update their scientific and technical manpower, their procedures, their management methods, and their installations and equipment. This means, very importantly, the introduction of new knowledge and skills through training their human resources, selectively hiring new personnel, using capable, experienced outside consultants in their projects, improving their information resources, going into collaborative research projects, establishing strategic alliances with other institutions at home and abroad, and so on.

(d) *Dealing with new types of problems*

ITRIs are sometimes under pressure to address problems that are new to them. An important one is environmental protection, which is becoming a growing concern for industry everywhere. In some countries the conversion from military to civilian production may have strong implications as demand decreases for defence-related work, and there is a need for institutes to attend to the demands of a different type of customer which has to be won over. This problem is especially acute in the Eastern European countries.

(e) *Reduction of State support*

Most ITRIs face worsening conditions as their state funding has shrunk, often on account of stringent fiscal policies that reflect the declining role of the state, while the demand from industry has seldom grown enough to compensate for that loss of revenue. This situation has led to poor salaries, lack of adequate library facilities, instruments and equipment, and in some cases a succession of crisis which have discouraged the scientific personnel and put

in jeopardy the very existence of the ITRI (a few, in fact, have closed down in recent years). The result is a vicious circle: ITRIs lose revenue and as a consequence the quality of their services goes down, which makes it more difficult to keep their clients, which means less revenue, and so on. This is leading to serious doubts about the sustainability of these institutions, at a time when they should play a significant role in the process of competitive restructuring, by helping to upgrade the capabilities of productive enterprises to compete successfully in the world markets.

## 1.3 THE EVALUATION STUDY OF UNIDO/UNDP: AN IMPORTANT PRECEDENT

In 1977, recognizing that Industrial Research and Service Institutions, IRSIs (equivalent to our ITRIs in the present report), had been in operation in some developing countries for up to 20 years, UNDP and UNIDO agreed to undertake a joint evaluation of the effectiveness of the technical assistance they had provided to these institutes and the subsequent performance of those that had received assistance. The study covered 33 IRSIs, of which 17 were multi-sectoral (see Case 14).

The findings of this study regarding ITRIs and their performance refer to the situation in the late 1970s, prior to the appearance of many of the issues and challenges we have reviewed. Many of the findings, however, are applicable today, even though the environment in which ITRIs operate has changed. Here are some of the most significant findings:

*On missions, strategies and plans:*

- Single-branch IRSIs usually have more clearly identifiable clients than multi-branch ones.

- A frequent shortcoming is a failure to appreciate the importance of identifying the proposed beneficiaries of services at the planning stage.

- A substantial amount of the work of single-branch IRSIs is covered by contract, but multi-branch IRSIs apparently find it more difficult to attract projects.

- The effort needed to "sell" an IRSI and attract clients is often ignored at the strategic and tactical planning levels.

- Many institutions having "research" in their name are primarily service organizations.

- R&D anticipated results and the plans for achieving them are often over-optimistic.

- Co-operative arrangements with other national and foreign IRSIs appear to have been useful in areas like exchange of information and experience, and organization of fellowships.

- While many IRSIs were created to serve small- and medium-scale industry, this sector, in practice, often shows neither an interest in nor an appreciation of R&D.

- In spite of the critical shortage of qualified staff in most IRSIs, plans to develop and expand staff capabilities are sometimes either not suited to the real requirements or are non-existent. While academic or technical qualifications are often good to excellent, industrial experience is usually inadequate.

- Single-branch IRSIs most often concentrate upon services, utilization of raw materials, and new (imported) technology; they seldom carry out innovative research. Multi-branch, multi-purpose IRSIs concentrate in the smaller and less developed countries upon testing and analysis. In the larger, more developed countries, they usually attempt to avoid routine services, concentrating instead on sophisticated testing and analysis and innovative R&D. Often, they do not have sufficiently specialized competence to be of help particularly with respect to process, equipment and vendor selection in technology transfer transactions.

- In many cases neither the government nor the IRSI clearly understands what the latter's contribution could or should be.

- In most IRSIs no systematic effort is being made to develop staff skills through different modes of training or learning.

- Few IRSIs have the information system needed to keep up to date on work being carried out elsewhere: an appreciable duplication of R&D work is therefore highly probable.

*On the interrelationships with government*

- There was little evidence of the strong political will and leadership needed to ensure the IRSI's continuing success.

- The IRSI's major contribution to government has been in the provision of various technical supporting services. Contributions, in terms of inputs to government decision-making on industrial and technological matters as well as the acquisition of foreign technology, can be substantially increased.

*On the interrelationships with industry*

- A serious communication gap exists between industry and many IRSIs which is partially due to: inadequate or non-representation of IRSIs on governing boards and working committees; absence of appropriate mechanisms to establish and maintain a continuous dialogue; shortage of staff with industrial experience; lack of appreciation by industry of the services available from IRSIs; failure to assess periodically the requirements of industry.

- The principal benefits industry has derived from IRSIs to date relate to various supporting and routine services (e.g. testing and quality control).

*On performance and potential*

- The potential of an IRSI depends almost entirely upon the quality, quantity and skill composition of its staff and management. And while the availability of Ph.D. and M.Sc. graduates may not present any crucial problem in this regard, the availability of intermediate technical staff and of engineers with industrial experience does.

- Given sufficient institutional maturity, there is a high potential for IRSIs in the area of technological planning and policy-making.

- IRSIs can assume important functional activities relating to technology transfer and adaptation: e.g. the provision of information and advice on alternative technologies.

- An IRSI's contribution to industry can be increased and improved through the use of intermediate institutions to reach a broader spectrum of clients.

*On the commercialization of research results*

- Spontaneous demand by enterprises in developing countries for assistance in self-improvement is weak.

- The best opportunities for the incorporation of technologies occur through the "pull approach", i.e. starting from the needs of industry and selection of the most inexpensive and immediate response to the identified technical requirements. The transfer of existing technologies is therefore, the most frequent solution.

- An IRSI interested in selling technology needs strong capacity for market analysis, project evaluation and industrial management.

- The use of the "push approach", i.e. research results developed exclusively or primarily in-house, is more effective in relatively well developed technical environments.

- Direct government support to innovative projects is justified because their social benefits are greater.

## 1.4 THE ITRI PROJECT

In mid-1991 conversations were held between representatives of the United Nations Industrial Development Organization, UNIDO, and the International Development Research Centre of Canada, IDRC, regarding the situation of ITRIs in developing countries, pareticularly in Latin America. It was agreed that some central issues needed to be examined, about the changing characteristics of the industry sector that ITRIs are expected to serve and the transformations taking place in the international environment. The role and organizational characteristics of ITRIs should be reviewed, in order to make them more effective and useful in the new context. This would imply developing innovative approaches to the design and management of ITRIs, using what

could be learned from the analysis of what makes some institutes more effective than others. Thus was born the "Industrial Technology Research Institutes" Project, or ITRI Project for short.

The purpose of the ITRI project was to analyze, on the basis of empirical studies, the issues confronting ITRIs in developing countries in the 1990s, and to make suggestions as to how such institutes may improve their effectiveness and assure their sustainability, in a changed environment characterized by new economic, technical and policy conditions, and by reduced state funding. The project was sponsored by UNIDO and IDRC.

Empirical work has comprised case studies of ITRIs in eight countries of Latin America, using a common set of guidelines to help comparability. Case studies in Canada and New Zealand have also been made as a contrast to the former. Summaries of the reports of the different case studies, prepared by the present author, may be found in the third chapter of this paper, the "Casebook", under Cases 1 to 8, and in Case 19 which incorporates short summaries of three of the case studies. Additionally, the present author conducted a series of meetings and examined written material from ITRIs and similar institutions in other parts of the world (Cases 9 to 18 in the Casebook).

Annex 1 describes the general characteristics of the ITRI Project and the approach to the case studies which was adopted. The methodology employed was based to a large degree on the proposals made by D. Chudnovsky and R. Bisang in a paper commissioned by UNIDO (see Case 20).

Within the broad purpose mentioned above, the project pursued a number of specific objectives:

- How to facilitate the restructuring and transition of ITRIs so they can operate effectively in the new market environment, with a capability to respond to the technological requirements of industrial firms that want to be competitive in the newly emerging scenario, and to participate in interactive innovation processes.

- How to assure the sustainability of ITRIs in the new context, characterized by reduced government spending, looking into funding strategies that include private sector participation and income from sales of research and services.

- How to make ITRIs more effective, in terms of providing relevant services and technological inputs to industry, and how to balance such demand-driven work with long-term work oriented to future requirements of industrial development rather than to immediate needs of industry.

The issues analyzed in the case studies were, in summary form:

- The changing context, with a globalized and liberalized environment influencing the technology needs and demands of industrial firms; implications for the role of ITRIs.

- Interaction of ITRIs with other institutional actors in innovation processes (i.e. suppliers, engineering firms, universities, etc.).

- Strategy: service-mix (functional activities) adopted by the ITRI; how does this respond to an explicit strategy of how the institute fits into industrial development and technological innovation processes. Establishment of stable links with enterprises.

- Organizational and managerial aspects, personnel policies including training and remuneration, acquisition of equipment.

- Evaluation of ITRI activities and programmes and of the research personnel.

- Changing organizational characteristics inn adapting to the new market environment, and in seeking effectiveness and sustainability.
  (i) Sources of funding; increase of non-state component;
  (ii) Scope of activities; wide spectrum or sectoral specialization;
  (iii) Centralized model (a single institution) vs. an institutionally decentralized model (a network of centres of excellence); geographic decentralization.

- Influence of different entry points and patterns of organizational evolution.

The work carried out in the different case studies, and therefore the resulting reports, could not follow closely the full range of questions, on account of limitations of time and resources available for each case study. On the other hand, the ITRIs studied are far from being a homogeneous set; they strongly differ in their particular milieu, history, fields of work, type of clientele, and so on. The peculiarities of the different cases made it difficult to get away from their idiosyncratic characteristics. To a certain extent, *each case is a special* case, and it is not easy to draw conclusions and recommendations of general applicability.

Three working meetings took place with the participation of the researchers in charge of the case studies. The first one, in Montevideo, August 1992, reviewed the methodology and introduced some adjustments. At a second meeting in Caracas, February 1993, the draft reports of the case studies were presented and discussed. A final meeting took place in July 1993 in Buenos Aires, to review the results of the empirical work and extract conclusions from the comparative analysis.

## 1.5 MAIN FINDINGS OF THE ITRI PROJECT

In spite of the shortcomings we have mentioned above, many interesting aspects have come out of the ITRI Project. This section presents the most important findings, as they appear to the present author. Some of the observations and conclusions presented by F. Machado in his synthesis paper (Annex 2) have also been included.

### (1) Evolution towards maturity

When an ITRI is founded, there is an expectation that it will become a well established, mature institution, which achieves a relatively steady mode of operation and fulfills efficiently the objectives for which it was created.

A new ITRI has a long way ahead of it until it gets to such a point. We may picture this process in the form of an S-curve in which we plot time against, say, the degree of achievement of the institution's long-term goals.

The institution, when young, has to cope with a multiplicity of short-term objectives relating to its growth, among them funding and the training of human resources. At the beginning its energies will be largely spent in solving these growth problems. If all goes well, as time goes on the institute will be fulfilling an increasing proportion of the objectives for which it was originally created, and at some point we may consider it to have matured and achieved a stable mode of operation, or "steady state".

At this point the ITRI will have acquired an adequate size, a reasonably competent professional staff, adequate physical facilities and equipment, sufficient knowhow in its specific fields of technical competence and in the business of managing its operations as well, good links with its customers, and - in the best of cases - an efficient insertion into the country's innovation system.

For its progress along its development path the institute requires special attention, sufficient funding, and much patience from its sponsors. While pushing it along, the sponsors should not prematurely ask for practical results, for which the institute may not yet be ready.

The concept of a steady state should not be taken in a static manner, since the objectives may change according to different circumstances. In many developing countries an important change in objectives is starting to take place, as the policy of import substitution industrialization gives way to the adoption of a different mode of industrial evolution, which looks for innovation and competitiveness in order to compete in world markets. Most if not all of the ITRIs studied are in such a position. The case of INTEC is of great interest, since it had to change bearings more than once as political and economic condition changed. CODETEC was recently forced to adapt to a completely different economic model, and the same has happened in the case of NCL (Case 9).

A favourable environment becomes an important factor in the successful development of a scientific and technological institution. A new ITRI in a developed country can readily obtain adequate professional staff by hiring it from other established institutions. However, this may not be a possible solution in a developing country. Though it may be able to start activities by bringing in foreign, expatriate personnel (like CIEPE, Venezuela) or nationals who are working overseas and can be lured back (like the Korean Institute of Science and Technology, KIST), sooner or later there will be need to recruit local people and offer them training both at home and overseas. This is costly and takes much time. It also requires that reasonable pay and working conditions be given to trained professionals, who may otherwise choose to stay abroad or look for a different employment.

ITRIs in Canada and New Zealand (Cases 7 and 8) show maturity or are clearly on their way to it. Some developing country ITRIs for which information has been gathered, the National Chemical Laboratory of India (NCL, Case 9) and the Industrial and Technological Research Institute of Taiwan (Case 11), can

also be considered mature. In the case of NCL, this has required at least two decades, with continuous support by government, and has led to a situation in which the institute has acquired a level of expertise that allows it to compete internationally.

One of the interesting things coming out from the ITRI Project case studies is that *several of the Latin American institutes did not manage to achieve a satisfactory steady state.* Only the Chile Foundation, CODETEC, INTEC and perhaps CIIM may be said to have done so.

Is this is a characteristic of this part of the world, or would we also find it in other regions? The present author feels - and this should be checked - that a significant proportion of ITRIs in Africa and parts of Asia are also in a state of arrested progress towards maturity, and that in some cases there has been a retrogression similar to what has been experienced by the Latin American ITRIs reviewed in Case 19.

Such ITRIs require many more efforts if they are to be revitalized and achieve effectiveness, since they have to be brought to a mature state, through invetsments in human resources, knowhow and physical installations, and the introduction of modern management techniques, while caring for the new needs brought about by the new techno-economic situation and industrial policies of the 1990's.

## (2) Role and objectives; activities

*Objectives pursued*

Similar types of objectives have been pursued by most of the Latin American ITRIs. In the case of INTEC, which may be taken to be typical, the original objectives of the institution, still valid today, were defined as: (a) to copy, adapt and create technology for industry and extractive metallurgy activities, (b) to develop processes and products, (c) to assist the productive sector in its production problems, and (d) to give advice to the government on technology matters.

According to Machado, most of the ITRIs lack a clear 'vision' and have not defined their mission with the necessary precision. Ths may be due to a combination of reasons: (i) a high political instability which makes it difficult to predict changes, opportunities and threats, as a result of which the institute ends up having "crisis management"; (b) the lack of trained managers; (c) an autocratic style of leadership, inadequate for rapidly changing conditions; (d) the assumption that government guidelines are immutable; (e) little awareness about likely competitors.

*Concentration of efforts*

The Latin American ITRIs reviewed have often dispersed their efforts by attempting a wide coverage of different industrial activities. However, three of them show a clear concentration in a limited number of technological areas, and coincidentally may be regarded as having approched a state of maturity: the Chile Foundation (resource-based industries: agroindustry, forest products, aquacultural products), CODETEC (fine chemicals, pharmaceuticals) and CIMM

(metal-mechanics, materials). In the case of INTEC, as it attempted to become self-sufficient financially, an important concentration of efforts also took place.

These examples should be followed by other ITRIs, which should attempt to focus more sharply their efforts. This may take place on two different levels. First, the particular parts of industry to be cared for. All of agroindustry may be too much; a concentration on certain important products and processes may permit efficiency. Secondly, the types of services to be offered to industry. This could follow an examination of the market possibilities for services, including new concerns of industry that require attention.

*Activities*

The activities of an ITRI may be classified in different ways (see Table 1). A classification *by function*, as suggested in the UNIDO/UNDP evaluation report (Case 14), comprises (i) supporting services, (ii) extension services, (iii) research and development and (iv) training.

A classification *by purpose*, as suggested by H. Charles (case 15), perhaps more adequate for planning purposes, would distinguish (i) services paid by clients, including R&D, (ii) strategic long term R&D funded by the state, perhaps through a contestable fund such as in New Zealand, and (iii) "speculative R&D" funded by the ITRI with an eye to its exploitation

.

The research activities carried out by most of the Latin American ITRIs have focused on the use of local natural resources, the development of new products, and minor innovations.The themes pursued have frequently been chosen by the researchers themselves, with the result that the transfer of research results to industry has in general been poor (see for instance the case of ICAITI). Such a situation used to exist in the traditional government research institutions of New Zealand (Case 7) and Australia, and in both cases the dissatisfaction with the state of affairs led to a restructuring of the government science sector.

Machado found a tendency towards vertical integration of services, rather than towards complementarity with other service providers, showing the weakness of a "national innovation system". He feels that all of the ITRIs seemed to be in a position to offer complete 'technology packages', including engineering and industrial design services. The present author, however, is of the opinion that most of the ITRIs still have to go some way before reaching that situation.

*Emphasis on technology acquisition and diffusion*

In the new situation of the 1990s, with a large and expanding stock of technology available internationally, countries may find it better to concentrate on capturing, mastering and diffusing foreign technology that is relevant to their needs, rather than on developing their own technology. In fact, Latin American small and medium enterprises have relied principally on the acquistion of foreign technology. Dahlman (1993) points out that, first in Japan and much later in Korea, research centres have played in the past an important intermediary role in assessing, acquiring, adapting and improving

## TABLE 1

## CLASSIFICATION OF ACTIVITIES OF AN INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTE

The activities carried out by ITRIs are of two principal types, research and services. The borderline between both is somewhat blurred, and depends perhaps on the level of development of the country - what would be considered research in one could be taken to be a service in a more developed country.

There are in principle two ways of classifying such activities. The first is functional: it looks at the nature of the activity. The second is by purpose: it looks at what is to be done with the results of the activity. Let us quote an example of each.

### *Functional classification of ITRI activities*

The 1979 UNIDO-UNDP evaluation study proposed the following scheme:

1. The provision of *supporting services*, carried out at the institute itself, such as: chemical analysis of samples; physical testing of products; provision of technical information; economic evaluations; and, in the case of some institutes, the preparation and issuance of industrial standards, quality control and certification testing.

2. The provision of *extension services* to industry, including: trouble-shooting process improvement; process rationalization and industrial engineering, and quality improvement. Such services are provided on the spot and are classified as extension services as long as they do not require appreciable laboratory experimentation or direct institute facilities backup.

3. If laboratory experimentation becomes necessary, it falls into the third category, namely *Research and Development*, usually oriented towards: product development; process improvement or development; materials R&D, and application R&D. Such laboratory experimentation may range from relatively minor support work and tactical R&D for particular extension service activities to long-range and strategic R&D.

4. The *training of personnel for industry*. This activity is aimed at either improving the technological level of local industry (e.g. through quality control training) or introducing (i.e. transferring) new technology.

### *Classification of ITRI activities by purpose*

In an interview which took place in October 1992, Dr. Hollis Charles, former President of WAITRO and long time Director of CARIRI, suggested to the present author that the work of ITRIs may be said to cover three areas:

**Table 1 (cont.)**

(i) *services*, including R&D services, responding to demand from clients, which should be put on a commercial basis; the four categories in the UNIDO-UNDP classification above could be used here, viz. supporting services, extension services, R&D services and training services;

(ii) *strategic R&D*, for long-term purposes, undertaken at the request of the government, and funded by it;

(iii) *speculative R&D*, made by the ITRI with resources of its own, which may or may not pay off; somewhat in the nature of venture capital. This usually takes place in the utilization of raw materials, or the solution of uniquely local problems, and involves work which should be carried out with strict control of time and inputs.

Perhaps a fourth category could be added, *free* or *curiosity oriented research*, a certain amount of which is regarded by many as desirable for the exploration of new scientific areas and to allow the institute's scientific personnel to find their work exciting and intellectually rewarding. This is to be funded by the Institute or, perhaps, through goverment grants.

This classification scheme would seem to be useful for planning on the part of the ITRI.

foreign technology for use by the productive sector, before focusing more on basic, pre-commercial research as the economy matured and it became difficult to obtain technology from abroad. In Taiwan, public research institutes still primarily serve that intermediation function.

However, this type of function does not seem to have been a major concern of the ITRIs reviewed, save in the cases of CODETEC and very especially the Chile Foundation, which is explicitly engaged in technology diffusion (Case 1).

The main activity of the Chile Foundation is to bring into the country proven knowhow in areas of commercial importance and diffuse it to local users through various means, particularly the creation of "demonstration enterprises" that apply commercially the technology and show its viability.

The Chile Foundation is atypical in several respects, principally the emphasis on diffusion activities rather than on research, and the use of an important tool of diffusion, the creation of new enterprises . We should also remember that the Foundation has been working in an expanding economy, and was originally endowed with ample resources.

The success of the Foundation's work, and the impact it has had on the local economy by helping the creation of new productive activities, show a way for other ITRIs, which should consider whether approaches of this type may be applied in their future work.

In the case of CIMM (Case 4) the author of the case study has suggested that the institute should consider as a major activity the creation of technology-based enterprises. "The Centre should develop technology for products and services of very high value added, around which an enterprise would be created. CIMM would participate in the risks. Once the business has been shown to be viable, it may be sold and a new enterprise created... Practical implementation of this suggestion depends on the detection of high value added opportunities. One of them, in which the technology has already been mastered by CIMM, is the set of special materials it has developed in past years... The weakness of the proposal is that access to credit is difficult nowadays in Argentina. It is to be hoped that as the economy becomes stable, strong risk investors will appear, particularly from overseas".

Machado remarks that most of the ITRIs are unable to help enterprises in technology transfer via joint ventures and strategic alliances, an area where they could perhaps associate with consulting and engineering firms, universities and producers of capital goods while they build up their capabilities in technology management.

*New types of services*

The new technological conditions of the 1990s would make it necessary for ITRIs to offer assistance to industry in areas which had not been sufficiently covered so far. As an example, we may mention the case of CIMM. The suggestion by the author of the case study is that four types of services should be offered to the client firms: tests of specified, normalized types; quality-related services; automation-related services; and services in the area of industrial waste. The last three are new to the institution and would require

the acquisition of expertise, possibly through association with other institutions.

Machado finds some interesting trends for the future service mix in the ITRIs, which seem to be evolving towards the supply of true technology packages and the creation of new ventures. Some new types of services are: consultancy in technology management, technology transfer and production systems; use by industry of ITRI installations, such as the rental of pilot plants; new services on environmental issues; involvement in the creation of new enterprises.

Regarding the first item in that list, Machado suggests that ITRIs should offer services of strategic planning and technological planning to industrial firms, including diagnoses of the competitiveness and the technological position of the enterprise, systematic searching for new business and product opportunites, total quality, incremental innovation, etc. The ITRI should ask questions like the following: How relevant is technology for the customer? Which are the critical technologies for the success of the customer's business? Which of his strategies needs technological innovations? Where can the technologies be obtained, and under what conditions? On which technologies should creative efforts be made? On which should the customer buy new knowhow? What are the possible mixes of technology acquisition and R&D?

Such services would be a new departure for traditional ITRIs used to research activities and not too complex services of a technical type. Involvement in the technology management activities of a firm may, on the other hand, allow the identification of research projects which may be the subject of contracts between the enterprise and the ITRI, changing the present situation of an institute looking for clients for the technologies it has developed.

*Clients*

ITRIs have been founded to serve industry and therefore their principal clients are industrial enterprises, in the public and private sectors. Public enterprises are on the wane in the countries analyzed in the ITRI Project and this may remove some important clients if the new owners create their own technological facilities. In many cases the main industrial clientele is made up by small and medium firms which have little demand for research and technological services, like in Central America (see Case 5, ICAITI), and this presents a challenge. Government is another important customer, requiring various services of a short-term nature and sometimes placing contracts for long-term research. It is important for an ITRI to identify and characterize its clients, and the services they need, in order to better define its objectives.

*Redefining role and objectives*

In view of their past experience, of the requirements brought about by the new conditions of the nineties, and of the need to deal with new types of problems, ITRIs in developing countries are increasingly finding that they need to reconsider their objectives.

This will depend on the particular circumstances, but a few pointers may be suggested from what has been learned in the ITRI Project:

- efforts should be concentrated on a limited set of technological fields related to industrial activities of importance to the country;

- there should be a careful identification of clients and their demands, present and future;

- research should be aimed at the concrete needs of industry and other clients; long term, strategic research should be carried out only when funding is available;

- technological services should be provided according to industry's demands, and the ITRI should concentrate on those that cannot be supplied by facilites in industry or by small firms of technical services;

- there should be emphasis in supporting the process of technology acquisition, use and diffusion;

- new concerns should be introduced, such as automation, quality and the environment, on which assistance may be given to industry;

- strict attention should be given to the generation of income through the sale of research and services;

- there should be a balance between research and services since too much of a dedication to the latter will drive away the most gifted scientists and lower the scientific standards of the institute.

### (3) Legal regime

Five of the Latin American ITRIs were in the public sector (INTEC, CIMM, CIEPE, ITINTEC and IIT), one was an international organization (ICAITI) and two were private institutions (Chile Foundation and CODETEC).

Of the five institutes in the public sector, two of them have recently disappeared, IIT in Colombia (Case 6) and ITINTEC in Peru (Case 19), and CIEPE in Venezuela is facing a very critical situation (Case 19). All of them have had long struggles with their personnel. They were unable to dismiss staff that performed inadequately, and had to cope with combative personnel associations. A vicious circle appeared as the best people gradually left and those that remained were discouraged and did not perform well, thus affecting the clientele and deepening the financial crisis.

The two other public sector institutes reviewed, INTEC and CIMM, may end up being privatized. INTEC is in the process of becoming a private foundation, and conversion into a private enterprise was suggested for CIMM, as a way to endow it with the required flexibility and autonomy for effective performance. We should also mention the debate on "ITRIs in the 1990s: Government or Market Players ?" that took place at the recent WAITRO meeting (Case 15), in which the vote was for the vision of ITRIs as private sector institutions.

It is a clear result from the ITRI project that institutes in the public sector have strong disadvantages and find it difficult to be effective. A few of the drawbacks may be mentioned:

- the difficulty to retain top personnel that cannot be remunerated at competitive rates, and to get rid of personnel that underperforms;

- the obstacles to obtain foreign exchange for the purchase of equipment and materials, subscription to scientific and technological reviews, travel of staff members to meetings overseas, etc.;

- the difficulty to link up with industry, transfer or sell technology to it, and enter into joint commercial ventures;

- the possibility of sudden changes in ITRI authorities when the government changes.

It may be concluded that some way out of the rigidities of the public sector should be sought if developing country ITRIs are to be efficient and achieve an impact through their work. This may consist of a special regime allowing them enough flexibility and autonomy, or in their transformation into private enterprises. In the latter case, however, the state may still have to play a role in helping the institutes to invest in new facilities, in funding strategic, long term research, and in providing some sort of subsidy for services rendered to the small scale enterprise sector. As Machado warns, the apparent benefits of privatization (autonomy, flexibility, agility, among other) do not make an ITRI invulnerable to political interference from the government when the latter is the main source of funds.

The recent experience of the two OECD countries analyzed in the Project is relevant here. In Canada (Case 8) the search for flexibility has taken two main forms: (a) turning over to a private company the management of a Federal laboratory, and (b) privatization in the case of a provincial research institute. In New Zealand (Case 7) "the previously existing government science agencies had been regarded by many observers as largely divorced from the productive sector, engaged in topics that in general were of interest to the researchers and not necessarily to eventual users, and hampered by the usual public sector limitations from linking up with industry in a meaningful way. A survey of technology-minded industrial firms rated the agencies poorly as a source of technology." These agencies were restructured, "using their people and their assets to form new Crown-owned research institutes, with autonomy and flexibility, as well as full commercial powers to provide a much larger range of options for the transfer of technology". It is interesting to notice that CRIs will stay under public ownership, with a special regime that will allow them to operate as commercial companies.

### (4) Relations with industry

The difficulty of forging good links with industrial firms is perhaps one of the main shortcomings of the Latin American ITRIs reviewed. The case of the Chile Foundation is an outstanding exception to this general statement, and this institution has managed to establish a steady clientele in the areas in which it works. This has been a consequence of high quality in its technical

services, an excellent diffusion work, and persistent public relations efforts to develop and mantain a favourable image. Let us remember, however, that this institution has worked in a buoyant economic environment, and has purposely limited its field of action, which does not include some activities that other ITRIs undertake, such as certain specialized technological services or contract research for clients.

There are several problems in developing good links and a stable clientele. Here are some that have surfaced in the ITRI project:

- Industrial entrepreneurs show little interest in the services of ITRIs, as a result of a long existing situation of import substitution industrialization in which an increase in productivity did not appear as a significant need;

- Industry has had resource to technology imports to satisfy its needs;

- Most of the potential clients are small and medium enterprises, with low technological levels and a lack of understanding so far of the possibility of benefiting from the services of an ITRI;

- Most enterprises lack science-minded personnel with whom the ITRI may conduct a dialogue on technical matters. The example of MIT's interaction with industry (Case 13) shows how important such people are to allow a fruitful in terchange, and eventually to identify and carry out meaningful research projects.

- Researchers have often shown unhelpful attitudes, being interested more in their own work than in the needs of industry. The choice of subjects has usually followed the inclinations of researchers and seldom has come out of a specific demand by industry;

- ITRIs have taken a long time to understand that the commercialization of their services requires them to create a unit with specialized skills;

- There has been a scarcity of national policies and schemes to incentivate demand on the part of industry.

Regarding the lack of interest on the part of industry, some of the ITRIs surveyed expect that under the new situation, with competitiveness at a premium, entrepreneurs will gradually understand the need for research and for sophisticated services such as in the area of quality.

The creation of an industrial clientele is easier when the ITRI concentrates on providing technological services rather than research. There is a problem however if the ITRI attempts to charge full costs while industry expects a much lower "promotional price" .

Some of the ITRIs have created special departments for marketing their services. Though little can be said as yet about their effectiveness, it would seem that such units are becoming increasingly necessary. This may be an interesting topic for further research.

The participation of industry people in Governing and Advisory Boards is normal in most Latin American ITRIs. It was not clear however to what extent

such people had influenced the orientation of the institute's work and the creation of new opportunities to serve industry. This should be contrasted with the New Zealand experience, where Research Associations and Crown Research Institutes have obtained a strong and effective participation of this type. A good example is the four industry-sponsored Research Advisory Boards at the New Zealand Forest Research Institute, which assist in defining research projects, obtaining the necessary funding, and ensuring that the research results are used effectively (Case 7).

### (5) The environment in which ITRIs perform

Latin American ITRIs have not generally functioned in stable political and economic environments. One extreme case is that of INTEC, which started life under a democratic, centrist regime, continued under a leftist government, suffered a change to a military dictatorship, and much later a new change to a democratic left-centrist regime. In spite of the political changes this ITRI was able to keep part of its senior staff over the years and to maintain a "spirit" peculiar to the organization. In other cases, however, political changes have meant changes in the authorities of the ITRI, such as in ITINTEC and CIEPE.

The policy environment in Latin American countries is now suffering a sharp change, with the replacement of import substitution by a different policy model which stresses liberalized trade and requires firms to compete in the world market.

Import substitution policy, as Machado points out, had the purpose of promoting national industrialization through the integration of productive chains and the establishment of industrial complexes. For this purpose it employed tax incentives, tariff and non-tariff protection, easy credit, the production by the state of 'strategic' goods, regulation of technology imports and of foreign capital investment, etc. Most of the Latin American ITRIs were created under this policy , and were intended to be an instrument of it.

The economic crisis in Latin America, the retreat of the state from economic activity, the process of trade liberalization and the cut in official subsidies, have signified fundamental change in the milieu in which ITRIs work. The privatization of public enterprises and the difficult situation of small and medium enterprises have reduced the demand for their services. The effects of this change in the economic model are making life difficult for ITRIs. Their budgetary funding by the state is being curtailed, and they are losing some of their important state customers such as state enterprises and certain government programmes (as in CODETEC, Case 2).

As Machado remarks, pushed by their governments to become self-sufficient, ITRIs have put emphasis in the offer of routine services at 'real' prices. However, often they lack an updated infrastructure, do not enjoy the necessary autonomy , and face a growing competition from private labs, universities and enterprises. Machado asks whether ITRIs will be able to attract enough customers under such conditions: no wonder that the privatization or closing down of ITRIs are options now being discussed, and in fact two of the institutes studied have disappeared in recent years.

The case of INTEC is illustrative (Case 3). The change in Chilean economic policy in the 1980s brought about a sharp decrease in state funding for INTEC. It was clear however that the demand from private sector enterprises would be unable to make up for the funding shortfalls for some time. In its search for self-financing - which was successful for a limited period of time - INTEC concentrated its efforts on fewer industrial branches and increased the share of services as against R&D. However, this affected the scientific level of the institute, which lost some senior people. The conclusion was that state support is still needed. This has been understood by the authorites in Chile, which are paying for INTEC's investment in new installations and are creating a contestable fund to finance long term strategic research.

Regarding the issue of continuing support by the state, we should mention here some corroborating experiences frm the contrasting case studies in OECD countries. In Canada (Case 8), a recently privatized provincial research organization is trying to regain an annual operating grant from its province, since it has been unable to generate sufficent contract income. An interesting approach is that of New Zealand (Case 7). The new Crown Research Institutes are expected to develop a market for their services, but they can look to support from the Public Good Science Fund, which gives modest direct grants to the CRIs and provides contestable funding for strategic research.

Regarding policies aimed at promoting and increasing the demand for the services of ITRIs, the Latin American countries now have much less than used to be the case. Authorities have become less interested in issues of technological development in industry. In Brazil industrial policy is currently beng revised, and direct state intervention - such as the control of technology transfer, the direct purchase of ITRI services, and risk-sharing schemes with industry - is being shunned. Chile, on the other hand, has designed a technology policy to help industrial innovation through a special fund for applied R&D. In other countries like Argentina there is almost a complete lack of measures to promote the demand side; interesting credit schemes that supported technology intensive projects have been discontinued.

Hence, the policy environment at this point of time is not altogether favourable for ITRIs in Latin America, and this is aggravated by the shortcoming of the physical infrastructure which makes efficient operation difficult.

## (6) Resources

*Financial resources*

With the exception of the Chile Foundation, the Latin American ITRIs reviewed have suffered chronically from a shortage of funds, and this situation has become more acute in the past few years.

The main sources of funds are contributions by the State, the sales of services and R&D to local clients in industry and in government as well as to foreign clients, income from the exploitation of technology developed by the institute, and international cooperation.

International cooperation, from UNIDO and other sources, has been crucial for several of the ITRIs. Funds have been provided, at the time of foundation as well as later in the life of the institute, for investment in equipment, library material, training of personnel, etc., for paying running costs, for overseas travel. Through such cooperation, moreover, the institutes have been able to acquire knowhow and useful management practices. Some of the ITRIs would have found it very difficult at certain times to keep going without funds from external cooperation, and in fact such funds are still crucial for the continuing operation of ICAITI.

The state has been and still is the main source of funds, mainly through direct contributions made to the institute's budget. With the increased emphasis on the reduction of state expenditures, Latin American ITRIs have not escaped a worldwide trend towards becoming more self-supporting, and in fact have sometimes been explicitly pushed by their governments to do so.

While the income from the exploitation of ITRI-generated technology has been negligible, except for the Chile Foundation, some of the ITRIs reviewed have been successful in increasing their sales of technological services, and to a certain degree of R&D, to clients in industry and in government.

However, save for the Chile Foundation, which counts with a considerable endowment, half of which was originally contributed by the government, none of the ITRIs has managed to become completely self-supporting in a stable manner. INTEC was able to do so for a short period in the late 1980s, but paid a price as senior personnel left the institution, noticeably weakening it. However, INTEC is now again receiving state support. Similarly, an important provincial research institute in Canada that went private some years ago is now seeking a resumption of state support (Case 8).

Can ITRIs sustain themselves in Latin American and other developing countries? Or are we to conclude with Machado that ITRIs are not viable on their own, and that they need continuing support from the state? This question, important as it is, cannot be answered conclusively on the basis of the evidence collected.

State support may take place in different ways. Traditionally the government has contributed directly to the budget of the institute, and sometimes this has been supported through special levies (for instance, in Peru a 2% of the net income of industrial firms was used to fund ITINTEC). Such financial support by the state funds *inputs* and the institute is left to decide what outputs it will produce.

Government however can put in place mechanisms to fund *outputs*. Beyond what happens in a natural manner when a government department becomes a client of the ITRI, asking it to perform by contract a variety of services it needs, one or more *national research funds* may be set up to support "strategic" research of particular relevance to the needs of the country, as Chile is planning to do within a loan operation with the Inter American Development Bank.

The New Zealand example is worth considering by Latin American countries. As Case 7 shows, a new contestable funding system was put in place in 1989. The funds that were formerly allocated directly to the budget of government

scientific institutions have been placed in the "Public Good Science Fund", which finances *strategic research* to support long-term national needs in any of 40 "output classes". These are areas that reflect the economic objectives felt to be important for New Zealand. Research projects, which need not be of immediate 'commercial' value, are funded with the expectation of achieving useful discoveries or knowledge that will underpin economic growth and sound environmental management.

The allocation of funds is made annually and involves two distinct stages. In the first stage, the goverment decides on the total amount to be allocated by the PGSF and its distribution by output class. In the second stage, funds within each output class are allocated to competing research projects presented by the Crown Research Institutes and other "science providers". This is done by the Foundation of Research, Science and Technology through a careful process that involves peer judgment for the appraisal of scientific merit and committee review for that of relevance.

This has meant a radical change in funding practices, away from supplying funds to institutions on an input basis, to *purchasing science outputs* from the institution best able to produce that output in terms of quality and cost.

Contestable funds from the PGSF make up a very important proportion of the budget of the official science institutions, and though the latter have taken some time to adapt to this *modus operandi*, the results appear to be positive as research becomes more relevant to the country's needs.

*Human Resources*

Though at the time of their foundation the Latin American ITRIs may have placed a strong emphasis on adequately recruiting and training their scientific and technical staff, in recent years these functions have often been poorly planned and executed. As Machado points out, some of the institutes had low staff seniority levels and high staff turnover; incentives based on results or merits were almost non-existent, thus doing away with a basic instrument to motivate personnel; except for the Chile Foundation, little effort seems to have been devoted to the development of human resources; no mention was made of personnel exchanges with industry; personnel evaluation systems were absent, or were not applied; there was a dearth of strategies to cope with human resource issues.

In some cases, financial shortages have led to the loss of top scientists and the recruiting of new staff fresh from the University, thus lowering standards and the quality of work. At the same time insufficient attention has been given to training, resulting in inadequate coverage of new fields in which the ITRIs will be increasingly involved as a result of the introduction of new technologies into industry. . The Chile Foundation, and to a lesser extent CODETEC, are however exceptions to this.

At present training is needed in two major areas. First, in new scientific and technical fields, through formal training at home and abroad, the participation in research activities at good foreign universities and research institutions, and participation in international meetings and conferences. Here UNIDO is in a position to help ITRIs through its International Centre for Science and High Technology, which aims to offer advanced training in

selected new fields to scientists and technologists from developing countries, at a time when it is becoming increasingly difficult to arrange for this in traditional universities.

A second major area for training is that of management and marketing. Such skills are in short supply in most of the ITRIs, but will be increasingly required as the institutes become more commercially oriented than heretofore.

The motivation of the staff is an important prerequisite for high performance and exceptional efforts. Once again, most of the ITRIs were at fault here. An analysis of the organizational culture of ICAITI (Case 5) has shown a number of problems in the institution, prominent among them the insatisfaction of the personnel, an attitude of "just complying with the working hours" and little identification with the institution's objectives and goals. Such attitudes are probably present in other ITRIs in the sample, and are in need of correction.

The use of outside consultants to supplement in-house skills is not usual in the ITRIs, except for the Chile Foundation. This is an important source of knowhow which should be tapped by ITRIs interested to improve their services to industry.

*Physical Resources*

The installations, equipment and library resources of most ITRIs appear to be outdated, and it will not be easy to bring them to the necessary level that would enable the institutes to cope with recent advances, particularly in new technological fields, and with the need to open new fields of work.

## (7) Organization and management

*Structure*

The structural characteristics of most Latin American ITRIs - mostly rigid and pyramidal - are not adequate for efficiency and impact. Machado points out that a matrix structure (little used except for CODETEC) would not be approprate because of the conflicts it would tend to generate, and suggests an *organic* type of structure, with high participation and low formality, a high degree of communication, interdisciplinary teams and flexibility in the face of changing circumstances. It is important for an ITRI to have organizational flexibility and the capability to change according to the requirements of its environment.

*Limited industry involvement*

As we have already remarked, there is only a limited degree of effective participation of industry in the Latin American ITRIS, either in a management or an advisory capacity. This participation has not generated a significant demand for ITRI services, and has principally fulfilled promotional purposes, . This should be contrasted with the active participation of New Zealand industry in most Research Associations and some Crown Research Institutes, as decision makers, advisers, suppliers of funds and clients for collective and firm-specific projects.

*Management functions*

The main management functions of planning, programming, budgeting and evaluation in the Latin American institutes can in general be vastly improved through the introduction of modern, adequate management techniques, like those adopted by the Chile Foundation, where management procedures were successfully transferred from the foreign partner, ITT, with the necessary adaptations to the local conditions. This should be complemented, as we have already indicated, with the training in management skills of managers who are often former scientists.

As we have indicated above, most of the ITRIs have not defined clearly their missions, do not count with a 'business plan' such as is common in New Zealand institutes, and have carried out little strategic planning. Machado stresses the need for strategic planning as a means to update institutions periodically. An ITRI should learn about impending changes in its environment, including technology trends, the characteristics of their clients, and the likely evolution of the clients' technology needs: it should identify new markets and areas of work, choose the best research lines, etc. On the basis of such an analysis it should take the necessary anticipatory decisions regarding its market strategy, service mix, development of critical capabilities, changes in its structure and operating systems, etc. to allow for the fulfillment of its "vision" and to achieve a speedy response to the needs of its clients.

*Marketing*

If ITRIs are to become increasingly self-sufficient by selling more outputs to industry and other clients, they need to improve their marketing function, through the creation of a department or group devoted to it, and through training of their personnel. Here again the Chile Foundation is a good example.

Machado remarks that few of the ITRIs had clear market strategies, regarding the size, growth, and structure of the market, the threat posed by competitors, the search for new markets and opportunities, and the establishment of strategic alliances. The clientele should be carefully analyzed, and there should be efforts to produce a faster reply to clients' requests. There is a need to train the staff in sales techniques. On the other hand, clients should be 'educated' to regard technological development as a continuous process, and not wait until a crisis looms to get help from the ITRI. The image and the prestige of the institution should be promoted, through diffusion in the media about the quality and the results of projects and studies, and through publications and presentations in local and international forums.

The careful management of scientific personnel is a crucial aspect in need of improvement in most Latin American ITRIs.We have already touched on issues of human resource management in a previous subsection. One important aspect has to do with the effect of concentrating on the production of technological services that industry demands, while reducing the research effort that keeps top scientists happy. In such a situation the institute runs the risk of losing its best people. A delicate balance is necessary between working for the market, which should be the 'culture' of an industry-oriented institute,

and working 'for science'. Here the availablity of funding for strategic, long-term research becomes very useful. This may take place through a contestable fund like in New Zealand.

Machado refers to the 'organizational culture' of the institute, relating to the values, internal norms, myths, etc. which shape the attitudes and behaviours in the organization. In this respect the Latin American institutes were found wanting for a variety of reasons: their rigid functional structure, the less than adequate profile of their management and low systematic training at the management level, the prevalence of a University type of culture (where the aim is to publish rather than to be of use to industry) and other organizational aspects. Their cultures would seem to need a careful revision in order to make them more effective. Only the Chile Foundation presented concrete values of orientaton towards the market, pragmatism, autonomy, innovation in services and models of transfer of technology.

### (8) Outputs and Performance

The selection of areas of work and research topics by the Latin American ITRIs is gradually being oriented towards the market rather than towards the interests of the scientists, but much remains to be done in some of them to achieve a "demand-pull" situation like in CODETEC and the Chile Foundation (as well as in the New Zealand Research Associations).

Technological services of varying degrees of complexity are the main products Latin American ITRIs provide to the industrial sector and other clients. The production of "technology packages" as an end result of R&D is not yet common. There is very little patenting; possibly the institutes do not generate sufficient original, patentable research results, or pay little attention to a strategy of industrial property.

Save for the Chile Foundation there appears to be a limited involvement of the ITRIs in technology acquisition from outside the country, and in the subsequent adaptation and diffusion of such technology. It is to be hoped that in the future more attention will be devoted to this, in close collaboration with industry, particularly in generic technologies of wide applicability and in "soft" technologies related to business and production management.

An important shortcoming of most ITRIs surveyed is that they do not seem to control closely the quality, timeliness and relevance of their work. This is perhaps because "accountability" is not yet a significant characteristic of theirs. Governments require a modicum of it, principally regarding financial transactions, and there is usually no formal procedure to evaluate the efficiency of the institute and the impact it has had on industry and the society. In most cases the case studies did not mention any client surveys on the performance of the institute. External evaluations of the scientific performance were also notably absent.

Machado points out that the underlying criterion of success of an ITRI is its capacity to fulfill its mission, particularly transferring technologies to the productive sector, to which he adds the capability to learn from its experiences and to perceive and deal effectively with its problems. He feels that, in this light, the most successful Latin American institutes surveyed are CODETEC,

Chile Foundation and INTEC, the rest showing relative (or outright) failure. These three institutes have learned from their errors, attempted to understand the structure and rationality of activities in the branches they cover, changed their "service mix" as needed, and offered their clients packages with integrated solutions rather than routine services or isolated R&D projects. To do this they have developed their own organizational culture, selected their market niches and evolved novel marketing strategies, through the use of strategic planning, the development of their capabilities to manage change, and the training of their human resources. They have identified the gaps existing in the innovation systems of the areas they cover, filling them by expanding their service mix, and have procured sufficient resources from the state, at the same time avoiding undue interference from it.

The less fortunate ITRIs, suggests Machado, have remained prisoners of their old vision, tied to a main 'product' of R&D (usually more R than D) for which the demand of the productive sector has been only latent and implicit. In most cases these ITRIs have not been successful in changing a bureaucratic-university culture, and have been unable to build up a professional management team. They have suffered chronic financial crisis and have not been able to deal effectively with their own problems, which have now become more acute in the new environment. Sometimes they have experienced disruptive government interventions.

Finally, we may mention that the ITRIs have tended to work on their own, with little collaboration with other scientific and technical institutions of their country. To the present author's mind, ITRIs should look at the possibility of increasing considerably their links and their cooperation activities with other local scientific and technological institutions, and thus contribute to the formation of a national innovation system.

# CHAPTER 2

# REVITALIZATION OF AN ITRI: GUIDELINES

## 2.1 Introduction

By "revitalization" we understand the process of transforming an existing ITRI into an *effective* institute, with an efficient operation and a high impact on development.

We have referred above to the concept of a "mature" institute. Maturity is a necessary but not sufficient condition of effectiveness. An "effective" institute needs to be mature, if it is to operate efficiently, but in addition it has to fully serve national goals and industrial needs. Many ITRIs are mature, efficient industrial R&D laboratories but have not become fully effective.

A number of ITRIs in developing countries have been able to carry out the transition from an "R&D laboratory" to an effective ITRI. Among the cases reviewed in Latin America, probably only CODETEC and INTEC have done so. The Chile Foundation should also be considered an effective ITRI, though here R&D is not a central activity. Of the other cases covered in the Casebook, a good degree of effectiveness seems to have been achieved by the New Zealand Forest Research Institute, the Taiwan Industrial and Technological Research Institute and the National Chemical Laboratory in India. Other such examples exist, such as KIST in Korea and INVAP in Argentina, not reviewed in the Casebook. By and large, however, it would seem that a good number of ITRIs in developing countries are still far from being effective, and it is of great interest to consider what revitalization efforts they could undertake.

In actual practice we may find two types of situation. First, the case of an ITRI that has reached a reasonable degree of maturity but needs to adapt to a change of circumstances, mainly the new techno-economic situation and the policy changes being introduced by most countries, to which we have referred in Chapter 1.

A different situation is that of an ITRI that has not yet reached maturity. This is probably a widespread condition, and the revitalizaton of ITRIs here will require considerably larger efforts. When an ITRIs has not managed to achieve maturity after many years of operation, and is still struggling with its own development process, the problem of helping it to revitalize and become effective it is not just a question of correcting different factors and adjusting to new environmental characteristics. The ITRI would require asistance in the first place to complete its development, through the development of human resources, the acquisition of knowhow, the increase in the efficiency of management, and other aspects. At the same time an eye should be kept on the new needs stemming from the current developmental paradigm, the changed policy environment and the increasing scarcity of state funding, which would call for a change in the original objectives established at the time of foundation. All this would require further investments, and would not seem possible without adequate financing from the state or other sources.

Sometimes the situation may have deteriorated to a point where it may not be feasible to revitalize the institute. Three Latin American ITRIs have disappeared in recent years, in spite of strenuous efforts to keep them alive, and a fourth one is in danger of doing so (see Case 19, "Death of an ITRI"). When such retrogression has set in and a number of "vicious circles" have been operating for some time, the best alternative may be to close down the institute and create a new one that can be endowed with the best structure, characteristics and conditions to make it effective.

The way a particular ITRI may be revitalized will depend on a variety of factors, such as the characteristics of the national economy and of the policy environment, the peculiar history of the ITRI, its size, its chosen fields of concentration, the peculiarities of its clientele, the support it can get from the state, the industrial environment in which it operates, the limitations to which it must adhere, etc.

*Each case is a special case*, and therefore it is not easy to come up with suggestions and recommendations of general applicability. The inclusion in this paper of a "Casebook", with summaries of the different case studies and other relevant material, is a recognition of this ample diversity, as well as an attempt to supply the reader with a collection of examples, so that he or she may find what experiences may be more applicable to the institute on hand.

## 2.2 An effective ITRI

A high degree of effectiveness in an ITRI may be said to have two components. First, high *efficiency* regarding the way operations are carried out and outputs are transmitted to the users. Second, the achievement of a satisfactory *impact* in favour of the county's goals, taking into account the new environment of the 1990s.

There is no easy way to quantify these parameters, with the exception perhaps of some aspects of efficiency, but expert observers will in general be able to pass a qualitative judgment on them.

Of the ITRIs reviewed in case studies of the ITRI Project, we may point out to two interesting examples of reasonably effective ITRIs.

The Chile Foundation (Case 1): This institution has defined carefully its objectives and its field of action, adopted a legal and a managerial structure that allow it to conduct its operations with high efficiency and flexibility, established excellent relations with the productive sector, and achieved a high degree of maturity, including self-financing.

The New Zealand Forest Research Institute (Case 7, Section 7): This ITRI covers the whole cycle that goes from the genetics of relevant tree species to the exploitation of forests, the industrialization of wood, and the commercialization of wood products. It has developed a strong scientific base and produced significant applied R&D findings within its fields of specialization. At the same time it has managed to build up excellent relations with the different productive sectors it attends, and to service them well with research and technological services. The recent change in its status, from a traditional public sector science organization to a Crown Research Institute, has endowed

it with flexibility and commercial powers that are likely to allow it to become even more relevant to the important wood products sector in the country. FRI is not yet self-financing; it enjoys a significant support from the state, mainly through the funding of strategic research by the contestable Public Good Science Fund, but the generation of income from sales to customers of its R&D and services is sharply increasing. It should be noted finally that FRI has been in many ways a blueprint for the concept of Crown Research Institutes, a set of effective S&T institutions created in the recent reform of the government science sector in lieu of the unsatisfactory science departments formerly in existence.

*Some characteristics of an effective ITRI*

Though the notion of what constitutes an effective ITRI may vary from country to country, it is possible to draw up a list of aspects that are common to many effective ITRIs:

(a) *General features.*

The ITRI should have achieved maturity, as well as a size which assures a minimum efficient "critical mass". Its legal status should assure flexibility in its operations (allowing all types of commercial operations) and in the management of personnel. It should have an explicit mission statement shared by the whole organization and complemented by clear objectives and responsibilites, responding to a vision of future development in line with the country's goals and with the needs of industry.
It should avoid the dispersion of efforts and select a limited number of technological areas and types of services, including R&D, to be offered to clients.

(b) *Outputs*

Research and development topics should be carefully chosen. In the case of strategic research, choice should be made according to the relevance to long term national needs, as established through consultations with people from government, industry and universities rather than unilaterally by the institute.. In the case of short term research, it should closely follow client demand, ascertained through close contacts with clients and familiarization with their needs, and there should be an effort to produce "technological packages" of direct applicability. The institute may carry out projects for a single client, or for several clients (such as pre-competitive technology projects);

The product mix of technological services should be dictated by the market. There should be a periodic review of the outputs, suppressing those for which there is little demand and creating new types of services for which demand is growing. Machado points out that the present environment calls for new roles on the part of ITRIs, with services such as: (i) *enterprise consultancy* in a wide range of areas: strategic planning, technology management, organizational structure and culture, application of informatics, total quality, setting up strategic alliances and accessing technology through them, services related to transfer of technology (search, evaluation and selection of technological suppliers, negotiation of contracts, technology brokerage), and benchmarking of important parameters to compare enterprise performance;

(ii) *consultancy for financial institutions* such as the analysis of future competitiveness of enterprises seeking loans and the evaluation of technology in investment projects; (iii) *innovative ways of exploiting existing assets*, such as the rental to firms of pilot installations.

(c) *Clients and marketing.*

The institute should forge strong, stable links with industry, through different means such as industry membership in the Board of Directors and in Advisory Committees, the formation of consortia with industry, periodic visits, the exchange of personnel, public relations efforts, the economic analysis of the client sectors, etc. The marketing of the ITRI's outputs should be a specialized task, which may be entrusted to a special department or unit in close relation with the technical units. The institute should fully understand the industrial branch or branches it is serving, and to this end should carry out economic and market studies. As Machado suggests, it should acquire a good knowledge of technologies and productive activities in those branches, leading to an understanding of clients' values, problems and opportunities, and thus to a pragmatic and creative approach by the ITRI.

(d) *Human Resources.*

The ITRI should count with a cadre of capable scientists and engineers, well trained and highly motivated. This staff should be managed carefully in the different aspects of recruitment, training and updating, and evaluation. Annual staff turnover should be low, reflecting favourable conditions regarding work satisfaction and remuneration. The access of scientists to world science and technology should be encouraged, particularly through exchange programmes and the assistance to international seminars and meetings.

(e) *Physical resources*

Adequate physical installations are needed - buildings, equipment, computing, communications, etc. There should be regular updating of these facilities in line with scientific and technical progress.

There is also the need for adequate information and library facilities including subscriptions to reviews,

(e) *Management.*

The institute should have sound, modern management practices, including a long term strategic plan and a short-term (2/3 year) business plan. There should be a sustained internal activity of strategic planning, technological forecasting and scenario building. This is to be supplemented by the development of an organizational culture that will support the mission statement. Managers should receive thorough training in management and in marketing techniques.

As Machado suggests, the institute should identify and build up critical capabilities, including the capability to learn from clients and other actors, and that of carrying out new types of services as suggested above. There should be a careful choice of partners, national and foreign, in strategic

alliances that will allow the institute to open new opportunities and go into new fields and new types of services.

Most if not all work undertaken in research and services should be organized as projects and funding should be assured at the outset. Projects should be managed carefully both at the design and execution stages. The institute should assure the quality and timeliness of the research and services produced.

(f) *Finances.*

The institute should count with stable, adequate funding, a high proportion of which should originate in sales to its clients, and in the commercial exploitation of the technologies it has developed or introduced into the country.

## 2.3 Examples of ITRI revitalization

Some of the Latin American case studies carried out in the ITRI Project show attempts that have been made to change and restructure the institute under study. This has happened with CODETEC and INTEC when a change in the policy environment eliminated some important customers, lowered government support, and brought about demands for different R&D and technological services. In both cases reforms were introduced and the outcome seems to have been a happy one. In the case of ICAITI a thorough strategic planning exercise has provided recommendations which, when put in practice, will affect many aspects of the institute's operation, though not its main structural characteristics. The case of CIMM is of interest too since the author of the case study, together with the senior staff, has advanced a proposal for a deep change in the legal framework (privatization), the fields of concentration (a new emphasis in what industry is now needing: R&D and services in automation, quality, waste processing) and the notion of "producing" technology-based enterprises. The proposal may be the basis for a thoroughgoing revitalization exercise at some time in the future.

The most important example of restructuring reviewed in the ITRI Project took place in New Zealand (Case 7). This country has undergone a series of changes and adjustments in recent years, as it became clear that the economic model previously followed by the country, with a largely protected economy relying on the export of agricultural commodities, did no longer generate enough wealth to mantain reasonably full employment and income growth. The restructuring of science and technology in the public sector is one of the most interesting chapters of such changes. The functions of S&T policy-making, R&D funding and R&D execution were separated. A fund was created to support "public good" strategic R&D. The four main science agencies were restructured: ten new Crown Research Institutes took their place. They are focused on sectors and problem areas rather than disciplines, and have been endowed with full autonomy and commercial powers in the hopes of linking them closely to the productive sector.

We should also mention a recent proposal for the revitalization of the Thailand Institute of Scientific and Technological Research, TISTR. As expressed by a

local observer, this institute lacked a focus and a clear mandate, and was disconnected both from industry and university; limited resources were spread too thinly; scientists dreamed up projects, published papers, established their own international connections; salaries were low, the best people had left, and the institute could not attract good people.

Prof. Martin Bell developed In 1989 a proposal to reform this institution, in order to increase its interaction with and impact on the productive sector (Case 10). He remarked that this should involve fundamental changes in a wide range of deeply rooted and interacting problems which underlie the current situation.

Bell suggested that three categories of issues were to be addressed. First, *status and governance*, including flexibility, performance related accountability and higher generation of income from clients. Second, *activities*, where there should be a radical change and concentration,focusing the Institute's R&D on supporting manufacturing industry, assisting it in the use and improvement of imported technology. Third, *internal resources, management and organizational structure*, where TISTR should (i) enhance and re-structure its human resources through training, the hiring of new staff with the required kinds of expertise and experience, and the creation of a system for funding and managing human resource development; (ii) strengthen its management skills and procedures through training, developing management procedures, paying attention to mechanisms to originate new projects and programmes, and focusing the organization on particular client industries; (iii) substantially improve physical resources to the level required for effective operations.

Secondly, Bell proposed that transforming and reinvigorating the institute should be organized as a project, with a planning phase of 4 months that would result in a set of recommendations for action, and an implementation phase of 18 to 24 months. A small Task Force, independent of TISTR (though including TISTR senior managers and Board members) would be in charge of the planning phase and the progress reviews during the implementation phase. Specialized advice would be sought from individual experts from other countries, and one or two workshops would be organized with their participation, in order to draw on the experience and advice from a range of sources, while helping to develop consensus and support for the actions to be taken.

## 2.4 Guidelines for the revitalization of an Industrial Technology Research Institute

Some ITRIs have conducted strategic planning exercises, trying to peer into the future and designing strategies, policies and actions for the institution. There is however a very important difference with a process of revitalization. Strategic planning usually accepts the main structural characteristics of the institute, and considers most government policies as given. Revitalization, on the other hand, should go much further. It should explicitly aim at introducing desirable changes in all aspects of the ITRI's structure and of its legal status, and should make explicit proposals to the authorities regarding new policies, as well as changes in existing policies, that will help the institute to increase its impacts and thus become fully effective.

The revitalization of an ITRI needs attention to many interrelated issues. Principal among them would be the policy environment for industrial technology development; the restructuring and improvement of the ITRI itself; cooperation of the ITRI with industry; cooperation of the ITRI with other institutions in the country, principally S&T centres and universities; foreign and international cooperation, and scientific and technical cooperation with foreign ITRIs and S&T institutions.

The preparation of a revitalization proposal can be a lengthy and complex process, in which many different stakeholders should take part beyond the management and staff of the institute. The result can be cast in the form of a *feasibility report* covering the many substantive, legal, economic, financial, administrative and operational details that are required for a satisfactory solution.

## (1) Aspects to be considered

To help in the revitalization exercise, we have listed the principal aspects that should be reviewed, in the form of a *checklist*. This may be used to examine the many areas where action may have to be taken, or induced, to revitalize the ITRI. The different topics are ordered by main subject.

For each aspect there should be a diagnosis, i.e. an examination of the present situation, and an indication of the desirable evolution towards the revitalization of the institute, and its transformation into an effective institute in the sense we have mentioned above.

The comments and suggestions made in this paper, as well as the examples from the case studies and other "cases" in the Casebook, should be of help to those who carry out an exercise of this nature. We should remember however that each case is different, with its own combination of different external and internal factors - policy environment, industry characteristics, history of the institute, size, fields of specialization, support from the state, and so on - and will therefore require a particular solution.

It should be noted that this list does not intend to establish a sequential or linear procedure for the revitalization exercise. There is a strong interrelationship among several of the items, and therefore the procedure should be one of successive iterations.

### Checklist for ITRI revitalization

1. Environment in which the ITRI works

   - Government policies and their changes under the influence of new international techno-economic conditions (fast technological progress, global competition, globalization); this would be expressed in things such as short-run stabilization policies, opening up of the economy, and policies for higher productivity and competitiveness
   - Stability of government policies and programmes

- Influence of political and economic upheavals, such as wars, sudden price changes of raw materials in the international market, internal violence, etc. (this marks a strong difference between, say, Denmark and Jordan)
- Obstacles such as the difficulties in importing publications, equipment, reactives, supplies
- Existence of a "development infrastructure" helping the ITRI to interrelate with government, industry, and other science and technology institutions
- Explicit government policies in favour of technological development in industry: (a) existing measures (b) measures that may be proposed.

2. Characteristics of the ITRI

- Ownership and legal regime of the ITRI
- Present ITRI objectives, formal and actual; how do they differ from the original objectives
- Maturity of the ITRI
- Productive sector r sectors towards which it is aimed; technoiogical areas it covers
- Clients
- Services (See Table 1)

3. Resources

3.1 Financial resources
- Origin:
  - Government, through: a budgetary allocation; grants; contracts for strategic R&D; other
  - Industry, through: membership fees; sales of multiclient services, including R&D, applicable to a group of companies; sales of services, including R&D, to individual companies
  - Sales of services, including R&D, to other clients, such as government agencies, other S&T institutions, etc.
  - Sales to clients outside the country
  - Income from propietary technology developed or procured by the ITRI, through sale, licensing or joint ventures
  - Adequacy of funding: ample, barely sufficient or subcritical

3.2 Human resources
- Structure of personnel
- Level of scientific and technical staff
- Availability and utilization of outside consultants

3.3 Physical resources
- Installations: buildings, equipment, instruments
- Computer system, communications network

3.4 Knowledge and Information resources

(a) For scientific and technological purposes

-Documentation
- Library
- reception of S&T reviews, periodicals and publications
- connection to S&T information systems
- Scientific and technological intelligence activity
- Personal access to international scientific and technical information
- assistance at technical meetings, locally and overseas
- training and specialization of scientific personnel, particularly through stays overseas
- Participation in collaborative research and other activities with other local and foreign institutions
- Participation in scientific networks
- Use of outside consultants
- Procurement of foreign commercial technology by purchasing, licensing and other means

(b) For economic, commercial, regulatory and other purposes
- Library
- Reception of publications
- Contacts with industry, government, academic circles, and the media

4. Management

4.1 Structural characteristics
- Organizational structure
- Flexibility - legal, actual
- Level of management skills of persons in management positions

4.2 Planning, programing, budgeting, evaluation
- Strategic planning
- Annual business plans and production programmes
- Programme formulation for R&D projects and other types of activities
- Budgeting, formation of reserves, internal allocation of resources
- Efficiency with which programmes are implemented
- Evaluation, ex-ante and ex-post

4.3 Human resource management
- Recruitment
- Training and upgrading, including assistance to scientific and technical events
- Staff exchanges with industry
- Adequacy of remuneration: salary; incentives
- Motivation and work discipline: a "university" or a "production" setting
- Evaluation of personnel performance
- Degree to which key personnel is retained in the long run
- Recruitment and utilization of outside consultants, national and foreign

5. Outputs and Performance

- Performance indicators: financial and other types
- The performance of individual functions
  - Research and development
    - Type of R&D - basic, applied, adaptive; strategic, speculative, contract research for a client
    - How topics are chosen
    - Relevance to country's short and long-term needs
    - Relevance to customers' needs
    - Efficiency in performance of research
    - Quality of the research
  - Patenting of results
  - Acquisition of foreign technologies that are relevant for local use
  - Development of usable, commercial technology packages on the basis of research results and technology inputs from outside
  - Transfer of technology to users
  - Technological services: information, consultancy, testing, metrology, extension, etc.
- Performance of ITRI as a part of the national innovation system
- Characteristics affecting efficiency and relevance

6. Relations and cooperation with industry

- Industry participation in Board and Committees
- Links with industry
  - Types of links
  - Barriers to demand from industry
  - Policies encouraging such demand
  - Behaviour of industrial firms: their technology strategy, their need for doing in-house research or using the ITRI labs; their involvement in planning, development and support of the ITRI:
  - Involvement of ITRI in technology transfer to local companies from foreign sources
  - Industrial surveys and marketing studies made by ITRI
- Organization of consortia of enterprises for cooperative research
- Image of ITRI in industry
- Marketing by ITRI of its services
- Licensing of technology developed by the ITRI

7. Cooperation with other national institutions

- Cooperation with other ITRIs
- Cooperation with basic and applied research institutions which are not primarily concerned with industry
- Cooperation with universities
- Reinforcement of the "national innovation system"

8. International cooperation

- Multilateral cooperation programmes, particularly with UNIDO and the UN system
- Bilateral cooperation programmes
- Cooperation with ITRIs in developed countries. Twinning.
- Cooperation with ITRIs in other developing countries. Participation in WAITRO and in regional networks.

## (2) Guidelines for the revitalization project

We now outline how the revitalization of a particular ITRI may be carried out, with the proviso that, since each case has its own characteristics, the actual procedure may vary in practice from the ideal sketched below.

*(i) Initial conditions*

The first stage is to carry out a diagnosis of the ITRI in its present state, showing its strengths and its shortcomings, as well as the changes taking place in its environment, and identifying the possibilities for improving the ITRI and transforming it into an effective institute. The diagnosis may follow the different points of the checklist above.

It is important to establish whether the ITRI has achieved or not a reasonable degree of maturity, and in the latter case, whether it is *prima facie* feasible to revitalize it.

*(ii) Design of the revitalized institute in its desirable new steady state*

The second stage is to design in detail how the revitalized institute should be - its long term objectives, structure, outputs, clients, resources, and so on. This would constitute the new *steady state*, contemplating the different factors that contribute to making an effective institute, i.e. one that combines efficiency with high impact favourable to the country's goals.

The diagnosis carried out in the first stage would already have the seeds of the new design. The checklist would continue to be used in this new stage of design in an iterative way, helping to evolve successive revised and improved versions of the design. The first few attempts would aim at setting the basic aspects of the new solution; once this is agreed, a more detailed phase would follow, specifying in successive iterations the full particulars of the desired steady state.

Here the work may receive guidance from the findings of the ITRI Project, the teachings offered by other cases, and outside expertise.

Among the most important aspects to be taken up are those related to legal status and structure. In some cases very fundamental decisions will have to be taken relating to whether the institute will continue in the public sector or will be transformed into a private institution. This may require an extensive round of consultations with different stakeholders, and with the government.

*(iii) Proposals for policy adjustments*

As an important part of the revitalization process, the policy environment in which the ITRI operates should be examined and proposals submitted to the government for changes and additions. Two groups of policies bearing on scientific and technological development should be examined: explicit and implicit.

Explicit policies are those that directly address the scientific and technological variable, such as the financial support granted to scientific institutions, a scheme for promoting innovation projects in industry, the regulations on technology transfer from abroad, an educational programme for scientific or technical personnel, etc. A review should be made of the present set of laws, regulations, policies, mechanisms and institutions that directly affect the institute and the technological development of the branches it services. Proposals should be prepared for changes or additions as deemed necessary.

Implicit policies are policies aimed at variables other than science and technology, but having lateral, unintended and often negative effects on it. Examples may range from labour laws, affecting the institute's flexibility in managing its human resources, to exchange regulations that make it difficult to send scientific personnel to attend meetings overseas. Once again, such policies should be examined and proposals prepared for changes in them. These proposals should be realistic and feasible, covering the modifications and exceptions that it is possible to obtain.

*(iv) Design of the transition towards the new steady state*

The fourth stage is to map out how to go from the present state to the new steady state. Sequences and time schedules should be established, taking into account the need to draft and adopt new policies on the part of government, change the legal status and the organizational structure, discontinue inadequate staff, hire new personnel, train scientists at home and abroad, particularly in new fields, impart marketing and management training, carry out necessary investments in buildings, equipment and other assets, and so on. The costs of these items should be carefully estimated and the necessary funding should be procured from national and international sources.

The difficulties, the time required, and the costs of the transition will be much higher in the case of an ITRI that has not yet achieved maturity.

*(v) Discussion and approval of the proposal*

Once the previous stages have been completed and a full feasibility report has been prepared, discussions should be held with the government and other interested actors, with the aim of getting the proposals approved and securing sufficient funds to carry them out.

This will probably require lengthy and extensive rounds of negotiation, particularly if the institute is in the public sector. It may be necessary to cut or modify the original proposals. A good deal of lobbying will probably be required.

The prospect of a long debate demands that the feasibility report should be as forceful, positive and clear as possible. Efforts should not be spared for good editing and a flawless graphic presentation.

*(vi) Organizing the revitalization exercise.*

To carry out the first five stages of the above exercise, probably the best solution is to appoint a special planning group or task force, including in it the best experts in the country, a number of foreign experts, and some people from the ITRI itself. Ample consultations should be held at different moments with the "stakeholders" in the country, as was done in New Zealand when the new Crown Research Institutes were established. In this way a broad consensus may be built which will bring in support for the revitalization project, and later for the revitalized ITRI.

*(vii) Implementation of the revitalization proposals*

Once the previous stages are completed, approval has been obtained, and funds have been marshalled, the Institute's management may start the task of implementing the revitalization proposals. To do so it needs continuing support from its sponsors, as well as from government, industry and the science system.

It should be remembered that the transition to a new steady state will follow an "S" curve which cannot be overly accelerated; the ITRI can only start producing the expected outputs and results when people, installations and proper funding are in place, the new techniques have been mastered, and the clientele has materialized - a process that may take several years.

# CHAPTER 3

# ROLE OF UNIDO: GUIDELINES FOR A PROGRAMME OF ACTION

## 3.1 Introduction

UNIDO has been instrumental in setting up Industrial Technology Research Institutes in many developing countries, and in assisting them to develop and grow. The joint review carried out by UNIDO and UNDP in 1977 (Case 14) covered 33 institutes, a good part of which had enjoyed UNIDO technical cooperation. After that time UNIDO continued to assist in the creation of new ITRIs, and in the improvement and expansion of already established ITRIs.

UNIDO also promoted in the late 1960s the creation of the World Association of Industrial and Technological Research Organizations, WAITRO, and assisted this institution both substantively and financially over the years. Though at present this support is not as important as it used to be some years ago, UNIDO continues to participate actively in WAITRO's meetings and biennial conferences, and informal talks have been held between both organizations for cooperation on subjects such as the networking of the member institutes of WAITRO and the training of Directors of institutes from developing countries.

Technical cooperation and other activities for the benefit of Industrial Technology Research Institutes should continue to be an important area of concern for UNIDO. However, we suggest that *UNIDO's efforts should focus on issues of revitalization.*

There are ample reasons for this suggestion. The number of ITRIs in developing countries is in the hundreds. They employ large contingents of high level human resources, and count with a great deal of specialized installations. As the 1977 UNIDO-UNDP review showed, in many cases these resources were not used effectively, and the institutes had not been able to contribute fully to the industrial development of their own countries. The ITRI Project has not contradicted this early finding: more than half of the institutes surveyed were far from being effective.

The opportunity cost of these partly used resources can be very high in countries where capital and skilled human resources are scarce.

Moreover, as we have seen in this paper, the new techno-economic situation of the 1990s places additional burdens on ITRIs. New scientific and technological fields have to be covered; the range of services offered should be expanded in order to satisfy the new needs of industry; the sales of R&D and services have to be increased at a time when state support is seriously eroding in most countries.

It is likely that a significant proportion of ITRIs in developing countries would benefit from efforts aimed at making them more effective in the new economic and technological environment of the 1990s, and countries would

also profit from an increase in the effectiveness of their ITRIs. To this end UNIDO may carry out very useful cooperation activities, which can be put together in a programme of action to be executed over a number of years.

In developing the present guidelines for such a programme we have used several inputs: the results of the ITRI Project, the opinions and suggestions of the researchers who have participated in the ITRI project, and the important contributions made by K. Venkataraman and P. Ellwood of UNIDO, to whom we are especially grateful.

## 3.2 Elements for a UNIDO Programme for the Revitalization of Industrial Technology Research Institutes

The purpose of this programme would be to facilitate the transformation of existing ITRIs into sustainable and effective institutions, in the face of the challenges brought about by the new conditions of the 1990s.

The programme includes promotional, research and technical cooperation activities, some of which would be carried out centrally by UNIDO as a support to field activities in member countries.

### (1) Diffusion and sensitization

The previous experience of UNIDO, and the results of the ITRI Project, have allowed the Organization to accumulate a great deal of knowledge about the problematique of ITRIs in developing countries as they face the new techno-economic situation of the 1990s.

*(a) Diffusion.*

This knowledge should be widely diffused to those who may profit from it, through publications, workshops and meetings. UNIDO should seek for this purpose the cooperation of IDRC, which is very interested in fostering the application of the results of research it has sponsored.

A special group to be aimed is that of ITRI Directors, for which regional meetings may be held to discuss the issues uncovered in the ITRI Project. This could be done with the cooperation of WAITRO. Such meetings could also discuss the possibilities of collaboration among ITRIs through cooperation networks and other means which are mentioned below.

Small and medium entreprises are another group to be especially targeted, and here UNIDO could join forces with interested parties in certain developing countries to make SMEs aware of their needs for science and technology inputs and of the role that could be fulfilled by local ITRIs.

*(b) Sensitization*

A task of sensitization of policy makersshould be envisaged in order to build their awareness of those issues and transmit to them the importance of revitalizing institutes that were established time ago and have not evolved adequately. This may be done through carefully prepared briefings, and

through short texts written for non-specialists - a "20 minute read" as Prof. Oldham has put it.

Once again, UNIDO could seek the collaboration of IDRC in the sensitization activities it undertakes.

**(2) Studies**

The ITRI Project has mainly consisted of a number of case studies of ITRIs in the Latin American region, which have employed a common methodological approach. Two other cases, in Canada and New Zealand, have provided useful perspectives for comparison. The present author was able to collect useful information in some other cases, which has thrown additional light on the issues analyzed.

Even though the complexity of the subject and the limited time available have not allowed as deep and detailed a work as would otherwise have been desirable, the Project has been able to produce much useful empirical material in a problem area where before there had mostly been general descriptions and unstructured essays.

The impulse gathered in this work should not be lost. Further research should be envisaged to deepen our understanding of ITRIs and their problematique, and to cover ITRIs in other geographical regions.

For this purpose the following actions are suggested:

*(a) Workshop to review the results of the ITRI Project and identify further research activities*

This would be a two- or three-day meeting, organized by UNIDO and co-sponsored by IDRC and WAITRO. It could be held in early 1994, with a limited number of participants, not more than 20, which would include representatives from the sponsoring organizations, some of the researchers involved in the ITRI Project, and outside experts. Plans could be made for another round of studies, to be started in the second half of 1994, dealing with some of the areas mentioned in the following subsections. Collaboration on diffusion and sensitization activities could also be discussed, and plans drawn up.

*(b) Research on issues common to most ITRIs*

This would be research aimed at a deeper understanding of ITRIs and their problems, as global techno-economic conditions continue to change and countries adopt new types of economic and industrial policies. Some possible subjects could be:

- Issues of ITRI efficiency and effectiveness; development of indicators.

- Benchmarking for comparison purposes.

- Organizational models adequate for ITRIs.

- Application of modern management techniques in ITRIs.

- Problems in the marketing of ITRI outputs.

- Development of teaching materials for training in management and in marketing topics.

*(c) Empirical studies of ITRIs in other regions*

Further rounds of empirical research should be envisaged in developing countries' institutes in other regions of the world - Africa, Asia, the Middle East and Eastern Europe. The methodology employed in the ITRI Project would probably have to be adapted to the different general conditions in each of these regions - for instance, the presence of mainly non-mature ITRIs in Africa, and the peculiar situation of institutes in Eastern Europe that are caught in a transition process towards the free market.

*(d) Analysis of the applicability of ITRI Project results to other types of scientific and technological institutions*

Much of what has been learned in the ITRI Project would appear to be applicable to other applied S&T institutions in developing countries, such as university-based applied laboratories, applied research laboratories, agricultural research institutes and technological service organizations. We suggest that a study should be conducted on this subject. The results could be extremely helpful for the attempts now being made to make all of science and technology more relevant to the development objectives of developing countries.

(3) Data base

We suggest that UNIDO should develop a data base of industrial technology research institutes in the world. This would require a careful definition of an ITRI, as a prelude to a survey of existing ITRIs and the collection of information on them according to pre-established guidelines. Results of the ITRI Project case studies and other studies would also be included.

The data base would be useful for UNIDO and other international and national organizations interested in ITRI issues, and for the ITRIs themselves, to help them understand the universe of which they are members, become aware of the problems and solutions of other ITRIS, and establish cooperation with ITRIs worldwide.

(4) Technical cooperation

The information presented in this paper about specific institutes that have been studied in the ITRI Project, and the suggestions made on how a revitalization exercise may be conducted, may constitute a starting point for a technical cooperation programme by UNIDO aimed at assisting in ITRI revitalization.

This programme would have two types of activities:

*(a) Advisory services*

Short-term advisory services would be provided, utilizing expert consultants from a special roster. The main purpose of these missions, lasting from a couple of weeks to three months, would be to examine the situation of an ITRI, its capabilities and its problems, in the light of the expectations of the government and other sponsors, and to recommend a way of solution, which may involve the revitalization of the institute. Advisory services could also be aimed at specific problems such as the improvement of relations with industry, the setting up of a marketing department or the development of capabilities in a new field

*(b) Revitalization projects*

This activity would involve UNIDO for substantial periods of time, typically 18 to 30 months, and would render assistance to the complete revitalization process described in the "Guidelines for the revitalization project", Section 4.2 above.

The first phase of assistance would be in the preparation of the revitalizaton project. This would comprise the following stages: (i) analysis of the initial conditions, (ii) design of the revitalized institute in its desirable new steady state, (iii) drafting of proposals for policy adjustments, (iv) design of the transition towards the new steady state, (v) discusion and approval of the proposal, and (vi) organization of the revitalization exercise.

The second phase, implementation of the revitalization project, would involve UNIDO either in an advisory capacity or in an executing capacity. In the latter case it would perhaps be preferable to perform this task through a separate project, since it would probably require experts with a different background than those in the first phase.

(5) Training

This is an important instrument for UNIDO in its purpose of helping to improve the efficiency and effectiveness of ITRIs in developing countries. Two main types of training activities are proposed:

*(a) Training of scientific and technical personnel in substantive areas*

The cases studies in the ITRI Project have shown a need for further learning on the part of junior scientists and technologists who are recruited fresh from University. They may require training in theoretical and practical aspects. This may be carried out at home or abroad.

Senior people would principally be in need of specific training opportunities in new technology fields, through stays at first rate research institutions abroad where they can participate in advanced research activities.

UNIDO can help to identify training opportunities internationally, in universities, research institutions and other ITRIs, and to marshall the necessary funds for individual or group training. An interesting possibility is to organize training programmes for ITRI personnel at the two UNIDO-sponsored institutions located in Trieste, Italy: the International Centre of

Science and High Technology, and the International Centre of Genetic Engineering and Biotechnology. Both are well prepared to undertake this task. Their emphasis so far has mainly been on the training of scientists from universities and research centres, but it should be possible for them to address scientific and technical personnel from ITRIs. For the Trieste institutions this change of focus may allow them to have a higher impact on development, since ITRI personnel is much closer to the productive sector and can be expected to apply in practice their new knowledge with little delay.

*(b) Training of managers*

An important finding of the ITRI project is that in most cases ITRI Directors and their collaborators in top management would benefit from training programmes specifically aimed at building up their management skills, including marketing aspects. Of the Latin American ITRIs studied, the Chile Foundation offers the best example of how attention to this feature can bring about an effective operation. The Foundation's managers were trained through working with a foreign associated institution. However, this would not seem to be a real possibility in the case of other ITRIs.

A specific programme for the training of ITRI managers could be organized and implemented by UNIDO. This could have a very wide coverage in a relatively short time, through a succession of courses held in different parts of the world.

Perhaps a fully fledged training programme of this nature should be preceded by a more modest effort, which would allow UNIDO to try out the best approach, refine the methodology, build up the teaching materials, and put together a team of specialists as instructors. In this case, UNIDO could follow up on an informal proposal to train ITRI Directors made by WAITRO, the World Association of Industrial Technology Research Organizations. We now turn to this course of action.

*A joint UNIDO-WAITRO programme for the training of ITRI Directors*

At the end of 1992 WAITRO officials informally approached UNIDO, through the present author, to indicate the interest of their organization in the training of ITRI Directors, and suggested that both institutions could collaborate in developing and carrying out a programme for that purpose.

The idea discussed with WAITRO at that time was that a first course could be held in the second part of 1993. The output of the ITRI project could be used as one of the sets of teaching materials. The course would also include a strong practical, hands-on component, through enabling each participant to spend some time in a well-functioning ITRI.

In conversations that the present author held with the President of WAITRO, Dr R. Nigam, a possible structure for the course was envisaged. The participants would be ITRI Directors, or persons about to become Directors, and their number would not be higher than 20. The course would have a minimum duration of one month, with two-thirds theory and one-third practical involvement of each participant as the "shadow" of the Director of a successfully run ITRI. This may be translated into two full weeks of theory, followed by about two weeks of practice and a three-day roundup

and discussion. To keep down costs, the theoretical part of the course, as well as the final discussion sessions, could be held in a location close to the half a dozen ITRIs where practical training took place. A venue in Europe, such as Vienna or Trieste, would be appropriate. Dr Nigam suggested as an alternative that the course could be hosted by the Shriram Institute in Delhi (where Dr Nigam is the Director) and the participants could be sent for their practical training to selected ITRIs in India. This would lower the costs even further.

A first course of this nature could take place in mid-1994 (rather than the original 1993 date proposed), giving enough time for planning the course, searching for funds and allowing the outputs of the ITRI project to become available. Should this first course be successful, a series of such courses could be envisaged, making this a regular activity to be carried out jointly by UNIDO and WAITRO.

### (6) Cooperation with ITRIs of developed countries

Perhaps one of the best ways for an ITRI to improve its efficiency and develop its knowhow in new areas of knowledge is to cooperate closely with a first class industrial research institution in a developed country, through visits, stays, training and joint research projects. This has been done frequently in the past by some serious scientific institutions in developing countries; for instance, the Metallurgical Laboratory of the Atomic Energy Commission of Argentina was for many years collaborating with the US's South West Research Institute, with very good results.

Though such cooperation may be done informally, formal agreements are probably more effective, as a result of a written understanding which will often include a programme of action. The cooperation may be carried out on a commercial basis, with the outside institution receiving fees for the services it renders. Or it may take place at no cost to the developing country ITRI, for instance if the activities receive funding from the cooperating ITRI's own government or from another source such as a private foundation.

A particularly interesting mechanism is the 'twinning' of the cooperating institutions, which implies a stable relationship in which the senior institution takes on a special concern for its junior partner.

UNIDO may carry out two activities in relation to this issue. First, it may analyze the experience of a number of ITRIs regarding collaboration with outside institutions. Research on this may be started by inserting a few items in the questionnaire sent to ITRIs for the purpose of developing the data base mentioned above; once information is collected, a few cases can be selected for detailed analysis. Secondly, UNIDO can guide ITRIs to find a suitable partner and to establish the best possible type of relationship.

### (7) Cooperation among ITRIs of developing countries

The present author feels that cooperation and networking among the ITRIs of developing countries can be a powerful instrument in their favour, and that

this should preferably be envisaged in a subregional or regional arena, with explicit UNIDO support.

In a short paper prepared by request of the WAITRO Consultative Committee, in October 1992, the present author suggested that the WAITRO network should be consolidated and considerably strengthened if it is to become a true system that will assist members to expand into new technological fields, increase their efficiency and heighten their impact on sustainable industrialization. Crucial aspects of this consolidation are a stronger, more stable Secretariat, and a significantly higher level of funding. Such a course of action would help improve the value of WAITRO to its member organizations, particularly those in the developing world.

Perhaps a suggestion of this nature would not be easy to follow on the part of WAITRO, since quite apart from the practical problem of gathering the necessary funds, there is bound to be a problem in establishing a network with members that are very different - strong, powerful ITRIs from developed countries; weak, not yet mature ITRIs from Africa; problem-ridden ITRIs from Eastern Europe, etc.

It is preferable, in the opinion of the present author, to create cooperation networks of ITRIs in certain subregions (like the Mahgreb and ASEAN) or in whole regions. As an example of the advantages to be gained by this, and of the characteristics and activities of such a network, we present below a concrete proposal for the creation of a network in Latin America. This may be the basis for similar proposals in other parts of the world.

*Latin American Industrial Technology Institutes Network (RITAL)*

There are numerous advantages in creating a cooperation network among the several dozen institutes devoted to industrial technology in the different countries of Latin America. Such a network, which could be named "Red de Institutos de Tecnología Industrial de América Latina", RITAL, would link together its member ITRIs and facilitate their cooperation.

The network would allow the member institutes to profit from each other's experience, exchange scientific personnel, carry out joint research and other activities, and negotiate jointly with international organizations and foreign research institutions. It would help them to collaborate in a number of applied scientific and technological fields, and to participate in a joint learning effort, at a time when a single ITRI of small to moderate size (as is usually the case in Latin America) finds it increasingly difficult to keep up to date and to develop and maintain an expertise on its own in the fields of work it has chosen, particularly those involving new technologies.

The main elements in the network would be the following (Araoz, 1981):

(1) The **nodes**, i.e. the institutes that would make up the network. They may assume different characteristics, but in general would have a strong component of R&D and technological services aimed at industry.

An operational definition of what constitutes an eligible ITRI should be established beforehand, and the candidate members should comply with it. For instance, the network may or may not include "captive" R&D labs within industrial companies, or university labs even though oriented to industry.

A survey should be carried out to identify the likely candidates before attempting to constitute the network. The number of members from different countries would vary according to the country's size and the stage of its industrial development; a large country like Brazil has many more ITRIs that are potential members than a small one like Ecuador.

(2) The **nucleus**, or central unit of the network, in charge of coordinating the activities carried out within the network. This could be organized as a Secretariat which would be independent of the nodes but would report to a Board made up of the latter's representatives.

The Secretariat should be small, with very few professionals under fixed-term contracts (to avoid creating a bureaucracy). Whenever necessary it would employ consultants to develop projects, carry out joint activities, etc. It should operate flexibly, but at the same time enjoy a good measure of institutional stability. This may be obtained by attaching it to a regional project sponsored by UNIDO. In this way it could count with a a chief officer (or Secretary) and supporting staff, hired for several years, and budgetary resources covering structural costs during that period.

The Secretariat would actively organize and promote various types of flows between the nodes, and joint activities among them. It should be prepared to help institutes in their development and improvement, for instance by organizing technical and training programmes for them, particularly as part of revitalization efforts. It would also engage in activities relating to information, training, the holding of symposia and meetings, consultations on different aspects of industrial technology, relations with institutions outside the region, and so on.

(3) The **links** between the nodes, or channels through which flows would take place. A smooth circulation of flows depends on stable and reliable links. The establishment of such links is one of the more important tasks the nucleus should undertake at the time the network is created.

Traditional links include postal and telephone exchanges, periodic newsletters and bulletins, periodic meetings, formal consultation mechanisms, and (very importantly) informal personal contacts of different types.

More modern methods would include fax, electronic mail, teleconferencing, computer-based libraries, and other such means. A distant possibility would be some type of satellite linkage as was proposed some years ago by the WAITRO Secretariat.

(4) The **flows** circulating through the network, between the nucleus and the nodes, and between the nodes themselves. Such flows may include the following types of "knowledge resources": (a) *knowledge*, comprising in

the first place substantive (scientific and technological) knowledge on the different hard and soft fields covered by the ITRIs in the network; a second category of knowledge would be policy and management knowledge relating to the organization, development and operation of an ITRI; (b) *technology*, usually in the form of "packages" of readily applicable solutions rather than just a research finding or "basic" engineering knowhow ; (c) *technical and scientific services*, such as analyses, documentation, engineering, training syllabuses and materials, advice on various problems, formulation of programmes and projects, etc.; and (d) *information and intelligence*, on knowledge resources, social and economic subjects, specific experiences, etc.

Many of these flows will originate within the network, often as a result of joint activities. There may be significant flows coming from the outside, for instance those captured through technology monitoring and assessment in different fields, which would ideally be circulated throughout the network.

Particular issues may come up in the case of flows of technology where propietary rights or commercial considerations may impede free transmission to other nodes.

(5) The **joint activities** undertaken by two or more members of the network, such as: research and development projects; technology monitoring; technology assessment; training courses; the establishment of common standards, specifications, procedures, norms and codes; the formulation of common policies, for instance for joint action at the international level, etc.

These activities may be set up and carried out as projects, which should be carefully prepared by the participating nodes with assistance from the Secretariat. Joint projects should be adequately funded, from sources other than the regular budget of the network. A joint project will constitute a temporary cooperation network around a single topic, and will generate intense flows between the participanting nodes.

R&D projects would be of two types. In the first place, they may refer to substantive questions in a particular scientific or technical field. Secondly, they may deal with policy issues which need "policy research" of a multidisciplinary nature, possibly with the participation of economists, social scientists, lawyers, etc.

(6) The **objectives** pursued by the network members through the functioning of the network. A set of long term objectives should be carefully spelled out when designing the network and should gain the agreement of the founding members. It should be possible to modify them when other institutions join the network or when circumstances change. Short term tactical objectives to guide activities in the network should be adopted at the periodic meetings (annual or bi-annual) of the Board, and would normally be expressed in a work programme for the coming period. This may be drafted by the Secretariat on the basis of suggestions by the nodes.

(7) The **funding** of the Secretariat and of the activities to be carried out within the network. The importance of this element should not be

minimized, since the smooth and efficient functioning of the network depends on it. Pluriannual budgets should be prepared and financial resources gathered; projects and joint activities should not be started if specific funding is not assured. The main sources of funding would be the participating institutes themselves, which should contribute a membership fee, and cover part (sometimes all) of their own expenses in activities in which they participate. Other sources would be international cooperation, preferably through UNIDO; bilateral cooperation; various foundations, etc.

The RITAL network should ultimately become a true cooperation system. This requires that several conditions be met: clearly defined long term objectives that are shared by the member institutes; firm and stable links among the latter; an intense circulation of flows so that systemic relationships are established through them; the sharing of flows (mainly information, knowledge and technology) originating in outside institutions; joint activities carried out with sufficient continuity; . If these conditions are obtained, and the network acquires systemic characteristics, there will be a much higher probability that the efforts and resources assigned to cooperation in RITAL will produce high returns, through a significant improvement of the efficiency and efficacy of the member institutions.

A feasibility study should be prepared before constituting RITAL. This study, which could be funded by UNIDO, should indicate whether the network is viable from the technical, political and financial points of view, and should provide an initial design as well as a preliminary budget for at least three years of operation. If the findings are positive, a meeting could take place with the participation of the most important candidate members, in order to discuss such findings and, if all goes well, to launch the network.

### (8) Cooperation with other international organizations

Several international organizations are interested in improving the performance and impact of industrial technology research organizations, and UNIDO should explore how to collaborate with them for this purpose.

A firtst step has been taken in the collaboration with IDRC on the ITRI Project, which has been very successful. We have already suggested that both institutions should continue their collaboration in activities of diffusion, sensitization and research, and that they could identify specific areas for cooperation through a workshop which UNIDO could organize.

A number of agencies in the United Nations system are active in science and technology affairs, and UNIDO should explore the possibility of collaborating with them on ITRI issues. Examples are UNDP, UNESTD, UNCTAD, UNESCO, ILO and the UN Regional Economic Commissions. These agencies meet periodically at a specialized UN Task Force dealing in questions of science and technology. UNIDO should present its ITRI Revitalization Programme at the next meeting of this group, and explore what cooperation could be established to implement that programme. Additionally, the question of the applicability of the ITRI Project findings to other types of science and technology institutions should

be explored and possible collaborative projects on this should also be identified.

Cooperation with the European Community, and with some of its programmes like FAST, should also be explored by UNIDO, among other things, the EC is increasingly interested in the problems of scientific and technological activity in the countries of Eastern Europe, an area which is also of concern to UNIDO.

Finally, UNIDO should endeavour to cooperate with WAITRO, which is an international organization of a non-governmental type. We mention below a few ideas on this:

*On UNIDO support for, and cooperation with, WAITRO*

ITRIs have a worldwide association, the World Association of Industrial Technology Research Organizations, WAITRO, which has a membership of some 100 institutes from both developed and developing countries. UNIDO had an important role in the establishment of WAITRO in the early 1970s, and kept a significant level of support until some years ago, when principally due to financial shortages this support has been sharply reduced.

Expectations about WAITRO's impact in helping the ITRIs of developing countries have only been partially fulfilled, and WAITRO as an organization is facing a number of problems. It has not been able to attract institutes from certain important developed countries like the USA, Germany and Japan, and it has lost some members, particularly from Latin America. Its financial means have suffered a decrease, which has resulted in a smaller budget for the biennium 1992-94.

WAITRO's Board, however, has expressed a clear desire to expand the membership, both in developing and developed countries, and carry out a significant programme of work.

WAITRO is potentially a very important organization for the developing countries. There are several ways in which it can assist ITRIs to improve their effectiveness in providing industry with the technological and R&D services required to face the new techno-economic conditions of the 1990s. One of them is the establishment of cooperation links between well developed, effective ITRIs and those that need expansion, upgrading and improvement. This can go all the way from cooperation in specific projects to the "twinning" of institutes, a practice that WAITRO wants to revive. Other ways are study tours, seminars and courses, and technical cooperation to give advice to ITRIs. The Work Plan for 1993-94 includes several actions of this type in the chapter entitled "WAITRO strategic plan for institutional capacity building". This document also includes suggestions for action regarding SMEs, Environment, Women in Technology and Technological Information. All these fields are of direct concern to UNIDO.

The present author feels that UNIDO would be well advised to resume close collaboration with WAITRO.

This may be done in a number of ways that would not require significant financial resources, such as inviting WAITRO to join in the sponsoring of further research on ITRIs, to which it would contribute advice and the experience of its members, and helping WAITRO to distribute information products through the INTIB network. Other areas for collaboration would require the formulation of specific projects and the search for funding, such as the training course for ITRI Directors, to which we have referred above.

## (9) The synergy with other UNIDO programmes

UNIDO has a number of current programmes with which the ITRI Revitalization Programme could cooperate. This could be done in such a way that synergistic effects take place, each collaborating programme helping the other to increase its efficiency and outputs.

One way of doing this is to employ installed capacity in ITRIs as an input to activities in those programmes, and to use the latter to push the ITRIs into areas new to them (for instance, activities related to technology transfer, investment promotion and feasibility studies).

Here is a prelimary list of UNIDO programmes with which the new programme in ITRI revitalization could fruitfully cooperate:

(a) Operations-Technology.

(b) Industrial Institutions, particularly in the area of technical institutions and in that of planning.

(c) Transfer of Technology - advisory and training activities

(d) Technology Management

(e) Industrial and Information Technology Bank

(f) Investment Promotion

(g) Feasibility Studies

(h) Training

UNIDO should explore the possibilities of synergistic collaboration between the Programme proposed in the present Guidelines and other existing programmes in UNIDO. This may be done through a series of meetings once the present Programme has been developed in detail.

## CHAPTER 4

## CASEBOOK

The Casebook comprises twenty-one texts of three different types, all of which we have labelled "Cases" for the sake of simplicity.

The first group of eight cases consists of summaries of the case studies carried out under the ITRI Project, six of them on Latin American ITRIs and the other two on New Zealand and Canada. (Two other cases studies in Latin America under the same project have also been summarized very briefly in Case 19 below).

Case 1. Fundación Chile: Technology transfer and diffusion through demonstration enterprises

Case 2. Brazil: CODETEC

Case 3. Chile: INTEC

Case 4. Argentina: New outlook for CIMM

Case 5. Central America: ICAITI, a regional ITRI

Case 6. Colombia: The demise of IIT

Case 7. New Zealand: Science restructuring and new modalities of industrial research

Case 8. Canada: Some recent initiatives in industrial research

The second group of five cases includes summaries of additional cases from other sources, four of them about Asian ITRIs and the fifth about a first-rate research university in the United States. These cases do not follow the methodology adopted for the ITRI Project, and therefore they are not strictly comparable to the cases in the first group above. However, we have felt them to be worthy of inclusion since they cover other geographical areas of the world, and add to our understanding of the issues facing ITRIs and of what may be done about them.

Case 9. India: The National Chemical Laboratory

Case 10. Thailand: Towards reforming the Thailand Institute of Scientific and Industrial Research

Case 11. Taiwan: The Industrial and Technological Research Institute

Case 12. Pakistan: Improving science-industry links

Case 13. United States: Interactions of MIT with industry

The third group of eight cases summarizes texts of a more general nature; they refer to groups of ITRIs, focusing on the issues they face. The first text is about the conclusions of an important evaluation study of ITRIs made some years ago jointly by UNIDO and UNDP; many of the conclusions are still valid today.

Case 14. UNIDO-UNDP: Evaluation study of industrial research and service institutes

Case 15. WAITRO Seminar: Observations on ITRIs

Case 16. Europe: Cooperative research between ITRIs and small industries

Case 17. Europe: Contract Research Organizations

Case 18. Brazil: Industrial R&D Institutions

Case 19. Death of an ITRI: four examples

Case 20. ITRI Project: Role of ITRIs and proposed guidelines for case studies

Case 21. India and China: High technology R&D institutions

CASE 1

# FUNDACION CHILE: TECHNOLOGY TRANSFER AND DIFFUSION THROUGH DEMONSTRATION ENTERPRISES

*The Chile Foundation offers a very interesting contrast to the usual industrial technology research institution in a developing country. It is self-sustaining, shows a strong commercial outlook, hardly makes research, and has had a strong impact on the productive activities of the country in key export sectors. This review of its approach and activities is based on a paper by J. Cordua, "Rol de los institutos tecnológicos industriales en el nuevo contexto social y económico mundial: Estudio de casos de Fundacion Chile", Fundación Chile, Santiago, February 1993.*

## 1. INTRODUCTION

The main activity of the Chile Foundation is not research and development, but rather bringing into the country proven knowhow in areas of commercial importance and carrying out an active task of technology transfer and diffusion to local users. This is done through traditional methods and, increasingly, through a novel method of setting up *demonstration enterprises* that apply commercially the technology and show its viability. Such enterprises are sold to the private sector once the demonstration effect has been achieved. Thirty one demonstration enterprises have been set up since 1982, and six have already been sold.

The Chile Foundation was created in 1976 through an agreement between the goverment of Chile and the ITT Corporation, as part of a broad settlement for the expropriation some years before of ITT property in that country. Each partner agreed to contribute US $25 million over a period of ten years for the creation of a private non-profit corporation with the aim of "scientific and technological research, its development and the application of its results to the economy". During the first ten years of its life the Foundation was administered by, and received technical advice from, ISEC, a subsidiary of ITT. It is now run by nationals of Chile.

The Foundation's full-time staff currently numbers 180, of which 75% are professionals. It uses an even larger number of short-term consultants and experts from Chile and abroad. The annual cost of its operations is in the order of US $10 million. Since 1986, costs have been fully covered by the income from the sale of services, the results of the enterprises created and the interest on financial investments. The Foundation's assets are currently $56 million, higher than the sum of the original contributions.

## 2. ORIGINS AND EARLY DEVELOPMENT

The creation of the Foundation took place at a time when the country was starting to apply a new development model, by opening up the economy, providing incentives to export activities and to national and foreign

investment, and searching for a higher stability of the economic and legal conditions affecting productive enterprises, particularly regarding inflation. These policies were maintained with few changes during the Foundation's formative period. The good results obtained by the Foundation are largely explained by this policy environment, particularly its export bias.

Chile's economic policies were to a large extent continued by the democratic government that came into power in 1989. The country's economy has steadily grown and diversified, making up what is now called "the Chilean miracle". Export policies were successful in integrating the Chilean economy into the world markets. Exports have increased steadily and now represent 38% of GNP. They have diversified: copper, historically the main export product, now represents less than half of exports, while products attended by the Foundation have grown in importance: wood products 10%, agro products 9.5%, marine products 8.8%.

In 1978 the Foundation started to provide testing and certification services to the food industry, using its new laboratories. During the following years it carried out many activities related to agroindustry such as: freezing of berries and of horticultural products; development of a Swiss-style yogurt; study of varieties of peaches and apricots for the fruit canning industry; introduction of new varieties of green asparagus; sanitary improvements in the dairy industry. In marine resources, feasibility studies were made on the culture of salmon, trout and other species. Work on forest products began somewhat later, in 1983. Activities in electronics and communications that had started early were gradually phased out because of the lack of a sufficiently large market in the country; they were replaced by work on the industrial application of microprocessors. More recently the Foundation has started activities related to software production.

As we can see, the orientation has principally been towards the dynamic export sectors, which had not been adequately covered by other institutions in the country. The Foundation has adopted a practical approach to ensure that sufficient revenue is generated from its activities. In 1981 it received government authorization to officially certify quality of export fruits and vegetables, the starting point for an activity that has become an important source of revenue as well as of knowledge about the problems of these sectors.

## 3. CHARACTERISTICS

The innovation system in Chile has been characterized as comprising four large functional subsystems: *incorporation of knowledge* (from abroad or locally generated), which includes the eight universities that perform R&D and the more than ten government-supported research institutes; *utilization of knowledge*, made up by productive public and private enterprises, *intermediation of knowledge*, the purpose of which is to link the two previous subsystems, and includes firms providing consultancy, technical support and services, and information; and *education*, comprising the universities and the institutions which train professionals and technicians.

In this scheme, the Foundation belongs intrinsically to the third subsystem, intermediation of knowledge, but it has important activities in the other subsystems.

The Foundation's structure comprises four technical Departments, Agroindustry, Forestry, Marine Resources, and Development and Marketing, and three modern Laboratories in the chemical, chromatography and microbiology areas, which offer a wide variety of tests and analyses mainly related to the needs of the export industries, including quality certification. There is, additionally, a Department of Finance and Administration.

The Foundation has specialized in economic sectors chosen on the basis of the country's and the institution's comparative and competitive advantages. Within those sectors *it has been guided mainly by market signals*, which was a novel concept when first used since at that time other institutions followed orientations derived from the concept of "strategic needs" of national development.

The Foundation now contributes technology and services to four of the most dynamic sectors of the economy: agroindustry, forestry, marine resources and informatics. It has achieved prestige and comparative advantages in them.

## 4. TECHNOLOGY TRANSFER ACTIVITIES

To transfer technologies to the country's enterprises, the Foundation employs both traditional methods and its own method: the creation of demonstration enterprises.

The main traditional instruments in technology transfer employed by the Foundation are:

- Diffusion, through seminars and the publication of three specialized reviews in its areas of specialization;

- Training, through courses and workshops in the Foundation;

- Technical assistance, through service contracts, principally for the development and commercialization of new products and services;

- Quality control and certification, one of the Foundations's most developed activities on account of the income generated and the prestige accruing from it;

In 1982 the Foundation started to apply a model of creation of enterprises for the demonstration of new technologies, as a tool for the efficient transfer of technology. The Foundation studies and develops a project, converting it into a functioning private enterprise that demonstrates the validity of the technology incorporated. To do so it looks for the best know-how existing abroad and uses it in the new enterprise. The wide diffusion of the initiative and its achievements motivate other entrepreneurs, by imitation, to invest in the new activity. A diffusion chain is created in this way, and is regarded as complete when the new economic activity is consolidated. At that time the demonstration enterprise is sold, recuperating at least the invested capital. Thus take place the transfer of technology and the creation of a new productive activity.

The Foundation has been outstandingly successful in its technology transfer projects. But there have been failures, such as the introduction of the cultivation of sweet lupin and jojoba, the development of products based on cereals, and the treatment of milk to solve lactose intolerance. Other unsuccessful activities have been the creation of a Technological Assistance Centre for the canning industry, and that of a programme of technical assistance to the dairy industry; in both cases insufficient income was obtained from the sale of services.

## 5. THE CREATION OF "DEMONSTRATION ENTERPRISES"

One of the characteristics of the Foundation's model of technology transfer is the creation of "demonstration enterprises". Their purpose is to show in the country the technical and economic potential of a technology, already proven overseas, which can generate new production opportunities based on a technological innovation in Chile.

The Foundation prefers to create the new firm by itself, but may do so through a partnership with private entrepreneurs. The latter procedure is used when the project's success depends on having available a lengthy experience in the productive sector, particularly in the marketing aspects, or when the investment is very large in relation to the Foundation's resources.

The transfer and diffusion cycle is closed by selling the firm (or the Foundation's share) once it has achieved the purpose of demonstratin practically the technical and economic advantages of the new technology. The Foundation's experience shows that the cycle has an average length of four to seven years.

The phases of the cycle are:

(a) Identify an opportunity for a new productive activity, preferably with export possibilities, for which there is a proven technology abroad which has not yet been used in the country.

(b) Introduce the new technology through a demonstration enterprise.

(c) Assist the new enterprise in different areas, particularly marketing, quality control and troubleshooting.

(d) Diffuse the new technology in the country.

(e) Sell the Foundation's share in the demonstration enterprise, once it has stabilized and started to show profits.

(f) Search for a new opportunity to restart the cycle.

The success of this approach depends to a large degree on having ample financing and a stable, autonomous and flexible operation.

Some of the advantages of this mechanism of technology transfer and diffusion are:

- for an industrialist, the best argument in favour of a new technology is the commercial success enjoyed by whoever has applied it;

- an institution that aims at technological innovation will be more likely to implement high risk projects than a private investor;

- the active participation of a technical institution in the investment and operation of the project shows its trust in it, which in turn gives confidence to prospective investors.

There are also problems, such as:

- a potential conflict of interest between the institution's aim of technical assistance to producers in an area and the fact that it is at the same time a producer in the same area;

- the management of a number of enterprises demands a high managerial capability which normally is not available in a technological institution.

In spite of such problems, results have been very positive in the case of the Chile Foundation. A total of 31 enterprises were created in the following sectors: agroindustry (13), aquaculture (11), wood (5), and informatics (2). Six of them have finished the cycle and have been sold with good profits. One was closed down, and a few show problems. The remaining, about 18, are doing fine (see the attached table).

The most interesting consequence has been the spate of followers in many of the cases. Salmones Antartica S.A., the first demonstration company, founded in 1983, promoted a rapid development of the salmon industry, which did not exist previously. During the first six years after its creation, more than 60 salmon producing firms were established, and salmon production went from 94 metric tons in 1983 to 35.000 in 1992. Chile is today the second world producer of salmon in captivity, with exports of US $200 million a year.

## 6. ORGANIZATION, MANAGEMENT, AND MARKET STRATEGIES

As a private corporation, the Foundation enjoys a great degree of autonomy, and it has extended this characteristic internally. Departments enjoy great independence in their operations, and define the strategies, tactics and actions needed to implement the policies laid down by the Board, including marketing, budgeting and operational aspects. On creating a demonstration enterprise, the department in charge carries out the initial phases until the enterprise starts operating and is turned over to a manager.

The salient characteristics of the Foundation's institutional model are:

- *Orientation towards the market.* The three main areas of specialization - agroindustry, marine resources and forestry - have been excellent choices: in 1976-90, while Chile's exports grew 40% in real terms, their exports have more than doubled. Great importance is assigned to market studies and to income generation opportunities in project selection.

- *Pragmatism.* The Foundation employs a wide array of instruments to transfer and diffuse technologies, and has been able to change substantially its approaches and policies when the market has not responded.

- *Autonomy.* Its status as a private non-profit corporation and the equal participation of government and ITT representatives on the Board has allowed it to function with great autonomy.

- *Specialization.* By concentrating on four productive areas (agroindustry, forestry, marine resources and informatics) the Foundation has been able to acquire high technological skills in each of these areas, and to generate confidence in the main enterprises operating in them.

- *Professional management.* The techniques for managing technological activities brought by ITT were adapted to the conditions of Chile and the specific characteristics of the Foundation. This permitted the use of very effective packages for the programming of activities, budgetary control and management of professional personnel, including management by objectives, training programmes and executive development.

- *Own model for technology transfer.* Beyond using traditional mechanisms for transfer and diffusion of technology, the Foundation has developed and used successfully a new mechanism, the creation of demonstration enterprises, which the private sector finds particularly attractive since it lowers the risk inherent in adopting a new technology.

The Foundation prepares each year an Annual Plan of Operations, detailing the agreed activities for the different operating units. On the basis of this, a permanent evaluation and control is made of projects, operating units and persons. Each project generates a monthly report and is subjected to review twice a year. All staff members are evaluated annually on their performance.

The Foundation has been able to attract a distinguished group of professionals, and this has allowed it to achieve high productivity levels and carry out a large volume of activities with a relatively small professional staff. The frequent use of outside consultants, both national and foreign, significantly amplifies the capabilities of the permanent staff. Managers have a commercial, profit-seeking spirit, which has made for good economic results.

The concept that the professional excellence of its personnel is the main factor for the success of the institution is reflected in the Foundation's personnel training policies. The staff is encouraged to participate in international courses and meetings, in order to update their knowledge and establish personal contacts. The wide use of consultants is also a rich source of knowledge and experience for the Foundation's staff.

The Foundation charges for all of its services and thus has to adapt its programmes and the services it produces to client demand. The enterprises created by the Foundation are an important source of contacts, leading to new clients wanting to duplicate the experience and needing the Foundation's support for this.

The Foundation's main comparative advantage is its excellent image, based on a great credibility and prestige. The credibility comes from a first rate track

record on providing effective technical assistance and an effective transfer of technology. The institution's prestige brings frequent invitations to its managers and professionals for participation in technical meetings, both national and international. The Foundation enjoys a high coverage in the media of its activities and achievements, and its three serial publications are also important promotional instruments.

# EMPRESAS DEMOSTRATIVAS DE FUNDACION CHILE

| AREA Y EMPRESA | PRODUCTOS | Año Creación | Año Venta | Propied 1992 (%) | PATRIMONIO 31.12.91 | |
|---|---|---|---|---|---|---|
| | | | | | Millones $ | Miles US$ |
| **AGROINDUSTRIAL** | | | | | | |
| *Agricola Esmeralda S.A.* | *Frutas semitropicales* | *1989* | | *100* | *246.66* | *663.18* |
| *Granjanova S.A.* | *Verduras no contaminadas envasada* | *1989* | | *100* | *646.57* | *1739.21* |
| *Punto Verde S.A.(*)* | *Comercialización de hortalizas* | | | *100* | | |
| *GranjaSur S.A.* | *Manzanas frescas export. / jugo* | *1989* | | *100* | *568.59* | *1529.55* |
| *Agronova S.A.* | *Cítricos de exportación* | *1989* | | *100* | *795.49* | *2138.82* |
| *Agroinversiones Huacán S.A.* | *Experimentación en hortalizas* | *1990* | | *100* | *214.75* | *577.40* |
| *Agric. y Vitivinícola Itata S.A.* | *Vino fino de exportación* | *1989* | | *100* | *308.68* | *829.95* |
| *Tecnagro Cautín S.A.* | *Bayas y espárragos* | *1987* | | *55* | *46.09* | *123.91* |
| *Tecnofrío S.A.* | *Procesam. bayas y espárragos* | *1988* | | *55* | *144.92* | *389.64* |
| *Berries La Unión S.A.-C.P.A.* | *Bayas de exportación* | *1985* | *1990* | | | |
| *Indust. Berries La Unión S.A.* | *Procesadora de bayas* | *1985* | *1990* | | | |
| *Procarne* | *Carne envasada al vacío* | *1983* | *1989* | | | |
| *Caprilac(**)* | *Queso finos de cabra* | *1983* | | | | |
| **RECURSOS MARINOS** | | | | | | |
| *Cultivos Marinos Tongoy S.A.* | *Semillas de ostras del Pacífico* | *1983* | | *100* | *396.42* | *1065.56* |
| *Cultivos Achao S.A.* | *Ostras del Pacífico* | *1989* | | *100* | *107.23* | *288.31* |
| *Finamar S.A.* | *Salmón Ahumado* | *1988* | *1991* | | | |
| *Salmotec S.A.* | *Salmón del Pacífico y Atlántico* | *1988* | | *100* | *541.81* | *1456.76* |
| *Tecnofish S.A.* | *Juveniles de Turbot(***)* | *1991* | | *66* | | |
| *Granjamar S.A.* | *Juveniles de Turbot* | *1990* | | *100* | *194.09* | *521.85* |
| *Cultivos Mares de Chile S.A.* | *Engorda de Turbot* | *1991* | | *100* | *316.81* | *851.80* |
| *Semillas Marinas S.A.* | *Juveniles de abalones* | *1990* | | *100* | *64.62* | *173.75* |
| *Campos Marinos S.A.* | *Engorda de abalones* | *1990* | | *100* | *34.76* | *93.46* |
| *Salmones Huillinco S.A.* | *Juveniles de salmón del Atlántico* | *1987* | | *25* | *121.23* | *325.95* |
| *Salmones Antártica* | *Salmones y truchas* | *1982* | *1988* | | | |
| **FORESTAL** | | | | | | |
| *Construct. e Inmobil. 2000 S.A.* | *Viviendas energitérmicas* | *1989* | | *100* | *19.61* | *52.71* |
| *CENTEC S.A.* | *Partes y piezas de muebles* | *1989* | | *100* | *1216.55* | *3271.11* |
| *Ignis Terra S.A.* | *Aserrío y Comercialización de lenga* | *1991* | | *10* | *53.64* | *144.21* |
| *Tecnoplant S.A.* | *Vivero forestal* | *1990* | | *50* | *91.92* | *247.13* |
| *Lumber Ram S.A.* | *Madera estructural* | *1989* | | *33.33* | *75.48* | *202.93* |
| **INFORMATICA Y OTROS** | | | | | | |
| *Auprin S.A.* | *Servicios automatización industrial* | *1987* | *1992* | *60* | *55.86* | *150.19* |
| *Capitales e Inversiones S.A.* | *Capital de riesgo* | *1988* | | *12.5* | *47.97* | *128.97* |

CASE 2

## BRAZIL: CODETEC

*This Institute, born within a university and later evolving largely on its own, has undergone a series of adaptations and transformations as it went from a liaison mechanism for Campinas University to an instrument of Brazil's import-substitution policy in the field of pharmaceuticals and finally to an ITRI that, keeping to the technological field where it has built strengths, is trying to survive and prosper in the new liberal economic regime installed two years ago. The following is a summary of the paper by Jose Adeodato de Souza Neto and Jose Vidal Bellinetti, "Case Study of CODETEC", Sao Paulo, Feb. 1993.*

### 1. ORIGINS

Brazil's Company for Technological Development, CODETEC, is based at the University of Campinas, in the state of Sao Paulo. It was created in 1976 by the joint initiative of the university, the Federal Ministry of Industry and Commerce, and a group of more than 20 companies.

CODETEC was organized as a private company with the objective of providing services in research, technology, engineering and consulting, mainly in the fields of fine chemicals and biotechnology, with special emphasis on pharmaceutical products. It was based on a "science push" approach: good research results were available and deserved being tried in the market. It was expected that this would make a significant contribution to the national objective of maximizing autonomous technological development.

### 2. THE MILIEU

To understand the role of CODETEC and its strategy, we need to discuss the evolution of economic policy in Brazil, from import substitution industrialization to liberalization.

During many years the main objective of industrial policy was to develop local industry, by integrating production chains, building industrial complexes and diversifying capabilities. The main instruments for this policy were tariff and non-tariff barriers on imported products. This attracted foreign investment to a number of industries like automobiles, electric power equipment, cosmetics, entertainment electronics, etc. Foreign investment brought to the country capital, technology, and managerial skills.

In some sectors like petroleum, electricity, steel, communications and others, the decision was to have state-owned enterprises exclusively. The policy also reserved certain sectors for Brazilian private capital, such as capital goods, pulp and paper, petrochemicals, segments of electronics (communications and mini-computers) and others. In some cases, like petrochemicals, investments were made through joint ventures with foreign capital.

There was additionally the need for a clear policy of technology transfer, with the purpose of absorbing technology in a way that would allow future independent developments. This policy was defined by Act No. 15 of the National Institute of Industrial Property (INPI) and complementary decisions.

During this phase there was a predominance of projects dealing with commodities. Since such products compete basically on price and need few sales services, this was helpful for the success of the strategy. A measure of this success is shown by the fact that today Brazil imports only 6% of its GNP, and that half of this is oil.

By the 1980s, the model of import substitution had become exhausted, but only in 1990 was it replaced by a new policy, the Industrial and Foreign Trade Policy, PICE, which changed the objective of building an industrial basis to that of improving industrial competitiveness. Non-tariff barriers were removed. Targets for tariff reduction were set. A restructuring is taking place, and it is expected that some industries will flourish and that others will vanish. .

The new policy called for a significant reduction in government intervention in the technology transfer process. Act 15 was replaced by Resolution 22 and its annex. The Industrial Property Law is now under revision, among other things in order to include patents for food, chemicals and pharmaceuticals. Other changes in regulatory legislation are underway for the purpose of making more homogeneous the principles of foreign trade: for instance, industrial standards committees are being set up within the MERCOSUR cooperation agreement with Argentina and Uruguay.

## 3. EVOLUTION. FOCUSING OF ACTIVITIES.

(a) In a first phase, until 1983, CODETEC was involved in the development of products and processes resulting from the University's research in Applied Physics and Chemistry, like solar energy flat collectors, electrolysers and products derived from bagasse.

During this time CODETEC worked within the university campus and enjoyed the facilities available, including free space, consultancy by university staff, etc. One of the interesting early results was the generation of half a dozen spin-off companies, in cryogenic vessels, energy applications, computer technology and other areas. CODETEC eventually concentrated in biomass, and carried out large projects that supported independent research teams, pilot plants and other facilities.

(b) In 1985 the government took the decision to develop technological capabilities in the pharmaceutical field, in order to assist the Brazilian pharmaceutical companies, and to lower their dependence on imports. CODETEC was invited to become the National Reference Centre for pharmaceutical active principles. The authorities looked for an institution of a special kind, free from bureaucracy and capable of quick responses. Past experiences with small university research teams had not been satisfactory, because there were too many units involved, showing little or no synergy among researchers.

The negotiation of the contract lasted for over a year. It was necessary to solve a number of problems . The first problem was confidentiality; since it was difficult to maintain this in a university environment, CODETEC solved this by leaving the Campinas University campus. Second, it became necessary to pay much higher salaries than the university to be able to recruit personnel from industry. Third, there was an implicit constraint: CODETEC was required to stay away from other fields and specialize in pharmaceutical active principles.

As a consequence of this decision, CODETEC concentrated in the fields of fine chemicals, natural products and biotechnology. The fine chemicals programme took off in 1984, with the construction of R&D labs and pilot plants adapted for organic synthesis, and the recruiting and training of a capable team.

At that time the consumption of pharmaceuticals in Brazil was rather low, about $ 2 billion a year. If the minimum requirements were to be met, with the population having full access to medicines, a market close to $ 5 billion was estimated. The government was determined that this should be supplied with internal production to the maximum extent.

The goverment supported this strategy through CEME, the National Medical Drug Agency of the Ministry of Health. Since patents for pharmaceuticals were not recognized under the Industrial Property Law, the copy of products was not illegal. The establishement of the National Reference Centre at CODETEC was the starting point of a long range policy of nationalization of pharmaceuticals production, which included R&D, use of patent information, training of personnel, adquisition of non-patented knowhow, etc.

CEME financed selected companies to enable them to hire CODETEC for the performance of R&D in specific products. This included investment in labs and pilot plants that would finally be left in the ownership of CODETEC. Once the products were available, CEME purchased them from the local producers, and distributed them to hospitals and other health services providers.

About 40 to 50% of the total value of a development was financed by the government though CEME, often with a risk sharing clause that waived the debt if the development did not succeed. One half of the projects were related to the official list of basic pharmaceuticals.

Client companies expected CODETEC to provide operational assistance, consulting engineering, and help in equipment procurement and installation. Few of them sought assistance in new product development. Brazilian pharmaceutical firms are followers of the multinational market leaders, and copy what the latter do. It would not be easy for them to support the enormous expenditure of developing and putting in the market a new drug.

During the following years CODETEC developed processes for some 70 pharmaceuticals, of which 14 are now being produced by industry; others will go into production in the near future.

Five multipurpose plants have been established, and three are under construction, using CODETEC's technology. Of a total expenditure in projects of US$ 10.2 million in 1984-91, $ 6 million came from the CEME sponsored projects.

(c) The above model with its "buy Brazilian" approach was abandoned between 1990 and 1992, as the country adopted a new policy of liberalization of the economy. The "buy Brazilian" approach was replaced by standard price-quality purchase criteria.

In August 1990 all of the ten ongoing R&D projects involving CODETEC were cancelled, together with other contracts with CEME for specialized services and technical information. The amount of the unpaid balance - $ 1m, for an annual budget of $ 3m - almost drove CODETEC into bankruptcy.

These events caused policy changes in CODETEC, towards being less dependent on large government contracts. The Institute now tries to maintain a larger number of small consulting and service contracts, as a means to stabilize income.

## 4. PRESENT CHARACTERISTICS OF THE INSTITUTION

The organizational chart of CODETEC is shown in the attached Figure. CODETEC has enjoyed a large degree of autonomy, since by statute the participation of the government, directly or through state firms, cannot be more than 50%, and no shareholder may own more than 25% of the capital. Until 1992 there was an agreement to reinvest all profits, but this is now being revised.

The recent financial difficulties forced CODETEC to adopt emergency measures. The budget for 1992 has suffered an important cut, and the full time scientific staff has been reduced from 130 to 70. There has been a shift in the product mix, towards less R&D and more services. The production of chemical batches, the rental of multipurpose plants, and the provision of services associated with the operation of those plants, provide an income of about $ 50,000 a month. Other services rendered to industries and other organizations represent another $ 100,000 a month. Such performance, achieved by the last quarter of 1992, would be enough to make CODETEC self-sustaining. Profits were reinvested until 1991, but this policy is under revision with the objective of bringing in new partners.

CODETEC preserves a good managerial degree of freedom, since by statute the participation of government in its capital, directly or via state-owned firms, cannot reach 50%, and the participation of any shareholder cannot exceed 25%. This guarantees its private character and preserves it from being controlled by a single individual interest.

CODETEC uses three types of contracts with its clients: cost plus, lump sum, and by results (risk). The typical value of a contract is $ 200 to 300 thousand, although there have been $ 1 million contracts. Cost plus contracts have been preferred, and contracts by results have been used only twice in the past. However, CODETEC is now favouring risk contracts in which it gets paid in equity of the future business.

The company has 70 graduates among its full-time employees, including 6 doctors, 14 masters and 50 bachelors in the fields of chemistry, chemical engineering, pharmacy, micro-biology and other areas. Some of the professionals have industrial experience. The only avenue of participation of employees in the results of CODETEC are the equities taken in the spin-offs by

two foundations, the first one, CODEQUIMICA, established by the orignal founders of CODETEC, with 13.5% of the capital, and a new one currently being organized by the employees.

CODETEC's assets are worth about $ 10 million. It occupies some 2900 square m. of buildings, including 1200 for chemical synthesis labs and 900 for biotechnology labs.

## 5. NEW ORIENTATIONS

The Company new strategies now include the support of a policy of generic pharmaceuticals in Brazil enhanced specialization in Fine Chemicals, diversification of services, expansion of the venture capital activity, accepting new partners, and a reduction of dependence on government programmes.

The Brazilian industrial policy is currently under revision, and it is likely that selected medicines will have to be prescribed and commercialized under the generic name of the main active principles. This will change deeply the profile of the internal market, in which generic drugs now represent only 8% and the government currently purchases 40% of the total market.

It is expected that competition will depend less on brand name and more on quality and price, for which an industrial technology capability is an important factor. This opens oppotunities for chemical firms to diversify into the production of generic pharmaceuticals, as opposed to the previous strategy of having the manufacturers of final pharmaceutical products integrating backwards towards raw material production.

Should this be the case, the strategy adopted by CODETEC of enhancing its specialization on fine chemicals will help it to better meet the demand for R&D and services of fine chemicals industries. Instead of defining its business according to the criterion of the client or that of the market, CODETEC is using the criterion of technology. Now it offers the same technology and services (relating to organic syntheses, multipurpose plant design, technical and economic information on fine chemicals, etc.) to clients other than pharmaceutical labs, and to markets other than the pharmaceutical industry.

At the same time, CODETEC can supply these markets with process development, pilot production, analytical testing, techno-economic feasibility studies, multipurpose plant design, venture capital, assistance in the procurement of equipment, etc.

The liberalization policy will bring new opportunities in the international market. Recently CODETEC has developed a strong presence in MERCOSUR. It is negotiating interchanges with Cuba in the fields of biotechnology and organic syanthesis. The Centre for Pharmaceuticals and Chemicals in that country was partly designed by CODETEC.

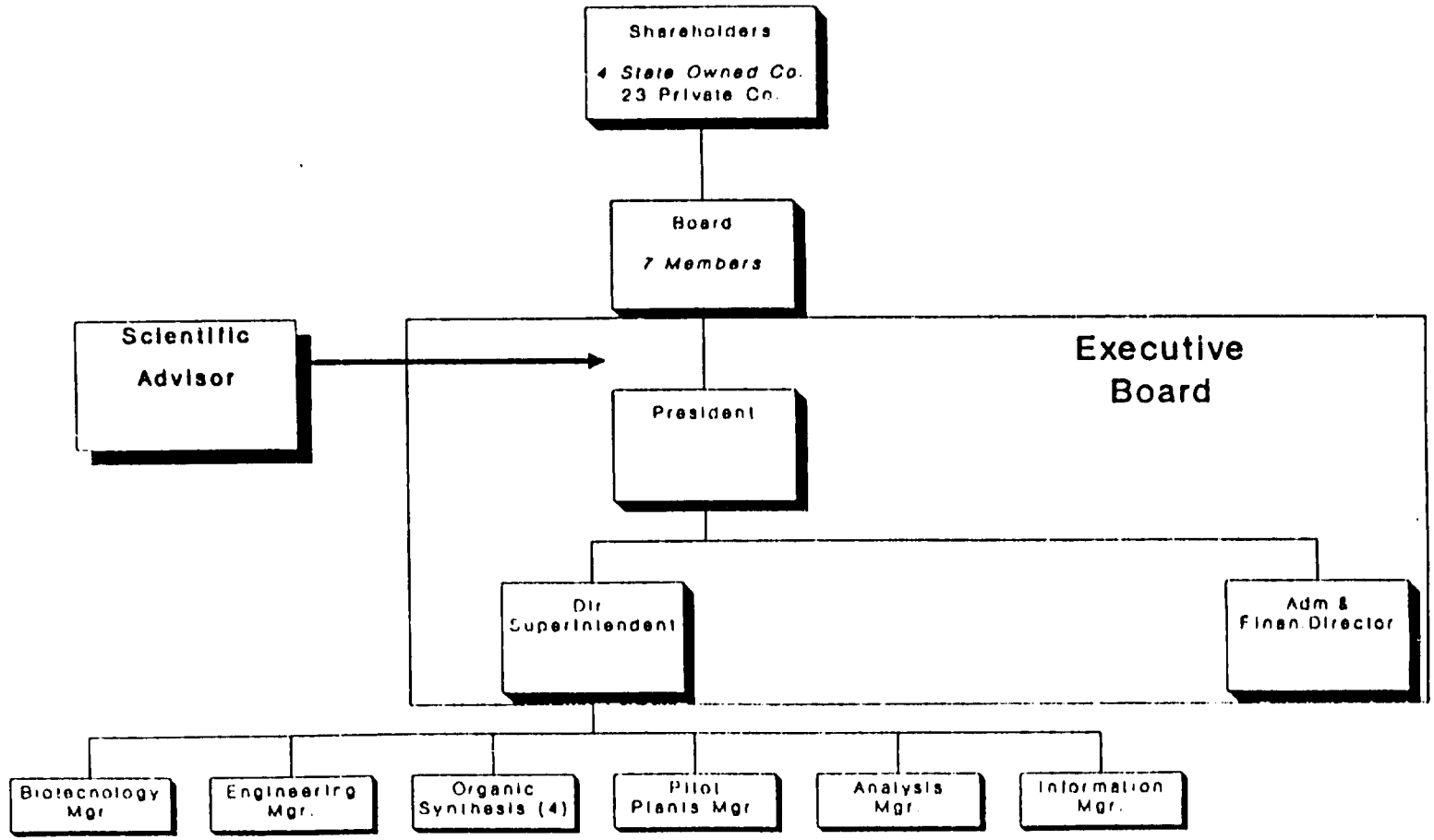
The company also provides technical follow-up services for IDRC projects in countries of Latin America.

Recently a small group of investors in the chemical field have joined CODETEC to enhance the venture capital strategy, with the purpose of promoting joint

ventures in market niches. The new group has brought in an investment of $ 1m and has asked for a revision of the existing shareholders agreement to reinvest profits.

Finally, CODETEC is trying to diversify its clientele to avoid concentrating on contracts with government clients, which have brought about a bitter experience in the past. However, a government fund, PACDT, has recently approved five proposals by CODETEC on which work will start soon.

CODETEC: ORGANIZATION CHART



CASE 3

CHILE: INTEC

*We take up here the case of an ITRI in Chile which has effected a successful transition to the present "liberal" setting. Chile was the first country in Latin America to abandon the import substitution model and open up its economy. This happened ten years ago, and eventually led to a sharp increase in exports and a high and steady rate of economic growth. Adapting to the new model was not easy for INTEC, and the way it was done has interesting teachings for other developing countries.*

*The text below follows closely the case study report prepared by Luis Soto Krebs, "Evaluación del Instituto Tecnológico de Chile", Santiago, January 1993. Mr Soto was one of the original founders of INTEC, and his re-visit 20 years after he had to leave it makes for a deep and heartfelt review of the Institute and the ways in which it has dealt with the challenges and problems it had to face.*

## 1. EVOLUTION

The Technological Institute of Chile, INTEC, was created in 1969 as a multisectoral and multidisciplinary technological institute, within the Corporación de Fomento de la Producción (CORFO), the state development corporation.

Three dynamic professionals were chosen to start the new institution, and the following areas of work were established: electricity and electronics; chemistry, food technology and extractive metallurgy, and mechanics. Other units were an information centre; a unit for techno-economic studies; two pilot plants for metallurgy and food technology, respectively; laboratories for services such as tests, chemical analyses and the construction of electronic equipment, and administration.

By the end of 1970, INTEC had acquired a staff of 80, of which 24 were senior professionals (including 4 PhD's and 4 MSc's) in the substantive areas. It had its own building, and had entered into a number of contracts. Funding was provided by CORFO, though by the end of 1970 some 8% of the operation costs came from contracts with the productive sector.

The objectives of the institution were defined as: (a) to copy, adapt and create technology for industry and extractive metallurgy activities, (b) to develop processes and products, (c) to assist the productive sector in its production problems, and (d) to give advice to CORFO and the government on technology matters.

The principal characteristics of INTEC have been maintained in later years, through successive adaptations to widely different political and economic conditions.

During the first two years of its life, INTEC lived under a democratic, politically centrist regime. Industry enjoyed high protection levels. The government was keen on industrialization and created a number of enterprises that needed technological support. Private industry found it easier and more profitable to lobby for higher prices or further protection than to invest in technological development, though the latter could be atttractive for state enterprises. High national growth was achieved in the mid-sixties but became moderate by the time of INTEC's foundation, despite high prices for copper, the main export. The import substitution scheme was starting to lose force.

In 1970 a new President, Salvador Allende, was elected. A leftist regime came into power, and put emphasis on the country's economic and technological independence. CORFO became a fundamental instrument for central planning and the transformation of the manufacturing sector. A large number of industrial enterprises and banks were taken over or purchased by the government.

As time went on, the economic situation increasingly deteriorated. The money supply increased greatly through emission. By September 1973 the public deficit was equivalent to 55% of the government budget; inflation increased dramatically; production fell. Social tensions became overwhelming, and the country's situation bordered into anarchy. Following a bloody coup, a military Government took over in September 1973.

During the Allende period access to foreign technology became difficult, and the research institutes, particularly INTEC, received preferential attention. As a result, the demand for INTEC's services grew vigorously. New areas of work were added. INTEC absorbed an 80-person group on protein-rich food (mainly using fish for enrichment), and units for low-cost furniture design and management technologies were inaugurated. As a consequence, the Institute's personnel increased to about 300 by the end of 1973. No significant changes took place in the Institute's structure. Hardly any new equipment was added save for that brought along by the Protein group. Almost all the funding came from CORFO. INTEC became an arm of the government, practically losing its contacts with private industry. Because of the violent structural changes suffered by the country, and the climate of near anarchy reigning at that time, the work of INTEC could not have a great impact. But in spite of the upheavals, and of the drop in salaries, an important part of the professional personnel remained in INTEC, keeping its mystique and values.

The military government that came into power in September 1973 adopted a "liberal" economic policy. After a few years of gradualism, which was not really effective, the economy was reoriented radically through a shock therapy and profound structural changes which included reprivatization, the unmaking of the agrarian reform, a gradual lowering of tariffs, the elimination of barriers to imports, periodic adjustments of the rate of exchange, and in general an opening up of the economy. A difficult period ensued, with a high level of unemployment and many enterprises going into bankruptcy. After 1982 imports started to grow, industrial output expanded and the economic activity gradually improved.

Since 1990 Chile is ruled by a democratically elected regime of left-centrist leanings, which has basically retained the liberal economic policy but has

greatly emphasized the social area in order to correct social inequalities that had deepened in the previous years.

In the period 1973-90 an important role was assigned to technology, but the government played a subsidiary role. Contestable funds were created, which had an important role in increasing the competitivity of national production and strengthening the technological infrastructure in productive enterprises and research institutes. However, there was no direct financing for the institutes to work in the medium and long term. This has now been corrected by the new government, which is making funds available for that purpose.

It is in this setting that the adjustment of INTEC took place. Already in the mid-seventies there were intimations from the government to technology institutes that they should come closer to the productive sector and enhance the sale of services to it. By 1982 there was an explicit request to increase self-financing. Annual goals were imposed for this purpose, which in case of non-compliance could eventually lead to the privatization or closing down of the institution. This pushed INTEC into a profound change, in order to adapt to the new rules of an open economy.

As direct transfers from, and contract studies performed for, CORFO were reduced, the pressure to generate income in the short run increased. This brought about a number of effects. A major consequence of the goal of self-financing was the relative increase in service activities, to the detriment of research activities. Services are easier to sell, and allow a rapid increase in earnings. The reduction in salaries, the loss of senior personnel, and the general aversion on the part of enterprises to contract projects for the generation of technology, pushed the institute towards activities closer to routine services.

From this perspective, up to 1990 INTEC was increasingly ceasing to be fully a Technology Institute and was taking up tasks that are typical of a Centre of Technological Services. This trend has been revised as a new government took over.

## 2. INTEC TODAY

### 2.1 The context

Chile's economy has enjoyed during the last few years stability and growth, particularly in the export sector, where the participation of marine, wood and agricultural products has increased strikingly. Industrial production grew at a strong clip in recent years, reaching a rate of 11.8% per annum in 1992; 7.6% is expected in 1993. There are currently discussions regarding a further stage in the growth of the economy, involving the production and export of products technologically more complex and with a higher value added.

The present government has decided to allocate funds directly to technology research institutes so that they may carry out work in medium and long term problems.

It is in this setting that INTEC has carried out its adjustment since 1982, and is now preparing for its future activity.

2.2 Objectives and organization

INTEC continues to have the same objectives as at the time of its foundation, but because of the self-financing imperative it has moved on to tasks that are easier to sell, closer to routine services than to technology generation.

INTEC's structure is shown in the attached Figure. Policies are defined, and their implementation reviewed, by the 8-member Council. Members of the Council are senior government officials plus an important industrialist from the private sector, who is the Council's President. At the executive level there is an Executive Director, and the Directors of the five Departments - three technical departments (Food Technology, Chemistry and Metallurgy, and Other, including pollution control), Planning and Marketing, and Administration. The five Directors make up the Executive Committee, which meets with the Executive Director once a week.

The Institute counts with a well trained and experienced management team. It uses a system of management by objectives, and has a matrix organization, with a structure by projects that cuts across the structure by thematic areas. Projects have more weight at the time of executing contract work, which in the last resort is the lifeline of the Institute. Such a structure has been very important for the success of INTEC. The operational unit is "the Project", with a Project Leader under the supervision of an Area Chief. The project leader is entrusted with full responsibility for the project, and is given the means to carry it through.

2.3 Personnel policies

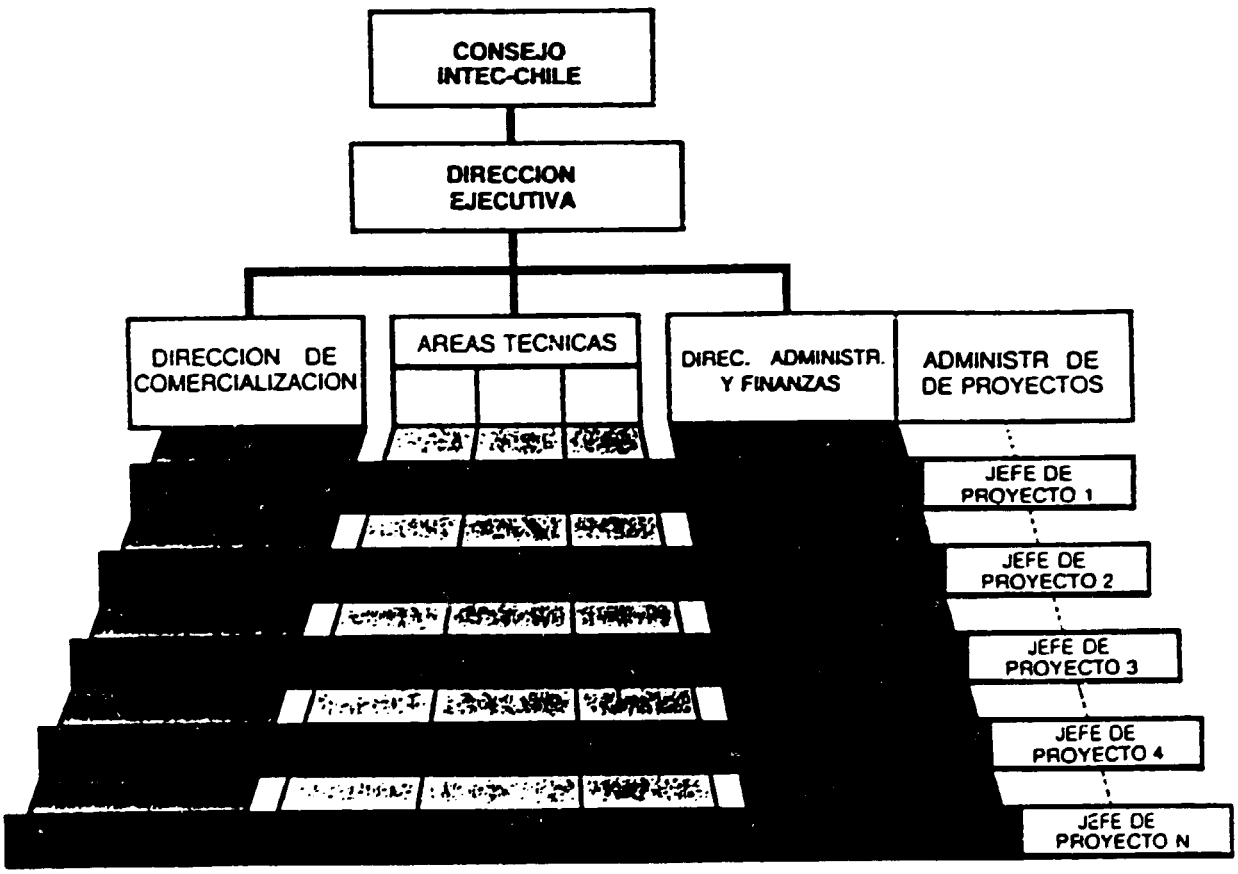
Some of the INTEC personnel is under permanent contract, with all the usual guarantees in public sector personnel, including stability, but their earnings are limited to what is allowed in the public sector. The rest have shorter contracts and are paid fees which may reach 80% above the former level, but their stability is much less. Personnel in both groups are submitted to the same controls and evaluations.

At present INTEC does not have a scheme of incentives for its personnel. Such a scheme was tried at the beginning of the adjustment process, with additional premium payments depending on sales to industry and to non-CORFO government departments, carried out during the three previous months. A person who only did contract work could double his salary. The system was very important in helping to achieve self-financing, but it created serious problems in the medium and long run: services were emphasized, to the detriment of research supported by CORFO funds, and there appeared a privileged group of individuals who only worked on the non-CORFO projects, so that the *esprit de corps* was weakened. On account of these problems, the scheme was discontinued as soon as salaries could be improved and self financing achieved.

2.4 Clientele

INTEC has some 2,000 clients; 150 are habitual ones, and include 4 industrial associations and 80 large enterprises, among which five of the largest in the

STRUCTURE OF INTEC



country. About 90% of the current client enterprises are producing for export. Large enterprises generally ask for projects and not for services; medium enterprises ask for both, and small enterprises only buy services.

INTEC's track record and prestige help it to attract clients, which it searches by different means: its own contacts, contacts of Board members, courses for managers, periodic invitations to industrialists to visit the Institute and participate in meetings, presentations, visits to enterprises by senior personnel, and the creation of "sponsoring committees" with entrepreneurs from branches where INTEC is active. This work is coordinated by the Department of Marketing and Planning.

INTEC has the strategy of educating its customers so that they may become permanent clients, on understanding that technological development is a continuous process.

The change in the Chilean economic model did not modify the behaviour patterns of entrepreneurs for several years. A double standard was evident: the entrepreneurs asked the state not to interfere in the workings of the private sector, but demanded from it assistance and subsidies every time protection was removed and they were exposed to the market. As liberalization increased, many enterprises disappeared, not having understood that competition means, among other things, the need to remain up to date in soft and hard technologies. This process of cultural change in industry followed the typical "S" curve of learning processes. It is only during the last two years that INTEC is experiencing a higher demand from clients that find it can help them to compete in their home and foreign markets.

2.5 Funding

INTEC has four main sources of funds: the sale of projects and services to the productive sector; sales to the state sector, including CORFO, various Ministries, the Armed Forces, and several agencies; direct transfers from CORFO, and bilateral and multilateral technical cooperation.

Income from sales grew after 1982 and the Institute achieved 100% self-financing in the years 1988 and 1989 (this includes the income from studies contracted by CORFO). After that time, income from sales stabilized as INTEC reached full capacity, but CORFO's direct transfers increased to allow the physical expansion of the Institute, which is currently adding 400 sq. m. to its built installations. Total income was US $2.5m in 1988, $2.9m in 1991 and $4m in 1992.

The sales of INTEC are currently distributed in the following way: studies 13%, creative projects 36%, routine projects 36%, and services 15%. The Institute wants in the future to increase the share of creative projects and lower that of routine projects.

2.6 Current trends

The structure of the Institute remained almost the same until the end of 1992. At that time a strategic planning exercise was carried out, analyzing the strengths and weaknesses of INTEC and defining four priority areas. As a

result, INTEC is now being restructured, including the removal of certain legal rigidities to make it more flexible.

The Planning and Marketing Department, created in 1974, has had an important role in guiding the Institute towards self-financing, finding windows of opportunity, analyzing outside demand, training technical personnel and management in marketing and administration techniques, helping sales and negotiation efforts, and carrying out a diffusion programme. This Department also is in charge of planning, and organized the strategic planning exercise to which we have referred above.

In 1973 INTEC counted with 300 persons. This went down by about 50 after the government changed. Some left for philosophical reasons in view of the change in the rules of the game that meant a shift to demand-pull work. Others were asked to resign since the new authorities considered them activists.

At present INTEC has a staff of 215, of which 157 are professionals and technicians. Additionally the Institute employs external consultants, about 60 to 80 a year, and generates work for personnel in national external groups, in tasks like detailed engineering, that complete the chain for incorporation of the technology into the productive sector.

There was a significant loss in 1986-87, when 13 out of 30 senior professionals left the Institute at a time when remunerations hit their lowest point. This was a grave blow to INTEC, not only for the loss of senior personnel who are the life of an institution of this nature, but also for the loss in clients which in some cases followed a professional to his new institution. After 1990, with a higher support from government, it was possible to improve salaries and hire more people. Because of low salaries the replacements were done with professionals recently graduated or with little experience.This had two consequences. First, the young people tend to consider INTEC as a place to learn before going elsewhere. Secondly, the "INTEC School" has suffered, and its *esprit de corps* is somewhat affected.

To correct such a situation the new management of INTEC has been able to obtain funds that will allow an increase in salaries, and has decided to incorporate well known professionals to fortify once more the "INTEC School".

In any case, INTEC still has a good professional staff and a high reputation that enables it to enjoy sufficient demand in most areas. In fact, INTEC has today more demand than it can accept in most of the areas it attends. The areas with insufficient demand are being eliminated, and the personnel retrained to work in different areas. At the same time, the strategic planning exercise has shown that there are priority areas with unsatisfied demand. The Institute is preparing itself to attend them, using the personnel from the areas to be closed down.

INTEC has been able so far to respond to demands, but it has reached the limit of its capabilities. In order to continue having success, it is now starting to expand in personnel, equipment and floor space.

## 3. TRANSITIONS AND ADAPTATIONS

INTEC has lived under a variety of political and economic regimes. It has shown much flexibility throughout these changes, and has now been able to restructure and adapt successfully to a liberal economic regime with open markets.

The author finds that this success is due to a number of causes:

- INTEC adopted from the beginning certain positive characteristics that have persisted: creativity and mental aggressiveness; mystique and *esprit de corps*; organization of work by projects; a continuous search for self-financing; an explicit purpose of giving service to the user. The way in which an institute is born, how it is originally structured, what procedures it adopts and persistently follows, can be important factors in its later success.

- INTEC was able to constitute and retain a high quality professional staff.

- INTEC made a good choice of the areas and technologies where it would perform, later making anticipatory changes when needed, and training its personnel with care.

- The team that led the transition knew well the institute and enjoyed the trust of the staff.

- This team also had clear indications from the political levels about new policy orientations, and enjoyed their strong support to carry out the transformation.

- It used adequate instruments for this purpose like:

  - a serious effort in planning and marketing, for which a special unit was formed. This group identified opportunities and designed a programme to approach industry and sell to it. All senior staff were given training in marketing;

  - a strict scheme of management by objectives and the search for efficiency and impact. More recently, total quality management is being introduced at all levels;

  - excellence in the provision of services;

  - an effective incentive system.

In order to help bring about INTEC's transformation, the government defined strict annual goals for the generation of revenue. The institute was able to achieve total self-financing after a six-year period.

In seeking to achieve this goal the personnel of INTEC underwent strong "cultural changes", that were positive and fundamental but at the same time involved costs for the institution. Such costs should be taken into account when planning transitions of this nature.

The drive towards self-financing meant:

- the concentration on activities closer to routine technological services, to the detriment of more creative and long term work, which is the essence of an ITRI;

- a drop in salaries leading to the loss of some personnel, especially within the senior staff, which is the backbone of an institute;

- a loss of human capital as less resources were available for training or for hiring high level people;

- postponing the purchase of equipment for laboratory, pilot plant and data processing, so that the Institute became somewhat outdated.

Once INTEC got adapted to the new conditions, the liberal economic policy became a positive factor for the increase of demand and for the Institute's growth. The liberal policy has brought about a boom in exports, and at present some 90% of INTEC's clients are engaged in production for export as their main activity. The transition from producing for a protected internal market to producing for a competitive international market has induced enterprises to look for soft and hard technologies as one of the most important sources of competitivity. This is contrary to what used to happen in a protected, closed economy, when enterprises found it more profitable to lobby the government for protection, price raises or the closing of imports.

The reaction of the demand has not been immediate; there was a lag while entrepreneurs got used to the new situation and made adjustments in their firms and their markets. This delay meant that the Institute had to continue relying on the state for assistance to ensure its survival while it adjusted to the new circumstances; at the same time the state forced it to change, become efficient, sell its capabilities, and create a ready markets for its products.

## 4. SOME FINAL REFLECTIONS

The experience of INTEC, and its succesful response to the challenges of changing economic conditions and policy environments, has prompted the author to some reflections that may find application in the case of other ITRIs.

(a) ITRIs should not look for complete self-financing. They should count with resources that allow them to peer into the future, prepare for it, and encourage the creativity of their staff. This would need a level of funding of some 30 to 40% of total funds. The present government has understood this and has given INTEC adequate funds for those purposes.

(b) In any case, it is important that such funds be applied to very precise goals and used through a project system with all the strictness which is usual in a project contracted with a productive firm.

(c) Because of the dynamism of changes in the world markets and technology, institutes to be created or transformed should enjoy flexibility. This means that they should have

- the capacity and the structures needed to forecast technological, industrial, market and economic trends in order to identify sufficiently ahead of time the "windows" for which it may prepare;

- a personnel structure that includes a stable senior team of very high quality, capable of looking into different areas of knowledge. At the same time they should have the organizational and legal capability of putting together and disbanding teams to face specific tasks; it should be possible to incorporate and dismiss with ease local and foreign personnel.

(d) In ITRIs of the 1990s and the next century the central core, more permanent, should not be more than 40% of the total project personnel.

(e) ITRIs should work both with hard and soft technologies, in contrast with times past when they concentrated exclusively on the former.

(f) In the new economic environment, it becomes necessary to re-educate entrepreneurs to compete in an open market using a variety of tools, in particular technology. The government should explicitly help in this regard, mainly through diffusion and training programmes. The institute has an important role to play here.

CASE 4

## ARGENTINA: NEW OUTLOOK FOR CIMM

*CIMM is a relatively small public sector ITRI in Argentina, founded in 1963, which has been able to make only limited progress, despite stability of its management and strenous efforts to serve local industrial firms. The author of the case study, with a lengthy experience of his own in building up and managing successfully an applied research institute (INVAP, which he created and led for twenty years), has made a careful analysis of CIMM and has set forth a number of suggestions for restructuring and revitalizing it under the new policy environment the country has recently adopted. The following text summarizes the main points of the paper but falls short of doing full justice to the wealth of information and the rich analysis presented by the author (C. Varotto, "Hacia un nuevo rol para los Institutos de Tecnologia Industrial en los paises en desarrollo: Estudio del Centro de Investigación de Materiales y Metrologia", Buenos Aires, January 1993).*

### 1. INTRODUCTION

The Centro de Investigación de Materiales y Metrología, CIMM (Centre of Research on Materials and Metrology), was felt to be an interesting case to study, for two main reasons. First, it has enjoyed a high degree of stability (only three directors in 29 years, the last one since 1972), is linked with the local industry, the University and the government of Córdoba Province, where it is located, and has made many efforts to build up a clientele and supply it with the research and services needed by it. Second, CIMM is a part of the system of research centres of the National Institute of Industrial Technology, INTI, and as such it faces the limitations of a public sector institution.

The reasoning that led to the choice was to see how well can an ITRI fare within the limitatons of the public sector when it enjoys reasonably favourable conditions - stability, good links, a steady though not too generous funding from the state, and the possibility of largely deciding what activities it will undertake.

Unfortunately, the answer in this case is that the Institute has not done well enough so far.

What can be done to increase the effectiveness of this particular ITRI? How can it adapt, prosper and assist industry under the new policy environment that has now come into being? The author, in close cooperation with the senior staff of CIMM, has been able to develop a number of suggestions, which are now under discussion with the authorities of INTI.

### 2. CHANGES IN THE POLICY ENVIRONMENT

Import substitution industrialization in Argentina had its roots in the industrial efforts made at the time of World War II, which were continued

thereafter through a series of measures, such as nationalization of transport and public services, the protection of industry, a strong support for the development of heavy industry, programmes to promote industry in the country's interior, the regulation of foreign investment and of technology imports, the support for R&D (though with many ups and downs), the creation of technical schools and since the 1960s the creation of many public and private universities.

During this period the country achieved a considerable degree of industrialization, but it also showed chronic inflation, bordering into hyperinflation in the mid 1970s and again in the late 1980s, when growth rates became negligible.

Beginning in 1990 the country changed the course of its economic policy, and adopted a number of liberalization measures. The economy was opened up, market forces were increasingly relied upon, and a process was started for privatizing state enterprises. At the same time the MERCOSUR agreement was signed with Brazil and Uruguay for the development of a common market among the countries in the South of the continent.

The results of this new policy have been very positive. Inflation has come down sharply, growth rates have increased to 8-9% per annum in 1991-92, and unemployment has declned.

The new policy does not consider that the technological development of industry should necesarily rely on the direct support of the state. CIMM and the other Centres of the INTI system will have to look for ways to provide industry with the technological inputs it requires in the changed situation, and to assure their own permanence in a new setting in which they can no longer count with the state's largesse.

## 3. EVOLUTION

CIMM was founded in 1963 as the Centre of Metallurgical Research, within the system of research centres of the National Institute of Industrial Technology, INTI. The name changed to Centre of Materials Research in the early 1970s, and Metrology was added to it in 1982, when CIMM absorbed another INTI Centre, on Metrological Research and Services.

INTI is a complex institution which counts with a central administration, a group of Central Laboratories by disciplines (Chemistry, Physics, Food Technology, Electronics, etc.), and more than twenty largely autonomous Research Centres attending industrial branches (Fruits and Vegetables, Plastics, Pulp and Paper, Leather, Meat, Machine Tools, etc.), which have been set up by agreement with industry, universities and local governments. The Centres are funded by contributions made by INTI (the main source) and their other sponsors, as well as by the sale of services. In theory the Centres have a great deal of autonomy, but in practice they operate as public sector institutions.

At the time of CIMM's foundation, the city of Cordoba, capital of the province of the same name, was becoming the main concentration of metal-mechanic (engineering) industries in Argentina.

The original sponsors of CIMM were INTI and the Facultad de Ciencias Exactas, Fisicas y Naturales (equivalent to a School of Engineering) of Córdoba National University. A year later an important automobile producer, Industrias Kaiser Argentina, joined the sponsors, but left in 1974. In 1969 the government of Córdoba Province joined as a sponsor, and also brought into the Board a representative of the Chamber of Metallurgical Industry of Cordoba.

Originally, the basic objective behind the creation of CIMM was to link up the National University of Córdoba with the productive sector of its zone of influence. The contribution of the Centre to import substitution industrialization was an objective which was implicit in its cooperation with a strongly protected industry.

In the end, the University's insertion in the productive milieu was not achieved, and everything seems to indicate that this outcome was not the fault of CIMM. The University helped CIMM at the outset in developing its scientific research capabilities, but not its practical activities related to industry. It gradually became disengaged from the activities of CIMM. On the other hand, a part of the entrepreneurial world regarded CIMM as a university institution. This did not help CIMM in fuctioning as the link between university and enterprise, or to show that the role of the technologist is very different from that of the scientist or the entrepreneur.

Four stages can be identified in the evolution of CIMM:

(i) 1963-1970: formation of the infrastructure, creation of working groups with young people from industry.

(ii) 1970-87: constitution of R&D groups to work in the iron and steel sector (this turned out to be too ambitious a goal), and in the extractive metallurgy sector, which did not evolve as strongly as expected. At the same time CIMM developed and consolidated its short-term service activities for a wide spectrum of users. The latter activities accounted for the greater part of sales. R&D work did not have industry support in the majority of cases; it was principally funded by institutional money, and to a small degree by funds obtained from the National Research Council and the Córdoba Reearch Council. A marked separation appeared between groups performing R&D and groups in charge of services, leading to a conflictual situation on account of the different characteristics of the activities, which made interaction very difficult.

(iii) In order to set things right, the Centre's structure was modified in 1987, and the three activities of testing, technical assistance and technological development were made to coexist within each Department.

(iv) Since early 1992 CIMM is looking at new possibilites of organization, in line with the conditions now obtaining in the county.

## 4. STRUCTURE

CIMM has an Executive Commitee made up of one representative from each of the sponsors: INTI, Cordoba National University, the Ministry of Industry of

the Province of Cordoba, and the Chamber of Metallurgical Industry of Cordoba.

CIMM is led by a Director and his deputy, under which there are five departments: Machinery and Equipment (with sections on mechanics and electronics), Metallurgy (testing, metallography and corrosion, non-destructive testing), Materials (chemistry, magnetic and ceramic materials, processes), Quality and Metrology (quality asurance and certification, metrology), and Commercialization (technical information, marketing).

CIMM defines its present objectives as follows:

- To serve industry through technological developments, technical assistance in problems requiring interdisciplinarity, and the guaranteed measurement of quality attributes.

- To put and maintain industry in a "state of calibration" and contribute to develop and improve national metrology.

The Centre has enjoyed great continuity in its management, which allowed it to adapt to the changing events and circumstances experienced in Argentina during the last 30 years.

On management questions CIMM faces strong limitations on account of the restrictions inherent to the public sector. One of the major problems is the inability to offer competitive salary levels to its scientific staff. This is a key point in the institution's search for effectiveness and permanence.

INTI carries out a *de facto* annual evaluation of CIMM through the process of approval of the budget, but there is not a formal methodology for evaluation. Internally, management makes an annual evaluation of each project and of each staff member. However, since it is not possible to give premiums or to significantly improve salaries, this means that in practice personnel evaluation loses its meaning.

CIMM has recently put much effort in developing its formerly weak commercial capabilities. Efforts to have the Centre's own technical personnel carry out commercial functions have not been successful. At present this personnel acts in an advisory role to the people in the marketing group.

## 5. ACTIVITIES

CIMM orients most of its work to the metal-mechanic industry. Its activities fall into the following categories:

(a) Activities directly related to the industrial sector. These comprise

i) Testing, analyses and other short-term services, typically needing only a few days, which CIMM would prefer enterprises to do by themselves;

ii) Technical assistance, needing 2-3 months, for subjects such as fault analysis and process problems;

iii) Research and Development projects, needing considerably more staff and time (up to 2-3 years) than the previous activities.

(b) R&D activities of a strategic nature, addressed at future needs of enterprises as identified by the Centre. Three main fields are covered:

i) Materials, comprising metallic materials and industrial ceramics. Examples: filters for alloys, $UO_2$ sintering.

ii) Metal-mechanics, electronics and electric sectors. Examples are the design of parts, development of equipment, control of processes.

iii) Non-conventional materials, such as magnetic materials.

(c) Training for industry personnel on metallurgy, non-destructive testing, metrology and quality. The courses last 20 to 45 hours each. A total of about 1700 persons have been trained so far.

(d) Qualifying and certifying of operators of non-destructive tests (some 300 instances) and welders (some 150 instances).

(e) Documentation. Through its library and its links to other specialized reference centres, CIMM provides a very complete documentation service for industry.

During the last decade INTI has placed a strong pressure on its Centres to increase the share of income from sales within their total budget. This has led CIMM to concentrate in activities of type (a) with a strong decrease in those of type (b).

Under the import substitution policy subsisting until 1990, firms did not have incentives to improve quality, create new products and compete in the international market. CIMM did not receive clear indications from industry about the areas where it should apply its best efforts. As a result, there have been many cases of projects which have been discontinued in order to start other projects which were expected to obtain a solid support from industry.

## 6. RESOURCES

(a) Human Resources

CIMM has a stable staff of some 60 persons, of which more than one half are professionals. The level of salaries for experienced professionals at CIMM is much below the levels of private industry, by a factor of 2 in technical and 3-5 in management activities. CIMM counts additionally with 14 last-year students and recent graduates of technical careers, who work as interns with one-year scholarships. This category has become the way to incorporate new people into the Centre, since there is no possibility of offering high enough salaries to atract more senior people. As a result there is a strong gap in seniority and in experience between both groups, old time professionals and recent recruits.

Financial constraints, conflicts between R&D and service activities, and lack of clear guidance from industry regarding fields of concentration, are

circumstances that have conditioned the Centre's policy towards the training of its staff. CIMM did not develop a clear training policy for its personnel, which in general have acquired their knowledge and experience through training on the job, plus short courses in national institutions and in a few cases training overseas. CIMM has generally not been able to retain staff that received foreign training. Of the 12 persons that undertook overseas training for periods of more than six months, only three are still at CIMM.

(b) Equipment

CIMM counts with good facilities and equipment, contributed by INTI and the University, for a wide range of technical activities. . It will be receiving shortly some specialized equipment for its magnetic materials laboratory, through a contribution from the German cooperation agency, GTZ.

(c) Finances

The 1992 budget of CIMM was US$ 1.2 million, of which 70% came from INTI and 30% from the sales of services. About 70% of that amount went to salaries, 8% to investment and 22% to other items.

Support from the University has been in kind, through the use of buildings and maintenance personnel. This has now ceased, since the Centre moved to new quarters at the end of 1992.

The majority of CIMM's services are strongly subsidized: they account for 80% of expenditure but only return 30% of resources.

The income from sales cannot be applied to the payment of salaries, but may be use to hire the services of outside experts.

## 7. CLIENTELE

CIMM has interacted with 900 enterprises, 10% of them in a stable manner, during its 30 years of life . The number of R&D clients has been 17, three of them large state firms, one a large private firm and the rest SMEs.

Although the services to industry are strongly subsidized, industry has not been keen in making spontaneous use of CIMM. The reasons for this are several: the background of many entrepreneurs who have progressed through trial-and-error, and find it difficult to trust outsiders; the fact that many of the local enterprises manufacture products for a market which is not too demanding; the inclination of enterprise professionals to solve things by themselves (which the author thinks shortsighted); the thought that a competitor may also ask CIMM to solve the same problem; the unfavourable image that prospective new clients have of CIMM as a state organization, with the label of slow, non-confidential and expensive ("since we pay taxes, the services should be free"), or as a university-related institution where students will be put to do the work.

## 8. OUTSIDE RELATIONS

The author has surveyed the relations of CIMM with other institutions. Some of the more interesting aspects are:

- There is a very close relationship with INTI, since CIMM is part of the system of centres and receives from INTI 70% of its budget. In spite of this, the operative autonomy of CIMM is surprisingly high.

- CIMM is interacting with Córdoba National University in a few areas. It provides facilities to graduate students of the Doctorate in Engineering for carrying out their thesis work. It is asking the new Business School to train its staff in marketing, and to help convince entrepreneurs that it is in their interest to work with CIMM. A recent development is the beginning of cooperation with the Faculty of Mathematics, Physics and Astronomy for research on boron steels and magnetic materials.

- The government of Córdoba Province interacts with CIMM through its Departments of Industry and of Science and Technology. A clear position regarding CIMM has been put forth, recognizing that CIMM suffers from the lack of an explicit industrial development policy at the national level, that it will be privatized at some moment, that it should improve its relations with the University, and that it should concentrate its resources in a limited number of areas, particularly in supporting the development of the dairy, agricultural machinery and fine chemicals branches, and in the field of quality.

- The Chamber of Metallurgical Industry has a weak relationship with CIMM, even though it has a representative in the Executive Committee. In the past it has not had any participation in the choice of areas of work for CIMM, reflecting the little use industry has had of the Centre except as a provider of routine services. However, with the change in economic policy, there has been a change of mind in the Chamber's associates. The Chamber now envisages the need for support to its SME associates in the following aspects: improvements in the organization of firms, total quality, advice on the choice of technology and equipment, and on the need to update them, and advice on issues of productivity and competitiveness.

- The connection with the national system of innovation takes place through interactions with Córdoba National University and with INTI.

- Interactions with foreign agencies took place in the past through the participation of CIMM in two internationally funded projects: Non-Destructive Testing (funded by UNIDO) and the Multinational Programme of Metallurgy (funded by the Organization of American States). At present CIMM is negotiating two technical cooperation projects, one with the German agency GTZ for support of a laboratory of magnetic materials, and the other with the Japanese agency JICA on design, simulation and automation of manufacturing processes for the metal-mechanic industry.

## 9. FACING THE NEW SITUATION.

We have already referred to the new economic and industrial policies adopted by the country in 1990. Their impact on CIMM is taking place directly through

the need to improve the Centre's financial basis, and indirectly through an expanded and somewhat different set of immediate demands and long term requirements from industry.

CIMM is facing the new situation through two well defined actions: (i) making its marketing function more professional, and (ii) searching for areas where industry is bound to require CIMM's services in the future.

The search for new areas of activity is being made by trying to answer the basic question: where are the enterprises heading on account of the drastic change in the industrial policy, and how should they - or better, how would they like to - be accompanied by CIMM.

The author believes that the answers to questions of this nature should be framed within an overarching objective: the "permanence" of CIMM as an organization promoting industrial development in the framework of a fundamental change in economic policy. It should be remarked that the author uses the Spanish term "perdurabilidad", which we have imperfectly translated as "permanence", and contrasts it with a situation in which the institution barely vegetates, carrying out a passive existence, without contributing much to industrial development.

The author feels that the efforts now being made by CIMM to face the new situation show great merit, and that it would not be easy to come up with other types of effort that could be carried out, given the present institutional situation and the limitations faced by CIMM. However, in spite of such efforts, the future under those conditions is to vegetate rather than to achieve permanence. A different approach is required for CIMM that will allow it to escape the present strictures.

In preparing his suggestions, the author interviewed CIMM managers and staff, as well as different actors, related to the local industrial scene, in business, government, university and science circles. He was also able to use the results of studies recently carried out on the Córdoba industrial sector, which have addressed issues of industrial competitivity, support for small and medium industry and total quality control.

Some of his observations follow:

(a) *Clients*. The new policy of privatization will mean the disappearance of public enterprises, which have been important clients of CIMM, and were supplied by it with complex services, including R&D. The clientele in the future will principally consist of small and medium enterprises, which at present tend to demand simple and routine services.

(b) *Services*. (i) CIMM should keep on supplying systematized (standardized) services in fields where it is capable of being a leader on account of the skills of its staff and the quality of its equipment. It should take care that sufficient funds are generated, so that it may be enabled to carry out other activities involving more risk. (ii) Regarding routine services, CIMM should help enterprises to perform these services by themselves. (iii) On technological development and other technical asistance services of a certain degree of complexity, it will not be easy to surmount the passivity that enterprises have

shown so far, but as the need is increasingly felt to improve competitiveness, the market is bound to grow.

c) *Entrepreneurial attitudes.* The author analyzes for different types of enterprises their likelihood of becoming clients for complex services of CIMM. Those that are more prone to do so are: (i) innovative enterprises devoted to the internal market, which are a minority; an interesting precedent is the R&D work on magnetic materials carried out for one such firm in recent years, although the results have not yet been applied because of lack of funding for the experimental development and basic engineering stages; (ii) innovative enterprises in the area of capital goods, which have found a market niche; (iii) potential technology-based enterprises, which would make up one of the most promising fields for CIMM; (iv) enterprises that sell in both the internal and the foreign market. The preceding would be the types of enterprises better prepared to use CIMM's services, principally homologation tests, and developments which are complementary to advances made by the firm or originating from the outside.

d) *The influence of MERCOSUR.* The current salary differential between Brazil and Argentina is a disadvantage for the latter country, and the relatively higher costs can only be compensated with a higher degree of automation. This necessitates the replacement of certain pieces of equipment and the upgrading of others. An interesting field of action opens for CIMM in this regard.

e) *The new realities for the services rendered by CIMM.* The author feels that CIMM will face much competition in metrology, chemical analyses and non-destructive testing services, while it has good market possibilities - if it keeps a technological lead - in the areas of materials, metallurgy, corrosion, magnetic measurements, development of magnetic materials, and implementation of quality assessment and total quality programmes. Automation and the treatment of industrial wastes are promising fields of work if CIMM develops a capability in them, or joins up with institutions that have it.

f) *Analysis of some parameters of CIMM.* A quick analysis of budgetary and sales figures shows that (i) CIMM has an operating annual loss of $ 870,000, which is currently made up by INTI's contribution; (ii) per capita expenses are as low as is possible for an organization of CIMM's calibre (and are even lower if the scholarship holders are considered), and a further significant reduction does not seem possible; (iii) the metal mechanics sector firms are not the predominant client group.

g) *CIMM and the criteria of permanence.* The question here is how can CIMM achieve permanence as an organization devoted to technical assistance and the development of industrial technology, within the setting of a fully open economy and a non-interventionist state. The author presents several "permanence criteria": (i) an adequate organization; this needs an appropriate "institutional memory", which requires a sense of belonging, which in its turn needs clear professional objectives and a proper remuneration; it also needs an adequate renewal of personnel, requiring that the institution should have a free hand in hiring people. CIMM fails in these aspects; (ii) the capability of anticipating change and adapting to it, which CIMM is now developing; (iii) a specific area of activity where products and services with economic value may be provided; here CIMM is making efforts

but clients are not easy to come by; (iv) the purpose of bringing about change, a feature which is present in CIMM; (v) very crucially, the avoidance of operating losess, and ideally the making of a profit; CIMM is still far from this desirable situation.

The author concludes that under the present circumstances CIMM does not satisfy the permanence criteria, and that a radical change is needed.

## 10. SUGGESTIONS FOR RESTRUCTURING

### 10.1 The proposal

On the basis of the preceding analysis, the author presents a basic proposal for the restructuring of CIMM, which starts from the hypothesis that the new economic policy will question the present system of technical assistance to industry, and will inevitably require it to be self-financing.

The author explores the possibility that CIMM should concentrate on extension activities, but thinks that this would not be economically feasible for CIMM on its own, on account of the characteristics of the Centre and of the local industry, which is used to cheap subsidized services.

The author suggests that a viable alternative for CIMM, allowing it to achieve permanence and usefulness for industrial development, is *to transform it into an enterprise*, with two well defined activities:

a) *Provision of services*, which would include

i) *Tests of specified, normalized types*. CIMM should only provide services that can be sold at full cost plus a profit.

ii) *Quality-related services*. Here it is proposed that CIMM, rather than staying in an advisory role, should try to implement a policy of shared risks. The compensation of CIMM would be on the basis of results, such as a percentage on the savings achieved through the improvement of production or the lowering of rejects.

iii) *Automation-related services*. CIMM does not yet have sufficient capacity in this area. The author suggests that CIMM should expand its capabilities by becoming associated with an organization that may complement the design capacity and the existing equipment of the Centre. This could be INVAP, with which CIMM has subsequently had talks promoted by the author.

iv) *Services in the area of industrial waste*. This case is similar to the previous one, and a similar solution is suggested. CIMM has the advantage of having a very good knowledge of most of the enterprises in its zone of influence, in metal-mechanics and other branches. An important aspect here is the recuperation of valuables from the wastes.

b) *Creation of technology-based enterprises*. (i)The proposal is not that CIMM should become a "technology enterprise", or a technology-based enterprise by itself. Rather, *the product should be technology-based enterprises*. The Centre

should develop technology for products and services of very high value added , around which an enterprise would be created. CIMM would participate in the risks. Once the business has been shown to be viable, it may be sold and a new enterprise created. (ii) Practical implementation of this suggestion depends on the detection of high value added opportunities. One of them, in which the technology has already been mastered by CIMM, is the set of special materials it has developed in past years. (iii) Enterprises with an innovative mind could accept CIMM knowhow as equity, and this would be a quick way to exploit the knowhow. (iv) The weakness of this proposal is that access to credit is difficult nowadays in Argentina. It is to be hoped that risk investors will appear, particularly from overseas, as the economy becomes stable and strong.

10.2 Implementation of the proposal

The transformation of CIMM into a private enterprise would require it to leave the INTI system and become a corporation ("sociedad anónima"). The shareholders could include INTI and the CIMM personel.

Some of the transitional measures could be the following:

The equipment bought with INTI contributions would be sold in installments to CIMM, at current values less depreciation. Equipment originally provided by the University would be partly paid back with services, such as hosting doctoral candidates. The building may be rented to CIMM for a lengthy period.

The staff would be given the option of voluntary retirement, with the corresponding compensation paid by INTI, or of staying in CIMM under new contractual conditions, with a bonus of 50% of what would have corresponded in the previous case. People unwilling to accept any of the above alternatives would be retained by INTI.

INTI would make a loan to CIMM of a sum equal to the 1992 budget. There would be a 10-year grace period and a 5-year repayment period after that.

Finally, CIMM should concentrate its work and its resources, and would need to change periodically its main lines of work as it seeks to create new enterprises. From the organizational point of view, the divisional structure of CIMM is adequate in regard to the goal of increasing the capacity to interact with industry, but it should evolve towards a more matrix-like structure if CIMM is to concentrate its efforts as required by the restructuring proposal.

CASE 5

## CENTRAL AMERICA: ICAITI, A REGIONAL ITRI

*This case shows an ITRI with the status of a subregional institution, conceived to serve the industrialization process of the five Central American countries, which 30 years ago agreed to form a Common Market. The characteristics of Central American industry - small scale, technologically backward, oriented towards the local markets, demanding relatively simple services and hardly able to pay for them - have not made life easy for ICAITI, which has relied to a large extent on foreign and international cooperation to build up its capabilities and carry out research and other activities for its member countries. At present ICAITI has to find ways to improve its human, physical and financial resources, its efficiency, and its links to industry. (Fernando Machado "El Instituto Centroamericano de Investigación y Tecnología Industrial, ICAITI", San José, Costa Rica, February 1993).*

### 1. THE CONTEXT

#### 1.1 Economic setting

Thirty years ago the countries of Central America (Guatemala, El Salvador, Honduras, Nicaragua and Costa Rica) decided to join efforts and form a Common Market, with free trade of goods and services within the region and a common tariff system to help their industrialization. Results were very positive during the first ten years, during which economic and particularly industrial activity grew fast. After 1970 the growth rate declined, and in the 1980's a number of problems set in - unbalance of commerce, debts outstanding among the countries, high inflation, large foreign debt, unemployment, economic recession, and armed conflict between Nicaragua and El Salvador. These problems led to a reduction of commercial exchanges.

A new common tariff structure was adopted in 1985, with lower protection levels and more flexibility. However, in 1987 Costa Rica unilaterally adopted a policy to lower its tariffs over a number of years. More recently, all of the countries have started programmes of structural adjustment, that have accelerated the introduction of independent national policies for lowering tariffs, eliminating price distortions (subsidies and price controls), reducing the fiscal deficit and curtailing the participation of the public sector in the economy. On applying these policies, the five governments decided to adopt a maximum common tariff of 20%, starting in 1992/93, a clear indication of the trade liberalization process which is taking place in all of the countries in the region.

1.2 Industry

Industry in the region grew at an annual rate of 8.4% between 1960 and 1970, and its participation in GDP went up from 12% to 21%. This increase mostly went to local and regional markets. In the 1970s growth rate declined, as we have indicated above, and manufactured exports to third countries -mainly food products - decreased sharply.

It is estimated that there are about 15,000 manufacturing enterprises in the region, with 300,000 employees. Food industries are predominant, with 42 to 66% (according to the country) of the total manufacturing value added, followed by chemical and rubber products, with 8 to 20 %. Most of the companies are small; 80 to 90% employ 20 persons or less. Estimates of the rate of utilization of installed capacity in the region are between 20 and 70%.

A number of problems are faced by industrial firms, such as local raw materials of deficient quality, difficulties in obtaining raw materials from abroad, obsolete or inadequate equipment, low quality of production, lack of technical information, lack of finance, and high perceived risks for investing.

There was no well defined industrial policy in the region until 1990, with only isolated attempts by the different governments to stimulate foreign investment and exports, combined with the creation of free zones. The impacts expected from the liberalization policies have stimulated discussions on restructuring and modernizing the economy, and there is a growing awareness of the need to adopt specific measures in order to increase the competitiveness of industry. All countries are making efforts of industrial restructuring. There is the purpose of defining a regional policy on science and technology as a support to restructuring, and a Regional Commision for the Development of Science and Technology Policy has been formed.

1.3 Impact of the new policies on industrial development and on the industrial research institutes

Structural adjustment programmes have brought about concerns in government and industry about the long term possibilities of survival of the manufacturing sector, particularly its small industries component. The Chamber of Industries of Costa Rica, for example, feels that the new macroeconomic policies are menacing the subsistence of 5000 firms, 70% of the industrial sector, unless support is given to enterprise restructuring.

International experience shows that the achievement of competitiveness by enterprises depends basically on their capacity to design and implement adequate and creative competitive strategies, through rapid and effective innovations. Here technological innovations become critically important.

The author elaborates on this theme, suggesting that technology management is a critical capability to attain competitiveness and modernization. Work carried out by the author and his colleagues at CEGESTI, the Centre of Technology Management and Industrial Information of Costa Rica, has shown that the large majority of Central American manufacturing enterprises do not have this capability. ITRIs can supply it to firms, beyond the support it gives them on technical matters.

## 2. EVOLUTION OF ICAITI

### 2.1 Origins

The Central American Institute of Research and Industrial Technology, ICAITI, is a regional non-profit organization, established in 1955 by the five Central American Republics, on the basis of a study by the Economic Commission for Latin America. It was given the status of an international organization, and placed under the Comitee on Economic Cooperation of Central America, which acted on behalf of the governments.

Its objectives can be summarized as follows: to support the progress of the technology of production, and to carry out research and technical training.

During almost 8 years, until 1968, ICAITI was financially supported by the United Nations, which named its first Director.

### 2.2 Evolution; sources of funding

In 1960-64 ICAITI was able to receive a grant of about US $900,000, which when added to the contributions of the member countries allowed a considerable expansion of the staff and of the laboratory and pilot plant installations. The UN contribution gradually decreased from 1965 to 1972, but other funds were obtained through an increase in the contributions from member states and from work carried out for several outside organizations, notably the Organization of American States, OAS, the United Natons Development Programme, UNDP, the Inter American Development Bank, and the US Agency for International Development, AID. This allowed the Institute to consolidate its laboratories (chemistry, instrumental analysis, leather, food, wood pulp) and its pilot plants (textiles, pulp and paper), as well as to perform research on natural resources of the region like coffee, sugar and bananas.

In 1977-88 there was an economic recession in Central America. Since it was not possible to collect the contributions of the member countries, ICAITI turned for funding to several international agencies - UNESCO, GTZ of Germany and IDRC of Canada, among others - thus modifying its income structure.

On notably increasing its dependence from international technical cooperation, which in 1984-88 was more than 70% of its budget, the Institute found that its orientations were strongly influenced by the priorities of the outside funders. It became less close to Central American governments and enterprises, and its contribution to Central American development became somewhat passive.

As from 1989 ICAITI has endeavoured with some success to increase its efficiency of operation, strengthen its presence in the member countries, and design strategies to reduce its financial dependence from international sources by significantly increasing its income from services to local industry.

The Institute's budget for 1992 is US $2,05 million, of which 70.2% are to be spent on personal services (more than half of it on technical staff), 6% on materials and supplies, and 23.8% in investments and other items of

expenditure. From this last item one third will go to travel expenses, needed to cover the several member countries, while $75.000 will be allocated to investments, including 5,000 for technical bibliography, clearly insufficient amounts. The main problem, however, is whether the expected income for 1992 will materialize in full.

2.3 Service mix

The Institute does not seem to have kept registers of income by type of service, so that it is not possible to establish accurately the shares of R&D, testing services, and various studies. The author estimates that R&D projects accounted for less than 24% of income in 1991. Though the 1992 projections aim at a much higher share, the author feels that this will not easily materialize, and that R&D will maintain the same proportion in 1992, the rest - some 76% - corresponding to services.

2.4 Continuity

The financial difficulties faced by the Institute are affecting its capabilities and posing a menace to its survival. During the last five years the organization has lost highly qualified, competent technicians. At the beginning of 1992 it was obliged to reduce its personnel from 144 to 100. Fortunately it has been able to retain some experienced staff, particularly in management positions. However, the low level of salaries it offers are not favourable to recruiting and retaining new personnel of quality, and thus the institutional stability is affected.

## 3. RELATIONS WITH THE CENTRAL AMERICAN GOVERNMENTS

The Ministers of Economics, Industry and Commerce of the five member countries form the Governing Board. They appoint the members of the Industrial Consultative Committee, with one member per country selected among three candidates submitted by the respective Industrial Chambers. The latter Committee approves the Institute's five year plan.

ICAITI and its member governments have gradually become more distant. The Governing Board last met in 1989 to elect the Institute's Director, and will only meet again in January 1993 to examine ICAITI's problems.

Member countries agreed, at the time of ICAITI's creation, to contribute to it US $150,000 a year each, one half as subsidy and the rest as advanced payment for services to be received. By the end of 1991 the outstanding payments amounted to $5.5 million ($1.4 million in subsidies and $4.1 million in advance payments), enough to cover 2.7 years of operation.

In the January 1993 meeting the Institute will attempt to collect those sums and to create a permanent fund for stabilizing financially the institution.

ICAITI has not been actively involved in preparing and implementing the technology and industrial policies of its member countries, which in any case, with the exception of Costa Rica have not been explicitly formulated. Regarding regional S&T policies, ICAITI has participated actively in preparing the regional programme on S&T coordinated by the Science and Technology

Commission of Central America and Panama, with the support of the Organization of American States.

## 4. ACTIVITIES AND PRIORITY SECTORS

The Institute has four technical divisions, a division of planning and marketing, and a division of administration and finances. We now examine the technical divisions.

(a) *Applied research Division.*

The aim of this division's work is to achieve a better use of natural resources. The following laboratories are active: chemistry, food technology, industrial microbiology, instrumental analysis, cellulose, pulp and paper, and leather and textiles. There is also a pilot plant for new product and process development.

ICAITI has carried out a total of 254 R&D projects from 1956 to 1992, which represented some 30% of all its projects. Of these, 140 were sponsored by international organizations and 114 were covered by contracts with the private sector. As a result, 10 patents on processes and products were obtained; one of the patents has been commercialized.

In 1988-92 the Division of Applied Research carried out 93 projects, 55% of which were funded by the private sector. They included 15 scientific research projects, 29 technical studies, 9 courses, 10 individual tutorials, 24 short term technical assistances, and 6 projects supporting S&T development.

The Division has also put out 38 scientific publications and supported 24 student theses.

These figures would show that the R&D activity not only is of low import in the Institute, but that it has a bias towards basic research, academic theses and publications, which is reflected by the low number of patents and the little amount of technology transferred.

There is however a positive aspect in that the technical level of this Division has been well appreciated by international organizations, particularly in the areas of food biotechnology and anaerobic digestion.

(b) *Energy Division.*

In this field the Institute has actively taken part in the search for solutions to the energy problem, and collaborated with the countries of the region by carrying out regional projects. Activities consisted mainly of energy audits (255 from 1983 to 1992) and training seminars (74 between the same dates). According to ICAITI, good results have been obtained, as measured by a more efficient use of energy resources (wood, oil and electricity) and the modernization of installations in industry, with a positive economic impact. There is some doubt however whether the recommendations of the audits were implemented to a sufficient degree, in which case the economic impact would be lower than estmated by the Institute (by a factor of 5 in Costa Rica).

Duing the last two years the people that had been trained in this area have largely left the Institute, and have installed their own consulting firms, with a loss in market opportunities for the Institute.

(c) *Analysis and testing Division.*

These services are provided to the public and private sectors, and focus on the certification of production and origin of raw materials for industry, which is necessary to guarantee the legitimacy of the products that enjoy free trade within the region. The main products tested are fresh and processed foods, pharmaceutical products, raw materials, water for domestic and industrial use, grains for the production of concentrates, textiles, leather and skins, and paper products. There has also been a growing demand for the determination of pesticide residues in meat and other agricultural products for export.

The high level attained in these activities has been given recognition by local users and by technical and health organizations in the US, Europe and Japan. The performance of the Division is surprisingly good when account is taken of the adverse organizational conditions it faces and of the obsolescence of a good part of the equipment.

(d) *Other techno-industrial services Division.*

Beyond its work in the energy area, ICAITI performs several other techno-industrial services:

- Studies on existing industries and the establishment of new industries, such as the identification of investment opportunities, preinvestment studies, techno-economic services for the industrial sector, development of new products, technical assistance for the design and implementation of new industries, market studies, selection of technology and equipment, optimization of production processes, and valuation of plant and equipment.

- Consultancy services on process engineering, including layout, design of processes and equipment, technical diagnoses of industrial operations, and commissioning and testing of new plants.

- Preparation of standards for the Central American industry; 1220 standards were emitted until mid-1989.

- Metrology services, which have been made possible through a $1 million technical cooperation project.

- Environmental protection services, still incipient, mainly on agricultural and industrial effluents.

- Services in the area of quality, which have recently been added to ICAITI's menu.

- Finally, information and documentation services, traditional (library, technical consultations, information searches, reproduction of documents) and non-traditional (on-line access to data banks, maintenance of own data banks, advisory and consultancy services, training, specialized publications).

The Division's 1992 budget was $38,000, of which one half was funded by contract work.

Having analyzed the information available and talked to the personnel, the author concludes that this Division is clearly deteriorating, with inadequate resources to maintain its previous level of excellence.

## 5. LINKS WITH THE SYSTEM OF INNOVATION IN THE REGION

ICAITI has prepared an inventory of national and regional institutions in Central America that carry out R&D and technical asistance for industry, and found that 33 of them were interested in collaborating with the Institute, among them the five national universities of the countries. However, no agreements were formalized and networking efforts were put aside in 1991 because of lack of funds.

There are opportunities for such collaboration, but also many obstacles, among them the question of national vs. regional priorities and the fear of ICAITI domination.

All seems to indicate that, except for occasional links with half a dozen Guatemalan consulting firms in the fields of energy and quality, ICAITI has not yet established links with other regional innovation agents such as industrial consultancy firms, manufacturers of capital goods, engineering firms, or technology management centres. Neither has it developed a strategy for the commercialization of its services that would imply links with clients in the industrial sector.

ICAITI's orientation therefore does not seem to have been directed towards technological innovation and its management. To its tendency towards vertical integration and the "easy life" provided by contributions from international sources and member governments, one should add its lack of regard for the different stages of the innovation process and the actors with which it could interact in that process.

Recently competition has appeared for the services of ICAITI, at least in Costa Rica, where there is now a set of institutions that can supply such services.

The author feels that ICAITI is at a crucial juncture. It has financial problems, it is still not well known by industry, and the activities of the country branches are in decline. Clients that were interviewed thought that a substantial improvement in the effectiveness of services should be sought. To define ICAITI's future role in the region represents a significant challenge, particularly as the demand for technological innovation and R&D is bound to grow as liberalization policies are fully adopted.

## 6. SCOPE OF SERVICES

We have already described the types of services provided by the Institute and the sectors and clients to which they are destined, and have mentioned its limited experience in the management of innovation.

The author sees an opportunity for developing the latter activity, particularly in the stages of management of product innovation, scaling up of processes and experimental development results, and management of the assimilation and marketing of technologies.

The Institute so far has approached the transfer of technology produced by it through "technology-push" efforts - joint work with industry on product and process development, visits, presentations and seminars for industry, collaborative applied research with universities, and publications. But other things have been missing - technological diagnoses of firms, assistance in the preparation of technological strategies, other mechanisms for identifying requirements such as total quality, and the integration of technological packages.

The results of ICAITI's technology transfer have been meager so far. Here is a list of cases:

- Screw press for coffee pulp and other materials. This is being manufactured commercially in two or three countries with pirated designs.

- Integral utilization of coffee pulp for different purposes, now being used commercially for the production of fuel.

- Effluent treatment by anaerobic digestion, which has reached industrial scale in two food processing plants; other application projects are on hand.

- Acid banana pulp, a process to allow temporary storage of banana pulp, has been tried out successfully in a small plant.

- Production of edible mushrooms, now being used by three agroindustrial firms which employ agricultural byproducts as raw materials.

- Formulation of a variety of food products, with specific contracts with several industrial branches (coconut, fishing, fruits and vegetables, pickles, cereals, ice cream and other).

However, the mere trial or application by one client constitutes the only success criterion for ICAITI; no follow-up is made of the use and profitability of the technology, additional services are not offered, and there is no feedback that would help the learning process and the improvement of the organization.

It would be important for the Institute to develop its own capabilities for managing all types of changes, and to introduce *in its own services* total quality and technological innovation .

## 7. STRATEGIES

### 7.1 The 1990-94 strategic plan

ICAITI started to formulate an explicit strategy for the first time in 1988-89, by recommendation of AID, which funded the exercise (for almost $1.6 million). Eight consulting firms were involved, and there was participation by ICAITI

staff, representatives of the member countries and specialized consultants. As a result, a strategic plan was prepared for the period 1990-1994, which included a number of analytical documents, and manuals on different aspects of administration.

The Institute's mission is defined in the following manner: "to advance the integral and rational development of Central American industry". A number of long-term objectives have been stated, dealing with support for the public and private sectors, increase in financial self-sufficiency, covering of the whole region, helping technological updating, enlarging technology transfer activities, and forecasting the social and economic implications of industrial development.

The areas of activity of the Institute have been defined as follows: (i) techno-economic studies, (ii) technical assistance (includes quality and productivity management, environmental management, industrial reactivation and restructuring, energy, technological packages, standardization, and technological innovation), (iii) industrial information, (iv) analyses and tests (analytical services, metrology, quality certification), (v) research and development (utilization of natural resources, treatment of industrial waste, biotechnology, development of products and processes), (vi) training, (vii) organizational development and institutional relations, and (viii) financial development.

Each Division is asked to establish its own annual operative plan on the basis of the Institution's strategic objectives (a detail of the 1992 plans is included in the author's report).

The total expenditure planed for the five year period 1990-1994 is of the order of $20 million. This includes investments in equipment and systems for Analysis and Metrology, and in buildings (including a Convention Centre) for the area of Training.

7.2 Comments on the strategic plan

The author makes a number of observations on this plan:

- Most of the planning efforts had to do with the structural reorganization of ICAITI, in particular the accounting and financial systems. However, the corresponding documents have not been made known so far;

- Emphasis was more on the result than on the exercise of planning, so that the exercise did not become an instrument for the comunication of strategic objectives, negotiation of internal cooperation among Division, and definition of the main changes; compatibility was not ensured between strategy, structure, organizational culture and budget;

- The Institute's mission as defined does not transmit the basic beliefs and values of the organization;

- Some important strategies are not clearly outlined, for instance, human resource improvement, the service mix, changes in the organizational culture, strategic alliances with other agents of innovation, etc.;

- There is no analysis of the present and likely competitors (especially in new areas like total quality and restructuring) in the face of changing conditions in the countries served and the policies of commercial opening, regional integration and globalization of markets;

- There is a bias towards presenting in an elaborate manner the programme areas, which leads to the thought that a central purpose of the restructuring exercise has been to produce attractive promotional material on ICAITI and its services, not only for the industrial sector but also for member countries and international organizations.

At the time of writing this report, ICAITI had not implemented its strategic plan to an important extent, justifying this delay on financial difficulties. There are however signs that there has been a lack of commitment with the changes contemplated in the plan, and little capability to undertake them. The interviews carried out by the author confirm that the present activities of ICAITI have an inertial, short-term impulse. On the other hand, the only funding available for long term R&D is still coming from international cooperation, in spite of the purpose of lowering the dependence on it.

7.3 Performance

ICAITI does not seem to have carried out formal evaluations of its performance, beyond the financial aspects of its operation. The author has attempted a rough appraisal, based on the little information available and the results of his interviews with clients and staff.

Between 1956 and 1992 ICAITI carried out 1,124 projects. There was a concentration of projects in Guatemala (over 64% of the 848 projects for the member countries). R&D projects were 254, some 30% of all projects; the main emphasis of the project mix was therefore on services.

Regarding the transfer of technology, 18 technologies had been transferred succesfully (according to the Institute's criteria: simple use or application by the client, rather than continued, trouble-free use for a year or more). This would represent 7% of all R&D projects. By Latin American standards the figure is reasonable, but a higher value would have been expected given the long experience of the Institute. The number of patents obtained, 10, was less than 4% of all R&D projects. Only one patent was licensed.

The above values would indicate a low originality of R&D results as well as low capabilities for their commercialization.

The management of R&D projects could be improved, possibly through specific training on the subject. Some 20% of the projects have gone beyond the original deadline, and 15% beyond cost estimates. There has been insufficient follow up of the projects (except in the case of those funded by international organizations) and no post-mortem analysis has been made of those that have failed.

Regarding services, the interviews with clients of ICAITI have showed that energy audits, as well as analyses and tests, have been of good quality, but the prices were considered to be too high, and the time taken to prepare proposals requested by clients was, at 2 to 6 months, too long.

## 8. ORGANIZATION

As a result of its strategic plan 1990-1994 ICAITI has adopted an organizational structure with three Departments: Technical, Promotion, and Administration and Finance.

Five Divisions make up the Technical Department: Standards, Analyses and Tests, Industrial Technical Services, Applied Research, and Documentation and Information.

The Promotion Department is in charge of marketing ICAITI's services. It has a Planning and Marketing Division and a Publications Division. It also oversees the operations carried out by the branches of ICAITI in the five member countries.

In December 1991 ICAITI had a staff of 170, but shortly thereafter there was a reduction because of financial difficulties. The permanent staff is now 101, ten of which are in branches in the other Central American countries. 50% of the total staff are professionals, and show an average experience of 15 years, two thirds of which in ICAITI.

The employees enjoy a number of social benefits, including retirement at age 55, and those with many years of seniority prefer to stay in the institution, in spite of the low salaries. No incentives are offered to the staff on account of good performance.

ICAITI aims at a matrix structure, but continues to have a largely functional structure, which is far from adequate on account of too may hierarchical levels, the tendency to passivity, the hostility between the different "fiefdoms", and the resulting blocking of communication.

An assessment of the organizational culture of ICATI was carried out by initiative of the author, using a four step methodology: analysis of documents, analysis of previous studies about the institution, utilization of a two-part questionnaire applied to a sample of 35 staff members, and structured interviews with 15 staff members. The results point to the existence of problems in the institution - ineffective communication, lack of group work, absence of training opportunities, existence of an autocratic style of management, insatisfaction of the personnel, an attitude of just complying with the working hours, and little identification with the institution's objectives and goals, which in any case are not clear to everyone.

From the above analysis, the author concludes that significant changes should be introduced into the structure and the organizational culture of ICAITI, which would greatly contribute to its performance and future survival. The structure should allow flexibility, favour internal discussion and help the development of the Institute's potentialities. This would need to create an atmosphere of high participation, a process of training, internal rotation of personnel and good information flows, a system of performance evaluation and incentives for the personnel, and a system for maximizing contacts with clients and suppliers of the Institute. It would also require a good management of patents and intellectual property, the training of staff in the management

of technology and innovation, a revision of the role of country b. anches. and a careful selection of the areas in which efforts should be concentu ted.

The marketing activities of the Institute could also be substantially improved. First, with a different service mix more in line with the requirements of the region, focusing on R&D, technological innovation, and the management of technology transfer, rather than on the fashionable services that attract international clients. Secondly, generating good project proposals, emphasizing total quality and technological innovation in its own services, and looking for feedback from the clients.

## 9. THE FUTURE

At the end of 1992 ICAITI was putting its hopes of recovery and survival in several funding possibilities: the payment of arrears by member countries, a loan from the Inter American Development Bank, the creation of a Science and Technology Fund for technological support to small industries with the Central American Bank of Economic Integration, and the creation of another fund with the same Bank for promoting new enterprises.

In the author's opinion, the chances of any of these options materializing are far from certain, and it would be advisable for the Institute to develop, together with likely users, a portfolio of good specific projects in its areas of excellence.

The author reviews the problems faced by ICAITI at this point of time, which originate not so much from present changes in its milieu as from certain unfavourable characteristics of its past evolution:

- The role of a "super-Ministry of science, technology and development for the region", which may have been justifed at the time of ICAITI's creation;

- Abundant international funding, which created an "easy life" outlook that made ICAITI lose sight of the need to link up closely with the industrial sector. ICAITI was unable to focus international cooperation towards projects that could make a significant impact on industry;

- The Institute has enhanced scientific research rather than technological innovation and technology transfer;

- It has lived on for more than 30 years without an adequate planning of its activities and its future development, and acquired an organizational culture and a style of leadership that has not helped it in pursuing its objectives.

ICAITI must now face the new conditions of its environment while being saddled with a number of drawbaks: financial difficulties, a deteriorating infrastructure, a lack of focus, a staff whose experienced members are near the age of retirement while many others are in an initial learning phase, low salaries, and other adverse characteristics.

The author feels that, in order to face the new conditions, the Institute should define well its mission and objectives, and sharply focus its capabilities. R&D should concentrate on priority areas related to the past experience of the

Institute, looking for technological innovation and not merely R&D. It is also imperative for ICAITI to develop a technology management capability that would allow it to take up other roles, such as the formation of research consortia, the promotion of technology based enterprises, the intermediation of technology, the updating of firms through a "gatekeeper" role, and the cooperation with other innovation agents in the region.

The principal challenge is to build up the necessary capabilities for these new roles, and at the same time solve the financial and other problems now being faced.

CASE 6

## COLOMBIA: THE DEMISE OF IIT

*The Institute of Technology Research of Colombia, IIT, was closed down recently and its assets were dispersed, marking the unfortunate end of a long crisis. How did this happen? Why didn't industry fight to salvage the only general-purpose ITRI in the country? These and other questions are explored in this case study, which we summarize below. (L.J. Jaramillo, "La larga crisis del IIT: dificultades para conformar una capacidad tecnologica industrial en Colombia", Bogotá, February 1993.)*

### 1. THE NATIONAL ENVIRONMENT

The author remarks that Colombian entrepreneurs have shown a great capacity for risk-taking in creating industrial enterprises, but not in technological change in their enterprises once established. There has been little or no demand for locally created knowledge on the part of the technologically simple Colombian enterprises. Industry was not convinced of the need to come close to an institution like the Technological Research Institute, IIT, either individually or collectively.

The lack of appreciation of the technological factor, as well as a lukewarm attitude towards cooperation among enterprises, did not allow an industrial compact to come into existence to sustain the validity of IIT and the need to renovate and improve it. On its part, the government, while supporting science in general, did not understand well the issues involved in industrial research. Meanwhile, the researchers and their sponsors were happy to assure research at the laboratory level but did not have the means or the inclination to transform the results into commercial applications.

### 2. ORIGIN AND EVOLUTION

The Instituto de Investigaciones Tecnológicas, IIT, was created in 1958, as a non-profit corporation, with the sponsorship of two official banks, the Agrarian Fund and the Bank of the Republic, and the National Coffee Growers Federation, which were soon joined by the Colombian Petroleum Enterprise, ECOPETROL, and the Instituto de Fomento Industrial, a state development corporation.

IIT's main objectives were stated as follows: to carry out technological studies and research in all phases of Colombian agricultural and industrial activities, and to stimulate the application of results.

The new institution had the inspiration and support of the Armour Research Foundation for its foundation and during the first phase of its life. The United Nations provided funding and technical suppport for some years.

IIT responded to the needs of the day - to support the agro-industrial development of the country - and played an important pioneering role in

characterizing natural resources and in studying agricultural products from the viewpoint of their industrial processing. However, the "contract research" model proposed by Armour could not be applied in the Colombian environment. IIT had to go through its own learning process.

IIT started with services for the formulation of fertilizers and pesticides for local conditions, and went on to study problems in the post-harvest stage, taking care not to duplicate what others were doing. Thus it took up the utilization of agricultural wastes for the production of alcohol and other products, and the development of coffe-based products.

The original structure comprised six units: Applied Chemistry and New Products Development; Agro Chemistry; Quality Analysis and Evaluation; Engineering; Economics, and Technical Assistance. (Later on, in 1972, a restructuring produced four divisions: Research, Industrial Services, Consultancy, and Administration and Finance). A number of international experts were brought for periods of one month to several years.

In the Applied Chemistry section, research was made at laboratory and pilot plant level, and continued on to engineering development. Among the subjects studied was the industrialization of guava and other local tropical fruits. This was the first formalized industrial research carried out in the country.

Technical Assistance became the strongest unit in IIT. It interfaced with industry, bringing in the latter's problems and demands and returning to it proposals for research and studies. Technical diagnoses of a number of industrial branches were made, and a proposal was prepared for technical assistance to SMEs. Other activities included courses and seminars, advisory services, and market and feasibility studies. Services provided to industry were free of charge during an initial stage. This had a good welcome and produced several successful outcomes. However, once the support of United Nations ended, there were no alternative sources of funding to continue this subsidy, until some years later when technical assistance from Germany allowed to partly subsidize those services.

During its whole life IIT was a focus for technical cooperation from international organizations (the United Nations, the Organization of American States), several foreign governments (USA, through funding programmes like Point Four and the Alliance for Progress, and later through agencies like the Department of Agriculture and USAID, the Agency for International Development; Germany; the Netherlands; Great Britain, and Denmark), and foreign institutions (Armour Research Foundation, University of Michigan, French Institute of Tropical Fruits, Arthur D. Little Inc., Denver Research Institute).

By 1982, on the occasion of its 25th anniversary, IIT could point out to its achievements: 1938 reports on studies and demand for services; 11,770 consultations and visits to industry; 112,356 samples analyzed with more than 400,000 determinations; 140 editions of its Technology Review with 175,000 distributed copies, and a number of other publications.

## 3. RELATIONS WITH GOVERMENT

During the time of import-substitution policies, the government paid much attention to different protection and regulatory activities, but little to technology related activities, where laissez faire reigned. In a National Seminar on Industrial Technology which took place in 1975, there was insistence on the need to define an industrial technology policy; but this did not subsequently take place. The only decisions made in questions of creation and assimilation of technology were those derived from the technological policy agreements of the Andean Pact, to which Colombia was part. But Colombia did not follow up the agreements except for the control aspects and for its participation in the Andean Programmes of Technology Development, in which IIT represented the goverment in the Contracting Committees.

IIT played a role vis-a-vis the government not as a key player in a practically inexistent technology policy, but as a provider of consultancy and services, which were commmisioned from it by different agencies, notably COLCIENCIAS, the official organization in charge of promoting science and technology. The latter also contracted with IIT some projects that involved R&D activities. One of the most interesting in this regard was the provision of technologies, developed by IIT some time before, for the formulation of processed food of high nutritional value and low cost.

One of the links with the Government was through the participation of official entities among the sponsors of IIT, notably the Bank of the Republic and the Instituto de Fomento Industrial. Since there was not a central libretto, IIT found itself in an uneasy position as each of these sponsors exerted its own type of influence.

In 1968 the government declared IIT an institution "linked" to the Ministry of Development. This damaged the image of IIT, which was regarded thereafter by industry as a public sector organization, making firms reluctant to pay for services which they felt were already covered by the taxes they paid. As the author says, "the private firms wanted to be subsidized, the public organizations asked for free services, the government did not provide funds, and the Institute suffered a progressive erosion". There was also a matter of the ambiguity of IIT's legal status. In 1980 a study was commissioned from which it resulted that IIT had a juridical nature unique in the country, and could not be regarded as an official institution, though the government was a sponsor through several of its institutions.

In any case, as a "linked" institution IIT was unable to capture the benefits of belonging to the public sector, principally a substantially higher funding level from the national budget. Though it gained from retaining its independence and its flexibility, it could not at the same time enjoy more significant links with the government.

Thus the ground was laid for the protracted agony of the Institute.

## 4. IIT AND THE INNOVATION SYSTEM

The Colombian policy in science and technology has centred on the creation of a "science and technology system" rather than a system of technological

innovation with industry as the central actor. It has not favoured the formation of "clusters" between enterprises, R&D institutions, engineering firms and financial organizations, which have characterized the export-oriented industrialization process in South East Asia. At one time however this appeared to be within reach in the field of food products of special social interest, when IIT participated actively in the National Research Programme on Food Technology and Nutrition, but lack of finance and of steady management did not permit it to happen.

Another area in which IIT could have had much activity was in the processing of coffee. Indeed, the Federation of Coffee Growers was one of the sponsors of IIT, but it contracted IIT's services only for agrochemical analyses.

The other sponsors of IIT also had a limited use for the Institute. ECOPETROL, the Colombian Petroleum Enterprise, created its own research organization. The Instituto de Fomento Industrial did not use IIT except for industrial consultancy studies. The two official banks hardly used the services of IIT.

The universities looked down on IIT and did not much engage in cooperation with it. One of them, the National University, became a competitor on establishing an Institute of Food Science and Technology, only a few blocks away from IIT.

One of the important outputs of IIT was the stream of qualified professionals that went on to industry and other sectors after having acquired experienced in IIT. The author reports that "someone called IIT the country's graduate school in research and development, in industrial technology advice and consultancy." In fact, the transfer of experts to industry was regarded as a normal task of the Institute.

## 5. SCOPE OF ACTIVITIES

IIT had a wide coverage in its activities: food technology, casting, metallographic analysis, plastics, leather, ceramics, chemistry of coffee and carbons. The main concentration of efforts was in food technology.

The activities included (a) applied technological research, (b) technical services for industry (analysis, tests, consultancy related with company decisions on the purchase of equipment or raw materials, the approval of a process, product or raw material, etc.); (c) quality control, mainly through inspection of lots in the enterprise itself; (d) industrial development studies, principaliy for the identification or evaluation of investment possibilities in agriculture and industry; (e) technical assistance for SMEs, during the first period of the Institute; (f) collaboration with other organizations, through training of their personnel and participation in technical committees; (g) complementary services in pilot plant, laboratory of sensory analysis and experimental kitchen.

A former director of the Institute felt that IIT had not been conceived to work in only one field of appplication, since such a thing "would only be possible when the enterprises linked to such an institution attained the numbers and the economic level that would allow them to finance an institution of their

own ... it is a strategic mistake to increase the number of institutions or keep those in existence if a critical mass cannot be reached".

The low demand for research, however, did not allow IIT to generate sufficient income. This created problems that reduced the capability of a higher offer of services and in its turn decreased the opportunities for more demand. In the words of a former Director of the Institute, "a vicious circle is created that hinders the steady development of the institution".

In an evaluation carried by a foreign expert in 1971, two concerns were expressed. First, that a great dependence on income derived from the sale of services made it difficult to programme activities in the medium term, for which purpose stable, sufficient funding was needed. Second, that there was a danger that lack of imagination and too much repetitive work would transform IIT in a place too dull to attract creative talent.

## 6. INFRASTRUCTURE AND HUMAN RESOURCES

Thanks to its unremitting efforts, by 1968 IIT was in possession of a large building with almost 9000 square metres, with pilot plant, laboratories, workshops, offices, library and a conference hall. Funding for this had come from international and foreign government organizations through their technical cooperation programmes.

One of the positive actions of IIT during its first decade of life was to contribute in bringing back to the country university graduates in technical disciplines at a time when this was not practiced by the universities.

In 1982 IIT counted with 51 scientists and technologists of varied backgrounds, which were supported by about 80 technical and administrative personnel.

Although foreign study programmes for the scientific staff were always supported by IIT, they were for periods rarely longer than one year, which some observers have felt to be insufficient.

IIT found it difficult to pay salaries comparable to those in industry, and this maintained a relatively high rotation of the staff throughout its life. It was estimated in 1971 that every year 15% of the staff moved on to industry, which paid better.

In any case, the users kept for many years their trust on the professional capabilities and the confidentiality of IIT, although this trust seems to have suffered somewhat in the last few years of its life due to the labour conflicts within IIT.

The difficulty in retaining the best staff slowly took its toll in quality and productivity. The deterioration was already visible in the mid-seventies. "The lesson", adds the author, "is that in an institute of this nature it is necessary to take the utmost care about the technical quality and the responsibility of the personnel."

IIT ended up in the late 80s with very difficult economic circumstances, and with a mass of unmotivated professionals, waiting for retirement and its

benefits, who had organized into a strong trade union that menaced the Institute with strikes.

Another vicious circle had appeared: low demand from users meant less resources and thus lower salaries, the best personnel went away while that of lower qualifications could not be got rid of on account of the union' pressure, and this in its turn had repercussions in even lower levels of demand.

## 7. PROBLEMS AND CONFLICTS

In spite of its mighty efforts and of some good results, IIT had a lengthy agony. Some of the noteworthy aspects were:

*Organizational and financial areas*

The status as a private institution contributed to the flexibility and relative agility of IIT. It could make expenditures without the usual interferences of the public sector. But it was unable to obtain a steady source of funding from the state.

The sponsoring institutions, while giving some funds to IIT, did not help in orienting technological development. They were far from providing the necessary drive to the Institute. The Board was largely made up of representatives of state institutions and did not include industrialists, which was a disadvantage. The members had little knowledge of the needs of industry or of technology management. The bearings provided by such a Board were not always clear and did not help the institution.

The model initially followed of first generating funds and then subsidizing research did not work. Analytical services are a limited source of income, and they also distract from research which is the activity that inspires credibility about the institution.

An institution is not viable in the long run without adequate long-term funding, which allows stability in research lines that can produce favourable results in industrial technology. In the beginning IIT depended almost wholly on the contributions of its sponsors. This represented 72% of all income in 1960, but as time went on it counted for less and less: it was 13% in 1982. Sales of services and international cooperation had by then grown in relative terms. In 1982 they represented, respectively, 66.5% and 9.5 % of total income. The funding available was however insufficient for the needs of IIT.

Among the problems occasioned by the shortage of funds were:

- "Who is going to pay for the work on local products which is not performed for an explicit client but is of broad interest for the country?"
- "If I sell, with what am I going to respond? I cannot engage and support a critical mass of well trained people against the expectation of future income"
- "How much can I charge for overheads? If I charge full costs, this will make the project more expensive and I may sell less, particularly in a market used to subsidized university work".

The financial shortcomings made life difficult for the Director of IIT and created the conditions for the formation of a trade union by the professionals.

As time went on the burden of retirement benefits grew and became a *cul-de-sac*. No reforms were possible if resources could not be found to deal with this problem.

*Marketing of services*

The milieu in Colombia, as we have pointed out above, did not encourage the demand for industrial technology services, a consequence of the import substitution industrialization model. In 1990 it was found through interviews with industrial firms that "excessive state protection and the lack of competition accounted for the lack of demand for technology for the modernization of the productive system". There was distrust about the quality of work and the ability to produce complete technological packages, rather than a collection of studies on partial aspects. This was linked to the perceived high risk of investing in knowledge that would then have to be transformed into plant and equipment. Outside suppliers were taken to be more trustworthy since they were aware of the international experience, and were preferably used as sources of knowledge.

It was felt that the foreign markets could become a dynamic force to encourage industrial research. Centres linked to the technology of production for export show better defined research priorities than those oriented towards local production activities of a monopolistic type.

IIT did carry out a number of market studies for its services, but it would seem that the results were not used to introduce practical corrections. Perhaps, as suggested by an expert, what was needed was a mechanism for public relations and market promotion.

There was also the problem of the cost of preparing quality proposals to clients who were eventually uninterested or could not pay the costs.

*Labour conflicts*

The "Association of IIT Professionals" was originally conceived as a pressure mechanism vis-a-vis the sponsoring institutions and the goverment. One of its first claims was to ask for a more open diffusion of research results, which it was not easy to do since a good part of the research was done under contract and had reserve clauses.

While the Association's genesis is understandable, it had the effect of making problems more acute. The climate of cordiality that had existed so far was altered. The fact that the personnel wanted to become public sector employees changed the rules of the game. The effects were opposite to the purpose of consolidating the institution which the Association had originally desired.

The consequences of labour union activity were grave. The IIT management felt unduly pressed as it was asked to pay without consideration of where the money would come from. The public image of the IIT professionals deteriorated. The sponsoring institutions were rudely confronted. An aggresive climate was introduced in the Institute which was inimical to

intellectual creativity. The renewal of personnel was blocked. There were extreme situations, such as a strike in 1983, with insults hurled at the sponsors through the public press. The great difficulty to find a consensual formula of agreement brought about forms of conflict which eroded the life of the institution, a new vicious circle that contributed to making IIT unmanageable. The trust of industry on the quality and confidentiality of the Institute's services was shattered. The image of IIT became much weaker and as a result there was a loss of interest in revitalizing it.

There were solutions, which were costly but still affordable. Funds were needed to pay what was owed to the personnel, and they would have to be contributed by the sponsors or other sources, since the Institute was not solvent. This was not done and the Director was left alone. What followed was the terminal stage.

## 8. CLOSURE

On the 5th of June 1991 the Board decreed the liquidation of IIT. The lack of money to pay salaries forced the definite closure of the institution. The building and the library were sold to local institutions, and the equipment was auctioned off in 93 lots when a single buyer was not forthcoming, thus dispersing at low prices what had taken years to put together.

Before this extreme outcome, there had been attempts to keep IIT going, and when this was not possible, to avoid the dispersal of assets. Several different formulas were proposed, such as to collect funds from industry and the government in equal parts and keep IIT going on; to allocate government funds by Congress (this was not accepted by the Ministry of Finance); to sell IIT whole to the National University (adjacent to IIT), or to the National Vocational Training Service, SENA. None of these solutions finally worked.

As a final reflection, the author extracts an important lesson. The behaviour of the different actors would show that there was an insufficient understanding of the Institute. For the industrialists it was a source of human resources that could be hired. For the sponsors, a source of worries and conflicts. For others, a good real estate site, a building, some labs. For a more sophisticated public, perhaps a valuable centre of technical information.

Unfortunately, these actors did not regard IIT in its true dimension as an industrial technlogy research institute, bent on creating a national technological capability and a community of interests around this strategic subject.

CASE 7

# NEW ZEALAND: SCIENCE RESTRUCTURING AND NEW MODALITIES OF INDUSTRIAL RESEARCH

*New Zealand has undergone a series of changes and adjustments in recent years, as it became clear that the economic model previously followed by the country, with a largely protected economy relying on the export of agricultural commodities, did no longer generate enough wealth to mantain reasonably full employment and income growth. The restructuring of science and technology in the public sector is one of the most interesting chapters of such changes. The functions of S&T policy-making, R&D funding and R&D execution were separated. A fund was created to support "public good" strategic R&D. The four main science agencies were restructured: ten new Crown Research Institutes took their place. They are focused on sectors and problem areas rather than disciplines, and have been endowed with full autonomy and commercial powers in the hopes of linking them closely to the productive sector (A. Araoz, "Restructuring of science and technology and new modalities of industrial research in New Zealand", Cambridge, Massachussets, March 1993).*

## A. SCIENCE RESTRUCTURING

### 1. NEW ZEALAND AND ITS DEVELOPMENT

New Zealand lies in the Southern Pacific, and consists of two large islands, North and South, and a few smaller ones. The total land area is about 270,000 sq. km, slightly larger than the United Kingdom and about the size of Ecuador or Romania. The landscape is dominated by mountain ranges and hill country, and the sea is a constant presence for many of the inhabitants. The climate is temperate though winters can be severe in the far South.

New Zealand is a small country, with a 1991 population of 3.4 million that grows 1% a year. The gross domestic product in 1991 was US$ 41.7 billion, with a GDP per capita of US$ 12,265. Per capita income grew well until the 1950s, when New Zealanders enjoyed a standard of living which was third in the world, but slowed down thereafter; it stagnated after 1986.

The economy depends heavily on foreign trade. After having long been "Britain's farm", products and markets have diversified in recent years. The relative contributions of traditional agriculture and manufacturing have declined. The more dynamic economic activities in recent years have been fishing, forestry and mining.

Towards the end of the sixties the economy suffered the consequences of the erosion in the terms of trade for primary agricultural commodities and the

successive oil shocks. New Zealand fought back with the introduction of new primary products, and some of them, like kiwifruit and radiata pine, generated good exports. But this was not enough. By the early 1980s the economic situation had sharply deteriorated. Wages and productivity increasingly lagged behind the standards of other OECD countries; unemployment and inflation appeared. The government sector dominated the economy, social goals were paramount, and there was in place a complex array of policies for industrial protection, subsides and tax-relief. It was evident that the old economic model was unable to maintain relative standards of living and that changes were necessary.

## 2. REFORMS IN THE ECONOMY AND THE PUBLIC SECTOR

From 1984 onwards a new, market-oriented approach was put in place, doing away with high protection levels and turning instead towards freer trade, deregulation of markets, removal of subsidies, neutrality between export and domestic sectors, and control of inflation.

The shortcomings of the New Zealand economy, however, were not easy to correct just with changes in macroeconomic policy. In July 1992 the government produced a statement announcing measures to be taken for achieving "a highly competitive economy, capable of matching it with the best in the world", which "requires attention by the private sector and the government to all the factors that determine a country's competitiveness, including efficiency of production, quality of output, attention to market needs, and maintaining and enhancing environmental quality." The government's strategy for economic growth would be based on four elements: macroeconomic policies to keep inflation low and encourage investment, helping business to build international linkages, developing human resources, and promoting a more competitive economy. Measures proposed for this last purpose are summarized in the attached table.

The government's statement emphasized the need for "better innovation", mentioning several successful examples of areas in which New Zealand has acquired international comparative advantages: navigation systems, card-based security access systems, lighthouse beacons, racing yachts, electronics, and software. The statement mentioned in particular the recent reform of the public science sector, which was undertaken in order to make science more pertinent to the needs of the economy and improve its contribution to business innovation.

The restructuring of the economy was accompanied by major reforms in government practices, expressed by the State Sector Act 1988, the Public Finance Act 1989, and the policies of"user-pays" (government services should, as far as possible, be charged to the user at full cost), corporatization (the adoption of commercially oriented principles by the government departments) and privatization.

As "The Economist" reported recently, "New Zealand has become the first country to publish a rational set of government accounts which includes a balance sheet of its assets and liabilities and an accrual-based operating statement of income and expenses - ie, similar to the accounts of a public company... This new system of financial reporting is part of a much wider

## A Competitive Enterprise Economy: Summary

In the longer term New Zealand's economic growth depends on our ability to get more value out of our resources - people, land and capital through:

- creating and realising of opportunities on world markets
- the management skill and entrepreneurial drive to take advantage of the opportunities
- competition, aided by openness to world markets, which drives better innovation, management performance and overall efficiency.

### Results so far

- Firms are making more innovative use of labour, which has increased the effective capacity of much of New Zealand industry.
- Private-sector innovation is becoming more effective on the world stage, as shown by a wide range of export successes involving new products and niche marketing.

### Government action

- Many regulations that acted to stifle competition and the innovative response of business have been removed, leading to a more competitive cost structure for New Zealand business
- Ten new Crown Research Institutes are being established to improve the linkage between public-sector science and the private sector.
- Outdated features of the tax system have been corrected, including revising the criteria used in setting depreciation rates to bring them closer to economic rates.
- Reform of the energy sector is underway including the removal of statutory barriers to competition in electricity and gas distribution, and the establishment of the Energy Resources Monitoring and Conservation Authority.
- Further reform of the public sector will be carried out in light of the 1991 Logan Report (State Sector Review).

### The future

The Government will continue to work towards achieving a highly competitive economy, capable of matching it with the best in the world. This will involve:

- strong growth in productivity with businesses making more effective use of the people and equipment they employ
- public- and private-sector management that rates among the best in the world
- a greater emphasis on developing products and markets with the aim of increasing the value of what is produced.

SOURCE: Minister of Finance Statement on Economic Strategy, 2nd July 1992

public-sector reform in New Zealand. Heads of government departments are now called 'chief executives'. Instead of permanent tenure they now have contracts for up to five years. They also have greater control over the hiring of staff and wages, and are expected to meet specific targets". In fact, goverment departments now prepare a yearly business plan, and tend to work as "commercially" as possible.

## 3. SCIENCE REFORM

New Zealand's science and technology sector is not large. In 1989 national expenditure on R&D was NZ$ 634 million, or about US$350 m, of which industry contributed 38 %. This represented 0.9% of GDP. The personnel involved in R&D and related activities was 9350. More than 4000 were in the four main government science agencies existing at that time, 1700 in universities, 850 in research associations and other private sector research institutions, and 2800 in industry.

Recent official documents in New Zealand have repeatedly recognized that research has a major impact on people's lives, though the limitation of resources in a small country like New Zealand makes it important to decide how much should be devoted to research, and to what areas of research these resources should be applied, assuring that "value is had for money".

In line with this philosophy, the science regime in New Zealand has undergone radical change over the last few years, within the context of the major changes in the economy and society.

In 1986 the government set up a Science and Technology Advisory Committee, which recommended in its 1988 report: (i) the separation of the three main functions of government in the S&T area: policy advice, allocation of funds, and performance of research, each to be performed by different institutions, (ii) the installation of a system of contestable funding based on considerations of scientific excellence, cost effectiveness and collaboration between researchers, and (iii) the establishment of national priorities in science and technology, based on wide consultations.

An important implication was that funding practices should be changed, away from supplying funds to institutions on an input basis, to purchasing science outputs from the "science provider" best able to produce that output in terms of quality and cost. This meant a complete break with past practices.

By the end of 1989 the key agencies in the new regime, the Ministry of Research, Science and Technology and the Foundation for Research, Science and Technology, were officially established. The government's funds for R&D were taken out of the budgets of the government science departments and placed into the "Public Good Science Fund" for the funding of "output research", with an annual budget of NZ$ 261 million (US$ 145 million) for 1991 92, to be kept at an unchanged level for the following five years.

The next reform was the restructuring of the science departments, using their people and their assets to form new Crown-owned research institutes, with autonomy and flexibility, as well as full commercial powers to provide a much larger range of options for the transfer of technology. A government-

appointed Science Task Group on CRIs assembled comprehensive information and carried out extensive consultations with the science community, users of science and other stakeholders. In its report it recommended to establish ten CRIs through restructuring of the four main science departments - the Department of Scientific and Industrial Research (DSIR), the Technology Division of the Department of Agriculture and Fishing (MAF Technology), the Forest Research Institute (FRI), and the Meteorological Service.

The proposals were put into practice without delay, and the new CRIs started their life on 1st July 1992.

## 4. NEW ZEALAND'S SCIENCE REGIME

These reforms have created a unique science regime in New Zealand. The government now buys its science and technology outputs from those sources best able to produce them in terms of quality and value, and maximizes the benefits from this investment through identifying the national priorities to be served. The focus has shifted from funding institutions to meeting the government's science needs.

The four key elements of the new science regime are (i) a focus on outputs rather than inputs, (ii) a contestable funding system, (iii) an emphasis on partnership between private and public sectors to achieve the best results from research, and (iv) the development of a forward-looking and cohesive research, science and technology policy to bind the various components together.

A central feature of the new regime is the separation of the government's involvement in research, science and technology into three areas of activity: policy, funding and operations. In the past, these functions had been completely mixed together, leading to a confusion of roles.

### 4.1 Institutions

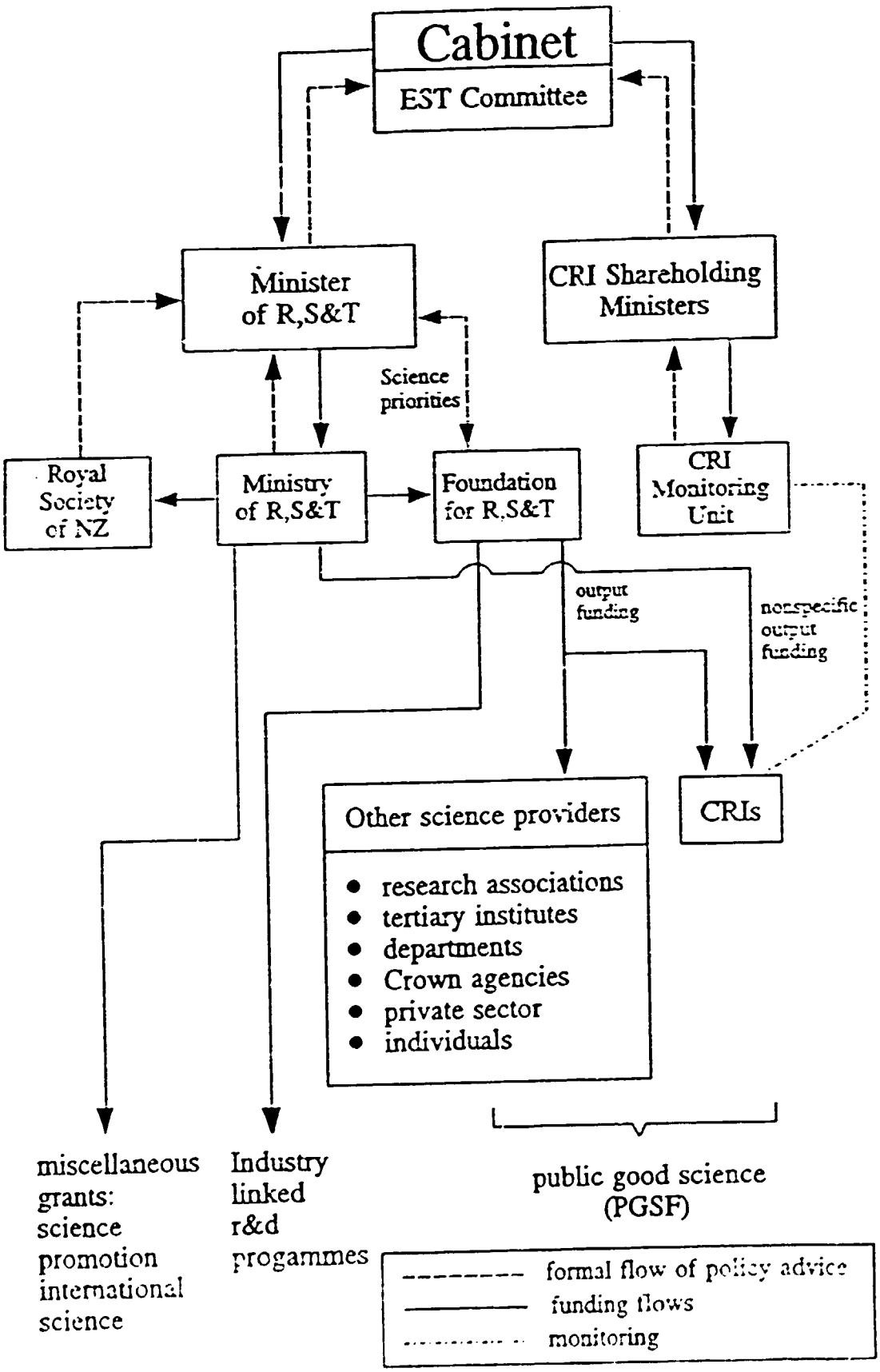
(a) Government bodies

The attached Figure shows the government bodies involved in science policy, the funding of S&T and the provision of S&T outputs. The most significant are:

- The Ministry of Research, Science and Technology (MORST), which provides policy advice to the Government, particularly on the level and priorities of funding. It is also in charge of science statistics, international S&T agreements, review of government-funded science, and the promotion of science and science education.It should be remarked that both the Ministry and the Foundation have been purposely kept as small bodies (40 persons in the case of the Ministry), with top professionals.

- The Foundation for Research, Science and Technology (FRST), which is responsible for allocating funds to "public good" science programmes on a competitive basis, from a yearly budget of US$ 145 million. It also provides about US$ 2.2 million for commercially oriented S&T through the Technology for Business Growth Scheme. In mid-1993 the government announced that this

THE STRUCTURE OF GOVERNMENT'S INVOLVEMENT IN THE SCIENCE SYSTEM




SOURCE: A Profile of Crown-Funded R&D in New Zealand, 1991/92, MORST 1992

will be increased to $10.6 million in 1993/94, and schemes are being considered for contingently repayable loans and loan guarantees in association with the TBG.

- Ten Crown Research Institutes, which are the main Government-owned research agencies. They will obtain most of their income from the PGSF, through the funding of research projects submitted to the latter as well as through "non-specific output funding" (a grant of about 10% of their budget). It is expected that commercial revenues will become increasingly important.

(b) Universities

New Zealand has seven universities with a 1990 total student enrollment of 78,919, of which 11,664 were in postgraduate programmes; 8,645 degrees were awarded in 1990 (including 1,000 Masters and 228 PhDs) of which 30.7% were in scientific and technological areas. Total research expenditure was estimated at NZ$ 100 million (US$ 62m), 90% of which in academic research. Some universities are emphasizing the applicability of their research results and in some cases have set up liaison units to link up with the business enterprise sector.

(c) The private sector

In 1989-90 the private sector spent in R&D was NZ$ 241 million, and it performed NZ$ 200 m (US$ 111 m), with 2825 research, development and associated staff (full time equivalents). Most of the work was conducted by private firms, but a significant part was carried out by 10 Research Associations owned and partly financed by certain branches of industry. Their focus is on adding value to the products produced by their industry group, and thus help them to gain competitive advantage in international markets. In 1990 the RAs employed 691 persons and had a total income close to US$ 30 million. RAs range in size from the Research Institute of Textile Services with a staff of 7 to the Dairy Research Institute with 285.

4.2 Funding

Science in New Zealand has been shrinking considerably while in other OECD countries it has been expanding vigorously. Total expenditure in R&D in 1989 was NZ $ 634 million (US$ 352 million), having grown at a nominal rate of 6.3% per annum between 1981 and 1989. In real terms, however, there was a decrease of 27% between those years. This compares very unfavourably to an increase in real terms of 52% for all the other OECD countries. R&D in New Zealand was 1.40% of GDP in 1981 and 0.91% in 1989, while for the rest of the OECD countries the corresponding figures were 1.37% and 1.70%.

Moreover, unlike other OECD countries most R&D spending goes to agriculture and other non-industrial objectives. An additional negative aspect is the relatively low share of industry-funded R&D, which stood at 38% in 1989, down from 40% in 1981. This is in contrast with the other OECD countries, where the comparable figure was 56% in 1989 and the trend was an increasing one.

By 1992 the total government-funded R&D was at an annual level of NZ$ 317 million (about US$ 180 million). The Public Good Science Fund had NZ$ 256m, of which $ 232m were to be allocated to R&D programmes by competitive bidding

(the estimated distribution was 92% for CRIs, 6% for RAs and 2% for others) and $24m for CRIs as "non-specific output funding".

Recently (mid-1993) the government stated that it would increase its science investment by 2 percentage points of GDP by 2010. Even with modest GDP growth this would represent a major funding increase.

University research, funded by the state through its grant to tertiary education, was estimated at NZ$ 111m in 1991, of which non-teaching related research was less than 10%. Universities will have access to PGSF contestable funds from 1993 onwards. The private sector's R&D expenditure of NZ$ 241m in 1989/90 was about 0.3 % of GDP, much less than the 1.0% in the small OECD countries. The most important research areas were manufacturing (33% of total expenditure), processing of primary products (33%) and infrastructure and services (21%). Research Associations performed close to NZ$ 60m of R&D, of which $ 13m came from the PGSF.

The Public Good Science Fund funds *strategic research* to support long-term national needs in any of 40 "output classes". These are areas that reflect the economic objectives that are felt to be important for New Zealand (see attached table). Research projects, which need not be of immediate 'commercial' value, are funded with the expectation of achieving useful discoveries or knowledge that underpin economic growth and sound environmental management.

The allocation of funds is made annually. It results from two distinct stages. In the first stage, the goverment decides on the total amount to be allocated by the PGSF and its distribution by output class. In the second stage, the Foundation allocates funds within each output class.

Let us look at the first stage. For the 1993 94 round of funding, a report was prepared by a Science and Technology Expert Panel, which conducted a nine-month exercise on priority setting, with comprehensive information-gathering and analysis, involving thousands of people across the whole spectrum of New Zealand society. The milestones in this process were a Science Priority Forum (which took place at the Parliament Building), the release of a public discussion paper, subsequent comments by many institutions, and the preparation of a final report with two alternatives, unchanged total funding or a slight increase (both in nominal terms). This report was submitted to the government, which chose the first alternative, and assured bipartisan support for the funding level and the priorities. The priorities thus defined will be followed by the Foundation to allocate PGSF funds in each output class through the coming round of contestable bidding.

In the second stage the Foundation invites the science providers to submit applications related to each of the 40 output classes. The applications are first subjected to peer review. The following step, merit review, is carried out by advisory committees, made up of widely experienced people from the scientific, academic and business communities, that assess the broader merits of applications. This is followed by grading by advisory committees, and final allocation by the Board of the Foundation. The projects selected are awarded research contracts. Through its purchasing, the Foundation can emphasize collaboration and coordination as well as competition between research organizations. It can also allocate funds for projects that take several years.

RESEARCH FUNDING, 1991-92, BY SOURCE AND OUTPUT CLASS ($ '000)

| OUTPUT CATEGORY | Adjusted Private Funds | Gov't PGSF | Gov't Op. & Oth | University Funds | TOTAL | Ratio Bus/Gov't |
|---|---|---|---|---|---|---|
| 01. Sheep Production | 3,917 | 14,635 | 0 | 1,800 | 20,352 | 0.24 |
| 02. Beef Production | 719 | 1,836 | 0 | 90 | 2,645 | 0.37 |
| 03. Dairy Production | 3,040 | 4,780 | 0 | 309 | 8,129 | 0.60 |
| 04. Alternative Animal Species | 1,548 | 5,642 | 0 | 820 | 8,010 | 0.24 |
| 05. Generic Animal Research | 702 | 12,918 | 0 | 3,271 | 16,891 | 0.04 |
| 06. Forage Plants | 1,650 | 22,063 | 642 | 2,469 | 26,824 | 0.07 |
| 07. Horticulture | 6,018 | 31,584 | 112 | 2,870 | 40,584 | 0.17 |
| 08. Arable & Other Plants | 982 | 13,172 | 939 | 2,488 | 17,581 | 0.06 |
| 09. Plantation Forestry | 2,030 | 11,029 | 82 | 981 | 14,122 | 0.17 |
| 10. Fisheries | 1,094 | 2,238 | 16,922 | 954 | 21,208 | 0.05 |
| 11. Meat Processing | 8,407 | 3,552 | 367 | 513 | 12,839 | 1.90 |
| 12. Dairy Processing | 31,495 | 2,718 | 461 | 911 | 35,585 | 7.70 |
| 13. Other Food Processing | 9,079 | 9,937 | 718 | 1,307 | 21,041 | 0.76 |
| 14. Fibre, Textiles & Skin Processing | 13,451 | 2,538 | 0 | 504 | 16,493 | 4.42 |
| 15. Wood & Paper Processing | 10,979 | 7,501 | 0 | 453 | 18,933 | 1.38 |
| 16. Materials & Industrial Processing | 18,771 | 14,034 | 0 | 5,036 | 37,841 | 0.98 |
| 17. Engineering | 17,601 | 1,974 | 122 | 2,512 | 22,209 | 3.82 |
| 18. Electronic & Instruments | 26,524 | 7,137 | 425 | 2,514 | 36,600 | 2.63 |
| 19. Construction | 3,555 | 3,803 | 18 | 2,571 | 10,247 | 0.60 |
| 20. Commercial & Trade Services | 4,478 | 77 | 276 | 432 | 5,263 | 5.70 |
| 21. Energy | 7,337 | 4,994 | 120 | 3,084 | 15,535 | 0.89 |
| 22. Transport Services | 5,241 | 906 | 1,337 | 635 | 8,119 | 1.82 |
| 23. Information & Communication | 22,728 | 1,509 | 3 | 4,670 | 28,910 | 3.68 |
| 24. Urban & Rural Planning | 543 | 857 | 151 | 714 | 2,265 | 0.32 |
| 25. History, Society & Culture | 162 | 425 | 3,202 | 2,618 | 6,407 | 0.03 |
| 26. Relationships & Wellbeing | 191 | 442 | 1,418 | 3,644 | 5,695 | 0.03 |
| 27. Political & Economic Relationships | 1,042 | 437 | 840 | 4,161 | 6,480 | 0.19 |
| 28. Education, Knowledge & Training | 79 | 293 | 7,394 | 6,591 | 14,357 | 0.01 |
| 29. Environmental Protection | 2,901 | 10,137 | 3,760 | 7,549 | 24,347 | 0.14 |
| 30. Geological Structures & Processes | 1,479 | 12,137 | 14 | 6,179 | 19,809 | 0.08 |
| 31. Land use, Flora & Fauna | 0 | 12,097 | 583 | 3,948 | 16,628 | 0.00 |
| 32. Marine & Fresh Waters | 349 | 18,425 | 545 | 5,430 | 24,749 | 0.01 |
| 33. Climate & Atmosphere | 16 | 8,741 | 1,645 | 2,075 | 12,477 | 0.00 |
| 34. Space | 55 | 496 | 0 | 1,374 | 1,925 | 0.03 |
| 35. Antarctica | 0 | 1,904 | 116 | 634 | 2,654 | 0.00 |
| 36. Fundamental Knowledge | 468 | 3,450 | 228 | 15,746 | 19,892 | 0.02 |
| 37. Health | 7,232 | 670 | 17,635 | 9,593 | 35,130 | 0.26 |
| 38. Defence | 0 | 28 | 6,651 | 0 | 6,679 | 0.00 |
| 39. S&T Education & Training | 0 | 0 | 0 | 0 | 0 | 10 |
| 40. S&T Services | 0 | 4,834 | 0 | 96 | 4,930 | 0.00 |
| 99. Unknown | 24,934 | 0 | 53 | 0 | 24,991 | 467.87 |
| TOTAL | 241,101 | 255,950 | 66,779 | 111,546 | 675,376 | 0.56 |

SOURCE: Report on Crown Research Institutes, 1991

## B. INDUSTRIAL RESEARCH ORGANIZATIONS

Two types of research organizations in New Zealand are oriented towards the demands and needs of the productive sectors: Research Associations, in the private sector, and Crown Research Institutes, in the public sector. The former are smaller, and tend to be closer to the immediate needs of industry. CRIs are much larger and cover not only industry but also several areas of agriculture and natural resources; only a few of the CRIs could be characterized as industrial research organizations.

### 5. RESEARCH ASSOCIATIONS

RAs serve the following industrial branches:

- Dairy (Dairy Research Institute, DRI);
- Wool (Wool Research Organization of New Zealand, WRONZ)
- Meat (Meat Industry Research Institute of New Zealand, MIRINZ);
- Building (Building Research Association of New Zealand, BRANZ)
- Coal (Coal Research Association of New Zealand)
- Heavy engineering (Heavy Engineering Research Association, HERA)
- Logging (Logging Research Institute, LRI)
- Pulp and paper (Pulp and Paper Research Organization, PAPRO)
- Textiles (Textiles Research Association)
- Shoe and leather (Shoe and Leather Research Institute).

The first four are the largest, led by DRI with a staff of 285 and a budget of NZ$ 20.5m (1990 figures), while the rest are small, some with less than 20 people.

The original concept for the RAs was that of a partnership between industry and government, with 1:1 funding. In recent years this has changed. Most of the funding now comes from sales of services to industrial firms and other customers, from contracts for research and other services funded from levies on the industrial branch, and from overseas customers in some cases. State funding accounts for less than 20% in most cases, and is no longer given as grants like in former times, but as PGSF contracts for R&D projects.

RAs are owned by the industry group they serve, and are run as commercial organizations. Their approach is not "public service" but "client satisfaction". They tend to concentrate more on processes than on products, and provide a variety of outputs to business firms: research and development, training for industry personnel, and technical services such as tests, development of specifications, consultancy, audits of different types (such as hygiene audits for food industry plants), etc. Most of the research in RAs is of immediate relevance to their industry owners. Some is "generic" research, applicable to the whole industry, and is generally funded collectively; some is proprietary research funded by individual firms. The fact that their income comes from contract work and not from grants helps to make RAs "demand - driven" organizations, fully attuned to the needs of industry and engaged in a continuous dialogue with it.

The commercial focus of RAs is expressed, among other things, in forward-looking management practices such as the preparation of a corporate strategy

and a multi-year business plan. This requires an intimate knowledge of the industry branch, its economic evolution and its technology needs.

In his paper the author presents the case of MIRINZ, the Research Association servicing the meat industry. This is an interesting case, which shows an applied industrial research organization that has been able to grow by diversifying its activity and successfully acquiring new clients through marketing efforts. Some 10% of its income originates from overseas contracts. In this way it has been able to counteract a falling demand from its own industrial group. MIRINZ has been able to maintain a balance between research efforts to solve immediate problems and those aiming at the long term. This is a result of successful bidding for PGSF funds, which now represent some 15% of total income and allow MIRINZ to maintain a reasonable effort in basic science. Finally, the positive organizational structure and management characteristics, and careful financial handling, have been instrumental in allowing the Institute to achieve such positive results.

## 6. CROWN RESEARCH INSTITUTES

The creation of Crown Research Institutes is one of the most innovative and significant aspect of the science reform process in the public sector of New Zealand. The existing government science agencies had been regarded by many observers as largely divorced from the productive sector, engaged in topics that in general were of interest to the researchers and not necessarily to eventual users, and hampered by the usual public sector limitations from linking up with industry in a meaningful way. A survey of technology-minded industrial firms rated the agencies poorly as a source of technology.

The restructuring of the agencies into a different type of research institution, dealing with specific productive sectors and groups of resources, and enabled to operate commercially, appeared as a desirable solution.

The Ministerial Science Task Group, set up in November 1990 to examine this general issue, analyzed documentation and statistics, and sought the opinions of a wide crossection of stakeholders in science, academic circles, business and government. Its report was submitted in July 1991.

The main recommendation was to establish, by 1 July 1992, ten independent Crown Research Institutes, focused on productive sectors or on groupings of natural resources. As the report said, "Their work will be vertically integrated. They will have a broad focus across a range of science and technology. Their purpose will be to work for the benefit of New Zealand, establishing research capabilities, carrying out scientific and technological research, and providing services. They will be completely new organizations with considerable autonomy, a company structure, boards and newly appointed management. CRIs will operate under their own Act, and their shares will be owned equally by the Minister of Finance and the Minister responsible for CRIs. Each CRI Board will have up to nine directors, appointed by Cabinet. While the Crown will be the major client for their research and services, CRIs should also develop relationships which favour increased private sector investment in research and development and technology transfer".

The goverment implemented very rapidly most of the recommendations. Parliament passed on 15 June 1992 an Act (the Crown Research Institutes Act 1992) which gave the legal framework for the new CRIs. Wide canvassing was made to identify candidates for the various Boards of Directors. Once the latter had been appointed by the government they were asked to select, from a field of candidates, the Chief Executive and the senior directors of each CRI. Concurrently, an intense activity took place regarding the transfer of personnel and assets to the new institutions, the drafting of diverse agreements and covenants, and many other practical details needed to effect the restructuring.

The attached table lists the CRIs, ranked according to size, with a brief description of their areas of work and a rough estimate of expected yearly revenues.

The report of the Science Task Group discussed many issues concerning the CRIs. We now mention some of them which are of particular interest:

- Autonomy: CRIs are to be corporate bodies, at arm's length from government, but accountable to it. Directors are to make decisions independent of political intervention. CRIs are empowered to borrow and invest in their own name, but without a Crown guarantee: failure could lead to liquidation.

- Financial viability: (i) CRIs should generate sufficient funds to service medium-term capital needs; major needs would be met from a capital injection by the owners (the two shareholding Ministers), from loans by the private sector, or from the sale of assets; (ii) outputs are to be priced so that an agreed profit target can be met; (iii) nil or very small financial dividends are to be paid to the Crown; (iv) CRIs are exempt from income tax until 1995 when this issue will be reviewed.

- Board of Directors: appointed for three years, with responsibilities similar to those in private companies. The members are to be selected from a wide field of candidates suggested by the different stakeholders.

- Funding: principally by the Foundation for Research, Science and Technology, in two ways: (i) through contracts for public good research programmes selected in the contestable process; many programmes will be multi-annual, thus enabling some stability; (ii) through non-specific output funding, about 10% of the PGSF, to be directly transferred to the CRIs for research on topics determined by the scientists without explicit reference to external priorities. (Note that an assured funding of only 10% of the budget makes life anything but easy for the CRIs, which will be obliged to spend many efforts preparing good proposals for the PGSF and other clients.)

- Sales to clients: it is expected that an increasing proportion of funding will come from sales of research and services to public and private customers (no estimates were advanced in the report).

- Transfer of technology: commercially valuable technology should be patented if possible, and transferred to the private sector through sale.

## THE CROWN RESEARCH INSTITUTES

*CRIs are ranked according to size, with a brief description of their areas of work and a rough estmate of their yearly revenue in New Zealand dollars (the equivalence is approximately NZ$ 1 = US$ 0.55).*

- New Zealand Pastoral Research Institute Ltd - research into temperate pastoral agriculture ($70 million)

- National Institute of Water and Atmospheric Research Ltd - research on rivers and lakes, the oceans, the atmosphere, their interactions, and their effect on New Zealand's climate ($52 million)

- The Horticulture and Food Research Institute of New Zealand Ltd - research on the production of high-quality horticultural products, including processing and international marketing ($47 million)

- Industrial Research Ltd, IRL - developing new technologies for New Zealand manufacturing ($38 million)

- Landcare Research New Zealand Ltd - providing a scientific basis for sustainable management of land environments ($29 million)

- Institute of Geological and Nuclear Sciences Ltd - providing a scientific basis for managing mineral and energy resources, assessment and mitigation of geological hazards ($27 million)

- New Zealand Forest Research Institute Ltd, FRI - research into production forestry and new and differentiated wood products ($25 million)

- New Zealand Institute for Crop and Food Research Ltd - research into production and processing of high-quality field and glasshouse crops ($19 million)

- Institute of Environmental Health and Forensic Sciences Ltd - research related to environmental health and forensic science ($16 million)

- New Zealand Institute for Social Research and Development Ltd - to monitor and analyze change in New Zealand society and the economy ($830,000)

Source: Report of the Ministerial Science Task Group, 1991.

licensing and joint-venture arrangements. Strategic alliances with the private sector may help to obtain early involvement in the design of R&D programmes.

- Relations with industry: in order to promote the application of research results, CRIs should be responsive to the needs of industry and actively develop links with industry sectors. CRIs should carry out considerable market research to assess the needs of industry before setting the direction of research.

- CRIs and change: CRIs should be regarded as agents of change: "apart from internally-driven changes, we expect mergers of CRIs and spin-offs from CRIs to provide relatively straightforward mechanisms for major structural adjustments in a changing market. CRIs will have, in great part, the responsibility for such adjustments. Responsibility for the operation of research will thus be devolved out from central government, and CRIs will largely control their own destiny... We would be disappointed if there are no significant changes in the number and foci of CRIs within the next decade."

CRIs are at this moment newly born institutions that have replaced older and more [illegible]rsome institutions. In most cases their personnel will have to learn [illegible]ely new ways of doing things, and industry will have to find how to interact with them. Though this is bound to take some time and will involve a number of false starts and mistakes, the overall outlook looks good.

A recent (September 1993) communication received by the prsent author states that after their first fiscal year the CRIs have reported generally good results. They are mostly financially viable, and forecasting growth in employment of researchers. Some of them are becoming active in offshore markets.

Two of the CRIs, Industrial Research Ltd and the Forest Research Institute, are closest to the industrial sector and may be regarded as ITRIS. We summarize below the descriptions made by the author in his paper.

## 7. THE FOREST RESEARCH INSTITUTE

FRI was founded in 1947, within the public sector, to deal with the scientific and technological aspects of the plantation forest activity and the processing of wood products. It had a distinguished trajectory as a first-class research institution which eventually covered the whole "filière" that goes from the biology of tree species to the export of wood products. It also excelled in building links with the productive sector and transferring to it the technology it developed.

When the time came for defining the characteristics of the new Crown Research Institutes, FRI was used as a model for several of those characteristics, and itself became one of the new CRIs.

The new institution has been endowed with all of the characteristics of a CRI that make for flexibility and efficiency. Some restructuring has taken place, but there has been continuity in the people, the physical facilities and the research and other activities being conducted.

New Zealand has introduced the species *pinus radiata* from California, which adapted very well to the local conditions and shows a fast rate of growth and good quality in its wood.

Forest products has become a key industry. Some 1.2 million hectares of radiata are now planted, and the country produces currently 13 million cubic metres per annum, supplying New Zealand's needs for timber, pulp and paper, and panel products, and leaving 3 m cubic metres for export, with a value of almost NZ$ 1.4 billion (US$ 780 million) a year, about 8.5 percent of all exports. By the year 2020 the country should be able to provide 25 million cubic metres of wood on a sustainable basis, with most of the increase destined for export.

FRI gradually went on to cover in a comprehensive manner research in plantation forestry, wood technology and environmental forestry. It is today the main research organization in forestry and forest products, with more than 80% of the research funds available. The total staff in June 1991 was 507, with about 150 scientists and 180 technicians.

In recent years, responding to the aplication of the "user pays" policy in 1987 and to the decrease of government funding, FRI actively looked for outside revenues. This meant a complete change in mentality. The Institute proceeded to strengthen its relationship with the forest industry and other clients. It increased its efforts to provide clients with technology and services, to commercialize research findings and new technology developments, and to sell services overseas. In this way it was able to lower its reliance on government funding from 99% to 66% by the time it became a CRI.

After being restructured in 1989/90 FRI had five divisions engaged in the following areas of research: forest technology, wood technology, ecosystems, harvesting and pulp and paper.

The last two divisions are Research Associations, set up with industry, the Logging Industry Research Organization (LIRO), and the Pulp and Paper Research Organization of New Zealand (PAPRO). The member companies contribute to the funding of research. For instance, PAPRO carries out fundamental and applied pulp and paper research, with special emphasis on radiata pine, the development of more efficient and environmentally acceptable pulping, bleaching and papermaking process technologies, and the development of improved products.

The main strengths of the Institute are the vertically integrated nature of its structure and its research activities, a reasonably good balance between longer-term strategic research and shorter-term applied or commercial research, and the high calibre of the research staff.

Research, both strategic and commercially oriented, is by far the principal activity at FRI. The main areas of research go from genetics and forest management to trade, marketing and economics. Collaborative research is also carried out with institutions of other countries.

Regarding services, FRI does work for the government, consulting and training for industry (particularly in wood technology and pulp and paper), assistance to outside organizations that interact with the forest sector, such as

chemical suppliers, machinery makers and transport companies, and consultancy services for overseas customers in more than 30 countries.

As its revenue targets increased, FRI saw the wisdom of patenting its new processes, an expensive but necessary step. About 15 new technologies have been patented since 1987, some of them in many countries.

One of the most interesting features of FRI has been the active and effective way in which it has related to the productive branches it serves. FRI has come to be regarded by industry as a "one-stop-shop" for research and technical advice. Technology transfer is achieved through personal contacts, reports, publications, software packages, conferences, workshops, seminars and training courses.

We should mention in particular the relationship with the Forest and Forest Products Research Organization (FAFPRO), which has four industry-sponsored Research Advisory Boards on forest technology, forest harvesting, wood technology, and pulp and paper. Each Board is connected with the corresponding division of FRI and helps to develop research programmes and coordinate the search for funds. The FAFPRO Boards have been of great value to FRI, in assisting its success in the bidding process for PGSF funds and in ensuring that research results are utilized effectively.

There is a feeling however that fundamental and strategic science may suffer when scientists become too involved in technology transfer or technology services. This is an issue that FRI shares with many applied research institutes the world over. A delicate balance is required between the more applied and the more basic reearch activities, and it may vary from time to time. To achieve the right balance is probably more art than science.

* * *

On 1st July 1992 FRI ceased to be a part of the Ministry of Forestry and became a Crown Research Institute, keeping all its divisions save for the greater part of Ecosystems. Except for this, few changes have taken place in the scientific and technical staff, and there is a very high degree of continuity with the activities of the old FRI.

FRI now has a staff of about 450 and a total budget close to NZ$ 30m (US$ 16.7m), of which 66% comes from the government through projects funded by PGSF plus a moderate but vital allocation by the PGSF of non specific output funds, of the order of $2m. Funds from non-government sources, mainly New Zealand industry, have contributed an increasing proportion of funding since 1987.

The new FRI defines its mission as follows: "To pursue excellence in research, innovation, development, and technology transfer in forestry and forest products for the benefit of New Zealand". As a Crown Research Institute, FRI will be enjoying a much greater flexibility to work closely with industry, financial institutions and other organizations in developing and commercializing new technologies. As an internationally recognized centre of excellence, with a proven record of achievements, FRI is well positioned to build on its existing close association with industry and to take advantage of the new opportunities presented by the CRI environment, principally a company structure with increased commercial flexibility and limited liability.

as well as non specific output funding that will allow it to undertake longer term research of its own choice.

As with other CRIs, the six members of the Board were appointed by the government following a selection from a group of candidates submitted by many organizations. They originate mainly from the research and the business communities, and bring with them an important amount of expertise.

FRI is led by a Chief Executive Officer appointed by the Board, the same person that had led the old FRI. It has an expanded structure by comparison with the old FRI, with 6 science divisions. There is a new Biotechnology Division, and two divisions, Wood Processing and Wood Products, replace the former Wood Technology Division. There are also 4 corporate divisions.

A business plan has been prepared, and much emphasis is being put in strengthening the relations with industry and other customers with the aim of increasing the commercial revenues of the Institute. As the Director of FRI said: "our scientists are progressively becoming more market aware. Before it was 'technology push', something that sounded like 'good science'. Now we have to be aware of the commercial value, of what is the market". Here much will depend on the two corporate divisions dealing respectively with strategy and with commercial activities.

Already under the old system, as part of the Forestry Ministry, FRI managed to develop a number of highly positive features. It acquired a high, recognized degree of scientific excellence, and integrated its research activities vertically throughout the whole forestry spectrum, from trees to finished products. It was able to build fruitful and efficient contacts with industry, in particular by establishing two Research Associations, LIRO and PAPRO, as Divisions of FRI. It developed its clientele both inside and outside New Zealand, and managed to produce revenues that covered 33% of its budget.

On becoming a CRI, the Institute is gaining a number of advantages in autonomy, flexibility and commercial possibilities which are bound to help it in expanding its activity and making it more efficient, as well as in taking advantage of commercial opportunities. It can, for instance, take loans from banks, or go into joint ventures with private industry partners to exploit commercially new developments. These are very positive features which, if properly used, would promise a bright future for FRI.

## 8. INDUSTRIAL RESEARCH LTD. (BRIEF NOTES)

The author was not able to collect much information about IRL, which is a totally new institution that came into being in July 1992 as a result of putting together three former divisions of CSIR. The Industrial Development Division was transferred whole to the new CRI; the Chemistry and the Physical Sciences Divisions only in part.

The Report of the Ministerial Science Task Group on Crown Research Institutes expected that IRL could count on a revenue of about NZ$ 38 million, of which $ 27m would come from the government through the PGSF (including $ 2.7m approximately as non specific output funding) and $ 11m from other sources.

IRL is led by a Chief Executive, who reports to a Board of Directors with 7 members, all of them from the private sector. It has more than 350 staff in 7 divisions: Business Development; Natural Products Processing; Measurement, Applied Mathematics and Analysis; Communication Electronics, Sensing and Information Technology; Materials Science and Performance; Production Automation and Control; and Packaging, Storage and Transport.

These divisions mainly have generic, horizontal capabilities, of value to many different branches, in contrast to FRI where divisions relate to specific branches. The following are considered groups of excellence: machine vision, semiconductors, earthquake engineering, and chemistry.

The Science Task Group had proposed in its Report that IRL should become a centre for core competencies "with a special role in leading the development of research strategies and in promoting the application of technology in a wide range of industries". This broad focus and diversity is in stark contrast with the concentration on a defined sector in the cases of FRI or the Research Associations.

IRL will then have a wide clientele in the manufacturing sector, which will include many small and medium industries, particularly in the mechanical, electronic and chemical branches, where New Zealand needs to develop competitive advantages.

In a published interview, the Chief Executive felt that IRL would be "using the commercial freedoms it will have as a company to get closer than ever to the commercial sector". IRL would still be doing a large amount of strategic research for the PGSF, but "by being able to form partnerships or joint ventures with industry, real improvements are expected in the take up and development of the results of research by industry. IRL will help manufacturers and exporters to get the competitive edge they need". On the other hand, "being closer to industry will help the institute focus its science to better meet industry's actual needs".

Shortly after its foundation, IRL engaged in a process of restructuring, to be followed by a strategic exercise with the purpose of finding out how best it may serve industry. This was felt to be not too easy, since New Zealand's industries are small and fragmented, and on the whole do not consider R&D as a strategic objective. However, there are hopes that IRL may become a catalyst to bind together firms in certain subsectors and define strategic objectives that may be shared by them.

IRL will be involved in strategic and commercial research, as well as in a variety of technological services such as metrology, testing, quality, trouble-shooting and training in many different subjects.

The largest customer is and will continue to be the government, through the PGSF, for which strategic research will be performed. Currently about 75% of the funding comes from this source. This is considered to be too high by the Chief Executive, who feels that industry should be induced to invest more in R&D, adding that for this purpose it would be necessary for the IRL staff to change its way of thinking. It seems clear, however, that IRL will not be able to do all that industry wants. It should avoid dispersion, and focus on the strong points, striving to maintain excellence. For instance, in machine

vision, the existing good capability should be further developed; companies should be brought in to exploit this capability and make early inputs in the development process.

Responding to short-term problems, such as corrosion, accounts for a significant proportion of IRL's income. Here there may be an element of research, but it is mainly the use of existing expertise that allows to solve problems at a deep level. Some companies, however, are starting to be interested in long term work, for instance in topics of environmental protection or in the detection of very small objects in products.

IRL has an exciting but far from easy task ahead. It must attend a disperse, heterogeneous market, and there is the danger of spreading efforts too thinly, and getting trapped into putting the best skills in providing services to industry rather than in research. On the other hand, IRL has inherited a scientific structure that had developed in the past following the thematic interests of the scientists, rather than the the requirements of New Zealand's industrial development or the demands of industry. It is likely that IRL will have to modify and adapt its capabilities in accordance with the latter factors, and this will require some time until new skills are acquired and physical facilities are expanded.

It is not easy to predict the ways in which IRL may ultimately develop. The CRI Report saw "a series of developments spinning off from this original CRI: joint ventures, perhaps research associations, and hopefully new CRIs. These should come about as clear research directions develop in the industries that make up these dispersed sectors".

## CASE 8

## CANADA: SOME RECENT INITIATIVES IN INDUSTRIAL RESEARCH

*We summarize here a paper that reviews a number of experiences in Canada which are relevant to the problematique faced by ITRIs in developing countries (J. Mullin, "Some Recent Canadian Initiatives in the Development of Industrial Technology", Ottawa, February 1993).*

The questions being faced by ITRIs in developing countries are by no means new, but the old replies are not at all useful in today's changing world: How can they organize themselves to create much closer relationships with the industries which they are expected to serve? How should they design their programs, set their priorities and keep abreast of the changing needs of their clientele? Are the personnel policies of government institutions appropriate to managing staff in such organisations? What is an appropriate public/private mix for funding?

A review of some institutional policies and innovations in Canada may provide some possible future directions useful to ITRIs in developing countries. The Mullin report analyzes the "technology policy environment" in Canada today and presents four case studies.

### 1. THE ENVIRONMENT FOR TECHNOLOGY POLICY

Canada's total R&D expenditure in 1990 was Can $9.2 billion, of which industry performed 56%, university 24%, the federal government 16% and provincial governments and others 4%. There were 1200 research units in 60 universities, 200 units in the federal goverment and 300 units in the provincial governments and others. The number of research units in industry was 3,700, but many of them were small. Staff affected to R&D was 47,000 in industry and 15,000 in the federal government.

There has been a continuing, long-term strategy pursued by the federal government, aimed at maximizing the performance of R&D by the industrial sector while maintaining the share performed by the universities.

On analyzing Canadian efforts to stimulate the competitiveness of industry and improve the adoption of new technology, it can be seen that the government is seeking to: (i) improve the capacity of government owned laboratories to act as sources of new technology; (ii) improve the capacity of private enterprises, of all sizes, to act as "receptors" for new technologies which are likely to be significant in the future; (iii) promote the development and absorption of the so-called "generic technologies" - informatics (including artificial intelligence and robotics), biotechnology and advanced materials.

For a number of years Canadian technology policy has been dominated by a concern for the promotion of international competitiveness, and here the actions of Governments tend to congregate around three broad themes: commercialization, technology diffusion, and the promotion of precompetitive

research. The most frequently favoured modality of action, it would seem, is the promotion of government participation in "technological alliances".

(a) Commercialization

A recent policy statement says that "the Technology Centres Policy is intended to commercialize the operations of various federal laboratories by involving clients more fully in the management of centres, fostering effective technology transfer from government laboratories, and facilitating the gradual privatisation of certain centres, where appropriate."

Technology Centres to be designated under this policy should establish a client-led advisory board to guide their technology support activities, and encourage the highest possible financial contribution from clients. The centres would be provided with incentives to permit them to be more responsive to the needs of clients.

The key issue is the nature of the financial incentive embodied in the new policy. Before 1986 the public sector centres could not retain revenues from sales, which were treated as "general revenue" and not returned to them. This has now changed and the centres can retain additional revenues beyond a certain figure, to be used freely, in particular to hire new staff.

It is also important to note that Canadian Provincial Governments have long insisted that their ITRIs earn a significant share of their income from contract research and the sale of services.

(b) Technology diffusion

In 1992 a draft federal policy on technology diffusion outlined ways to influence the processes and mechanisms by which companies source, acquire, adopt, adapt and manage technology. The objective was "to promote the competitiveness of SMEs by building the capability, within companies and government organizations, to deal with technology investments in the context of the whole enterprise".

It was proposed that (i) government activities should be aimed at helping firms to help themselves, with a focus on services as opposed to financial assistance; (ii) government should ensure that services are provided, not necessarily provide them directly; (iii) no firms should be excluded from consideration but any targeting should be determined by service providers in response to market demands; and (iv) government departments and agencies should cooperate in assisting clients, and should not compete for clients.

(c) Promotion of pre-competitive research

Canadian concerns for the development of more complex forms of industrial cooperation in pre-competitive research reflect important trends in the industrialized world, regarding the development of "strategic" or "generic" technologies that are knowledge-intensive and can be applied in many different fields.

Two significant policy instruments were created in the late 1980s for promoting research in strategic technologies: the $1 billion technology fund

created by the Province of Ontario, and the $240 million Federal programme for "Networks of Centres of Excellence".

These important and costly initiatives do not envisage a significant role for existing government laboratories, and the chosen vehicles for implementing them are networks and consortia, not central labs or single institutes.

One of the large policy questions for developing countries will be to determine if these new organizational forms can be as powerful when used in traditional areas of technology development as they are proving to be in the new areas of "strategic technology".

(d) Support for small and medium-sized enterprises

There has been in Canada a long-standing concern to promote the economic performance of small and medium scale enterprises. This concern, in the field of technology policy, is reflected (i) in the existence of at least 89 federal and provincial programs, each of which purports to assist the innovation process at the level of the individual firm; (ii) in the existence of the series of ITRIs across the country, especially those at the Provincial level, with explicit mandates to perform R&D and offer technical services to the small and medium-scale enterprise sector of the economy; (iii) in the important expenditures on "related scientific activities" such as science and technology information services, industrial extension programmes, and testing and standardization, all of them aimed, in particular at the SMEs; (iv) in the existence of governmental programmes to enhance the access of SMEs to foreign technology and to foreign investment in their technological development.

The report describes three programmes aimed at SMEs. The first, and largest, is the IRAP program, managed by NRC and implemented in part in cooperation with the Provincial Research Councils; it encompasses elements of technical advice, financial support and technology transfer, and is an important policy instrument for linking Canada's ITRIs to SMEs. The two other, TIP and the Investment Prospecting Program, smaller in size, are aimed at the importation of foreign technology. The author also indicates that research institutions find it easier to work with larger, more sophisticated enterprises, and that services to industry and working for SMEs are not enough to maintain a lab's own level of expertise.

The attached table summarizes the main interactions between policies and programmes at a general level.

## 2. CASE STUDIES

The report presents four cases, which we now summarize.

### 2.1 A Government-Owned Company Operated Laboratory (GOCO)

The US modality of turning over the management of a federal laboratory to a private company is being tried out in Canada's Wastewater Technology Centre since July 1991. Policy objectives and financial terms, however, are very different than in the US cases. In the latter, the original purpose had been to

CANADA: MAIN INTERACTIONS BETWEEN TECHNOLOGY POLICIES AND PROGRAMMES

| Policy Theme | Financing of R&D | Provision of Technical Services | Performance of R&D |
|---|---|---|---|
| **Commercialisation** | Government agencies have been able to retain, as supplements to their regular budgets, an increasing share of the revenues which they generate from contract R&D or the sale of technology. | These services are seen as potential sources of revenue for the laboratory providing them. | Government labs, with significantly increased and more influential advice from industry, are focusing their R&D efforts on narrower areas with better identified industrial potential. |
| **Technology Diffusion** | Government assistance provided via different programs to subsidise the adoption of either domestic or foreign technology, particularly by SME's | Government wishes to encourage the private provision of such services and may be willing to contract out to the private sector the management of such services as a first step in full privatisation | Programs such as IRAP-R were designed to support the diffusion of the results of government R&D. Evaluation of performance, and incentives for good performance, increasingly are tied to diffusion activities. |
| **Promotion of Pre-Competitive research** | Both Federal and Provincial Governments are focusing significant shares of their resources on precompetitive research in the new "generic" Technologies. | Government Labs which provide technical services are active in seeking to harness the new technologies which are applicable within their fields of activity. | Government Laboratories, particularly at the federal level, see their niches as being at this level of research activity since a larger variety of firms can become associated with any single program. |
| **Support to SME's** | While programs such as IRAP were designed to meet the needs of SME's they remain open to all companies and work on "generic technology" has involved extensive participation by large firms. | There continue to be a multiplicity of extensive programs, at both a federal and provincial level, in these areas. Coordination and avoidance of competition among programs is a continuing concern. | There is a tendency at the federal level to find larger and more sophisticated firms to be easier partners. It is in the Provincial Research Councils that is found the most consistent pattern of R&D being performed for SME's. |

avoid the constraints of the personnel policy of the US Civil Service. In Canada, the policy objective was to experiment with private sector management of a government laboratory in order to enhance its potential for the commercialization of the technology it would produce.

The Centre is engaged in programmes related to pollution control, biological processes, residue management and waste containment, and uses the inputs of a number of "enabling"technologies of biotechnology, advanced materials and informatics.

The company in charge of management, RockCliffe Research, felt it would contribute three key things: (i) managerial know-how on commercial technology transfer, (ii) a programme of incentives for the staff, and (iii) access to venture capital markets.

All WTC staff became employees of RockCliffe; the former government employees were granted leave-of-absence without pay, and a bonus scheme was established, financed with 20% of profits.

Financial arrangements included a guaranteed purchase by the government of specified services and outputs, the sharing of revenues from the sale of technology and services, and a fixed management fee. Profits would be divided up with 45% going to RockCliffe, 20% to be distributed among the employees and 35% to the Federal Government which would reinvest one-half in additional R&D projects at WCT.

An evaluation is to be made during the first half of the third year of operation, and its results will determine whether the contractual conditions carry on.

It is too early to draw firm conclusions on the extent to which the GOCO experiment will create a viable technology supplier, able to work on a commercial basis, out of a government laboratory. GOCO is a straightforward route to removing staff from Public Service limitations. It is not yet clear whether the GOCO modality may be carried on for prolonged periods of time (as in the US practice) or whether it is a stepping stone towards full privatization of the laboratory.

### 2.2 Promotion of pre-competitive research through the PRECARN consortium and the IRIS network.

The PRECARN consortium is devoted to "pre-competitive research" in the fields of Artificial Intelligence and Robotics. It consists of a group of 36 companies (some of them multinationals), producers and users of new technologies and products in those fields, that have joined together to finance and participate in such research which will eventually lead to practical applications. The other essential partners are the universities, some of whose staff are engaged via their participation in the Institute for Robotics and Intelligent Systems, IRIS, a network of 120 researchers from 18 universities, with a Federal funding of Can $24 million for 4 years.

PRECARN and IRIS are two overlapping networks (though half the universities in PRECARN projects are not involved in IRIS activities).

Funding for PRECARN comes from a number of sources - member contributions ($11.7 m), federal government ($19.1 m), provincial governments ($8.3 m). The figure for member contributions is 0.5% of their known R&D budgets, which is $ 2.26 billion.

Projects are multidisciplinary and highly sophisticated. They deal with potential applications that are highly pervasive, with a huge economic potential. They are subjected to a detailed feasibility study before being approved. Intellectual property is owned jointly by the participants in the project, and all members of the PRECARN consortium have the right to a royalty-free licence to use the technology developed.

At present there are four projects under way, with durations of 4 to 5 years, on (i) application of expert systems to advanced process analysis and control, (ii) active vision of a mobile robot in a known environment, (iii) telerobotic development system, and (iv) intelligent graphic interface for real-time monitoring and control. Other projects are in the pipeline.

The PRECARN case shows that it is feasible to put in place an extensive and coordinated programme of research and technology diffusion, with wide sharing of risks, as an alternative to a single "national institute".

### 2.3 The National Research Council and its involvement in pre-competitive research

NRC is an eighty-year old institution that undertakes a wide variety of science and technology functions, to which it devoted in 1989 close to Can $500 million, almost 17% of all Federal R&D expenditure; however, both figures are in decline. Like its sister institutions in other past and present Commonwealth countries, its mandate has changed over the years and it accepts today that providing technological support to industry is its primary *raison d'être.*

NRC is increasingly involved in undertaking pre-competitive research on behalf of Canadian companies in a carefully selected series of high-technology niches, and is involved in a very large number of alliances, principally joint research projects with industrial partners in which participants fund their own activities but share ownership of any technology developed.

The government's "commercialization policy" discussed above has had profound effects. NRC continues to maintain its tradition of fundamental research and its insistence on "quality", but it can now retain part of the revenues generated from contract research and sale of services, which provides an incentive for the expansion of its commercial activities. It has restructured its laboratories, from a discipline-based structure into 17 principal institutes or programmes (see attached table), with a focused mission, managed research programmes often involving large numbers of researchers as an alternative to each researcher pursuing his personal interests, and an annual "business plan" dealing with the generation and allocation of resources. Incentives, both financial and scientific, will be used to reward staff in commercially oriented activities.

INSTITUTES OF THE NATIONAL RESEARCH COUNCIL OF CANADA

| **Institutes of "Pre-competitive Research".** | **Institutes of Fundamental Research** | **Institutes of Applied Research and Service Programs.** |
|---|---|---|
| **The Biotechnology Research Institute;**<br>**The Industrial Materials Institute;**<br>**The Institute of Aerospace Research:**<br>**The Institute for Information Technology;**<br>**The Institute for Environmental Chemistry;**<br>**The Institute for Microstructural Sciences;**<br>**The Plant Biotechnology Institute.** | The Herzberg Institute of Astrophysics;<br>The Institute for Biological Sciences;<br>The Institute for Marine Biosciences;<br>The Institute for Marine Dynamics;<br>The Steacie Institute for Molecular Sciences; | The Canadian Institute for Scientific and Technological Information;<br>The Canadian Institute for Industrial Technology;<br>IRAP;<br>The Institute for Mechanical Engineering;<br>The Institute for the National Measurement of Standards;<br>The Institute for Research in Construction. |

ALLOCATION OF RESOURCES IN THE ENGINEERING INSTITUTES OF NRC

| | **Present distribution** | **Target Distribution** |
|---|---|---|
| Support of the "Public good" ( usually long term research without an identified application or customer) | 40% | 20% |
| Support of national infrastructure (in transportation, construction, etc) | 40% | 40% |
| Support for "Wealth generation" | 20% | 40% |

A recent review of the NRC institutes in the area of Engineering showed that there was still a need to change the allocation of resources within this group towards "wealth generation" rather than "public good" (see attached table).

Another change has been to replace traditional "Associate Committees" of leading scientists, that reviewed developments and orientations of different scientific fields, by Advisory Boards for each of the new institutes and programmes, with the mandate to advise on strategic and management issues, and conduct a yearly assessment of overall performance. The quality and expertise of the people appointed to these structures has been an essential factor in the success they have enjoyed in the two years since they were put in place

NRC was reported to participate in 1462 "alliances" in 1990/91, to which it contributed $67.6 million against $80.3 million of its partners. Two alliances were of particular significance: the ARK programme of PRECARN, devoted to developing an autonomous robot to use in a known environment, and the Solid State Optoelectronics Consortium which is working on the technology of optoelectronics integration.

Further organizational change is likely in NRC, in order to allow its institutes to play important roles in the research programmes of industrial consortia in selected, high-technology fields of potential long-term industrial significance. There may also be a narrower range of fields of concentration, but with more NRC staff per programme, a recognition that a subcritical effort is unlikely to provide practical rewards in the long term. For the individual scientist, the research milieu has changed from that of freedom to choose the individual's own research activities, as in a traditional university, to that of a mission-oriented lab with teams of researchers working together as parts of a defined multi-year programme. The issue is still pending whether to continue targeting SMEs as an undifferentiated group, which may not be the most cost-effective use of its resources, or to selectively target technologically aggressive firms, regardless of size.

## 2.4 The Provincial Research Councils

Provinces in Canada act in the technological development area in increasingly important ways. There are 8 Provincial Research Councils, PRCs, with a mandate to promote economic growth, and most of them deal very extensively with small companies. They all typically have a "corporate" structure, with an outside Board of Directors. One of them, BC Research, became a fully private organization in 1988.

The aggregate 1990 income of all PRCs was $170 million, about 2% of Canadian total R&D expenditure, and they employed 2200 people of which 974 were qualified scientists and engineers. The largest one in terms of income, $ 57 million, was the Alberta Research Council, which has a significant involvement in research consortia in energy and resource technologies, with very large corporations as partners.

Income sources of PRCs are grants from the respective provincial governments, contracts from the federal and provincial governments, contracts from Canadian and foreign industry clients, and royalties, sale of

publications, etc. The revenues from industrial clients are consistently increasing, while those from governments are declining.

Two unfavourable trends show up on analyzing the financial and employment figures for the PRCs. First, expenditures have become larger than income in recent years; with the present recessionary climate in Canada this may lead to reductions in staff. Second, salaries as a proportion of income have increased from 56% to more than 60%, although this figure is still much lower than the usual 90% or more in Latin American institutions.

The author has selected two PRCs for particular comment since they represent two attempts to manage an ITRI with minimum grant support from the government.

- **BC Research** chose to be privatized, in order to escape the negative factors which flowed from the status of being a government organisation: "the biggest gain we made by becoming private was to remove the identity crisis which plagued us in the past - that was to denigrate what we did well, serving our clients, by comparing it adversely with a wish to do long-term research of provincial or national importance". The transition was not easy; in 1991 a significant operating loss was recorded and has given rise to a "survival strategy", with staff reductions, salary freeze, postponing of capital expenditures. BC Research is now opening talks with the provincial government seeking restitution of the annual operating grant. It is clear that, in a climate of recession, it would be unable to survive over a prolonged period on contract income alone.

- **ORTEC International**, established in 1928 in Ontario, has built up a strong industrial customer base, both inside and outside Canada , in the areas of auto engine technologies and fuels, certain related materials technologies, and clean technologies. The proportion of its income from foreign sources (mainly in the USA) has been growing significantly in recent years and it may exceed 25% for fiscal 1991.

ORTEC offers services "in product and process design and development, problem solving, analysis, testing and evaluation." It does not describe itself as a Research Organisation, since it is convinced that its industrial customers rarely believe that their primary need is for research; it prefers other terms which convey a sense of practical mission addressing the kinds of difficulties faced by SMEs. ORTEC does, of course, undertake research on- behalf of clients, but much of its work lies in the adaptation and introduction of best practice technologies into companies seeking to improve their technological performance.

On the surface, ORTEC is doing many of the right things needed to ensure its long-term viability; however, four consecutive years of operating losses and a growing obsolescence of much of its equipment testify to problems which ORTEC is addressing in an as-yet-confidential strategic plan. One of the main problems is its dispersion over too many areas; it will have to focus its activities on its "core competencies". On the other hand, the economic problems faced by its clients during the ongoing recession adds to the difficulties of convincing small or medium scale enterprises in Canada to invest in technical change. ORTEC needs to to employ people with professional expertise in the area of marketing, to render more efficient its administrative

procedures in order to reduce its overhead cost structure, and to seek further assistance from the provincial government in order to refurbish some of its important but outdated facilities.

*The author summarizes his observations on the Provincial Research Councils in the following matrix of interaction of policy and programme.*

MAIN POLICY-PROGRAMME INTERACTIONS IN PROVINCIAL RESEARCH ORGANIZATIONS

| Policy Theme | Financing of R&D | Provision of Technical Services | Performance of R&D |
|---|---|---|---|
| Commercialisation | All PRO's are dependent on external finance for much of their research, but generally have inadequate revenues to allow them to move effectively into new and emerging fields. | An essential function of the PRO's, but even here they are coming under increasing competitive pressure from new, small enterprises with ultra-modern equipment. | All perform research under contract (typically about 20%) of their activities and Technical Development is their most important role (typically about 35% of their efforts) |
| Technology Diffusion | | One of the main purposes of the PRO's is to help diffuse "best practice" technologies to SME's and much of this they do by providing services..... | .....and by transferring the results of research and particularly of development projects to the project sponsors. |
| Promotion of Pre-Competitive Research | PRO's generally do not have sufficient internal resources to act as a financial source for precompetitive research; some may use their own resources to allow themselves to become participants in relevant consortia. | | Some PRO's are now participating in consortia undertaking precompetitive research, but as their equipment ages most will experience difficulties in keeping abreast. |
| Support to SME's | Some have governmental financial support to allow them to assist SME's in R&D; others need to charge commercial rates even to SME's. | All provide extensive technical services to SME's both through their roles in IRAP and through their own programs. | The PRO's may need to receive an adequate base grant from their Province if they are to continue to do R%D for traditional SME's - but this is likely to be difficult to obtain. |

CASE 9

## INDIA: THE NATIONAL CHEMICAL LABORATORY, NCL

*A visit was made by the author to India's National Chemical Laboratory, in Poona, a large public-sector ITRI with a distinguished trajectory, which has in recent years adopted an active marketing policy for its services. Here is a summary of his conversations with Dr A. Mashelkar, the Director of NCL.*

### 1. THE INSTITUTION

The National Chemical Laboratory, NCL, was founded in 1950, to serve the chemical industry. During its first decade of life it built scientific competence in chemistry and chemical engineering, and in the 1960s it turned to technology and installed pilot plants. By the mid-seventies it had been able to commercialize a few processes, and got to know how to take an invention to the market. During the late 70s and the early 80s it acquired full confidence in its capabilities on scientific research, innovation and engineering.

The institution currently employs 1200 people, of which 500 are researchers. The main areas are catalysis, polymers, biotechnology, organic chemical technology (here they look for the biochemical route). Interdisciplinary work is considered very important. NCL is internationally competitive in catalysis, a field in which they sell processes and provide process engineering.

NCL relies on the government for the larger part of its funding, but client income already represents 33% and hopefully it will be at a level of 50 to 60% in a few years. They have contracts with government departments and with industry. They are putting emphasis on the latter. In FY 1992 (April to March) two-thirds of the value of contracts came from industry, up from one third three years before. They are also increasing the participation of private industry in that amount, and at present private industry contributes 90% while public industry has seen its share reduced to 10%.

Indian industry does little research, some 20% of the total R&D expenditure of the country. It is the chemical labs (NCL and three others) that are closest to industry, possibly because the chemical industry is the most disposed to innovation.

### 2. ACTIVITIES

NCL has developed and successfully commercialized a number of technologies: organo-phosphorous pesticides; endosulfan; anti-cancer drugs based on local plants; vitamin B6; acrylates; a new catalyst of very good characteristics; plant tissue culture; a water-absorbing, biologically degradable polymer, etc. The next big programme will be the production of chemicals from starch.

In all these cases the technology has been licensed and commercial production is on. Additionally, many existing technologies have been transformed. In some cases it has been a question of technology push, in others of market pull.

An interesting case was the development of a novel-shaped zeolite catalyzer, for hi-tech catalysis of petroleum. This was a UNIDO project which started in 1987, and it has been overachieved: 9 catalysts were developed (of which 3 non-zeolitic) and are now being manufactured, commercialized and exported. Some 90 papers and 63 patents have resulted. Today all zeolite catalysts are locally produced in India, and there is export to Holland. There is no subsidy. A US company has set up a factory in Poona, close to NCL, and uses the latter's services. The selling price is four times the cost of manufacturing, but this is still two thirds of the imported cost.

NCL has sold technology so far through lump-sum or royalties. Licensed companies pay a 15% royalty. The division that produced the innovation uses 70% of this to fund equipment, resarcher time, etc. There is no extra remuneration for the researchers.

NCL is now considering opportunities for joint ventures with industry, putting the technology as equity and going for profits.

NCL is carrying out interesting work in plant tissue culture, particularly on trees. A pilot tissue culture facility is producing about 100,000 plantlets of eucaliptus, bamboo and teak at almost a commercial level, funded by the government's Department of Biotechnology. This is all destined to experimentation. But production will be increased tenfold in coming years and the plantlets will be sold; NCL will then be carrying out semi-industrial production of plants using bio-reactors.

## 3. RECENT INDUSTRIAL POLICY CHANGES AND THEIR IMPACT ON NCL

On 25 July 1991 a New Industrial Policy for India was announced by the Government, involving a significant departure from past policies. It attempts a shift towards a market driven economy, and opens up industry to foreign investment and technology collaboration, in order to "obtain higher technology, increase exports and expand the production base". It speaks of self-reliance as "the ability of Indian industries to pay for imports through its own foreign exchange earnings", and of the development of domestic technologies as "developing technologies for processes and products which are competitive internationally".

NCL reacted without delay to the new policy, publishing a report only two months later on "Impact of the New Industrial Policy on R&D at NCL". Two types of impacts were identified:

- In the short term, there is the expectation of a period of adjustment in the economy, which may last from 2 to 5 years. Industry is expected to adopt a "wait and see attitude", with a decline in investments and particularly in R&D, which would affect strongly NCL's income.

- In the medium and long term, the prognosis for R&D is thought to be "certainly bright; experience shows that innovation and discovery do thrive in a truly open economy". However, this could take ten years to materialize. In the meantime, the chemical industry would not have sufficient resources to upgrade knowhow from foreign sources, and would have to do so with local inputs, improving the prospects for industrial R&D.

The report then went on to list a number of criteria for domestically developed technologies: they should be oriented to the global market and not just to the Indian market; they should use local raw materials; NCL should consider offering complete technology packages, if necessary in collaboration with foreign engineering companies; efforts should be put in upgrading processes and products, including energy and process optimization, alternative routes for cost reduction and new product grades.

The new situation, as a result of the change in official policy, reinforced a deliberate change in NCL's policies which had already started some time before. As Dr Mashelkar put it:

> "We have understood the importance of business. We now have a professional group in charge of negotiations, with lawyers for patenting, and with marketing people. We are aware that if we don't sell, we're done. In 1991 India opened its economy and the government started to reduce the funds it allocated to public sector laboratories. But we had started to change before that. We had realized that we should become internationally competitive. In fact, we were the first government laboratory to start this."

## 4. FINAL COMMENTS

A number of general questions on ITRIs were then put to Dr Mashelkar, who answered them on the basis of NCL's experience:

(a) How can the performance/effectiveness of ITRIs be measured or assesed?

Answer: There is no high technology without high science. In NCL we have a balance of both. The indicators for performance are different for each:

(i) *Technology:* it has to be commercialized and produce revenue. Our indicators have to do with sales. We try to generate maximum returns from industry. Every year we give a prize to the group with a highest per capita return. A second indicator is invention: the number of patents. We file the largest number of patents in India, 50 to 60 a year, and we put special value on patenting in foreign countries. We give recognition to those who have developed technologies that give rise to a patent.

(ii) *Science:* the indicator is papers in international journals. We keep track of this and give recognition to people who have produced papers in the best journals, whose papers are quoted, and who present their papers in international conventions.

(b) Existence of "Strategic Thinking" in ITRIs

Answer: We have a short-term plan (1 year) and a long-term plan (5 to 10 years). At this moment we are carrying out an exercise of where we want to be in the next ten years. This is something new to us, and we are having internal debates, industry views, outside experts, etc. This is a structured exercise but we do not have a rigid methodology.

When the new industrial policy of India was announced in 1991, this lab was the only one in the country which was prepared to produce a position paper, "Impact of the new industrial policy on R&D at NCL", which was published within two months. This has recently been updated in a 1992 paper on "New industrial policy: some implications on the future of Indian R&D."

(c) Alternative organizational models and funding mechanisms for ITRIs, in the light of the new global regional context which now predominates.

Answer: The annual budget of NCL is 120 million rupees. At the current exchange rate of some 28 rupees per dollar, this is equivalent to about US $4.3 million, which carries much farther because of the low cost level in the country. Two thirds of this is footed by the government and one third comes from other sources.

We feel there should be a "globalization of national research". This can result from: (i) R&D collaboration with foreign countries; (ii) services sold to foreign countries; (iii) income from patents; (iv) export of software services, and (v) transfer of technology to less developed countries We are the only Indian lab to globalize its services. We have good quality, and can offer competitive science and competitive technology. We have made some interesting sales overseas, including training on research management in China.

We use a variety of marketing methods. I use my membership in different committees to look for opportunities. In a recent trip to the Washington area I visited 7 companies to explore opportunities for collaboration.

(d) The interaction between ITRIs and industry (Institute/Clients interaction).

Answer: *We are both a technology-push and a market-driven lab.* Regarding technology push, we have certain inherent strengths. We can develop processes spurred on by our own ability to generate generic knowledge. We have looked at market possibilities as a guide for this sort of "speculative research".

Take linear alkyl-benzene, used for making detergents. The world leader here is a US firm, which uses a hazardous technology. We have developed on our own a much safer, "green" technology, and filed a US patent on it. A pilot plant will soon be installed by an Indian company, and if all goes well much work will be generated for NCL. How to carry on further? Perhaps the US firm will want to make a joint venture with us and the Indian company. We are learning this game. We will need good legal advice.

## CASE 10

## THAILAND: TOWARDS REFORMING THE THAILAND INSTITUTE OF SCIENTIFIC AND TECHNOLOGICAL RESEARCH

*The author had occasion to visit Thailand in July 1992, and held discussions on various aspects of technological development with people from government, science, industry and the UN. He also visited the Thailand Institute of Scientific and Technological Research, TISTR. This institution was recently studied by Prof. Martin Bell, whose 1990 report contains many interesting observations about TISTR, as well as recomendations on the process of reforming it. The following text covers some relevant parts of Bell's report.*

### 1. THE MILIEU

Economic growth in Thailand has been strong in recent years: almost 10% per annum in 1987-90, fueled by export growth rates of 25% per annum. Macroeconomic stability and high direct foreign investment, oriented towards exports, have been the crucial factors in this process.

The present policy of the Thai government is to encourage manufacturing business, induce foreign investment and ask companies to train people and transfer their technology. Many joint ventures have been installed in recent years, with a resulting industrial boom.

The export increase has taken place in conventional products. To sustain such a performance in the coming years may not be easy, in the face of increasing competition from other low-wage Asian countries, and of the higher degree of automation and use of new materials in developed countries, that is helping the latter to recover comparative advantages. So far the country has not developed a significant degree of competitiveness in products that employ sophisticated technologies. Hence the need to design and implement a strategy to help local firms acquire technological capabilities in an expanding range of products with higher value added, which are ever more important in world trade.

Such a strategy would have to find support in the institutions that are involved in research and development, and in the provision of technological services. Local industries have largely been left to fend for themselves in technology matters; research carried out at the universities and official research institutes, including the Thailand Institute of Scientific and Technological Research, has not been too relevant to their needs - "too much top-down, too little demand-driven", as one of the interviewed persons put it. Standards and quality are also big problems that should be tackled in order to develop subcontracting. Last but not least, Thailand is short of qualified human resources such as engineers, technicians and skilled workers.

The country has lacked a sense of direction in technology policy, but now the challenge has been taken up by the recently formed National Science and

Technology Development Agency, NSTDA. This institution was founded in 1985 as the Science and Technology Development Board (STDB). It was originally a division of TISTR, but more recently it has become a separate agency with a new name and enlarged functions. The latter include: (a) funding of R&D projects in the Universities, TISTR and other public sector laboratories, to the tune of about $ 8m a year (an important part of which comes from foreign cooperation assistance); a moderate amount is also given for R&D in the private sector, in the form of grants and loans; (b) support to industry development, by upgrading the S&T infrastructure so that it can provide services in standards, equipment calibration, productivity improvement, etc.; (c) policy analysis and policy making; the agency prepared legislation on S&T development, which was approved in 1992, leading to the present NSTDA with its wide mandate; (d) setting up new research centres, of which three are already operating, in biotechnology, microelectronics and materials.

Most of the funds for R&D projects go to universities. However, as expressed by a senior manager of NSTDA, "the best people in the universities have gone to the private sector" and thus "to keep R&D going we will have to set up our own R&D units". Much support is given to training: "We need thousands of engineers, we need to upgrade industry people".

## 2. THE INSTITUTION

According to one of its senior executives, TISTR was founded in 1963, about 30 years ago. It started with scientific research and has then gone into technological research. It is now "hoping to produce some technology for industry". It counts with about 750 people and has an annual budget of almost $ 10 million, of which 70% comes from the government. He mentioned the priorities: agroindustry, followed by building, ecology , energy , and new technologies. Regarding services: testing, analysis, metrology, consultancy and training.

In contrast to foreign-owned firms, which do not require local technological support, local firms which employ "low" technology, are the major clients of TISTR. "We are a semi-autonomous State enterprise. We need more flexibility, less Government regulations, more funding. We want to bring back Thai nationals working overseas (there are a good many of high quality) and pay them well. We want funds of our own for investments and demonstration projects. We want to establish an incentive scheme for our scientific personnel (for this purpose we could use 10% of our revenue from non-Government sources). These are our new orientations, and private industry is aware of them."

The TISTR executive added that there is a lack of recognition from the private sector. If people pay little they do not value the service, and thus TISTR is starting to charge higher fees. On the other hand, there is recognition on the part of foreign and particularly international organizations.

An outside observer felt that TISTR has not yet been able to prove its worth to the industrial sector, though part of the responsibility lies with industry itself. He felt that TISTR lacks a focus and a clear mandate, and is short of capable people. TISTR was founded on the basis of Australia's CSIRO, following "a conventional innovation model of basic research - applied research -

development - application", but without a real understanding of the country's needs in technology... The country has a number of labs, but lacks various kinds of technical services, like quality and information. TISTR was disconnected both from industry and university. Scientists dreamed up projects, published papers, established international connections. Limited resources were spread too thin. Salaries were low, the best people have left, and the Institute cannot attract good people. 'They are trapped'. These shortcomings cannot however be blamed on TISTR alone. Industry imports technology, and Thailand has never demanded that firms train people and absorb and improve technology. On the other hand, technologies are changing fast."

A representative of the Federation of Thai Manufacturers was more positive. He felt that TISTR is genuinely interested in linking up with industry and look at its needs, and that industrial firms will enter into contracts with TISTR for technical and research work.

**The Bell Report**

An important report on TISTR was recently produced by Prof. Martin Bell of Sussex University, who spent several weeks at the Institute analyzing its activities and the problems it faces (Martin Bell, "The Thailand Institute of Scientific and Technological Research: Outline of a project to enhance its productive interaction with the industrial sector", Science Policy Research Unit, University of Sussex, Oct. 1990).

Bell includes in his report a number of observations on TISTR which may be summarized as follows:

- The orientation of activities was 70% to manufacturing, 20% to construction and the environment, 5% to agroindustries and other. About 20% of the Institute's direct expenditure was covered by consultancy and service fees, but R&D contributed insignificantly.

- There is a very limited impact of the Institute on (a) direct application of research results (b) publications (c) strengthening human resources in its clients. Hence it appears to have had a very limited success as a research technology institution. This weak performance has persisted in spite of many studies, advisory projects and internal 'reform' programmes. Fundamental changes would be needed to improve this.

- Three categories of issues may be identified: status within the government and financing; scope of activities; internal resources, structure and management.

  *(i) Status and governance:* Flexibility is needed in the management of financial and personnel resources; new mechanisms are needed to ensure performance-related accountability; a higher proportion of income should come from industry.

  *(ii) Scope of activities:* TISTR needs a radical change in the scope of its activities, which should be much narrower. It should focus more on manufacturing industry, as the Board has already decided, as the "core" business, transferring other areas to other institutions; it should align

R&D as a complement to industry's use of imported technology: it should keep away from scattered R&D work but rather provide technical inputs and human resources for continuous technical and organizational changes in client industries, ensuring that this orientation of activities is complemented by strategic R&D performed elsewhere in the S&T system.

*(iii) Internal resources, management and organizational structure:* The Institute's human resources should be radically enhanced and restructured, including retiring such staff members that are unable or unwilling to transform their skills and work orientation. It should also train human resources for industry.

- Management skills and methods should be strengthened by training, better procedures, and mechanisms for project generation.

- The Institute's existing fragmented organizational structure should be integrated by focusing units on particular client industries and narrowing the range of industries attended.

- The Institute's physical resources need to be substantially improved through a sound, long term investment programme.

- TISTR's recently appointed Board has emphasised that the future strategy of the Institute should concentrate on providing R&D and other technological support for manufacturing industry. Success in pursuing that strategy will require dramatic change in the effectiveness of the Institute's industry oriented activities.

## 3. BELL'S SUGGESTIONS FOR REFORMING TISTR

Bell remarks that any new project to increase TISTR's interaction with, and impact on, the production sector, especially manufacturing industry, will have to involve fundamental changes in a wide range of deeply rooted and interacting problems which underlie the current situation. His report outlines the main features of a project to achieve that objective. We now follow closely his text:

### 3.1 Key Issues

Three categories of issues are to be addressed:

*(a) Status and Governance*

The project should address at least the following key issues.

- Changing the Institute's mode of governance, and perhaps also its formal status, within the structure of government in order to permit the flexibility in financial and personnel management that is required for effective operation as an organization providing technological support for the country's continuing industrial development.

- Correspondingly, introducing new mechanisms to ensure performance-related accountability for the use of public funds.

- Requiring the Institute to generate a substantially higher proportion of its income from its industrial clients - both as a means of strengthening its more flexible position within the structure of government, and as a mechanism to reinforce the development of closer links with its clients.

*(b) Scope of Activities*

The project should consider the desirability of radically changing the existing scope of the Institute's activities. In order to increase its own effectiveness it will be necessary to concentrate TISTR's resources on a much narrower range of objectives and activities. It is also a highly opportune time to re-consider TISTR's role within the overall structure of public scientific and tecnological institutions which have evolved considerably since the existing range of the Institute's activities was originally defined.

This should involve examining at least the following key issues:

- Reinforcing the Board's recent decision to focus the Institute's R&D on supporting (manufacturing) industry.

- Concentrating exclusively on that 'core business' by divesting the Institute of other activities which can be transferred to other organizations, thus contributing not only to its own increased effectiveness but also to greater rationalization in areas of fragmented and overlapping responsibilities in the existing public S&T system.

- Aligning those core industry-oriented R&D activities much more substantially towards a direct complementary role in, relation.to industry's use of imported technology for the 'mainstream' of industrial growth - assisting in 'mastering' those technologies and in their absorption, adaptation and further improvement by industrial enterprises.

- Consequently, changing the expected output of R&D activities away from the development of scattered, individual 'innovations' for industry, and towards the provision of technical inputs and human resources for continuous paths of technical and organizational change to be generated by and with selected client industries.

- Ensuring that this orientation of TISTR's activities is complemented by more 'strategic' industry-oriented R&D which might be most effectively undertaken in other organisations in the S&T system - in academic institutions and within the framework of further developments of the National Centres.

*(c) Internal Resources, Management and Organizational Structure*

The project should address at least the following issues.

- Radically enhancing and re-structuring the Institute's *human resources* by:

  - setting up a 'crash programme' to create from existing staff a core group of people with the enhanced and different skills and experience required for the newtypes of TISTR activity;

  - where necessary, hiring new staff with the kinds of expertise and experience required to provide leadership in the planned new types of industry-oriented activity;

  - putting in place a permanent system for funding and managing human resource development in order to expand the initial core of new skills over the longer term, and to allow explicitly for the objective of producing an output of people-embodied technology for industry;

  - setting up and financing a transitional procedure to facilitate the transfer or accelerated retirement of existing staff who may be unable or unwilling to transform their skills and work orientation in the directions that will be needed.

- Strengthening the Institute's *management skills and procedures* by:

  - incorporating substantial training and experience acquisition in R&D management for selected core personnel within the broader 'crash programme' of human resource development noted above; and then developing a regular programme to maintain and enhance the Institute's management skills and experience;

  - developing new and strengthened management procedures for identifying industrial needs and opportunities, for internal accounting and resource allocation, and for evaluating the 'impact' of activities undertaken;

  - focusing particular attention on mechanisms by which new projects and programmes are originated - giving specific attention to new procedures whereby significant influence on the content of projects and programmes might be exercised by industrial enterprises and/or by industry associations and'clubs'.

- Integrating the Institute's existing fragmented *organizational structure*, and the diversity of its industry-oriented activities, by:

  - focusing the main operating units of the organisation on particular client industries, while enabling those industry-focused groups to draw on a range of technical specialisms that are relevant across the range of industries which the Institute aims to support;

  - narrowing, at least in the short term, the range of different industries on which the Institute is to concentrate.

- Substantially improving the Institute's *physical resources* (instruments, equipment, plant, computer facilities, etc.) by:

  - defining the scale and content of an immediate short-term investment programme to offset accumulated past neglect and bring the equipment stock up to a 'minimum level' required for effective operations;

  - identiying the approximate scale of a regular investment programme for the longer term, and putting in place the associated new procedures for financial planning and management.

## 3.2 The Project for reforming TISTR

*(a) Basic Organization*

The project should not simply produce general recommendations based on yet another study of TISTR. It should be organised in a way which incorporates as an integral component a programme of action to transform and reinvigorate the Institute.

It should therefore be organised in two linked phases:

- An initial Planning Phase of 4 months which will result in a set of recommendations for action.

- A subsequent Transition Phase which would involve implementation of the approved directions of reform and restructuring, together with regular progress reviews. This may require 18-24 months.

A small Task Force should be created to undertake the Planning Phase and the progress reviews during the Transition Phase.

*(b) The Composition of the Task Force*

The Task Force should be as small as possible - perhaps eight people. It is suggested that it should be independent of TISTR, but that its membership should overlap substantially with TISTR's senior management and Board. Some of the types of expertise and experience likely to be appropriate are outlined in the report.

*(c) External Assistance*

In addition to drawing on information and wide-ranging consultation within Thailand, the Task Force may find it useful to draw on specialised advice from individual experts from other countries during the Planning and Implementation phases. Two other forms of assistance may be particularly useful:

- The organisation of one, or perhaps two, collaborative Workshops with small groups of senior overseas personnel. These Workshops would be able to draw on experience and advice from a range of sources, while

helping to develop consensus and support for the actions to be taken. They might be particularly helpful around the middle of the Planning Phase and during at least the first of the Progress Reviews.

- Specialized advice and assistance with ongoing TISTR operations after the main transitional changes have been implemented - perhaps organised through collaboration or 'twinning' agreements with relevant institutions in other countries.

It is also likely to be highly productive if the Task Force should commission detailed and well focused studies on key aspects of relevant foreign experience, with the direct involvement of some of its own members.

*(d) Costs and Funding*

It was not possible at this stage either to prepare detailed estimates of the costs of the various components of the Project or to indicate the possible sources of funding that will be required to meet those costs. However, three points may be noted:

- During the Planning Phase the costs of the Task Force (honoraria, fees, support services and travel) are likely to be in the region of 2.5 million Baht (approx. US $100,000).

- Assistance in organizing one or more international collaborative Workshops might be sought from a foreign donor agency.

- Significant costs are likely to be involved in implementing the main components of the Transition Programme itself. Whatever may be the sources of financial support to cover those costs, it will be important to maintain the distinct identity of the transition programme, and hence to ensure that the funding is not consolidated into the regular operating budget of TISTR (or any of the other institutions that may be involved). Instead budgets for implementation should be managed as explicitly temporary arrangements to support the Institute's transition and transformation.

By the end of the Transition Phase of the Project, it will be possible to start a further phase of change in the Institute's financial basis: an explicitly planned programme of progressive reduction in the share of operating costs that is covered by direct government funding, with a corresponding increase in the share covered by funds secured from industry - perhaps rising from the current insignificant level to somewhere in the region of 50% over three or four years.

## CASE 11

## TAIWAN: THE INDUSTRIAL AND TECHNOLOGICAL RESEARCH INSTITUTE

*Taiwan has achieved very high rates of growth since the 1950s and has become one of the world's most dynamic economies. An effective technology policy, which emphasized acquisition, absorption, diffusion, improvement and development of technology, was instrumental in the rapid industrialization achieved. One of the main institutions in this regard was the Industrial Technology Research Institute, which has managed to give effective assistance for the technological upgrading of industry. The following text follows closely the description and analysis of this institution contained in the paper by Carl Dahlman and Ousa Sananikone, "Technology Strategy in the Economy of Taiwan: Exploiting Foreign Linkages and Investing in Local Capability", The World Bank, Washington DC, December 1990.*

### 1. OBJECTIVES

The Industrial Technology Research Institute (ITRI), founded in 1973, is Taiwan's leading research institution in the area of applied industrial technology. Its main function is to help upgrade industrial technology in the country, serving as an important workstation for the introduction and development of new technologies and for their adaptation and transfer to industry. It cooperates with foreign research institutions and business enterprises to import new foreign technologies. It disseminates the results of technological research and imparts information on acquired foreign technology to local enterprises, primarily small and medium, to assist them in becoming more competitive. ITRI also renders a variety of technical services, from personnel training to turnkey technology transfer.

Policy makers in Taiwan have pointed out that industry depended too heavily on joint ventures, foreign technology licensing, and foreign technical assistance to acquire technology, and that firms seldom made long-term R&D efforts. As a result, various industries lacked the ability to create and innovate, which limited their ability to penetrate foreign markets. More recently, as a result of increasingly fierce international competition, Taiwan's industry has begun to understand the importance of technical innovation, and many firms have set up their own R&D departments. They also seek assistance from domestic R&D institutions and look for technology transfer to raise their technological levels and help them gain greater control of their technology.

ITRI assists in technology transfer through multi-client and single-client joint development programs, promoting joint ventures between foreign and local firms, helping new start-ups, training personnel, holding technical seminars, and making publications.

ITRI puts a heavy emphasis on the dissemination and commercialization of research results. It sees itself more as a bridge between academic institutions

and industry than as a basic research institution, unlike public sector R&D centres in most developing countries.

## 2. ORGANIZATION AND ACTIVITIES

ITRI is organized into seven laboratories, the first two predating ITRI:

- Union Chemical Laboratories, with research in chemical process technology, engineering plastics and high performance polymers, plastic processing, synthetic spinning technologies, and exploratory research on biotechnology. UCL has developed numerous processes and products, many of which have been transferred to industry. In addition, it has been active in process improvement.

- Mechanical Industry Research Laboratories. The main areas are: machine tools and industrial production machines, ultra-precision machining, computer-aided design (CAD) and manufacture (CAM), industrial robots and flexible manufacturing systems, automatic control systems and components, and power engine research and testing. In 1975 MIRL started developing precision milling machines and numerically-controlled machine tools, which were transferred to local industry. In 1982 it began designing articulated industrial robots for local production. Many of its projects involve developing customized CAD/CAM and other software. It has also been active in generally promoting industrial automation and mechanical parts standardization, in order to improve the productivity and efficiency of Taiwan's industry.

- Electronics Research and Service Organization, established in 1974, which does research on very large scale integration design and manufacture, design of integrated chips, computer system software and peripherals, digital TV and digital local area networks (LANs). ERSO has played an important role in the development of the electronics industry in Taiwan. In recent years it helped set up the Taiwan Semiconductor Manufacturing Company, a joint venture with Phillips, to manufacture application-specific integrated chips, and also established a special center for long-term research in leading-edge technologies such as parallel processing, artificial intelligence, and expert systems.

- Energy and Mining Research and Service Organization. The main areas of research are remote sensing and mineral exploitation, alternative energy sources, energy conservation, and pollution control. It has developed new technologies in remote sensing, geophysics, amorphous silicon solar cells, various types of solar heaters, energy conservation, and pollution control, many of which have found commercial application.

- Materials Research Laboratories. Its main areas include metallic materials; casting, forging, and powder metallurgy; high polymer and composite materials; fine ceramics materials; second generation semiconductor materials; material inspection services, and information. MRL has been successful in developing new materials and processes, as well as in providing services and technical assistance to local industry.

- Center for Measurement Standards. Set up in 1986, its main purpose is to maintain national measurement standards and provide measurement and calibration services to a network of secondary laboratories.

- Electro-Optics and Peripherals Development Center, ITRI's newest laboratory. It was established in 1987 and very soon developed several products and systems, such as Winchester disk drives, a laser engine, a system for modulation of laser beam printer, a servo system for optical disk drives. More recently it has focused on transferring these technologies to domestic manufacturers in order to promote the electro-electronics and peripherals industry in Taiwan.

ITRI also has computer databases for a variety of industrial technologies, which are available for consultation by industry. In addition, it publishes many periodicals and books and holds numerous seminars to disseminate technical information.

## 3. RESOURCES

(a) Personnel

In 1987 ITRI employed almost 4,500 persons, of which two thirds were directly involved in research. The rest were technicians, operators and those involved in non-technical positions. The caliber of professionals at ITRI is high; more than one-quarter have a master's degree or above.

(b) Revenues

Total revenues in 1980 were about US$ 40 million, increasing to about US$ 55 million by 1982. After that year there was a more rapid increase in both government and private industry contracts.For the fiscal year ending June 30, 1988 ITRI's total revenue was over US$ 230 million. This came from grants by the government (3%), government contracts (54%), industrial contracts (29%), pilot plant production (12%) and non-operating revenues (2%).

Government grants, which have been stable in recent years, are used to finance the infrastructure of ITRI as well as preliminary research projects. Government and private contracts have increased steadily, reflecting increasing confidence in the work of ITRI.

## 4. RESULTS

(a) Patents

Patent applications by ITRI, both domestically and abroad, have increased from just a handful in 1980 to more than 60 domestic patents and 100 overseas patents by 1988. Corresponding yearly patent approvals have also increased from just a few in 1980 to 27 in 1987 (seven foreign and 20 domestic), and 35 in 1988.

(b) Diffusion

One of ITRI's most important functions, conveying technology to industry, is accomplished through technology transfer, joint research and development, personnel training, and technical services. For example, in 1988 ITRI undertook 113 joint research projects and technology transfers, provided 31,084 technical services, and presented 16,968 technical seminars.

(c) Evaluation

In 1986 ITRI established the Industrial Economics Research Centre, IERC, to collect and analyze information on domestic and international industries, technologies, products, and markets. This information is fundamental for ITRI's technology development activities. IERC also evaluates ITRI's programs in order to provide directions for future work.

In 1987 IERC carried out a study of ITRI's impact on industry, which analyzed five programmes. In each of them the following aspects were reviewed: inputs, results, diffusion of results and economic effects.

The analysis of economic effects included assessing the impact of the programme on investment, output cost savings, reduced dependence on imports, and revenue from services performed. The results of the study suggest that the programmes analyzed have had a significant impact on local industry. For three of the programmes - computer industry, precision gear, and thermal energy technology, revenues far exceeded the reported costs of the programmes. The intangible benefits of the programmes are harder to evaluate by definition, but they are likely to have been important.

In the last two years ITRI has felt increasing pressure to justify how effectively it uses its resources as well as to demonstrate its contribution to the economic development of Taiwan. A major study is currently underway at IERC to evaluate more carefully the effectiveness of ITRI's various research areas and to examine more critically the contribution of the institution.

## CASE 12

## PAKISTAN: IMPROVING SCIENCE-INDUSTRY LINKS

*A UNIDO-UNDP mission recently made a one month visit to Pakistan at the request of the Ministry of Science and Technology, to analyze how to strengthen the linkages between industrial R&D institutes and industries, which the Ministry considers essential for the industrial development of the country. The experts looked into the cases of the Pakistan Council for Scientific and Industrial Research and the National Centre of Technology Transfer. We summarize below some of the key parts of the report (Carl Erik Wegener and J. Adeodato de Souza Neto, "Linkages between R&D organizations and industry in Pakistan", Mission Report, UNDP Project PAK/86/023, June 1992).*

### 1. INTRODUCTION: THE PROBLEMATIQUE

The following is meant to review concepts and set up a theoretical framework, under which the linkages of independent government R & D institutes with industries will be discussed.

#### (a) The role of industrial R & D institutes.

Under inspiration of the import substitution strategy, many developing countries established government industrial research laboratories in the 60's and 70's. Existing industrial research institutes were, at the time, too scientifically minded and usually did not have engineering and consulting services, which strongly hampered the technology transfer to industry. The new institutes included these functions and had autonomy to establish contracts with industry. They also provided an array of tests and analytical services, and the income originated from the contracts and services to industry became important indicators of performance, and a measure of the interaction with the clientele. The new organizations were modelled after different traditional research institutes of the Soviet Union, the United Kingdom and the United States. Although different approaches have been followed, many common features can be found in these institutes. They were expected to develop indigenous technology and to interact intensely with local industry. Yet, they were formally independent from industry.

This model has never performed to the satisfaction of governments or industries. The initial belief that good research results would automatically be used by industry was shown to be mistaken. Therefore, several mechanisms were implemented to facilitate and promote the linkages with the market. In many cases, specialized bodies were created to promote research results, provide venture capital funds, finance research activities under conditioned payback, set up nurseries for emerging technologies, etc.

#### (b) Technology Supply and Demand

All of these instruments acted upon the supply side of the problem (research driven approach). Very little consideration was given to the demand side,

trying to develop technologies that were needed by industries. A consensual finding in current literature is that 3/4 of the successful industrial innovations are of the "pull" type, i. e., they have been originally proposed by marketing or production people.

An illustrative example is the case of the telephone company in Brazil which directed its purchases to promote the equipment that was previously developed by research institutes, at the company's request. Telephone sets, small switching stations and other equipment represented 70% of the total investments of the company. By directing tenders' specifications to match those of the models, it could transfer the technology and employ local suppliers.

Another example is that of SRI International, of Menlo Park, California. They interviewed people at the Highway Patrol to find out their needs for product and services improvements. Once they were able to define the bidding procedure that would give preference to the desired improvements, the so called "product opportunity notice" was then publicized. Such notice called for meetings and discussions between R & D institutions and industry. The purchasing power represented by the new bidding rules usually enticed industry into R & D projects, which were carried out by industry alone or in co-operation with R & D institutions.

The important feature of this method is that it detects the innovations that the market is willing to pay for. Similar structures of demand can be found in large industries and other organizations that wish to upgrade suppliers or clients.

### (c) Technological innovation in a competitive environment

New challenges appear for R & D institutes with the emergence of the new techno-economic paradigm and the organizational changes that are slowly taking place in the world's economy. The phasing out of the import substitution model and the adoption of a liberalized trade policy is just one of the consequences.

The key to competitiveness of industry is associated to the cluster of actors organized around a business area. The innovation process cannot be seen as the achievement of one firm. The sense of alliance or partnership among some components of the cluster, along a production chain, is very strong, and has changed the innovation into a collective process.

With the intensification of international competition, licensing of technology to Third World Countries has also become less attractive. This may give the R&D institutes an opportunity to collaborate with local industries.

Understanding this new environment and reformulating objectives and strategies are essential conditions for the creation of effective linkages between R&D institutes and the productive sectors.

## 2. THE EXISTING SITUATION

The Mission found that the educational background of the staff of PCSIR and NCTT is of high standard and the laboratory equipment and other facilities are generally sufficient and of excellent quality.

But the linkage between the institutes and their clientele is generally deficient, if at all existing.

The communication between the two parties is sparse, the mutual professional respect is low and the attitude towards an improvement of the situation is negative. Nobody seems prepared to take the first step to change the situation.

The result of the described general lack of communication is that the individual scientists of the R&D institutes define and select the R&D projects based upon their own interpretation of the needs of their users. The selection is often based upon the import substitution model and not upon the national competitiveness model. The screening procedure before final approval of the projects does not orient the projects in a more relevant direction, as the users' needs are not sufficiently represented in the procedure. Though no exact data are available, there is the impression that only a very small part of the products and processes developed are utilized by the productive sectors.

A few examples of good and fruitful interaction observed by the Mission indicated, however, that the situation can be changed.

## 3. RECOMMENDATIONS

We review below those recommendations of the Mission that have direct relevance to the problems of the interaction between science and industry, leaving aside other recommendations on various topics.

### (a) Improving the links

The mission's recommendations for improving the interaction between the R&D institutes and their clientele are, first, to identify the needs for R&D, and second, to orient the R&D institutes towards these needs.

The *identification of the needs for R&D* is recommended to be carried out as 3 sub-projects:

- identification of the needs of the public sector for extending and improving the infrastructure and the public services.

- identification of the opportunities for developing competitive advantages in export markets.

- identification of the needs of the productive sectors for the domestic market.

The *orientation of PCSIR and NCTT towards the needs* should consist of:

- restructuring of PCSIR dividing the organization in smaller autonomous units according to business area and with user-oriented boards and professional managements.

- introduction of revised business- and service-oriented policies in both organizations.

- management training, human resources development and change of attitudes in both organizations.

**(b) Reorienting PCSIR: Guidelines**

The following are general guidelines proposed by the Mission to reorient PCSIR from a science driven strategy to one pulled by demand. It implies an increased participation of clients in the decision making process. No single measure will be effective, thus one has to regard it as a package of changes in structure, policies and attitude. Further, these changes cannot be achieved by means of a single pen stroke. They require a planned process, dedicated management, discussions and the right strategy.

*Structure*

- Reorganize PCSIR into smaller independent units according to the business nature, regional considerations and national priorities. The adequate size of each unit and the final number of units will result from regrouping and subdividing current units.

- The new independent units should be established, according to their objectives, in the form of institutes, companies, foundations or other convenient forms. Authority to borrow from banks, take equity in venture projects, hire and fire personnel, etc. should be assigned accordingly.

- Select the members of the Board of each unit to assure a strong representation of the clientele (industry or government agencies).

*Budgeting*

- Establish cost sharing of projects with clientele. This means that some units will have a significant participation of the private sector, and others will be almost wholly funded by government.

- Development projects should primarily be financed by industry. Examples are pilot plant construction and operation, market test, product development, engineering, etc.

- Basic research and exploratory studies should be stimulated with government funds, as they are meant to create opportunities for future investments.

- Establish adequate targets for cost sharing with industries, but do not allow these targets to drive the units into services which are typical of the private sector (avoid competition).

*Business Orientation*

- Technical, economic and commercial feasibility analyses, of appropriate depth, should be used for project selection, always comparing competing alternatives. On analyzing commercial feasibility, one should ask whether anyone is willing to pay for the products or services produced with the new technology.

- Carry out pilot studies to determine technological demands and clients for selected R & D units. These pilot studies should serve to establish the methodology for such work and train the unit's staff. It is suggested that big purchasers be interviewed to detect their needs for upgrading suppliers; if they are willing to pay for the additional quality (or for a new product), then a collaboration project can be established. Other situations which may be examined are supply to government investments, development of new, or adequate use of existing, products or equipment, changing material of construction, export market, import substitution, etc.

- Continuously survey opportunities and clients of the unit, organizing such activity in a permanent form. Train personnel in the market approach.

- Establish adequate contracting schemes, including risk taking, conditioned payback, payment of royalty, etc. Technology should be handled as an asset.

*Performance evaluation*

- Define appropriate indicators of performance and reporting procedures. Scientific output is usually measured by quality and number of publications. Technological output can be evaluated by number of processes and products leased out, number of patents, total revenue of services and projects, etc.

*Recognition and remuneration*

- Privileges, awards, distinctions and celebrations are common practices to demonstrate recognition for valuable scientific work. Part of the salaries should come from regular funding, and the other part should come from project income, according to agreed rules.

*Engineering and equipment manufacturing*

- No pride should be placed on in-house design and construction of pilot plants with no external help. Local engineering firms and equipment manufacturers should always be involved. This is a way of transferring technology and finding partnerships to sell technology to processing industries.

*Attitudes*

- The change of orientation of PCSIR from a science-based "push" concept to a market-oriented "pull" concept is a major task. It will require policy measures, board decisions, management efforts, information programs, etc. Professional assistance will be needed from organization and management consultants as well as from specialists in sociology. The possibility of employing young scientists and engineers with new attitudes should be considered in the coming years, when a large group of scientists are due to retire.

- A specially designed training program on R & D Management should be seriously considered. There is a need to broaden the views about the role of technology in the economy. Themes like economic development, industrial policy, intellectual property, the innovation process, project management, technology transfer, etc. should be discussed.

CASE 13

# UNITED STATES: INTERACTIONS OF MIT WITH INDUSTRY

*We present the case of a successful university, the Massachussets Institute of Technology, which has become a leading actor in many aspects of development in its country. MIT is not an ITRI, and experiences of this sort can rarely be transplanted in an easy manner, but there are some important teachings here for universities and research institutions in developing countries that are interested in improving their activities and making them fully relevant to the needs of the productive sector. Here follows a shortened version of a paper by the present author (A. Araoz, "How MIT interacts with industry: some teachings for developing countries", to be presented at the forthcoming Latin American Seminar on Technology Management, Bogotá, Sep. 1993)*

## 1. THE INSTITUTION

The Massachussets Institute of Technology, MIT, is not too large as an educational institution when judged by the number of students, which is less than ten thousand. But the very high quality of the student body as a result of a strict admission process, the large contingent of graduate students, and the dedication to research of faculty and students, have fashioned a unique institution where learning is not just the outcome of classroom teaching but comes from a deep involvement in pursuing knowledge at its frontiers.

The nature of MIT has been well characterized by the President of the Institute in a recent address: "Since its founding at the midpoint of the 19th century, MIT has been a rather unique institution... Great institutions of higher education are grounded in and learn from the past; interact to some degree with the world of the present; and aspire to influence the future. MIT is no exception, but in large measure the institute's uniqueness derives from the unusual extent of our engagement with the present and dedication to the future. We apply our talents to problems posed by contemporary society - by the institutions of industry, commerce, arts, healing and politics. Yet our minds are even more firmly engaged in shaping the future. This somewhat singular approach to our mission has enabled us, over the years, to define new forms of research and scholarship, and to establish new paradigms for education... MIT students, faculty and staff are deeply engaged in the process of learning in the classroom, in the laboratory, and from each other. There is an exhilarating sense of being at the cutting edge in all that we do... MIT has technology and natural science at its core, yet encompasses the work of humanistic scholars, social scientists, architects, planners, management experts and artists. The quality, style and content of our educational programs prepares students well for a wide variety of leadership positions in industry, academia, and public service - leadership that is essential to a vital future in an increasingly technological and interdependent world."

A few statistics for the year 1991-92 may help to give an overview of the Institute. Total enrollment was 9541 students, of which more than one half,

5216, were graduate students. The international student population was 2117, citizens of 103 countries, representing some 9% of undergraduates and 33% of graduate students. Women were 2589 (1433 undergraduates and 1156 graduate students). A total of 2721 degrees were awarded that year, of which 1039 bachelor, 1137 master, 31 engineer, and 514 doctoral.

A very important aspect is the financial aid granted to students. MIT's policy is to recruit its candidates only with an eye to quality, and then to look for means to enable them to attend the Institute. In 1991-92 financial help was extended to 56% of the new enrollment, for a total of $ 38.6 m, mostly in grant aid.

The faculty had 966 assistant, associate and full professors, 73% of whom were tenured. During the last 15 years there has been stability in the numbers of undergraduates and faculty, while graduate enrollment has grown by almost 1000 to its present level of 5200.

The total financial operations of MIT for the year 1991-92, including sponsored research, were $ 1.08 billion. Of this amount about one half, $ 509.7 m, was devoted to education and general expenses, $ 231.5 m for departmental and interdepartmental sponsored research, and $ 342.1 m for direct expenses of the Lincoln Laboratory's sponsored research. As a private institution, MIT does not enjoy government subsidies. Its current revenues of $ 1.07 billion for the year come mainly from tuition fees, federal and industrial research contracts (which incorporate suitable overheads), gifts from private donors and income from the Institute's endowment (now worth about $ 2 billion in market value).

MIT has five Schools, in which teaching and research are conducted: School of Architecture and Planning; School of Engineering; School of Humanities and Social Sciences; Sloan School of Management, and School of Science.

Research is an essential activity at MIT. In 1991-92 there were more than 3000 research projects under execution, covering a very wide spectrum. This work is performed by the almost one thousand faculty members, a full-time research staff of over 2,200, the more than 5,000 graduate students, and a host of undergraduate students as well. Industry sponsored nearly 300 research projects that looked for practical solutions to real-world problems.

Current research projects are described in an annual publication, "Research at MIT", which lists them under 72 units (departments, laboratories, centers, and other) in the following main fields:

Aeronautics and astronautics
Architecture and urban planning
Biological sciences
Chemical science and engineering
Civil engineering and transportation
Computer science
Earth, atmospheric and planetary sciences
Electrical engineering and electronics
(including the Lincoln Laboratory)
Health sciences and technology
Humanities and social sciences
Manufacturing and mechanical technology
Management and economics

Marine studies and ocean engineering
Materials science and engineering
Physics and mathematics

## 2. INTERACTIONS WITH INDUSTRY

MIT characterizes itself as a *research university*, committed to "fostering education and advancing knowledge for the betterment of the human condition". MIT's philosophy, combining education, research and service, has made it a sought-after model in Europe and other parts of the world, because of its strong values of real world problem-solving and commercialization.

From its inception in 1861, MIT has operated under a broad set of goals emphasizing both education and service to the community. Its focus was not only on the preeminent goal of providing the highest quality education, but also on ensuring that technology be geared to the practical needs of society and made available for its use. As expressed in a recent report by a Faculty Study Group, MIT has a "long-standing commitment to effective transfer of knowledge to the society at large".

MIT's interest in practical applications has implied close ties with industry, and made the transfer of knowledge from the laboratory to the commercial sector an important operational goal. MIT's charter and environment have given rise to a variety of policies and activities, such as encouragement of faculty consulting, initiatives to start new companies, industrial support for research, student internship programs, aggressive technology licensing activities, and the creation of the world's first industrial liaison program in 1948.

The complexity and richness of the interactions between industry and MIT's human and knowledge resources can best be examined by distinguishing the nature of the interaction and the different mechanisms helping the interactions.

We present this information in matrix form in Figure 1. We have marked with crosses the interactions privileged by each of the mechanisms.

Let us now review briefly the two sides of the matrix, starting with the different types of interactions.

## 3. TYPES OF INTERACTIONS

(1) *Human resources for industry.* Probably the most important interaction, on account of its pervasiveness and long-term impact, is the supply to industry of MIT graduates, particularly in engineering and management, with first-rate training in their fields of study, an ability for life-long learning and a good appreciation of technology and its role in industry.

(2) *Training of personnel from industry.* Managers, professionals and researchers from industry find ample opportunities for training at MIT in a wide variety of subjects, in regular or special academic programs, often focusing on the specific needs of a company. This allows participating

# HOW MIT INTERACTS WITH INDUSTRY

*INTERACTIONS*

| *LIAISON MECHANISMS* | 1. HUMAN RESOURCES FOR INDUSTRY | 2. TRAINING OF PERSONNEL FROM INDUSTRY | 3. INFORMATION, MUTUAL VISITS, PUBLICATIONS | 4. DISCUSSION OF RESEARCH ON INDUSTRIAL ISSUES | 5. CONSULTING FOR INDUSTRY | 6. R&D SPONSORED BY INDUSTRY | 7. LICENSING OF TECHNOLOGY | 8. CREATION OF NEW TECHNOLOGY-BASED ENTERPRISES |
|---|---|---|---|---|---|---|---|---|
| 1. DIRECT INTERACTIONS FACULTY-INDUSTRY | X | X | X | | X | X | | X |
| 2. LIAISON PROGRAMS OF LABS & CENTERS; CONSORTIA | X | X | X | | X | X | | X |
| 3. INDUSTRIAL LIAISON PROGRAM, ILP | X | X | X | | X | X | | |
| 4. TECHNOLOGY LICENSING OFFICE, TLO | | | | | | | X | X |
| 5. ACADEMIC PROGRAMS AIMED AT INDUSTRY | X | X | | | | | | |
| 6. MAJOR RESEARCH PROGRAMS ON INDUSTRIAL ISSUES | | | X | X | | | | |
| 7. PROMOTION OF NEW BUSINESS VENTURES | | | | | | | | X |

companies to update the knowledge and skills of its top personnel, and to survey new technologies and new opportunities that may appear.

(3) *Information, mutual visits, publications.* Informing industry about research work carried out in MIT, by formal means (bulletins, publications, special symposia) and informal channels (person-to-person contacts, telephone calls, mutual visits), is an important interaction and may later lead to long-term projects.

(4) *Discussion of research results on industrial issues.* The results of studies on general industrial problems such as productivity, manufacturing methods and applications of new technology are often discussed with industry, particularly in the case of firms that have been covered in the study and want to learn how well they are doing as compared to other firms.

(5) *Consulting for industry.* This is an established tradition at MIT. To encourage outside professional activities, faculty are expected to devote to them up to twenty per cent of their time during the academic year, i.e. one day a week. Summer months may also be used for consulting.

(6) *R&D sponsored by industry.* Industry-sponsored research is a strong activity. We have mentioned that industrial firms sponsor some 300 research projects on a wide variety of topics. The purpose is sometimes to make progress in an area that is important to the sponsoring company or companies, such as a ten-year arrangement with Exxon Research and Engineering Corp. on efficient fossil fuel combustion, or the Polymer Processing Program supported by a dozen companies. In other cases more short-term research needs may be addressed, as in a recent contract for the development of new products for a medium-size firm.

(7) *Licensing of technology.* The licensing of MIT-generated knowhow, which is treated below (see section on the Technology Licensing Office), has two main users: existing firms and new start-ups. There have been many successful cases, among them practical methods for the production of penicillin in the 40s, the magnetic core memory in the 70s, and inventions in the area of environmental technology in more recent years.

(8) *Creation of new technology-based enterprises.* This has been an important feature at MIT for many years, as faculty and graduates have exploited new opportunities brought about by inventions. The list of successful new enterprises is an impressive one. By 1983, it was estimated that faculty, staff and students from MIT had started over 1,000 companies in the Boston area alone. More recently, through the Technology Licensing Office, the Institute is taking a direct hand in promoting the formation of new ventures, even to the point of accepting equity as part payment for technology generated at MIT.

## 4. LIAISON MECHANISMS

(1) *Direct interactions between the faculty and industry.* These personal interactions, a common occurrence at MIT, are the expression of the "community" between MIT people and industry people which we have already mentioned. Through such interactions - in person, or by mail, telephone or

fax - graduating students are recommended, information is transmitted, problems are communicated, suggestions are put forth, programs for training, consulting and research are outlined, discussed, negotiated, agreed upon. There is great scope for the faculty in its dealings with industry, and more formal liaison mechanisms supplement rather than replace such spontaneous communication.

(2) *Liaison programs of labs and centers; consortia.* Some laboratories and centers have their own liaison mechanisms, which in the simplest of cases will consist merely of a list of contacts to which information is sent. More focused interactions may take the form of a "collegium" or "consortium", in which a group of companies interested in a particular field help to fund research in it - for instance, ceramic powders, polymer processing or environmental engineering.

(3) *Industrial Liaison Program (ILP).* This program was established by MIT in 1948, to raise additional resources for research and education while encouraging the transfer of knowledge to industry. Presently it is the largest such program in US universities, with a staff of 50 and 250 member companies of which half are foreign. The member companies pay a yearly fee (which averages $33,000 for US firms and $ 46,000 for foreign ones). In return they are helped to stay abreast of work at the institute, through special symposia, visits to faculty and labs, visits by faculty to the member company, summaries of research under way and distribution of publications.

ILP has 20 professionals, each of which maintains effective relationships with a number of companies. Total ILP income is $8 m a year of which 3 m is contributed to the Institute's budget.

There is advantage for a company in using the ILP to learn early about research of interest to it, and to obtain information and contacts with the faculty in an efficient manner. MIT's faculty generally find the ILP a useful vehicle for obtaining information from industry, and for staying abreast of advanced industrial research.

ILP contacts that do involve serious, substantial transfers of knowledge will frequently evolve into another form of relationship, such as sponsored research or consulting.

What do firms expect of their membership in ILP? This question was explored through a recent survey, which gave very interesting results. A company's primary reasons for developing relationships with MIT were to monitor technology, gain early access to research, build relations with the faculty, stimulate innovative thinking, and (particularly in the case of US firms, where this objective ranked second) recruit graduates.

Contacts arranged by ILP are only a part of all relationships MIT-industry, particularly in the case of US firms, for which it is relatively easy to maintain direct contacts with faculty and events at the institute.

(4) *Technology Licensing Office (TLO)* . As part of its commitment to the transfer of technology, MIT has a long-standing tradition of patenting inventions made by its faculty and students, and licensing them to new

entrepreneurs and to established companies. This activity has been entrusted to the TLO, with a staff of 8 professionals of different backgrounds.

An average of two inventions a day are produced in MIT. The TLO screens them and ends up filing 4 patents a week. In a number of cases the inventions will be licensed to industry. The flow has been growing in recent years; there were 15 licensing agreements in 1986 with royalties of $1.8 m, while in 1991 a total of 90 licensing agreements were concluded and $16m royalties paid.

MIT researchers are obliged to patent through TLO. They are given one third of the royalties as a compensation, which appears to be a satisfactory arrangement.

Beyond licensing, the TLO also endeavors to help in the establishment of new ventures based on MIT inventions, following the pattern of entrepreneurial activity that has long characterized the ethos of MIT. Over the years, new companies - usually in the most rapidly growing, high-technology fields - started by graduates and professors of MIT have contributed substantially to the US economy. Examples are Raytheon, Digital Equipment and Hewlett-Packard. Individuals related to MIT have started 57 software and 20 biotechnology firms in Massachussets alone since 1980. The coming tendency seems to be in the environmentally related industrial activities.

Of the 90 licensing agreements finalized in 1991, 8 were for newly established companies, which have been helped by the TLO to raise the necessary capital. Sometimes MIT keeps a small participation in the new firm's capital.

(5) *Academic programs aimed at industry*. We will mention three programs specifically oriented towards personnel from industry:

(a) The Center for Advanced Engineering Studies aims at giving key industrial people intensive instruction in a large variety of fields, from acoustics to VLSI design, through flexible study curricula, using existing academic facilities. The Fellows enroll for one or more terms.

(b) The Leaders for Manufacturing Program is a collaborative experimental education and research program with 11 major US manufacturing firms, which aims at discovering and applying guiding principles for manufacturing, and educating future manufacturing leaders. Its Fellows Program offers a two-year graduate experience integrating manufacturing and engineering, including a six-month internship in a plant. Since 1988 it has funded the education of about 180 graduate students.

(c) The recently set up Program on Productivity from Information Technology will parallel the Leaders for Manufacturing Program in the information technology area. Research will be conducted and personnel from the sponsors will be trained. Plans are now in the making for this new endeavor.

(6) *Major research programs on industrial issues*. MIT has conducted two important industrial studies which have involved strong industrial participation and have produced results of great significance. The discussions with industry on the results of these projects promise to have significant impacts.

The first of these studies was undertaken by the MIT Productivity Commision, and examined the reasons why a number of US industries have lagged behind foreign competitors in their productivity development. The results of the case studies were published in a succession of technical publications, and summarized in the book "Made in America". Such results have been widely discussed with the industries involved, and are starting to exert an influence in future business plans.

The second one, the Motor Vehicle Program, made a comparative survey of a large number of motor vehicle assembly plants in the US and other countries. This study not only produced abundant, detailed comparative data, but very importantly it developed the concept of "lean" production which has found application much beyond the automobile industry. Many reports and publications have resulted from this research. The book summarizing the main results, "The Machine that Changed the World", has been an editorial success. Results have been fed back to the sponsoring firms and the principles of lean production have been discussed with many industries.

(7) *Promotion of new business ventures.* These activities, which center on new high-technology undertakings, are carried out by some private groups in MIT premises. Two of them are in the form of clubs for new entrepreneurs, the New Venture Club and the Entrepreneurs Club, and organize meetings to pass on the experience of established entrepreneurs to aspiring ones and discuss new ideas for startups.

The third one, Enterprise Forum of Cambridge, which is affiliated with the MIT Alumni Association, is more ambitious in that it aims to provide "advice, support and educational services to innovative and technology-based enterprises of all sizes". It organizes two monthly sessions, aimed respectively at startups and at more established companies, during which the company's CEO presents his business operations, objectives and issues, and receives feedback from an expert panel, as well as from the audience, which in its turn learns from the proceedings. About 200 people usually attend. The Forum also conducts workshops, organizes every January a five-day course on "Starting and Running a High-Technology Company", publishes a newsletter and runs a confidential computer service that matches entrepreneurs with individual investors.

## 5. FINAL OBSERVATIONS

Several remarks may be made regarding the matrix of interactions we have described. In the first place, the liaison mechanisms shown by the matrix are those which exist at present, though the listing is probably incomplete. Former mechanisms have ceased to exist and it is likely that some present mechanisms will also disappear, while new ones will be brought into existence. There is great flexibility in this scheme.

Secondly, the interactions shown are those peculiar to MIT and may not be the same that take place elsewhere. In fact, certain types of interactions with industry which are common in other universities do not appear in the case of MIT. For example:

- in general, no proprietary research is made for industry; the sponsor gets first call on results but no exclusivity, and results are published;

- no MIT professors are allowed to be in the payroll of a firm; however, consulting and board membership are allowed;

- no extension work is conducted for small and medium enterprises;

- no technology park has been set up; however, MIT gave birth to the spontaneous "Route 128" phenomenon, the predecessor of all technology parks, which is still going strong after several decades;

- no enterprise incubator has been installed, and in fact there is a feeling that such a thing is not befitting, since it would provide an artificial environment from which new startups would find it difficult to jump into the real world. However, as we have seen, MIT may help form new ventures to exploit MIT inventions.

Finally, we must keep in mind that the matrix is only a simplified way of representing a complex and changing reality. *The essence of the interaction between MIT and industry*, which underlies the matrix but cannot be fully reflected by it, *is the sense of community between faculty, researchers, graduate students, alumni and industry people*. This is made up of countless interactions that happen on a person-to-person basis, as people work together and as they join up in academic events and in social pursuits. Such a community is little or not at all developed in traditional universities devoted to the pursuit of knowledge for its own sake. Building up a community of this nature and intensity is a very long process.

Reviewing the rich experience of MIT in collaborating with industry, Lampe and Utterback (1983) reached the following conclusion, which deserves to be quoted at length:

"MIT's long established tradition of cooperation with industry has helped it to serve industry as a source of innovative ideas and people. The research and educational programs at the Institute have, in turn, been enriched from these contacts with industry. It is difficult, however, to explain how this desirable synergy has been achieved. Many other universities with similar reputations and operating under similar conditions have been unable to duplicate the success of MIT in establishing strong and mutually rewarding ties with industry.

"No set of rules or arrangements can guarantee the success of such a complex relationship. Fundamentally, it is a question of attitude and perspective. *MIT's success has sprung directly from its underlying philosophy of active cooperation with the world of commerce and industry*, a philosophy that has been integrated into the culture of the university and supported by the community.

"Many universities have tried to remain apart from industry on the grounds that the corporate emphasis on applications and products may compromise scientific goals. Indeed, it is not easy to resolve the many conflicts that arise among the various valid concerns represented in a research university. The MIT experience shows that through a deeply held philosophy and set of values

it is possible to achieve a balance, which works for the benefit of the educational community, industry, and society as a whole."

## 6. IMPLICATIONS FOR DEVELOPING COUNTRIES

The case of MIT may be of interest for universities of developing countries, which generally show features that have become outdated in the modern world: their accent on traditional subjects like Law and Medicine, their emphasis on the pursuit of research as a value in itself, their shortcomings in producing graduates in the technical disciplines with a good grasp of the state of the art in their disciplines and an open attitude to research and to further learning.

The experience we have described offers interesting teachings on the role, organization and functions of a modern university that has become a powerful instrument for transformation and development, and particularly on how it has been able to develop a strong interaction with industry without lowering its standards of excellence in teaching and research. They may find application in the profound updating which appears necessary if those universities are to apply in a fully effective manner the significant resources they command for the benefit of their societies.

We may rescue two main teachings from the experience of MIT:

First, the idea of a *research university*, in which research and teaching are closely associated so that students learn the 'state of the art' of the subjects they study, and in many cases participate actively in pushing ahead the current state of the art.

Second, the concept of a *community* between university and industry, which brings about in a natural fashion a wide range of collaboration activities of great value to industry and to society at large. As we have already indicated, it takes time to build such a community, but once in place it is bound to become a very powerful force for modern development.

There are, no doubt, many problems in applying such concepts in a developing country, among them the insatisfactory level of many university teachers, the lack of a tradition of research closely connected with teaching, and the fact that few industries would now be in a position to interact fruitfully with a university performing state of the art research.

In spite of these obstacles, it may be worthwhile to attempt to introduce some of the concepts and procedures we have reviewed into an existing university, or into a fresh institution newly created. Because of the time and expense needed by such a project, it should perhaps be seen in a wider regional context, so that other developing countries could participate by sending students, exchanging staff and becoming associated in some of the research activities.

## CASE 14

## UNIDO-UNDP: EVALUATION STUDY OF INDUSTRIAL RESEARCH AND SERVICE INSTITUTES

*In 1977, recognizing that IRSIs (equivalent to our ITRIs in the present report) had been in operation in some developing countries for up to 20 years, UNDP and UNIDO agreed to undertake a joint evaluation of the effectiveness of the technical assistance they had provided to these institutes and the subsequent performance of those that had received assistance. The study covered 33 IRSIs, of which 17 were multi-sectoral. A group of distinguished international experts participated in the discussion of results. The report was published in 1979, and the following text includes the salient aspects relating to Institute performance ("Joint UNIDO-UNDP evaluation of industrial research and service institutes - Summary prepared by the Secretariat of UNIDO", ID/B/C.3/86/Add.1, 21 November 1979, UNIDO, Vienna).*

### 1. THE EVALUATION STUDY

The study starts by recognizing that developing countries need to acquire technological self-reliance if they are to have more control over their own economic development. For this purpose they require financing and technology. The acquisition of technology calls for mechanisms for providing supporting services, extension services, training, and research and development (R + D).

Industrial Research and Service Institutes are thought to contribute, to a significant measure, to each of the components. There is considerable controversy, however, as to whether IRSIs are the optimum route for developing countries to follow and whether more cost-effective alternatives might not be available.

The evaluation study defined an IRSI as "a multi-purpose or multi-functional technological institute (a) which provides services (functional activities), either to a group of industrial sectors (multi-branch) or a single sector (mono-branch), and (b) which possesses a major R&D component". It was believed that there were lessons to be learned from an exchange and analysis of experience, benefiting the IRSIs themselves as well as the governments of countries in the early stages of industrial development.

The study made some interesting findings. Vagueness and lack of precision had often existed in the design of projects for new IRSIs that UNDP and UNIDO had supported. The policy objectives usually have been the upgrading of existing industry, the transfer and adaptation of technology, the development of new technology and the optimum utilization of raw materials. Most institutes, however, had neither the capacity nor the capability to achieve all of these obectives and had spread their resources too thinly.

The strength of the institutes lies in the supporting services they can provide, particularly with regard to technical information, analysis and testing, the

establishment of standards, quality control, the certification of products, and the provision of basic routine services to industry.

Extension services were usually weak, due primarily to inadequate liaison with industry and knowledge of the problems of industry. Linkages between the institutes and their industrial clients were also found wanting in the majority of cases.

Most of the IRSIs reviewed, while engaged in some R + D, were principally service organizations. Research activities were usually the result of in-house initiatives and were frequently found to have limited commercial potential.

The evaluation study suggested measures to improve the interrelationship between IRSIs and government and to increase the institutions' capacity to serve more directly the needs of industry. It suggested that after the initial period, the mix of general subsidies and grants should be shifted to contract and mission-oriented work. In the more developed countries, IRSIs have significant potential for providing extension services to industry and assisting both government and industry in technological aspects of technology transfer and adaptation.

The multi-purpose, multi-sectoral institute requires a critical mass which for the less developed countries is difficult to achieve quickly. An institute needs a minimum of ten years to become established; longer if R & D is to be a principal function.

## 2. FINDINGS

The most significant findings of the study are worth quoting in full:

### Missions, strategies and plans

(1) In many cases, the relevance of an IRSI appears higher in terms of its long-term objectives (e.g., building up research capacity and capabilities) than in terms of its short-term ones e.g. solving specific industrial problems.

(2) In the case of single-branch IRSIs, the intended clients are usually clearly identifiable. With multi-branch IRSIs, however, the client (e.g. industry - cottage, small-, medium- or large-scale public or private) is not always as clearly or as explicitly stated.

(3) Performance histories indicate that a frequent IRSI shortcoming is a failure to appreciate the importance of identifying the proposed beneficiaries of services at the planning stage.

(4) A substantial amount of the work of single-branch IRSIs is covered by contract, but multi-branch IRSIs apparently find it more difficult to attract projects. The effort needed to "sell" an IRSI and attract clients is often ignored at the strategic and tactical planning levels.

(5) Many institutions having "research" in their name are primarily service organizations. Where a definite R&D function is claimed, the objectives are usually clearly stated, but even in such cases the anticipated results and the plans for achieving them are often over-optimistic.

(6) Linkages, twinning or similar co-operative arrangements with other IRSIs, either within the country or abroad, appear to have boosted the impact of the work of several IRSIs in such areas as exchange of information and experience, and organization of fellowships.

(7) While many IRSIs were created to serve small- and medium-scale industry, this sector, in practice, often shows neither an interest in nor an appreciation of R&D.

(8) In spite of the critical shortage of qualified staff in most IRSIs, plans to develop and expand staff capabilities are sometimes either not suited to the real requirements or are non-existent. While academic or technical qualifications are often good to excellent, industrial experience is usually inadequate.

(9) Linkages between institutions charged with promoting and developing new industry and those responsible for supporting existing industry are usually feeble.

(10) Of the 33 institutes covered in the evaluation exercise 17 are multi-branch. Single-branch IRSIs most often concentrate upon services, utilization of raw materials, and new (imported) technology; they seldom carry out innovative research. Multi-branch, multi-purpose IRSIs concentrate in the smaller and less developed countries upon testing and analysis. In the larger, more developed countries, they usually attempt to avoid routine services, concentrating instead on sophisticated testing and analysis and innovative R&D. Often, they do not have sufficiently specialized competence to be of help particularly with respect to process, equipment and vendor selection in technology transfer transactions.

(11) The desirability of integrating IRSIs into national development planning processes is widely and positively acknowledged. Actual implementation, however, is low. In many cases, neither the government nor the IRSI clearly understands what the latter's contribution could or should be.

(12) Competence, generally speaking, is usually high in the areas of testing, analysis and other supporting services, but less so in, for example, product and process development (R&D).

(13) Innovative research is generally found in the research strategies of IRSIs in large and relatively advanced developing countries, but seldom in the smaller and less developed ones.

(14) Technology transfer does not lend itself to many of the products of the least developed countries: empirical evolution is necessary for the upgrading of "traditional" technologies. In this situation, pilot scale activities are important.

(15) In the majority of the IRSIs reviewed, no systematic effort is being made to develop staff skills through different modes of training or learning. An insufficiency of training in local industry is very apparent. Much emphasis is placed on the acquisition abroad of degrees and knowledge, but appreciation of the real requirements and problems of local industry is lacking.

(16) The physical infrastructure appears to be least problematic in the development of IRSIs. Nevertheless, few of the IRSIs covered in the sample had the engineering capability to design and construct pilot plants by themselves. The alternative was to procure them from abroad at high cost.

(17) Few IRSIs have the information system needed to keep up to date on work being carried out elsewhere: an appreciable duplication of R&D work is therefore highly probable.

### Interrelationships with government

(18) The IRSIs reviewed in the evaluation showed little evidence of the strong political will and leadership needed to ensure their continuing success.

(19) The IRSI's major contribution to government has been in the provision of various technical supporting services. Contributions, in terms of inputs to government decision-making on industrial and technological matters as well as the acquisition of foreign technology, can be substantially increased.

### Interrelationships with industry

(20) A serious communication gap exists between industry and many IRSIs which is partially due to: inadequate or non-representation of IRSIs on governing boards and working committees; absence of appropriate mechanisms to establish and maintain a continuous dialogue; shortage of staff with industrial experience; lack of appreciation by industry of the services available from IRSIs; failure to assess periodically the requirements of industry.

(21) The principal benefits industry has derived from IRSIs to date relate to various supporting and routine services (e.g. testing and quality control). The benefits from specialized extension and technological services have been less pervasive.

### Performance and potential

(22) The potential of an IRSI depends almost entirely upon the quality, quantity and skill composition of its staff and management. And while the availability of Ph.D. and M.Sc. graduates may not present any crucial problem in this regard, the availability of intermediate technical staff - for whom the attraction of industry is much stronger - does. Another impediment to IRSI development is the lack of engineers with industrial experience, especially in the areas of design, construction of prototypes and pilot processing plants, and extension services to industry.

(23) The question of whether pilot plants should be developed by IRSIs or industry is a controversial one subject to definition and local conditions. In any event, they are costly projects whose potential value must be carefully weighed.

(24) Given sufficient institutional maturity, there is a high potential for IRSIs in the area of technological planning and policy-making.

(25) IRSIs can assume important functional activities relating to technology transfer and adaptation: e.g. the provision of information and advice on alternative technologies.

(26) The area of information gathering, analysis, storage and dissemination is a most suitable one for twinning and co-operative arrangements.

(27) An IRSI's contribution to industry can be increased and improved through the use of intermediate institutions to reach a broader spectrum of clients.

**Commercialization of research results**

(28) Spontaneous demand by enterprises in developing countries for assistance in self-improvement is weak: the industrial sector's great need for improved technology is sometimes misinterpreted as an expression of demand for such help.

(29) The best opportunities for the incorporation of technologies occur through the "pull approach", i.e. starting from the needs of industry and selection of the most inexpensive and immediate response to the identified technical requirements. The transfer of existing technologies is therefore, the most frequent solution.

(30) An IRSI interested in selling technology needs strong capacity for market analysis, project evaluation and industrial management.

(31) Industrial firms are usually more willing to undertake innovative projects when the necessary services are supplied as part of a coordinated package.

(32) Technology development corporations using the "push approach", i.e. research results developed exclusively or primarily in-house, are more effective in relatively well developed technical environments.

(33) Direct government support to innovative projects is justified because their social benefits are greater.

## CASE 15

## WAITRO SEMINAR: OBSERVATIONS ON ITRIS

*The present author had the opportunity of attending the Seminar on "R&D Strategies for the 1990s", organized by the World Association of Industrial and Technological Research Organizations, WAITRO, in Québec, 13-15 October 1992. He was able to collect a number of very interesting viewpoints and remarks on the problematique of ITRIs in developing countries, which have been woven into the previous chapters of this paper There were, however, two events which deserve to be recorded on their own. Here is a summary of them.*

### 1. INTERVIEW WITH DR HOLLIS CHARLES, COORDINATOR, ADVISORY COMMITTEE, WAITRO

Mr. Charles was President of WAITRO, 1988-90, and Director for more than ten years of the Caribbean Industrial Research Institute, CARIRI.

*(a) On the effectiveness of ITRIs.*

This is a difficult question. There are macro-economic indicators for a country, such as a 6% growth achieved. Can we say this is due to the country's ITRIs? Even within a company, how do you link results in the company accounts with resources spent in R&D? For instance, someone comes with an idea, the ITRI carries out research and economic analysis and perhaps pilot plant work, and recommends a certain technology. Two years later the plant opens - but it is the Bank manager that sits on the podium, while the director of the ITRI is in the audience. Why? Because many things have happened in those two years, and it is the Bank manager that is seen as the main actor. Economic decisions appear as overriding.

This is the problem in assessing ITRI performance - in the final analysis financial considerations are seen to be the most important. I once sat in a negotiation involving the purchase of technology. A lawyer was taking notes. In half an hour we managed to bring down the price by a million dollars. Our fees were $ 300, but the lawyer took several thousand!

Thus a first constraint is the problem of people's perception of the value of technical advice. It is the lawyers that pocket large fees.

And there is seldom a tangible result that can be valued, because so many other things need to be done. If one could identify the economic impact of what the ITRI has done, it would be possible to have an indicator of performance.

We have discussed this problem in WAITRO for 20 years and haven't found the answer.

One may want to look at this problem by exclusion: what will it cost the user if he does not have the answer (opportunity cost). However, the client does not have sufficient information to estimate this.

The work of ITRIs may be said to cover 3 areas:

(i) *services*, including R&D services, which should be put on a commercial basis;

(ii) *strategic R&D*, for long-term purposes, undertaken at the request of the government;

(iii) *speculative R&D*, made by the ITRI with resources of its own, which may or may not pay off; somewhat in the nature of venture capital.

The latter usually takes place in the utilization of raw materials, or the solution of uniquely local problems, and involves work which should be carried out
with strict control of time and inputs.

An example is the development made by CARIRI in 1975 of fruit juices based on local species, by contract with a government agency, the Industrial Development Corporation. This was highly successful as a technical endeavour, and big orders were placed when the products were shown at a fair in Lausanne. The IDC however commercialized the products in a very ineffective way - no promotion, no advertising, poor packaging.

Since that time CARIRI has carried out work in the development of other products, but has run itself the commercial operation. This has been successful. The technology was sold to a private firm, which however did not put sufficient resources in the commercialization. Perhaps there has been supply push?

In fact, all our experiences with the utilization of S&T for the development of products based on natural resources have been successful until the marketing stage was reached. The problem is the lack of experience in marketing the products.

We have also developed small-scale agricultural equipment, and sold the technology to a private firm which is doing about all right by specializing in products that work at a scale in which you cannot find outside technology.

So, to go back to the problem of assessing performance. One should first separate the outputs of the institute into the three above categories, viz. services (this category includes consultancy as well as contract R&D for a client), speculative R&D and strategic R&D.

You can assess services if you do them on a commercial basis, covering your costs and overheads, plus (hopefully) a profit . This is valid whether the client hits it or not (this is his problem, not yours). In speculative R&D you should ask whether you are making overall profits. You should think of this "venture capital" being spread over many projects. In strategic R&D, if the government says "you must do this" it should pay for it. At some stage

you may want to know how valuable the work has been for the country; but this is another matter.

In industrial countries there are intermediary organizations which place contracts with funds originally provided by the government. For example, the Biotechnology Institute in Canada, which funds biotechnology research through contracts. In the developing countries you don't have these intermediary organizations, and the funds are more clearly seen as coming from the government.

*(b) On strategic thinking*

There is no manager that doesn't do strategic thinking in some way. Approaches and methodologies exist to formalize this and make it more efficient. Their use depends on the level of sophistication of managers. The Industrial Research Institute of an African country reports every phone enquiry they get: should they embark on a strategic planning exercise? Perhaps the manager just needs to improve his thinking process, rather than carry out a SWOT analysis or write a strategic planning document. We should help him improve his analytical tools, paying attention to the level of sophistication.

Accompany the industrial sector? ITRIs should do it, but are not, doing it, among other things because they are not segregating their activities into the three areas already mentioned. Thus they confuse their roles. The strategic work for government gets confused with services for the productive sector.

*(c) On the organizational model*

This should contemplate the three areas as separate business activities, with different business objectives. Services should be fully funded. Speculative R&D would have mixed or joint-venture funding, with the participation of industry. Here you can include business incubators. Strategic research should have full government funding.

There is no place in this scheme for research to pursue the curiosity or particular interests of researchers. However, the ITRI should lobby the government for the idea that "one of the strategic things to do is to allow R&D work to satisfy the curiosity and interest of researchers" (devoting to this end perhaps 10% of the researchers' time). An important argument in favour of this is to avoid losing the initiative of people and to stem the brain drain.

*(d) On the interactions with industry*

These are of two types. First, in services (including R&D services) that are "fully commercial". This is driven by needs. For instance, the Quebec Centre of Industrial Research, CRIQ, has done this well with information services. Second, in speculative research in which the commercial sector participates and puts money. You must market your ITRI, and show that you are a good bet. In fact, you have to market yourself all the time.

On the approaches and mechanisms to reach clients: researchers are not good marketers. You need specialized people, and this makes for an internal interface problem, bedeviling all consulting operations. In an ITRI you need good interface inside the institute. One can see in different ITRIs (such as CRIQ and the I.N.T. of Brazil) the problems that exist between the researchers and the marketing people.

Thus, the question of marketing is very important. Linkages with R&D or with the technical capacity have to be very carefully worked out. Here we may learn from the experience of the engineering consultancy firms.

## 2. DEBATE: STATE OR PRIVATE ITRIS?

The Workshop that closed the Seminar dealt with "ITRIs in the 1990s: Government or Market Players ?" and took the form of a trial by jury, with presentations by two "attorneys" and several "expert witnesses".

Mr. Hollis Charles, former president of WAITRO and ex-Director of CARIRI, presented the case for ITRIs as public sector institutions. His main arguments were the need to preserve "strategic research" on long-term problems that market customers would not normally fund, and the need to supply research and technological services at subsidized costs to many customers that would otherwise not think of becoming clients of an ITRI.

Mr. Rustam Lalkaka, former Director of the UN Fund of Science and Technology, speaking for the other side, pointed to the growing tendency in the world towards privatization, and suggested that privatizing ITRIs would remove some important obstacles to their efficiency and make them more attuned to the needs of industry; regarding strategic research, he felt that this should be mainly the preoccupation of universities.

The "Jury", of which the present author was a member, voted for the vision of ITRIs as private sector institutions, but added two provisos in its recommendation to the "Judge": that ITRIs should engage in long-term strategic research through government subsidies or better through Government contracts for that purpose, and that in certain cases some sort of Government subsidy should be awarded to clients that were unable to cover the full cost of services rendered to them by an ITRI.

This decision was well received by most participants, but there were some ITRI representatives from African countries that thought it was not feasible to have ITRIs outside the public sector at the present stage of development of their respective countries.

Such a view should be taken seriously, and in fact the hypothesis should be explored that favourable conditions for private sector ITRIs will appear only at a certain stage in the development of an industrial system.

## CASE 16

## EUROPE: COOPERATIVE RESEARCH BETWEEN ITRIS AND SMALL INDUSTRIES

*This is a summary presentation of a recent report, "Cooperative Research in European Perspective," prepared by the Federation of European Industrial Cooperative Research Organizations, FEICRO (Danish Technological Institute, 1992).*

*The report is about industrial research carried out in collaboration between smaller companies and Research and Technology Organisations (this is equivalent to "ITRI", term which we shall use in what follows). Based on transnational evaluations of 84 successful projects from across Europe, the report identifies the "best practices" in the relationship between smaller companies and research centres, focusing attention on Cooperative Research as a practical instrument for the modernization of small and medium enterprises.*

### 1. THE MODEL OF COOPERATIVE RESEARCH

The case stories are described according to the major project phases. This linear model of perceiving the innovation process ignores the fact that a cooperative research process depends on communication and mutual learning between company people and the research personnel. Therefore, a second model for understanding cooperative research has been drawn which takes into account the circular interaction between the two parties within each of the project phases (see attached figure).

This co-generative model is the basis for discussing the good practices on project initiation, project operation and project implementation. The attached table presents them in a summary form.

### 2. THE GOOD PRACTICES

Relevant project themes are not only generated as a direct request from client companies (bottom up). Project ideas are very often formed at the initiative of the research centre or by the centre in collaboration with client company representatives.

*1. Good practices in project initiation.*

They fall into three types:

- Good practices for stimulating demand for research projects. These are not limited to the offer of research projects, but include other activities which encourage the companies to take their problems and possible projects to the ITRIs. The diversity of services that can be offered by the ITRIs will favour the launching of Cooperative Research projects.

- Good practices for translating company requests into cooperative research projects, i.e. projects that are widely relevant and may involve several companies in project execution.

- Good practices for appraising project ideas.

*2. Good practices in project operation.*

They reflect the need for active company participation in setting up project priorities. It is argued that for SMEs the goals should be defined in terms of clear benefit to the company rather than in general research terms. The economic aspects should also be presented as clearly as possible.

Good practices have also been identified on company participation in project work and in project management.

An effective way for enlarging the group of companies involved is to form "reference groups" or informal discussion groups in connection with the group of active project partners.

Essential to the success of Cooperative Research projects is the dedication of the client companies themselves. At best they should carry out project tasks which they can master, leaving the ITRIs to take charge of supervision, training, coordination and the provision of know-how and appropriate technical methods.

*3. Good practices in project implementation*

They include:

- Information activities (demonstration projects, information events, publications, software programmes, training courses)

- Accompanying actions for bringing the techniques into use (company specific training, transfer of people, counselling by RTO). Some project types (eg. development of "easy to use" software packages) require less additional activities even when the project results are aiming at a great number of users, while other projects may require more follow-up activities (eg. development of production systems based on self steering work groups). Thus, the necessity for accompanying assistance increases with the implications of change in the receiving companies.

- Spread, or multiplication, of project implementation by diffusing project results from few companies to many companies. Collaboration with the technological leaders (champions) in the industrial branch may permit demonstration projects where companies that are technological followers can learn from "real life" about the applications of the project's findings.

## 3. TRANSFER OF COOPERATIVE RESEARCH RESULTS

The report lists several means for the knowledge transfer of cooperative research. The list is not exclusive; in practice several of the knowledge transfer means are applied in the same project.

- "Hands on" demonstrations (laboratory or full scale exhibitions)

- Publications (reports, leaflets, handbooks, computer programmes)

- Meetings (regional or project bound)

- Training (workshops, seminars, knowledge module in courses)

- Company-specific actions (company visits, consultancy, transfer of people)

- Rules of operation between parties (technical norms, specifications, certification schemes)

## 4. SOME GENERAL CONCLUSIONS

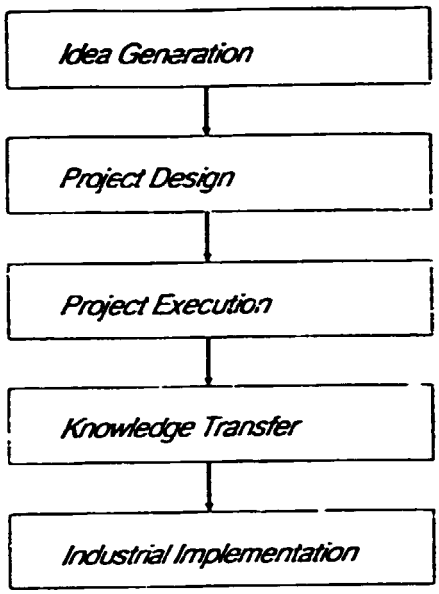
Cooperative Research projects are not merely products of science push from research or demand pull from the explicit request of client companies. The projects are to be considered more as products of circular processes where a continuous dialogue takes place between the two parties.

The operational aspects of the day-to-day collaboration is primarily a social process and secondarily a technical process. Every Cooperative Research project can actually be regarded as a learning process both for the research personnel and for the company people involved. The exchange of know-how is a two way process.

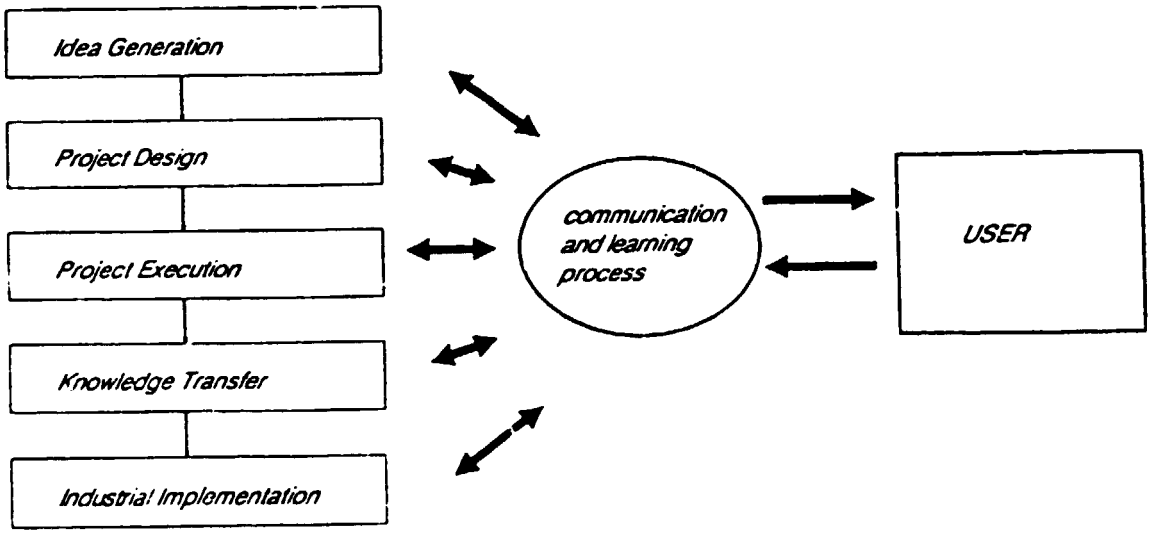
Assistance by the research centres to smaller companies will assume different characteristics, with different products and services according to the innovative capacity of the client companies. A project on a production process with the collaboration of a large scale machinery supplier may be carried out for the benefit of the small company with a scarcity of resources. There may be collaboration with the technological leader in the segment as long as the general objective is to reach the more conservative companies.

Accompanying actions may continue for a long time, for two reasons. First, it takes much time to go from development to general adoption when it is smaller companies that are to introduce innovations. Secondly, the identification of research topics requires continuous contacts so that the credibility of the research centres can be fully established and client companies feel that they are understood by them.

Linear analytical model of Cooperative Research




Co-generative cooperative research



## OVERVIEW OF GOOD PRACTICES IN COOPERATIVE RESEARCH

### 1. Good practices in project initiation

*- Good practices for stimulating demand*

-Idea generation as a spin-off of current testing and certification activities at the research centre
- Stimulation of demand by setting up a pilot demonstration unit (at laboratory scale)
- Successive formulation of projects: one project generates the next

*- Good practises for translating company requests into Cooperative Research projects*

- Formulation of a cooperative research project as response to a need diagnosed in one or several client companies
- Reformulation of the request from a company into a project with general relevance for client companies

*- Good practices for appraising project ideas*

- Technically relevant documentation on the project idea, which is of general interest to client companies
- Evaluation of the project idea with representatives of the client group

### 2. Good practices in project operation

- Definition of clear goals and their continuous adjustment
- High involvement of the RTO in the early stages
- Joint project design and operation between RTO and companies
- Project organisation with champion companies and followers
- Company representatives in project management
- Intermediate organizations linking RTOs and companies

### 3. Good practices in project implementation

- Find a balance in the collective status of the project
- Disseminate project findings to client companies through information activities
- Bring the techniques into use through accompanying actions
- Spread techniques from few to many companies

SOURCE: FEICRO, "Cooperative Research in European Perspective", 1992

CASE 17

## EUROPE: CONTRACT RESEARCH ORGANIZATIONS

*The author had opportunity to interview Mr Georges Mordchelles-Régnier, Chairman of the European Association of Contract Research Organizations (EACRO). The experience of this type of institution may be of help to examine some of the orientations which ITRIs in developing countries could develop. The following presents some of the main points covered. We have also used descriptive material published by EACRO to supplement some of the points.*

### 1. THE NATURE AND ACTIVITIES OF EUROPEAN CONTRACT RESEARCH ORGANIZATIONS

Contract research organizations, CROs, are independent research institutes, in the private or public sector. Their fields of expertise cover the full spectrum of scientific and engineering disciplines. They are very useful to industrial firms of all sizes in sustaining their competitive advantage by underpinning their own research activities with outside technology sources.

Working under contract, CROs carry out "adaptive R&D" to meet the needs of customers in many industrial sectors, producing innovative solutions to problems relating to new products, processes and methods, the environment, inspection, control, and quality. Each solution is tailored to the customer's industrial environment, and is ready to be used. Solutions may come in the form of feasibility studies, prototypes, production equipment, products, and manufacturing systems.

CROs employ as inputs (1) generic technologies, of wide application to different industrial sectors, (2) sector technologies from the sector where their client performs, (3) specific technologies from other sectors, and (4) company-specific technologies. CROs cannot be characterized as "technology push" or "demand pull" organizations. They combine both approaches. They function between basic research labs and the industrial market, drawing knowledge inputs from the former to be used in their adaptive R&D activity for the second. They also transmit messages from the market back to the labs.

The research work of a CRO produces "generic results", which are kept by the CRO for use on a variety of clients, and "specific results" that belong to the client. An example is the use by a CRO of experience built up in several years of work in compressors for nuclear power applications to the needs of a small industry for an efficient regenerative blower. Another example of a different type, more upstream, is a CRO's analysis of common needs in fluid mechanics of several French industrial sectors (cheese manufacturer: "my cheese paste mixture is not uniform"; ink manufacturer: "my ink does not adhere properly to certain types of paper"; medical equipment manufacturer: "my centrifuge for blood component separation gives me trouble"). The conclusion was reached that work was needed to understand the rheological behaviour of non-Newtonian fluids, a generic problem, the results of which would allow to tackle the particular problems posed by the industrial firms.

CROs cater for the needs of small and medium enterprises by helping identify new technological opportunities; providing assistance in all areas of engineering, design, prototyping, ergonomics, reliabitity analysis and personnel training; applying systems engineering, value analysis and quality assurance to the improvement of processes and products; and helping the customer to learn about and to apply new technology.

CROs derive a substantial part of their funds from their contract work. But there is also reliance on government grants for research work on generic technologies which can only be funded partially by customers. In Germany this takes the form of a budgetary allocation for the Fraunhofer Gessellschaft, and grants to SMEs that establish contracts with research organizations. The latter instrument is also employed in Italy. Government financing of pre-market research has developed in the UK. In France a grant has been paid since 1986 to CROs and to technical centres, proportionally to completed contract turnover.

## 2. NETWORKING OF EUROPEAN CRO'S

The European Association of Contract Research Organizations, EACRO, was founded in 1989. Members must comply with a number of requisites; they should: offer contract R&D and innovation services as their main activity; be commercially independent, active in more that one sector, and widely acknowledged as good professionals; have at least 5 years' professional experience; have more than 10 employees. By 1992 EACRO had 52 members from 12 countries, with an aggregate staff of 26,000, a combined turnover of more than 1.5 billion ecus (about US $1.8 billion) and some 50,000 customers.

EACRO has initiated a European Network of Technology to enable CROs to pool resources. It is expected that duplication of investments will be avoided, the most recent technologies will be made available, and the potential for cross-fertilization will considerably increase. Generic technology needs may be collected and analyzed, and ways to deal with them proposed. Relevant R&D projects may then be agreed upon, and executed by teams set up by CROs.

By 1992, four preliminary studies were in progress in the following areas: optronic sensors, composite materials, high-speed assembly and control, and thermal modelling of complex systems and processes. EACRO hopes in this way to build a high-technology infrastructure to help make European industry more competitive.

Another important collaboration initiative promoted by EACRO is the construction of a database of expertise and services offered by members. It will answer the questions: Who knows what? Who has what? Who's doing what? Whom to contact?

## 3. HOW A CRO WORKS. THE CASE OF BERTIN (FRANCE)

Mr Mordchelles-Regnier is Chairman of the largest CRO in France, Bertin & Cie, and used his company as an example. We now summarize his remarks:

*There are three stages in the contract research work of a company of this type: (a) Exploratory work: functional analysis of the requirements of the client; here you don't think about technology, but rather the solution to those requirements.*

*(b) Choice of the possible path of solution, and feasibility demostration of it in a simple way, with a computer model or a simplified application. This shows the technical performance and the probable cost (the future operational cost).*

*(c) Interfacing the new technology with existing technology, and producing an "incremental innovation".*

*We have had to select methods to follow this path. Our company, Bertin, developed its own methodology over many years. This is similar to the methodology employed by product designers.*

*Thus, we try to enquire permanently what are the needs for technology, what do companies need in common, what will be useful to many of them. Then we can invest in developing the technology that can be used by several client companies.*

*We make 1500 proposals a year, which are translated into 1,000 projects. This is a very successful ratio. But to do this we have to screen 10,000 problems, which are posed by companies and also by ourselves. We have to make two kinds of selections:*

*(a) the problems for which we have a possibility of finding a solution, and for which funding is available from the client, the Government, or the European Community through one of its programmes;*

*(b) the promising trends in new technologies, which we have to identify. By way of illustration, light strong structures need composite materials - how to develop technologies for making cheap composites? This is a generic technology, which can be used by many clients. We invest ourselves in developing this. "If we are not ahead of our clients, we don't make a profit".*

*We need Government support since no client will pay for the full cost of developing a new generic technology. In 1984 the French Government agreed to provide private contract research organizations with funds that they could use freely rather than through a previously agreed programme of work. The CRO would be judged by results every 2-3 years . Funds were allocated in amounts proportional to the contracts the CROs were getting. This made things much more flexible and helped considerably the development of CROs in France.*

*The most difficult problem is to translate scientific results into technology. I am trying to promote a relationship with scientists through a permanent dialogue. We try different types of combinations in our labs, and sometimes this results in a patent which we can then license. We devote much time to projects in the defence, aerospace and nuclear fields in order to know what's going on.*

*Our work is mostly teamwork. We have our engineers specialize in generic technologies. But most industrial problems need multidisciplinarity. We make a team for a certain project. The same man may work for different projects.*

*We publish a lot. We are known internationally as scientists. We exchange lots of information, shop for new ideas, try to be the first to apply new scientific results. We send people to other countries. We attend conferences. And "we run all the time".*

*Our marketing organization is very important. We have now marketing engineers, organized by branch of industry, "perpendicular" to the specialist engineers. Their job, a difficult one, is to identify the needs of firms in the branch, which requires a good familiarity with the branch. They must translate this in terms understandable to the engineers, and see that the proposals are written in the language of the customer. These people do not sell; that is the job of the Division Manager.*

## CASE 18

## BRAZIL: INDUSTRIAL R&D INSTITUTIONS

*This paper by J. Marcovitch and A. Medeiros ("Industrial Research and Development Institutions in Brazil", Sao Paulo, 1991) deals with the activities and performance of technological and industrial research institutes in Brazil. In our summary we have concentrated on those aspects of interest for other developing countries in Latin America and elsewhere.*

### 1. BACKGROUND

The authors state that Brazilian technological research institutes, and the technological centres of corporations and universities (all of which we will call ITRIs in this section), have played a fundamental role in the acquisition and transfer of technology, acting as a bridge between the sources of technical knowledge and productive enterprises, and transforming knowledge into industrial technology.

A survey made in 1987 identified 65 ITRIs in four main categories: federal and state public sector institutes (25); private institutes (5); institutes related to universities (28), and technological research centres in industry (7). The largest ones were in the public sector, with 19 ITRIs that had a staff larger than 330 persons (six of them had more than 1,000).

The authors remark that until the end of the 1970s Brazilian science and technology enjoyed significant progress. However, there was a retrogression in the 1980s, from which the science and technology sector has not yet recovered. In spite of a few isolated successes, they find the present-day S&T apparatus outdated and its human resurces unenthusiastic, and feel that measures should be adopted to stimulate technological and industrial research. This coincides with the conclusion of the National Research Council, CNPq, after a survey carried out in 1989, that it was necessary to take decisive action on the part of the state and to reformulate the actions and strategies of ITRIs.

In 1990 new economic and industrial policies were adopted by Brazil, encouraging a more efficient use of market forces, a substantial reduction in incentives and tariff protection, and the competitive reconfiguration of industry through an increase of productivity and the adoption of quality standards of international levels. To support these objectives the government has launched a "Brazilian Quality and Productivity Programme" (PBQP), and announced the modernization of existing research institutions and the creation of new ones in emerging areas.

Brazilian industry shows technological backwardness, having suffered from a substantial reduction of investment in the 1980s which affected the modernization of installations and the implementation of R&D activities. In contrast with the international pattern, industrial companies still present low productivity levels, deficient product quality, high costs, low inventory turnover, slow response to demand and low levels of flexibility in production.

In the Brazilian industrial scene, sectors of high technology coexist with traditional sectors whose rustic technology is rather immune to change.The international competitiveness of Brazilian industry is still based on the intensive use of natural resources and energy, and in factors such as low salaries and subsidies, but there are some exceptions, such as the aeronautical and auto components branches, that have used R&D from their own labs or from state institutes, respectively.

## 2. PRESENT SITUATION OF BRAZILIAN ITRIS

The authors characterize this situation in the following way:

- The relations between government ITRIs and the industrial sector are precarious; there is basically a separation between the activities of ITRIs and the needs of industry. The situation is less conflicting in research centres of private enterprises, in ITRIs of monopolistic state enterprises (oil, telecommunications, electricity and other branches), and in some university foundations that have linked up well with the productive sector.

- ITRIs frequently deviate from the original objectives that determined their creation. Many ITRIs have ended up doing too much basic research and thus duplicating the role of the university.

- Some efficiency problems have appeared on account of too many interruptions in government programmes, imposing constant changes in the work of ITRIs. Another unfavourable influence on efficiency is the obsolescence of laboratory equipment.

- Most ITRIS have not been instrumental in supporting the technological development of Brazilian industry. Few successful examples can be found of technology development and its transfer to local industry,and even less of contracts for joint development work. Industries have used other means to obtain technology.

- Ideas for ITRI projects have mainly come from the researchers themselves, inspired in technical publications, exchanges with other organizations, and their own training and experience. ITRIs are therefore in a "science push" situation.

- The relations of state ITRIs with industry have preferently taken place through analyses, tests, consultancies and technical assistance rather than through research activities. The technology generation and transfer functions in these ITRIs are not sufficiently structured.

A study by the National Confederation of Industry shows that, although there are centres of excellence with a reasonably high level of interaction with industry, the integration between universities, research institutes and enterprises is low, according to the opinion of 65% of the entrepreneurs that were interviewed. The following inhibiting factors were mentioned:

- industry not well prepared to receive R&D inputs;
- industry and institutes not integrating well in projects;
- difficulties in the negotiation and contractual clauses;

- uncertainty about the enterprise that will receive the technology or process developed by the institute;
- little institutional efforts to stimulate technology transfer and improve links with industry.

From the standpoint of industry, the main consequences of this lack of integration are:

- ITRIs sit on technologies that have not been commercially explored;
- absence of interactions oriented to commercial objectives;
- attitude of entrepreneurs of not looking for technology in institutes.

A recent study of three technological institutes identified the main problems affecting them:

- desertion of qualified personnel, mainly because of low salaries;
- lack of formal technical documents, making it more difficult to transfer the technology to the client;
- bureaucratic obstacles for importing equipment;
- management practices that are not streamlined, and little use of consistent criteria and specific techniques for project evaluation, planning and control;
- funds not properly allotted to each approved project, causing delays;
- lack of resources to develop new lines of R&D, so that researchers stay in their established lines of work, resulting in a loss of capacity to innovate;
- poor communication among different groups and programmes, causing duplications and inefficiencies.

## 3. IMPROVING THE SITUATION

The authors refer first to strategies to stimulate the links between research institutions and enterprises. They recall that several industrial sectors in Brazil understand the importance of innovation and participate in R&D activities, particularly the branches of chemicals and petrochemicals, mining and metallurgy, electricity and communications, machinery and equipment, food and beverages, and paper and cellulose.

ITRIs should understand the behaviour of industrial enterprises and adjust to industry's way of functioning, though with an eye on the orientations of the country's policies.

Industrial enterprises should define explicitly their objectives, and prepare a technological plan with its projects. The enterprise should decide how much technological dependence from its suppliers it is willing to accept.

The preparation of a technology strategy starts with the analysis of the present situation and the comparative advantages of the company. Political and economic changes should be anticipated, and likely changes should be foreseen in the technological area or areas where the company is active .

The main components of an enterprise's technological strategy are:

- routine measures for productivity enhancement;
- innovation projects for modernization and expansion;
- actions to face unforeseen technological developments, promoting strategic alliances or investing in new business units.

In dual economies like Brazil there are successive cycles of fast growth and recession, which the majority of enterprises accompany by investing in times of growth and hibernating during recessions. The innovative entrepreneur, however, is different. He foresees economic cycles, promotes innovation by anticipating opportunities and market needs, and approaches ITRIs for technology.

## 4. RECUPERATION OF ITRIS

The revitalization and improvement of ITRIs requires in the first place to identify and evaluate the causes of weakness and inefficiency. Symptoms of these shortcomings are the almost vegetative survival of many ITRIS, the loss of motivation of research teams, and the low or inexistent communication with industry

Some policies, strategies and actions that can help the recovery and consolidation of ITRIs are:

Policies affecting the institution

1. Government policies relating to industry and technology
2. Development of "industrial competitiveness poles"
3. Technological plans of industral enterprises

Layout of policies, projects and plans

1. Continuity and concentration in the allocation of resources
2. Technological "mix" and mobilizer programmes
3. Stable and well focused government policies
4. Association with the private sector

Institution's strategies

1. Improve and motivate its human resources
2. Increase the quality of products and services
3. Orientation towards the market
4. Anticipate the advent of new technology
5. Stimulate "project champions"

Immediate actions of the institution (deriving from the strategies)

1. Re-equip and update laboratories
2. Recycle human resources
3. Integrate the activities of the institution
4. Adequate the organizational structure
5. Create forums for assessment and orientation
6. Improve project creation, programming and evaluation

7. Increase support for technology transfer
8. Stimulate R&D projects in collaboration with industry
9. Show a competitive, efficient and trustworthy image.

CASE 19

DEATH OF AN ITRI: FOUR EXAMPLES

*Three industrial technology research institutes of the Latin American and Caribbean Region have closed their doors definitely in recent years, in Guyana, Peru and Colombia (this is treated in some detail in Case 6 above). Another one, in Venezuela, appears to be terminally ill at the time of writing this report. We present brief summaries of these cases.*

## 1. GUYANA

The Guyana case is striking in that the institute hardly had time to function and prove its worth. Our information, which is far from complete, comes from talks with UNIDO professionals who were involved in creating the Institute.

In the early 80s a United Nations project took place to design and set up the Institute, which was to be the first of its type in that country. The project was executed by UNIDO, and took several years while the physical installations were built and the personnel trained. However, sometime in the late 80s conditions changed radically. Guyana proceeded to adjust its economy, according to World Bank-IMF guidelines. This affected the Institute in several ways. The government was no longer willing to fund the new institution to the degree that had been originally envisaged. Industry, which according to the rationale of reform should pay the full cost of the services, was unwilling or plainly unable to do so. The ensuing financial crisis meant that salaries for the staff were set at very low levels. Many scientists that had been sent to study overseas were returning with high hopes, but in view of the changed circumstances several of them looked for employment elsewhere. The institute thus found itself ckeckmated on both counts, finances and scientists. The result was that a decision was made to "privatize" it, a euphemism for closing it down, since this meant that instruments, equipment, the library, etc. were to be sold in separate lots to the best bidders. By mid-1992 a new UNDP-financed project was being set up by UNIDO to carry out the privatization.

## 2. PERU

Our source for this case is the paper written for the ITRI Project by Isaias Flit, "El ITINTEC del Peru: un drama tecnológico", Lima, Jan. 1993.

The Institute of Industrial Technology and Technical Standards, ITINTEC, had been in existence for twenty years. It had a stable funding mechanism: 2% of the net income of industrial enterprises in Peru was retained for research work, either by the firm (with ITINTEC's approval of the project) or, if the firm could not or did not wish to do it, by ITINTEC in its own labs, frequently with the collaboration of other scientific institutions, particularly universities. This worked reasonably smoothly for ten years.

In the early eighties ITINTEC was increasingly asked to devote its efforts to services for industry, and to metrology and standards work for the state, taking it away from research and thus removing an important incentive for the best personnel. This made ITINTEC increasingly into a provider of services. At the same time, the country's economy was disrupted by a combination of causes. Terrorist and drug groups made the country insecure, and the economic problems common to all of Latin America were especially deep in Peru. Industry's interest in research was strongly reduced, and ITINTEC found itself increasingly researching in areas selected by its own researchers. This was felt as duplicating what the Universities were doing. The 2% mechanism was cancelled in 1991, which put a strain on finances. The government pondered what to do and finally created a Commission in mid-1992 to deal with the problem. After only a few months, in November 1992 the Commission recommended the closure of ITINTEC. Shortly afterwards a new government service institution was created to provide standards, metrology and other technical services, as well as "the defense of competition".

At the time the author wrote his paper it was not fully clear what the reasons were for closing down ITINTEC. The difficult political situation in the country, the scarcity of government funds, the increasing disinterest on research on the part of industry, and the feeling that curiosity-oriented research should be made in universities rather than in an industrial research organization, are some of the likely reasons for its demise.

## 3. COLOMBIA

The case of Colombia's Instituto de Investigaciones Tecnologicas, IIT, is taken up in more detail in Case 6. This Institute was founded in 1958 and focused its work - mainly services but also some applied research - principally on the agroindustrial sector. It enjoyed good funding for many years from foreign and international agencies, but was unable to generate sufficient support from industry or the government. Even though the sale of services got to represent a relatively large share of the total income, the financial situation was never flourishing. As a consequence it endured a number of "vicious circles" which led to a "long agony" as the best personnel left and the credibility of the institution suffered. Labour problems added to these troubles. Finally, there was no cash to pay salaries and other accrued labour costs, and in 1991 the Board decreed the liquidation of IIT. All efforts to find a solution failed, and the assets were sold separately.

## 4. VENEZUELA: AGONY OF CIEPE

We summarize here the paper prepared for the ITRI Project by R. Valdivieso, "Estudio de caso: Fundacion CIEPE", Caracas, Feb. 1993).

The Fundacion Centro de Investigaciones del Estado para la Produccion Experimental Agroindustrial, CIEPE, was created in 1973 by the Venezuelan Development Corporation to help the technological needs of agroindustry. An Israeli company, International Food Industries Development, was involved in the design and installation, and provided 12 experts in different aspects of agroindustry that remained at CIEPE for several years, while a group of local graduates was being trained overseas.

The institution worked in isolation from industry and from other scientific institutions; a review by the National Research Council indicated two main problems, lack of autonomy and little viability in its orientation towards export. In 1977 the focus was redefined as servicing industry through research, technical assistance and training. At the same time CIEPE was transformed into a Foundation in order to give it more autonomy. By 1979 CIEPE had 22 professionals engaged in research along five lines: new protein sources, use of agroindustrial residues, post-harvest problems, processing of fruits and vegetables, and partial substitution of wheat. It was able to sell technical services to industry, though not research.

In 1979 there was a change of Government in the country and the CIEPE management was changed. A period of consolidation started soon thereafter, and a master plan for 1980-85 was prepared. By 1981 CIEPE counted with 219 persons, 111 of which in the technical area. Of the latter, 37 were university graduates, of which 25 were researchers including 3 PhD's and 12 MSc's. The level of self-financing achieved its highest point, 17.8%. In 1981-84 CIEPE produced 14 technological developments, three of which were patented, but it did not place any products in the market.

In 1985 the new government named a new Director with close links to the party in power. From that moment things started to deteriorate. An important group of researchers left the institution, and politics came into it. A union was organized and rapidly picked up strength. The number of researchers diminished by more than half (10 researchers had been left by 1990) and the wear of the Centre accelerated. Activities were limited to the provision of services and to a few research projects internally generated. Once again CIEPE became isolated.

In 1990, under a new President of the Republic, a new economic model was installed through an adjustment programme. CIEPE was given extra resources, its mission was redefined and a new management team took over. However, after only a year this group resigned on account of union pressure and of the inadequate support received from the government. A new attempt to revitalize CIEPE was not successful. By the end of 1992 the prospects were not clear: the crisis was heightened and the Centre suffered further deterioration.

The present situation of CIEPE, according to the author, is characterized by a complete erosion of its human resources, low links with industry, no marketing capability, a physical plant too large and unbalanced, a strong budgetary deficit, and on top of it all, very strong political agitation. The Centre is no longer viable under these conditions. The author asks a key question: can it be revitalized, or is it better to close it down and start a new ITRI for agroindustry somewhere else?

## 5. FINAL REMARKS

In all of the above cases there is a feeling of inevitability in the way decline sets in, aided by one or more vicious circles that make it difficult to revert the process. The causes for this deterioration are varied, from political and managerial mishandling to the lack of support on the part of industry and government. The common thread is the loss of human capabilities, as the best

professionals leave the institution and cannot be replaced, and as union and political activism create a situation of increasing conflict which does away with any possibility of efficient work.

An important policy issue comes up. How can we decide that it is posible to stop and reverse the process of decay and carry out a revitalization of the Institute? When should the Institute be given up as doomed, and closed down, absorbing the losses but allowing the people and assets to be employed usefully elsewhere in the economy, perhaps in a new ITRI that starts with a clean slate?

The way this is answered will be different in different circumstances. Let us look at two opposing cases. In the case of CIEPE, in Venezuela, there has been a decided effort to keep the institution running, and the fact that it is state owned and in a certain favoured location may explain this. At the other end, the New Zealand Research Associations, as well as the newly created Crown Research Institutes, cannot expect the assistance of a generous state sector: should they be unable to make ends meet by selling their R&D projects and services, they are liable to disappear, and in fact two RAs have done so in the past. Here the criterion for revitalization is clearly an economic one, whilst in the case of CIEPE, and other ITRIs in the state sector, other types of considerations enter into the picture. Extreme cases will probably be found in the former socialist countries of Eastern Europe, where the virtual disappearance of state funding has put ITRIs and other scientific institutions in a critical situation.

CASE 20

# ITRI PROJECT: ROLE OF ITRIS AND PROPOSED GUIDELINES FOR CASE STUDIES

*We summarize here the paper by D. Chudnovsky and R. Bisang, "Towards a new role for ITRIs in developing countries", Buenos Aires, March 1992, which was used as a background document for the ITRI Project. The authors first deal with the situation being faced by developing countries at this time of great change, and the role that ITRIs could play. The guidelines suggested for the case studies are contained in the last section of the paper, and were the basis of the methodology employed by the ITRI project (see Annex 1).*

## 1. NEW CHALLENGES FOR ITRIS

The changing economic and policy environment in recent years have brought about new challenges for industrial technology research institutes in developing countries, which were born in a different context, having been conceived to serve the technological needs of enterprises operating in the import substitution industrialization model that was in place until the 1980s.

Though ITRIs may have performed useful purposes in the past and are certainly doing interesting activities today, the authors feel that "on visiting any of these institutions one gets the impression of a rather big boat floating in a turbulent sea without any clear direction and with its crew highly demoralized". State support has declined dramatically as governments have trimmed down their expenditure, resulting in low salaries, lack of new equipment and bad conditions of some buildings.

The authors feel however that the main problems cannot be cured simply through a substantial budget increase or through privatization.

A durable solution needs the discussion of more fundamental issues. It should take into account the new technology needs of firms operating in a more open and deregulated environment, and should discuss how the firms fill those needs and what role ITRIs may play in this.

The main purpose of the paper is to suggest the issues that should be explored in a set of case studies, regarding the role ITRIs have played so far and are expected to play in the new economic and policy environment in a number of Latin American countries. Before looking at those issues, the authors delve briefly on the changing technological and economic environment, and the current policy modifications.

## 2. THE CHANGING TECHNOLOGICAL AND ECONOMIC ENVIRONMENT

### 2.1 Technology and global competition.

A new techno economic paradigm has emerged, with new technologies and radical organizational changes. Here are some of its main characteristics:

- "Lean" manufacturing methods are increaingly coming into use. They require much less of most inputs, result in fewer defects, and produce a greater variety of products, as compared to the previous (and still predominant) "fordist" paradigm epitomized in mass manufacturing methods. Flexibility in equipment and in product mix, and greater importance of product innovation, are crucial elements in lean manufacturing, as well as just-in-time scheduling, which requires a close relationship with subcontractors.

- Innovation can no longer be viewed in a linear manner, but as a complex process, with continuous and numerous interactions and feedbacks within the firm, and between the firm and outside actors.

- Market signals (demand pull) and S&T expertise and infrastructure (technology push) are important, but so are various institutional factors, as well as the cumulativeness of technology creation.

- The ability to master technical knowledge in a firm is developed cumulatively over time, via the acquisition of skills from production experience, learning by doing and by using, imitation, and R&D expenditure.

- If a firm wants to benefit from opportunities from research spillovers, it needs an absorptive capacity, usually including R&D, which will allow it to identify and assimilate knowledge developed elsewhere.

- Thus, technology involves fundamental processes of learning by using and learning by interacting. Also important are networks of research institutions and firms, and linkages through inter-firm agreements. This leads to the notion of the "national system of innovation", which has been defined by Freeman (1987) as "the network of institutions in the public and private sector whose activities and interactions initiate, import, modify and diffuse new technologies".

- In the new manufacturing and innovation approach, there is a growing need for synergistic relationships between users, producers, sub-contractors and R&D institutions, helping the creation of "clusters" of industries, with vertical and horizontal relatioships, as a support to the competitiveness of enterprises.

The pressures towards globalization of production and innovation activities are also crucial features of the new situation. Value and wealth are increasingly produced and distributed within worldwide networks, with multinational corporations playing a key role. Here are some main characteristics of this process:

- Two main factors accelerating the trend towards globalization are financial globalization and new technologies.

- Increasing globalization has led to greater competition, through reduced prices and shorter life cycles of products, and to greater concentration, mostly through mergers and acquisitions.

- Economies of scale are still important.

- Entry barriers are very high in many high technology branches.

- Technological innovations are a key input in the globalization process. They are increasingly done in other locations as well as through international interfirms arrangements.

These trends are seen mainly in the developed countries, but some Asian developing countries are also involved. It is likely that other developing countries in Asia and Latin America are also going to be increasingly involved in the near future, reverting the marginalization process from the world economy that was accentuated in the 1980s

## 2.2 Difficulties faced by developing countries

With the emergence of the debt crisis in the early 1980s, the economic performance of most developing countries greatly deteriorated. Per capita production was lower than in the 1970s, investment collapsed, high inflation rates became common. Wide fluctuations took place in economic activity. There was a continuous fiscal crisis, which affected not only investment but also expenditures in health, education and science and technology, as well as the level of remuneration and the efficiency of state-owned firms and the public administration in general.

Latin America had its "lost decade" in the 1980s. However, export performance was one of the few relatively positive economic indicators, though it was not in general accompanied by the creation of new capacity but depended on low wages and the continuous devaluation of the currency - a "spurious competitive advantage" as some critics have termed it. This was international competitiveness in a rather regressive way; the growth in exports did not lead in general to a growing physical and technical capacity, as resources generated through export growth were consumed, put into financial investments, or sent out of the country.

In contrast, some countries in East and South Asia managed to have a good performance in the 1980s. Asian "newly industrializing countries" (NICs) and some ASEAN countries had a growth process led by manufacturing exports, with continuous increases in investment and domestic consumption.

Resources for education and R&D were strongly affected by the fiscal crisis and the slowdown in economic growth and productive investment. There is a telling contrast between Latin American and selected Asian countries in R&D expenditure in the 1980s: R&D was 0.4 to 0.6% of GNP in Argentina, Brazil and Chile, while it was 0.9% in India, 1.1% in Taiwan and 2.3% in the Republic of Korea.

Different branches were affected differently, and within each branch some firms did better. Firms based on low wages and natural resources, or producing commodities with subsidized fixed assets, increased their relative share compared to branches based on skilled labour. State enterprises deteriorated, and many of them are now in the process of privatization. Foreign investment flows only recuperated somewhat at the end of the decade. Local industrial groups became increasingly important, with skilled personnel, good technology, and joint ventures or technical cooperation agreements with partners of developed countries. In some branches small and medium firms have acted in an "offensive" manner, and have improved technologically.

Hence not all the firms emerged from the 1980s in bad technical shape. But in most cases there is need for technological upgrading, particularly in view of the strict requirements of the new policy environment.

## 3. POLICY MODIFICATIONS

(a) In developed countries and Asian NICs

The changes in the process of technology generation and diffusion in industrialized countries, and the growing globalization of economic and technological activities, have led to new approaches in industrial and technological policies.

The trend is towards defensive policies to restructure existing industries combined with offensive policies for emerging branches. Subsidies and non-tariff measures were widely used by OECD countries in the 1970s and peaked in the early 1980s. The new policy directions, expressed in a variety of government sponsored programmes, seem to be to apply horizontal incentives to encourage firms to upgrade their international competitiveness, through supporting investment in knowhow, better organization, and fostering the process of internationalization of enterprises.

Many European countries have set up well defined programmes to assist small and medium enterprises in adopting new technologies and new organizational techniques. On its part, the USA counts with State and Federal extension services for industry.

The way in which ITRIs and similar institutions have been modifying their roles to face the new challenges in manufacturing industry are being studied by the OECD, the World Bank, and other institutions (see the December 1989 issue of Research Policy). The case of the Korean Institute of Science and Technology is very interesting; this institute, created in 1966, has been changing its role in accordance with the new needs of the Korean economy and the new government science and technology policies (Lee et al., 1991). Another interesting case is that of the Industrial Technology Research Institute in Taiwan (see Case 11 above).

(b) In developing countries

In contrast to the case of developed economies and of some NICs, in developing countries significant policy changes are taking place without due attention yet to technology issues.

Short run stabilization policies however are not enough. Some structural changes are needed to ensure the closing of fiscal and external gaps, to resume growth and to foster productive investments.

The World Bank and other multilateral agencies recommend strict fiscal policies, tax reforms, positive interest rates, competitive foreign exchange rates, trade liberalization, encouragement of direct foreign investment, privatization of state enterprises, deregulation, and securing of property rights. There is an assumption that trade liberalization and internal deregulation will unleash market forces that will make firms react to the new conditions by reducing costs, introducing new products and processes, and improving the quality of their goods and services.

This approach, however, ignores that upgrading the technological capacity of firms is riddled with all kinds of market failures, and that there are externalities. Firms will underinvest in knowledge creation, R&D, design, training, etc. Beyond the "stick" of liberalization they need some well designed "carrots" to be able to upgrade their technology and their organization.

It is not an easy matter however to design and implement government intervention for such purposes, particularly at a time when the state is constrained by the fiscal crisis, the tremendous deterioration of public administration, and the prevailng "hands off" philosophy.

## 4. ROLE OF INDUSTRIAL TECHNOLOGY RESEARCH INSTITUTES

Under these conditions, governments should posess a technical capacity to propose and implement well defined proactive policies, while relying on competitive forces operating through the market (market-based solutions). "Good policy requires identifying (market failures), asking which can be directly attacked by making markets work more effectively (and in particular reducing government imposed barriers to the effective working of markets) and which cannot. We need to identify which market failures can be ameliorated through non-market institutions, with perhaps the government taking an instrumental role in establishing these non-market institutions. We need to recognize both the limits and strengths of markets, as well as the strengths, and limits, of government interventions aimed at correcting market failures" (Stiglitz, 1989).

One of the ways to contribute towards helping innovatory activites within the manufacturing sector is studying the role that may be played by an important non-market institution, the industrial technology research institute, that has until now been mainly supported by government.

At the time these institutions were created, the context was a very different one of import-substitution industrialization. Within this context, the higher technological requirements for entering into the production of consumer durable, intermediate and capital goods were often met through the licensing of foreign technology and through direct foreign investments. Local manufacturers in many cases adapted the foreign technology to local conditions, and generated some minor product and process innovations. However, some pre-competitive activities like standards, testing and certain

developments required resources that private firms could not provide. ITRIs were created to fulfill these tasks.

The activites of these institutions were enlarged and diversified, as higher technological requirements appeared as a consequence of advances in import substitution, particularly on account of stricter requirements of state enterprises and a shift from manufacturing only for the domestic market to manufacturing for exports. Some forms of private financing were introduced to meet the growing costs, but the main financial source continued to be the state.

An evaluation by UNIDO and UNDP *(see Case 14 above)* showed that the objectives of ITRIs were very wide, while in most cases they were not able to achieve them in full and had in fact spread their resources too thinly. Though ITRIs carried out some R&D, mostly responding to in-house initatives and with limited commercial potential, their strength lay mainly in some supporting services such as product certification, standards, quality control, etc., while critical extension services such as trouble-shooting, process improvement, and quality improvement were often weak due to inadequate links with industry and poor knowledge of industry's problems.

The role an ITRI should play has been discussed in several occasions in the literature, but, as the authors say, "so far no serious attempt has apparently been made to redefine their role not only taking account as in the past their internal problems but also and fundamentally the changing economic and technological environment in which they operate... Only on the basis of a thorough study of actual experiences would it be possible to propose a redefinition of their role and functions".

## 5. GUIDELINES FOR CASE STUDIES OF ITRIS

The main questions to be explored are:

- How to redefine the role of ITRIs, taking into account their internal problems as well as, fundamentally, the changing economic and technological environment in which they operate?

- How are ITRIs adapting to meet the new requirements of industry in societies where deep changes are taking place? How can they be restructured to meet those requirements?

The points to be covered in the case studies would be:

### 5.1 Structure and operation of the ITRI.

- Policy objectives and their evolution in time. Industial branches focused by the ITRI.

- Functional activities, users and impact

  - The following classification of activities is to be used: R&D, supporting services, extension services and training *(this is the classification scheme suggested in the UNIDO-UNDP evaluation report, Case 14).*

Questions should also be asked about other activities such as incubators, research parks, more general business assistance, seed capital and research centres.

- Main users of the ITRI's work. This may include, in addition to small and medium enterprises that in many cases are the main clients, state enterprises and large domestic and foreign firms.

- Marketing and diffusion mechanisms.

- Preliminary assessment of impact, through the direct application of research results, contributions to the solution of users' problems, publications, etc.

- Organization and managerial aspects. Presence of the private sector and its influence. How tasks are divided, inside the ITRI and between the ITRI and affiliated institutions; regional decentralization; management structure; how priorities are established; how results are assessed.

- Human resources. Main professional qualifications; areas of inadequacy; salaries and benefits; training; labour relations; evaluation system for personnel promotion.

- Equipment. Value; weak and strong points; priorities for its use.

- Financing. Sources of funds: contributions from the national budget and from users; allocation of funds to personnel, equipment,training and other items; how different services are sold and priced; participation of the private sector in decisions about allocation of funds, including long term research.

- Evaluation mechanisms. Their characteristics; use of internal and external evaluators.

### 5.2 Relations with other institutions and with industrial and technology policy

- The ITRI and the national system of innovation. Possible overlapping of areas of work; how the different institutions relate to each other through formal and informal channels.

- ITRI and foreign institutions. International and regional cooperation activities.

- ITRI and the industrial and technology policy. Role of ITRI in shaping this policy; coordination between the policy and the ITRI objectives; possible gap between both.

- External evaluation of the ITRI, its activities, and its relations to other actors. Has it ever been made?

## 5.3 Proposals for restructuring the ITRI

ITRIs have an important stock of human, physical and technological resources which should be fully utilized by modifying their functions, structure and mode of financing. They have a useful role to play under the new circumstances. Their restructuring should be a part of the process of redefining a new set of industrial and technological policies, but should not wait until the latter are fully specified.

Beyond the topics mentioned in the preceding sections, the authors suggest the following additional aspects:

- New demands and constraints.

  - There is an emerging situation in which macroeconomic imbalances in some countries are becoming less severe and structural changes are in progress, giving new roles to public and private agents. The framework is changing for industrial activities, on account of trade liberalization, financial reforms, privatization, and changes in state procurement practices.

  - Large economic groups and multinational corporations are redefining the strategies followed in the 1980s, to be able to compete in more open economies. The technological requirements of the emerging strategies will put a premium on cost reduction, flexibility in product mix and equipment, and higher quality.

  - Direct foreign investment and different forms of technology transfer, including strategic partnerships, are bound to increase the supply of foreign technology to some countries.

  - The reduced role of the state and the fiscal difficulties limit the possibility of using sectoral policies of the type used in the past, such as tariff protection and fiscal and financial incentives.

- Public policy issues.

  - The following issues are to be examined: What should the specific role of the ITRI be? What services should it provide? Should extension services be given priority? Will it have a wider role in diffusing innovations across the industrial sector (international search of technology and suppliers, identification of technological needs, assistance in the absorption and adaptation of foreign technology)? What type of R&D activities, if any, should be undertaken?

  - Once the most adequate type of institution for the current policy approach has been defined, the functional structure may be discussed.

  - Define the main manufacturing branches to be attended by the ITRI, and the profile of the users (SMEs, large firms, conglomerates, state firms, local subsidiaries of multinational corprations, private research institutions).

- Define the type of technology needs to be covered - not only production, but also management, marketing, before and after sales services.

- Define the ways of financing the ITRI.

- Define the procedures for appropriating the research results.

- Define a schedule and methodology for implementing the different technology programmes.

- Finally, on the basis of the previous definitions make a more precise organizational proposal, including aspects of internal structure, sources of funds, evaluation systems, internal production vs. subcontracting, and so on.

CASE 21

## INDIA AND CHINA: HIGH TECHNOLOGY R&D INSTITUTIONS

*In 1991 a review was conducted by the United Nations Development Programme on the impact of UNDP technical assistance to high technology sectors in India and China. The review included an assessment of 15 R&D institutions that had received UNDP assistance, ten in India and five in China. We present below a brief summary of some of the most important conclusions of this assessment. (L. Rudel, "Thematic review of high technology assistance in India and China", a report prepared for the UNDP Central Evaluation Office, May 1991).*

The Review examined the impact of UNDP assistance to high technology sectors in India and China. These countries have achieved a recognized competence in high level human resources and R&D institutions, but the output of their productive sectors is often regarded as inadequate by international standards.

An assessment was made of a sample of 10 institutions in India and 5 in China, all of which had received UNDP assistance for many years. A unified methodology was employed.

The attached table summarizes the results of the review in the 15 institutions, under the following headings: efficiency, potential for development, sustainability, alternatives, conclusions, and specific recommendations.

The exercise yielded findings of a generic nature that may have broader applicability to other cases in different countries. Here is a summary of them:

(a) Once technology became available at the R&D institutes, in general it was not successfully disseminated or communicated to users. The institutions did provide important testing, calibration and measurement services, as well as training, to their respective industries. However, "particularly in India, their respective roles in performing problem-solving R&D for their clients, and facilitating the technology commercialization process, was shown in the case studies to be rather limited. China' recent policy shift to eliminate public funding for R&D institutions, thereby requiring each institution to sell its services to user clients, has tended to encourage the creation of linkages between the R&D institutions and the producing units".

(b) The industrial sectors did not have the sufficient maturity, or the necessary human and technical resources, to seek problem-solving help from local labs, "which in any event did not command their confidence". They bought knowhow from abroad. The author examines the issues of why do enterprise managers tend to undervalue technological innovation and the results of R&D, why do they strongly prefer to acquire hardware rather than software, and why do they prefer imported technology. He suggests that there are a number of factors that contribute to these behaviour patterns: "lack of competition due to product scarcity conditions, aversion of investors to risk and uncertainty, fear of criticisms and absence of reward for innovating

management, and lack of a subcontracting modality arising from fear of loss of production control". He also concludes that the return on R&D investment in both countries would seem to be too low to attract the interest of industry, unless special efforts are made to stimulate the demand for technology.

(c) With only one exception, the Indian institutions do not appear to have any prospects of becoming financially self-sustaining in the foreseeable future, let alone be able to replace or upgrade their equipment without government support. The Chinese R&D institutions are being forced to become self-sustaining, but so far they are only able to generate resources to cover the cash requirements of operating costs.

(d) R&D institutions need foreign exchange to maintain "technological currency", i.e. to keep up with worldwide changes in the different areas of technology. Technological interchange is required in order to participate in the international science and technology evolution on an equal footing. This needs a lowering of the constraints inherent in the public sector to use funds for participation in international gatherings. The author mentions that one of the institutions, with 200 professionals, is only allowed to fund 5 trips a year, i.e. one trip per professional every 40 years.

(e) In the case of some Indian institutions serving government departments exclusively, they were regarded as being not fully responsive to the client's needs, and it was felt that they should concentrate more on short term problems than on long term research activities.

(f) The need was seen to link up laboratories, industry and educational institutions, so that there would be synergistic effects. The absence of such linkages means that human resources are exported while foreign knowhow is imported.

(g) Institutional growth and development should lead to self-sustaining operations, linked to the productive sector. Policies are required to stimulate the demand of the private sector.

(h) In China, a conclusion is that the greater the autonomy of the institution, the more likely it is that it will undertake R&D commercialization.

(i) An interesting observation relates to the difficulty for high technology to thrive in a sea of low technology. The author suggests that high technology projects should be clustered so that they support each other.

## Review of the Institutions

| Name of the Institution | Efficiency | Potential for Development | Sustainability | Alternatives | Conclusions | Specific Recommendations |
|---|---|---|---|---|---|---|
| INDIA | | | | | | |
| Central Soils and Materials Research Station (CSMRS) | Capacity not fully utilized; weak linkage with clients; a government organization serving only government clients | Increased potential if the Centre is set up as an engineering consulting company | Highly qualified staff but lacks business motivation - most revenues provided by government | No | Technical capabilities exist but are not fully utilized; little reward/incentives to staff for innovation/performance | --Expand mandate to serve states and private construction/ engineering firms; --Improve incentive structure to reward technologists who innovate and assist to commercialize |
| Central Water and Power Research Station (CWPRS) | High tech competence but limited by the centralized control from New Delhi; a government organization serving only government clients | CWPRS has reached its take-off point | Financial sustainability not complete; inadequate autonomy to charge clients full cost; no incentives for staff | No | Technical competence is at international level; good links with international network and clients; TCDC activities; almost financially self-sustaining; needs more autonomy to charge adequate fees and reward good performance by technologists | Increase independence of CWPRS. Allow them to operate like a consulting engineering firm |
| National Institute of Hydrology (NIH) | Serves only government clients; focus in on basic research and collection of long lead time data | Approaching the stage of institutional maturity; it will become key institution for the management of water resources | Lack of business motivation; no financial sustainability other than government funding | No | NIH is working more for the future and ignores the current needs; technical capacity exist; good links with international institutions; well equipped | --Increase staff involvement in water & power problem solving at state level for current problems; --focus on becoming an information center for hydrological information and network to allow access to such information |

| | Efficiency | Potential for Development | Sustainability | Alternatives | Conclusions | Specific Recommendations |
|---|---|---|---|---|---|---|
| Pesticides Development Centre (PDC) | Serves a few public and private clients but little impact on pesticides development/ formulations | PDC has not reached its take-off stage; needs restructuring to separate PDC from Ministry control, public sector company (HIL) and instead link to industry | No financial and technical sustainability | Might have been structured to be cooperatively managed by private insecticide producers | Performance so far is not impressive; UNDP assistance should be re-oriented; PDC needs to be restructured to increase direction by productive units and to move research results from laboratory to pilot plant stage | --Restructure PDC to allow for greater industry direction, less government direction; perhaps privatize<br>--PDC should undertake joint R&D projects with private Indian pesticides formulators<br>--UNDP can help to finance such work |
| Fluid Control Research Institute (FCRI) | Serves public and private clients for testing and calibration, also performs limited R&D for small-scale firms and conducts training | No major impact on the large scale producers but some potential with small and medium size firms | No financial sustainability foreseen | Yes, through linkages between small and large scale producers | Wrong location; weak linkage with the productive sector; other alternatives might be more effective to serve the needs of the productive sector (i.e., in-company R&D cells) | --Make FCRI into a repository of international technological information and network to allow easy access for producers;<br>--separate FCRI from IL and privatize |
| Central Electronics Engineering Research Institute (CEERI) | First class institution with capability to serve both public and private firms; needs to be more proactive to develop its market | CEERI has a large potential in technological/in-novation development process; needs some administrative changes and focus on marketing its services | Financial sustainability is the weak point | No, but now CEERI should receive more autonomy to provide incentives for technologists who support commercialization of research results | CEERI has mastered the technologies and adapted them; there is inadequate demand for its services; it underprices its services which render it financially dependent on government subsidies; it is a success story at this point | --CEERI to increase its marketing efforts;<br>--provide CEERI with adequate foreign exchange to allow it to maintain technological currency;<br>--reorganize to give CEERI greater autonomy (perhaps privatize) |

| Name of the Institution | Efficiency | Potential for Development | Sustainability | Alternatives | Conclusions | Specific Recommendations |
|---|---|---|---|---|---|---|
| Central Pulp and Paper Research Institute (CPPRI) | Some impact on environment; pulp and paper sector was largely private but major government regulation; now 20% government plants | Industry suffers from heavy government controls including set prices. No incentive for industry to modernize, thus CPPRI has limited scope | Not under present conditions | Possibly a privatized structure | CPPRI has little impact due to major policy and structural problems of industry | -Review status of pulp & paper sector with industry and government to encourage a more constructive policy framework |
| CHINA | | | | | | |
| Research Institute for Instruments and Meters (RIIM) | Research institute owned by a public electric meter production company which has clients that have requirements for instruments | Technology for designing and manufacturing capacitance transducers is mastered; the institute will transfer the product line to the parent company and may sell the technology to other firms | RIIM expects sales revenue in 1991 to recoup the initial costs of R&D | The parent company has used a number of alternatives to acquire and master technologies, i.e., licensing and development of its own technology | The institute has a national reputation but may be unable to maintain currency in this technology due to the shortage of foreign exchange for staff attendance at international meetings; no internal technical backup | --Provide foreign exchange to allow scientists to maintain technological currency;<br>--strengthen intellectual property rights to allow R&D institution to sell technology to gain return on investment |
| Salt Research Institute (SRI) | Technology is not fully mastered and there is still a great deal of work before any operational results can materialize | The institution has a large mandate but the project will have little impact on it until the technology is developed to a higher commercialization stage | In 1990, revenues were forced to meet the operating costs due to termination of government support | No | The project was not described as institution-building yet it is; it has made a profound impact on the focus of SRI's activities and has allowed SRI to remain solvent; too soon for UNDP to leave SRI; the shortage of salt will not be solved by this project | --Follow on T.A. is needed to protect the past investment;<br>--review the salt production problem to determine how SRI can help balance supply and demand |

| Name of the Institution | Efficiency | Potential for Development | Sustainability | Alternatives | Conclusions | Specific Recommendations |
|---|---|---|---|---|---|---|
| Computer Applications Software R&D Center (CAD/CAM) | CAD and MIS were provided, not CAM; MIS is the source of higher fees; client: state enterprises | CAM technology is the next stage of development | The center charges fees for services and does not receive support from its parent institution or the Ministry | No | Demand for technological modernization by production units is still weak with preference shown for imported technology; technology capability of the Center has been well established; it needs to transfer the technology out of the Center | ••Encourage demand for CAD/CAM Center services by such mechanisms as matching funds to reduce cost of services; also establish tax or preferential exchange rates to increase cost of imported technology;<br>••provide assistance to indigenize CAM technology |
| Institute of Engineering Thermophysics (IETP); Academia Energetica New Technology Center (AENTC) | Substantial profit from patents and services sold to various production units; extremely efficient in focusing R&D on that which is in demand and to market their services | Special position in this field in China; potential for development is high due to the high quality of staff and leadership | The institution has already reached self-sustaining operational status; good incentive structure to motivate technologists to commercialize R&D | No | The project succeeded well beyond the level of expectation of the project design even before its completion; support by the government was high as the Center's efforts served to reduce dependence on petroleum for energy generation by using coal instead of oil | ••Allow other R&D institutions to adopt similar incentive systems to encourage technical staff to market services which will lead to commercialization |
| Synthetic Fibre Research Center (SFRC) | Clients: plants producing synthetic fibre products | Technology mastered and being disseminated; new industrial uses of synthetic fibre should be next focus for SFRC but that would put their activities outside Textile Ministry | Financially self-sustaining but insufficient foreign exchange for attendance at international conferences to maintain technical currency | No | Some linkages with productive sector but demand by producers for technological upgrading is not evident | ••Need foreign exchange to maintain technical currency;<br>••incentives needed for technologists to encourage commercialization;<br>••mechanisms needed to increase demand by producers for technological upgrading |

| Name of the Institution | Efficiency | Potential for Development | Sustainability | Alternatives | Conclusions | Specific Recommendations |
|---|---|---|---|---|---|---|
| National Physical Laboratory (NPL) -Pressure and Vacuum Lab | Active institution with proper maintenance and impressive leadership; serves public and private firms by providing instrument calibration services | The laboratory has demonstrated the capability o develop measuring systems from foreign components on a lab scale; it should now develop its products for commercial use | Depends heavily on government financial support | No | UNDP assistance has allowed the scientists of this lab to achieve international parity with their peers in industrialized countries and to maintain this level of competence; government support is needed to ensure that after UNDP T.A. the status of the lab will not drift lower; it has achieved a worldwide reputation | --No specific recommendations |
| National Chemical Laboratory (NCL) | Serves private sector clients; works as consulting firm for them and has promoted commercialization of research results successfully | NCL has established its capability to perform R&D for commercial application in petrochemical industry; its linkage with the productive sector ensures relevance of its R&D programme and sale of its results | NLC is not 100% financially independent of government support due to requirements to perform certain research and testing to meet national needs; it provides substantial incentives to its scientists | No | Excellent example of a supply side approach to R&D that worked; excellent motivation of the scientists due to the system of incentives; follow-up of UNDP TA is needed to fund international linkage costs for maintenance of technological currency | --funding to build linkages with producers (i.e., establish in-company R&D or QA cells; joint development projects); --funding to allow NCL technologists to maintain technological currency |
| Automotive Research Association of India (ARAI) | ARAI is structured as an industry association, not a public institution; excellent linkages with its members; good impact on environment | Testing, certification and problem solving functions are mastered; ARAI wants to design a new engine to retrofit for passenger cars | ARAI is 85% self-supporting with balance provided by government subsidies derived from an industry cess | Assistance could have been provided directly to producers to set up or upgrade their in-house R&D operations | ARAI has not reached the take off point of self sustainability; thus UNDP should continue its TA | --UNDP should provide sustained assistance to bring ARAI to full take-off stage; --appropriate commitments from ARAI membership should also be secured; --establish and sustain international linkages with automotive research organizations |

## ANNEX 1

## THE ITRI PROJECT

### 1. INTRODUCTION

The purpose of the project "Industrial Technology Research Institutes" (the ITRI Project) is to analyze, on the basis of empirical studies, the issues confronting ITRIs in developing countries in the 1990s, and to make suggestions as to how such institutes may improve their effectiveness and assure their sustainability, in a changed environment characterized by new economic, technical and policy conditions, and by reduced state funding.

Empirical work has comprised case studies of ITRIs in several countries of Latin America, using a common set of guidelines to help comparability. Case studies in Canada and New Zealand have also been made as a contrast to the former. Two working sessions were held among the researchers on August 1992 and February 1993, and a final meeting will take place on May 1993 to review the results of the empirical work, extract conclusions from the comparative analysis and draft a set of tentative recommendations. There will be a wider meeting some time later to present the results to a larger audience.

The project has been sponsored by the United Nations Industrial Development Organization, UNIDO, and the International Development Research Centre of Canada, IDRC.

### 2. SCOPE

The ITRI project is concerned with the changing role in the 1990s of Industrial Technology Research Institutes (ITRIs) in developing countries. During the last 30 years many such countries have established technology institutes aimed at supporting the technological development of industrial firms across a wide range of sectors, and facilitating their access to industrial know-how and technology. Most were based on organizational models existing in industrialized countries at that time and were set up as national government research institutions, with a wide sectoral coverage. They put emphasis on research and development in topics of their own choice, but only on rare occasions did industry apply the results of such efforts. The "supply-push" approach has been largely unsuccessful. Many ITRIs run the risk of becoming marginal to the development needs of the industrial sector. They may also find themselves increasingly outdated in regard to the requirements of industry in the nineties.

There is a growing feeling in government and industrial circles of developing countries that the new technical, economic and policy environment of the nineties requires a different type of institution, if the capacity in science and technology already in place is to be used efficiently and with full impact on development. The subject has not received sufficient attention in recent years. It is a complex one, with many dimensions.

The ITRI project analyzes a number of crucial issues related to the efficiency of ITRIS, on their functioning in the deregulated, globalized and open market

environment of the nineties, and on their sustainability. The results are expected to be of value to policy makers, industry and research managers, as well as to the international organizations sponsoring this work.

The project includes an important empirical component, with eight case studies of ITRIs in Latin America and two in developed countries to provide a contrast to the previous cases on important policy options. Latin American ITRIs have been chosen for study on account of good access to them by the sponsoring agencies, easier comparability between countries with similar industrial characteristics as well as the same language and culture, and the availability of well qualified researchers.

A workshop was held in Montevideo in August 1992, to discuss and refine the methodology of work. A second workshop was held in Caracas in February 1993, to review the first results and introduce any needed corrections. A final meeting will take place in Buenos Aires in May 1993, with the participation of the project's researchers and a group of policy makers, industrialists and research managers, in order to compare the results of the empirical studies, draw conclusions and policy recommendations and suggest avenues for further research.

The project is expected to make valuable contributions in a number of areas, by:

- analyzing the role of ITRIs in the industrial development process of developing countries and the link with economic, technical and policy processes;

- supplying a body of data which will be of help in evaluating the present functions of ITRIs and whether they have provided "value for money" in terms of their contribution to the national economy;

- making suggestions to increase the effectiveness of ITRIs in terms of their contribution to the industrial development process in the nineties, leading to increased productivity and a better insertion in world markets;

- creating the basis for a long term research programme to further investigate issues identified in this study;

- providing results that may throw light on the wider subject of achieving an effective utilization of the existing science and technology capacity in developing countries. This includes university research departments, basic and applied research institutes not specifically connected to industry, agricultural research organizations and other components of the "science and technology infrastructure". Many developing countries have invested heavily in this infrastructure during the past two or three decades, but the impacts on development and on the quality of life have in general been limited. This is causing increasing concern in those countries. It is likely that the data and results from the present project will be useful in dealing with this situation. They may also be of help to Eastern European countries now facing a particularly difficult situation with their research institutes.

## 3. OBJECTIVES

The case studies will be aimed at improving our understanding of the circumstances, characteristics and structures that make some institutes more

effective than others. In carrying out this work, as well as in the comparative analysis of the findings, certain specific objectives will be kept in mind:

a) How to facilitate the restructuring and transition of ITRIs so they can operate effectively in the dereguiated and open market environment that now predominates in development strategies. Th' needs a capability to respond to the technolegical requirements of industrial firms that want to be competitive in the newly emerging scenario. It also needs a capability to participate in interactive innovation processes, requiring the technological institute to interact closely with firms and o.her institutional actors that play an important role in these processes.

b) How to assure the sustainability of technological research institutes in the new context, characterized by less direct state action and by fiscal policies aimed at reducing government spending. This raises questions about the continuing government support of such institutes, and about alternative funding strategies, including private sector participation and income generation from the sale of research and technological services.

c) How to make technological research institutes more effective, in terms of providing relevant services and technological inputs to industry, and how to balance such demand-driven work with long-term work oriented to future requirements of industrial development rather than to immediate needs of industry.

The policy and research issues identified in the following section address these three objectives.

## 4. METHODOLOGY

Preparatory work on the project was carried out in late 1991 and the first half of 1993.It included, notably, the preparation of a discussion paper by D.Chudnovsky and R. Bisang on the changing role of ITRIs in developing countries. The purpose was (i) to provide a framework for a comparative analysis of the experiences of ITRIs in different countries, with different institutional patterns and different approaches to the supply of research and technological services to industry, and (ii) to suggest guidelines for case studies of ITRIs. The paper was discussed with some ITRI managers, as well as researchers in 'echnology policy and management, and the guidelines were subsequently refined (see below).

The sponsoring institutions held discussions on the structure and activities of the project in its empirical phase, and the selection and briefing of researchers in charge of case studies.A methodological meeeting was held in Montevideo in August 1992, with the participation of the selected researchers.

The case studies were conducted during the second half of 1992 and the preliminary reports were reviewed at a mmeting in Caracas, February 1993.

The final reports, as well as a synthesis and issues paper, are to be submitted to a final meeting in Buenos Aires, in May 1993, to discuss the empirical results in order to arrive at conclusions and policy recommendations, as well as possible follow-up activities.

Issues analyzed in the case studies

Within the framework of the background paper by Chudnovsky and Bisang, a list of the issues to be addressed by the researchers was prepared and later refined through discussion. Although most issues are relevant for all cases (to make the comparative analysis possible), the questions to be made have to be adapted to the particular characteristics of the ITRI being studied. Here are the main issues:

a) The changing context: How is the new techno-economic paradigm that characterizes the present globalized and liberalized environment influencing the technology needs, and thus the demand for technological services, of industrial firms? What are the implications of this new environment for the role ITRIs play, and for the interaction between ITRIs and industry? How do ITRIs perceive their role in this changing environment? Have changes in the industrial structure and in manufacturing (i.e. predominant types of firms) had any impact on the role and objectives of ITRIs, or on the way they relate to industry?

b) Innovation system: Innovation is a complex process that is increasingly based on interactive processes, linking industrial firms with suppliers, users, technology institutions and other industrial firms. How do ITRIs interact with other institutional actors in innovation processes (i.e. suppliers, engineering firms, universities, etc.)? Do they play a role in innovation chains or innovation systems in specific sectors or technology areas, that link them with similar institutions in other countries (transnational relations) and with industrial firms? In what sectors or technology areas is this process more dynamic? Does this increase their effectiveness, in terms of industrial impact? What factors facilitate greater innovation dynamics in certain production sectors (or technology areas), increasing the effectiveness of ITRIs?

c) Strategy of ITRIs: What is the service-mix (functional activities) adopted by the ITRI? Does this respond to an explicit strategy of how the institute fits into industrial development and technological innovation processes? What strategy and instruments does the institute use to approach industry (clients)? Under what circumstances are these efforts more effective? How successful has the institute been in establishing stable links with enterprises in the sector it attends, both large and small firms?

d) Organizational and managerial aspects: What are the main problems in research management that limit the effectiveness of ITRIs? What problems appear in the area of personnel policies including training and remuneration? What are the problems in the acquisition, management and maintenance of equipment and research infrastructure?

e) Evaluation: How do ITRIs evaluate their different activities and programmes, in terms of their effectiveness and industrial development impact? Is research (or service) evaluation an important component of their management practices? How is effectiveness measured? Are evaluation results integrated into management decisions and strategic choices? How is the research personnel evaluated?

f) Changing organizational characteristics: In adapting to the new deregulated and open market environment, and in seeking to achieve effectiveness and sustainability, three main policy issues play a particularly important role in defining alternative approaches to the organization of industrial technological research:

f.1 Source of funding: What is the proportion of state funding (national budget) and market funding (sale of services)? What are the strategies to increase private-sector funding, using different forms of private sector participation? Is privatization of public research institutes a viable option? Under what conditions can this be successful? What are the main problems encountered? What funding strategy can the ITRI pursue in order to assure sustainability, in the present environment of fiscal constraints?

f.2 Scope of activities: Should there be industry-wide coverage or sectorial specialization (concentration in certain technological areas)? What are the functions of the wide-spectrum institute, as distinguished from those of the sectorially specialized one? Under what conditions is the one more effective than the other?

f.3 Organizational model: What are the pros and cons of a centralized model (a single institution) vs. an institutionally decentralized model (a network of centres of excellence)? Under what circumstances is the decentralized (network) approach more effective? Should there be geographic decentralization?

g) Entry point and organization development patterns: The ITRIs covered in this comparative analysis have different starting points (entry points), that have led to different organizational development patterns. For example, Fundación Chile, CODETEC (Brazil) and each of the national ITRIs have different origins and show a different pattern of organizational evolution. What can we learn from their differences and similarities? What has been the characteristics of each approach that has made it more effective, or has limited its effectiveness? Can the experiences of one be extrapolated to the other?

h) Perception and image of ITRIs: How is the role of ITRIs viewed by (i) industry, (ii) government, (iii) other actors such as development banks? What can ITRIs do to improve their image?

Field work

The researchers employed three main sources of information in carrying out their case studies:

a) Secondary data sources, to collect information on the volume of operations of the institute, the services it offers, the sectors it covers, its main clients, and how this has evolved over time; the sector of industry serviced by the technological research institute; other parts of the technological infrastructure in that sector of industry; industrial, technology or innovation policy issues currently under discussion

in the country, which may help to understand the context in which the institute operates, as well as its future development prospects.

b) In-depth interviews with ITRI managers and policy-makers. These interviews were complemented with reports and other relevant written material.

c) In-depth interviews with firms in the sectors in which the institute operates, in order to see how clients perceive the strengths and weaknesses of the ITRI.

## 5. THE CASES STUDIED

a) Argentina: Centro de Investigación de Materiales y Metrologia (CIMM), Córdoba.

b) Brazil: Companhia de Desenvolvimiento Tecnologico (CODETEC), Campinas.

c) Chile: Instituto de Investigaciones Tecnológicas (INTEC), Santiago.

d) Chile: Fundación Chile, Santiago.

e) Perú: Instituto de Investigación Tecnológica Industrial y Normas Tecnicas (ITINTEC), Lima.

f) Colombia: Instituto de Investigaciones Tecnologicas (IIT), Bogotá (a post-mortem analysis).

g) Venezuela: Centro de Investigaciones del Estado para la Produccion Experimental Agropecuaria (CIEPE), Caracas.

h) Central American Region: Instituto Centro Americano de Investigacion y Tecnologia Industrial, ICAITI (Guatemala)

From outside the region, the following cases were covered:

a) Canada: Pre-competitive Applied Research Network (PRECARN).

b) New Zealand: Restructuring of the public sector science and technology system and role of the new Crown Research Institutes.

## ANNEX 2

## F. MACHADO: SOME FINDINGS OF THE ITRI PROJECT

*This is a summary of a paper by Fernando Machado, "Institutos de Investigación Industrial en América Latina: su rol en los años noventa. Síntesis de los estudios de caso", which was presented at the closing Seminar of the ITRI Project in Buenos Aires, July 1993.*

### 1. Impact of the new environmental conditions on ITRIs

Most of the 8 Latin American ITRIs studied in the ITRI project were founded and grew under a policy of import substitution, which had the purpose of promoting national industrialization through the integration of productive chains and the establishment of industrial complexes. The instruments of this policy were tax incentives, tariff and non-tariff protection, easy credit, production by the state of 'strategic' goods, regulation of technology imports and of foreign capital investment, etc.

The economic crisis in Latin America, the retreat of the state from economic activity, the process of trade liberalization and the cut in official subsidies, have signified fundamental change in the milieu in which ITRIs work. The privatization of public enterprises and the difficult situation of small and medium enterprises have reduced the demand for their services.

Pushed by their governments to become self-sufficient, ITRIs have put emphasis in the offer of routine services at 'real' prices. However, often they lack an updated infrastructure, do not enjoy the necessary autonomy , and face a growing competition from private labs, universities and enterprises. Can ITRIs attract customers under such conditions? No wonder that the privatization or closing down of ITRIs are options now being discussed, and in fact two of the institutes studied have disappeared in recent years.

On the other hand, government incentives to technological innovation in enterprises (cheap credit, partial subsidies, risk sharing) erroneously assume that enterprises are aware of their technological needs, are able to make them explicit as innovation projects, and prefer to satisfy them with ITRIs.

The acquisition of foreign technology has been the most important source of technological innovation in the past for SMEs, but only CODETEC and the Chile Foundation have developed a capacity for supplying services in this area. ITRIs are also unable to help enterprises in technology transfer via joint ventures and strategic alliances, an area where they could perhaps associate with consulting and engineering firms, universities and producers of capital goods while they build up their capabilities in technology management.

The above conditions, together with the emergent and still unclear policies in favour of industrial restructuring and industrial competitiveness, have implications for the future of ITRIs.

## 2. ITRI strategy in the new context.

### *2.1 Strategic planning*

Machado stresses the need for *strategic management* and *strategic planning* as a means to continuously steer institutions towards excellence, survival and growth. An ITRI should learn about impending changes in its environment (technological trends, characteristics of their clients and the evolution of their likely technology needs), should identify new markets and areas of work, choose the best research areas (strategic and speculative), etc. On the basis of such an analysis it should take the necessary anticipatory decisions regarding market strategy, service mix, the development of critical capabilities, changes in its structure and operating systems, etc. to allow for a quick response to the needs of clients, the development of its human resources and the fulfillment of its "development vision".

With few exceptions, the ITRIs have not defined clearly their missions and have carried out little strategic planning. The reasons for this would include:

- a high political instability which makes it difficult to predict changes, opportunities and threats; as a result of this the ITRI ends up having "crisis management";
- often the top managers are former scientists with little training and experience in management, and do not have trained personnel to assist them;
- an autocratic style of leadership, inadequate for rapidly changing conditions;
- an interpretation of government guidelines as complete and immutable;
- a lack of interest about the future, on account of an easy life of government subsidies and little or no awareness about likely competitors

### *2.2 Services offered*

Regarding the mix of services offered by the Latin American ITRIs, a tendency appears towards vertical integration of services, rather than towards complementarity with other service providers, showing the weakness of a "national innovation system".

All of the ITRIs seemed to be in a position to offer complete technology packages, including engineering and industrial design services.

Some interesting trends can be observed for the future service mix in the ITRIs:

- new consultancy services in technology management, production systems, etc.
- new services using present ITRI installations, such as the rental of pilot plants
- new services of technology transfer
- new services on environmental impact, sustainability, etc
- involvement in the creation of new enterprises

This shows an evolution towards the supply of true technology packages and the creation of new ventures.

Machado feels that *ITRIs should offer services of strategic planning and technological planning*, including diagnoses of the competitiveness and the technological position of the enterprise, systematic searching for new business and product opportunites, total quality, incremental innovation, etc. The ITRI should ask questions like the following: How relevant is technology for the customer? Which are the critical technologies for the success of the customer's business? Which of his strategies needs technological innovations? Where can the technologies be obtained, and under what conditions? On which technologies should creative efforts be made? On which should the customer buy new knowhow? What are the possible mixes of technology acquisition and R&D?

*2.3. Marketing*

Few of the ITRIs had clear market strategies, regarding the size, growth, and structure of the market, the threat posed by competitors, the search for new markets and opportunities, and the establishment of strategic alliances.

There is a need to train the staff in sales techniques. On the other hand, clients should be 'educated' to regard technological development as a continuous process, and not wait until a crisis looms to get help from the ITRI.

The image and the prestige of the institution should be promoted, through diffusion in the media about the quality and the results of projects and studies, and through publications and presentations in local and international forums.

The clientele should be carefully analyzed, and there should be efforts to produce a faster reply to clients' requests.

*2.4. Industrial property*

The Latin American ITRIs are patenting very little. This may be because they do not generate sufficient original, patentable research results, because they pay little attention to a strategy of industrial property, or because of sector specific characteristics.

## 3. New organizational and management characteristics as a response to the present challenges

The juridical nature of the 8 TRIs studied includes 4 government institutions (CIMM, INTEC, ITINTEC and CIPEL), three private organizations (ITT, F. Chile, CODETEC) and an international organization (ICAITI). INTEC is at present in the process of becoming a private foundation.

Machado has several interesting observations on different aspect of the organization and management of ITRIs:

- *Privatization:* The apparent benefits of privatization (autonomy, flexibility, agility, among other) do not make an ITRI invulnerable to political

interference from the government when the latter is the main source of funds.

- *Self financing:* Complete self-financing of an ITRI does not appear to be feasible.

- *Concentration:* It is important to concentrate efforts and focus actvities but it is not clear what criteria should be used to select fields of concentration. The analysis of the economic and industrial situation may show the potential demand for ITRI services, but this is vague and insufficient. Concrete needs change, and with them the areas of concentration.

- *Flexibility:* Machado stresses the importance of organizational flexibility, and of a management and strategic capability of the ITRI *to change according to the requirements of its environment*, preserving the integrated character and the synergy of its activities.

- *Organizational structure:* The Latin American ITRIs show *functional structures* , which have not changed significantly throughout the years. This type of structure is not adequate for organizations like ITRIs. On the other hand, *matrix structures* would not seem to be appropriate because of the conflicts they tend to generate. Machado suggests that successful structures should stimulate the participation of staff through ad-hoc working groups, be organized along services that add value for clients, and use information technologies to help decentralize decision making and diffuse rapidly within the organization information, responsibilities and results. He adds that the most efficient R&D structures are of an organic and not a mechanistic type, with high participation and low formality, a high degree of communication, interdisciplinary teams, flexibility in face of changing needs and circumstances, low hierarchy values, and openness to new ideas.

- *Participation of industry in ITRI management:* This has happened only to a limited degree, principally for promotional purposes, and has not been able to generate a significant demand for the services of the ITRI.

- *Organizational culture:* This relates to the values, internal norms, myths, etc. which shape the attitudes and behaviours in the organization. In this respect the Latin American institutes were found wanting, on account of their functional structure, the profile of their management, the low systematic training at the management level, the possible adoption of the University type of culture, and other organizational aspects. Their cultures would seem to need a careful revision in order to make them more effective. Only the Chile Foundation presented concrete values of orientaton towards the market, pragmatism, autonomy, innovation in services and models of transfer of technology.

- *Human resources:* On this, the critical resource of an ITRI, Machado has several observations: (i) the profile of Directors or General Managers (25% of them had an entrepreneurial profile, 37% bureaucratic, 38% scientific and other. The style of leadership mainly seemed to be autocratic; (ii) some ITRIs had low staff seniority levels and high staff turnover; (iii) incentives based on results or merits were almost non-existent, thus doing away with a basic instrument to motivate personnel; (iv) except for the Chile Foundation, little effort seems to have been devoted to the development of human resources; (v)

no mention was made of personnel exchanges with industry; (vi) personnel evaluation systems were absent, or were not applied; (vii) there was a dearth of strategies to cope with human resource issues.

- *Perfomance evaluation of the institution:* with few exceptions, there were no formal systems.

- *Technologies generated and transferred to industry:* CODETEC and the Chile Foundation were the most effective institutes. In most cases there were no references to client surveys on the performance of the institute.

## 4. Conclusions and suggestions to increase ITRI effectiveness

### *4.1 Success and failure*

The underlying criterion of success of an ITRI, according to Machado, is its capacity to fulfill its mission, particularly transferring technologies to the productive sector (in quantity and quality). He adds another criterion: the capability of the institute to learn from its experiences and to perceive and deal effectively with its problems.

In the light of such criteria, the most successful Latin American institutes surveyed were CODETEC, Chile Foundation and INTEC, the rest showing relative (or outright) failure. These three institutes have learned from their errors and have attempted to understand the structure and rationality of activities in the branches they cover, including technology flows. They have changed their "service mix" as needed, and have offered their clients packages with integrated solutions, rather than routine services or isolated R&D projects.

To do this, they have developed their own organizational culture, selected their market niches and evolved novel marketing strategies, through the use of strategic planning, the development of their capabilities to manage change, and the training of their human resources. They have identified the gaps existing in the innovation systems of the areas they cover, filling them by expanding their service mix, and have procured sufficient resources from the state, at the same time avoiding undue interference from it.

On the other hand, the less fortunate ITRIs have remained prisoners of their old visions, tied to a main "product" of R&D (usually more R than D) for which the demand of the productive sector has been only latent and implicit. This predicament has become more evident with the present trend towards the trimming of government subsidies.

In most cases these ITRIs have not been successful in changing a bureaucratic-university culture, and have been unable to build up a professional management team. They have suffered chronic financial crisis and have not been able to deal effectively with their own problems, which have now become more acute in the new environment. Sometimes they have experienced disruptive government interventions.

### *4.2. Increasing ITRI effectiveness*

Machado mentions a number of factors for ITRI effectiveness:

(a) The Director General - his personality, vision, leadership, management capacity, entrepreneurial experience.

(b) Formulation of a *vision* of future development, embodied in a *mission statement* shared by the whole organization and complemented by clear objectives, goals, responsibilites,etc.

(c) Knowledge of technologies and productive activities in the areas of concentration of the ITRI, leading to an understanding of clients' values, problems and opportunities, and thus to a pragmatic and creative approach by the ITRI.

(d) Identification and building up of critical capabilities in the institute. This includes the capability to learn from clients and other actors, and that of carrying out technology management services.

(e) Strategic alliances with other national and foreign institutions that will help open new opportunities.

(f) The careful choice of partners in strategic alliances and of clients in the productive sector.

(g) Continuous internal activities of strategic planning, technological forecasting and scenario building, and the offering of such services to clients. This is to be supplemented by the development of an organizational culture that will support the mission statement.

(h) A legal setup allowing flexibility, autonomy and the working capital needed as state funding decreases.

(i) Efficient procedures to attract and keep human resources of excellent level, to train and update them, to appraise their performance and to provide them with incentives. This will lower personnel turnover, and will stabilize the lines of work, with positive results for the level of the work carried out and the relations with clients.

(j) The introduction of modern management techniques to assure efficient performance. The use of informatics becomes mandatory.

*4.3. New roles*

The present environment calls for new roles on the part of ITRIs, with services such as:

(a) Enterprise consultancy in a wide range of areas: (i) strategic planning, technology management, organizational structure and culture, application of informatics; (ii) setting up strategic alliances and accessing technology through them; (iii) transfer of technology in general: search, evaluation and selection of technological suppliers, negotiation of contracts, technology brokerage; (iv) total quality services

(b) Consultancy for financial institutions, such as the analysis of future competitiveness of enterprises seeking loans and the evaluation of technology in investment projects;

(c) Pre-competitive technology projects, financed by the state or by a group of firms.

(d) Multi-client innovation projects.

(e) Rental to firms of pilot installations, and other innovative ways of exploiting existing assets.

(f) Benchmarking of important parameters to compare enterprise performance.

*4.4 Fulfilling the proposed roles*

Can such new roles be carried out by present ITRIs? Will this make them compete against other agents of the innovation system, and is it all right?

Such questions cannot be answered in a general manner. The new conditions of the industrial and economic environment require governments to play an active role in promoting an increase in national competitiveness. Industrial enterprises, particularly the small and medium ones, seem to lack the capability to face by themselves the restructuring required by the liberalization of trade and the globalization of markets; support is needed from government, direct and indirect, the latter through the reinforcement and integration of the national innovation system. It is here that the ITRIs can fulfill a significant role.

The answers to the above questions thus depend on the specific context in which each ITRI is active, the characteristics of the present innovation systems and the nature of local demand which it is difficult to determine *a priori*. Only experience will indicate what is the appropriate service mix for each ITRI.

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