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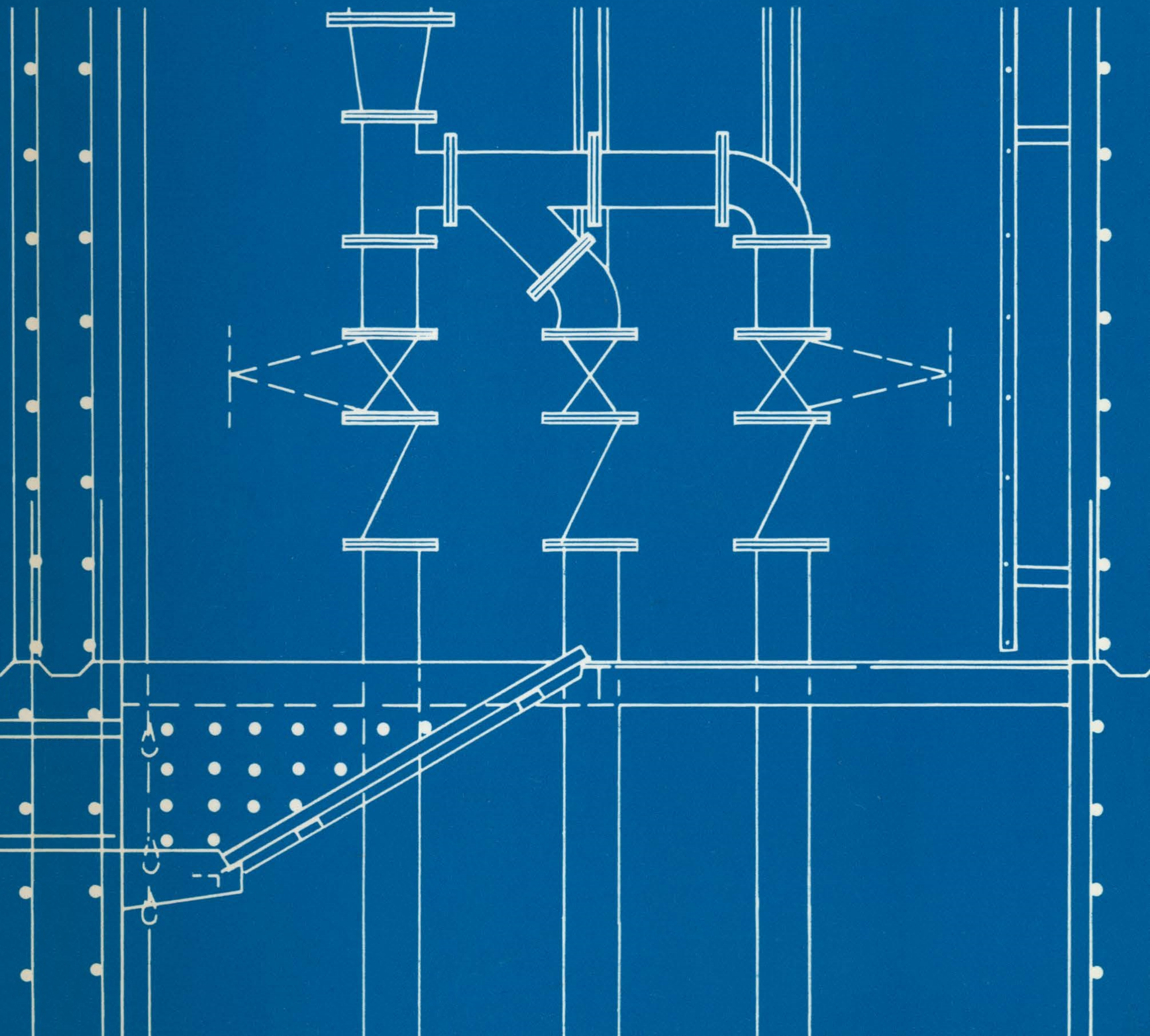
Consulting and Engineering Design in Developing Countries

Edited by Alberto Aráoz



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CONTENTS

INTRODUCTION

ALBERTO ARÁOZ

Modern industrial development, which implies the introduction of new technologies and complex investments, has brought about the appearance of intellectual and professional activities specializing in these tasks — consulting and engineering (C&E) activities.

These activities organize and apply knowledge for purposes of investment and production. In the case of investment, they are concerned with the planning and implementation of investment projects: formulation of the project, choice of the most appropriate product design and process technology, project evaluation, detailed design and engineering, procurement of plant, preparation of contract documents, supervision of construction, testing, and starting-up of new installations. In the area of production, they render valuable services for the operation and maintenance of the plant, the solution of management problems, and the training of personnel. When backed by research and development, they provide the necessary support for adapting imported technologies to the local environment and for creating and applying new technologies.

If a country lacks the capacity to carry out C&E activities by itself, projects will be designed and executed by outsiders, with a concomitant loss of local decision power and the danger of inappropriate technical solutions that do not correspond to local conditions and needs. In addition, opportunities to favour purchases of domestic equipment, inputs, and technical services and to create effective links between research institutions and the productive sector will be lost.

Optimal investment projects and self-reliance in technological matters depend crucially on having consulting and engineering capabilities of one's own and employing them properly. Developing countries should have an interest in establishing their own consulting and engineering design organizations (CEDOs), developing them so they can efficiently carry out their activities, and utilizing them in the most appropriate manner. This is increasingly being understood by some countries that have formulated policies for such purposes. In other developing countries, however, such a need is not yet properly appreciated.

Interest in the subject has increased in recent years, and a growing body of literature has become available since the early 1970s.[1] A number of relatively advanced developing countries, notably India, Brazil, Korea, and Argentina, have adopted legislation and policies to promote their C&E capabilities, with various degrees of success. The subject has also engaged

[1]See references at the end of chapter 1.

the interest of several development agencies, which have supported research and outlined programs for promoting the development of C&E capabilities. A short review of these activities provides a backdrop for IDRC's efforts on the subject:

- UNIDO (United Nations Industrial Development Organization) has been looking at the question for several years, has conducted a number of surveys, and has contributed to the creation of consulting and engineering capabilities in several developing countries, within industrial research centres or as separate institutions. In June 1978 it convened a meeting in Ljubljana to discuss the problems faced by CEDOs in developing countries and to appraise the possibilities of cooperation among them. The meeting found that industrial consultancy is a key element of industrialization programs because it contributes directly to evolving appropriate technical and economic solutions in harmony with national socioeconomic objectives, securing improved terms in technology acquisition, and achieving technical and managerial self-reliance through a more effective use of national resources: consultancy is the "software" equivalent of capital goods, which is the essential "hardware" input for industrialization.
- The United Nations Development Programme has been keenly aware of the importance of consulting and engineering for the formulation of appropriate development projects and has tried to enhance the participation of CEDOs from developing countries in the projects it promotes. In 1975 it sponsored a meeting on consulting services in Latin America and the Caribbean, and more recently it has supported work on the subject of cooperation in consulting and engineering services among developing countries.
- The Inter-American Development Bank has created several preinvestment funds in Latin American countries since the mid-1960s, with the purpose of improving project preparation in the public sector; such funds became explicit supporters of national consulting and engineering and have recently inaugurated a program of collaboration among themselves in which this support will be further enhanced.
- The World Bank has carried out careful studies regarding the use of Bank-funded projects for building up local technical and project capabilities, and the results have allowed it to draft improved procedures that have recently been incorporated as operative suggestions in the Bank's manual of operations.
- The OECD (Organization for Economic Cooperation and Development) has conducted studies on CEDOs of industrial countries and their activities in developing countries and has supported six case studies (in Cameroon, Colombia, Egypt, Ivory Coast, Peru, and Thailand), which were reviewed at a seminar in Paris in October 1978. An important finding was that CEDOs of developed countries are not much aware of the conditions and needs of the developing countries for which they design investment projects and tend to transplant solutions from developed countries to an environment where they may not be fully adequate. Such solutions tend to favour the purchase of technology, equipment, and production inputs from the country in which the CEDO resides; the possible supply by entities of the recipient country is not fully taken into account.

The International Development Research Centre has sponsored work on consulting and engineering since 1974, when it commissioned M.

Kamenetzky to carry out a study of the evolution of process engineering in Mexico and Argentina. Also, it sponsored the Science and Technology Policy Instruments Project, and a number of the participating teams identified the issue of consulting and engineering design services as one that warranted research. Several national studies were carried out and a technical meeting took place in Caracas, Venezuela, in October 1975, where papers were submitted by the teams from Argentina, Brazil, India, Korea, Mexico, Peru, Venezuela, and Yugoslavia. Observers from UNDP, the World Bank, the OECD, and the IDB-ECLA research group were also present and referred to the work carried out in their respective organizations. One of the conclusions of the meeting was that the subject was of great importance and that it was ripe for research.

Consequently, in October 1976, IDRC convened a meeting in Corfu, at which a number of people defined the outlines of a possible research project on this theme. A paper prepared by Dr Anil Malhotra on consulting and engineering design organizations served as a background paper. Since the Corfu meeting, a number of discussions have been held on ways and means of providing greater definition and focus to a CEDO research project. There was an agreement that the subject is complex and that an exchange of views should help to clarify the critical policy issues that are amenable to research and analysis.

As a contribution to this objective, IDRC asked me to draft guidelines for case studies of CEDOs to be carried out in several developing countries and to prepare a review of the subject, which, together with the case studies, could help to define an international collaborative research project. It was recognized that these case studies would be a necessary preliminary to the formulation of a more detailed research proposal on this theme.

The case studies were made in 1978–79 in four countries (Argentina, Brazil, Philippines, and Korea). Together with other material, they were reviewed at a meeting convened by IDRC in St. Jovite, Canada, in October 1979. This meeting was attended by participants from several developing countries who had been directly concerned with the subject as practitioners, policymakers, or researchers. After several days' work, a research proposal was drafted for submission to IDRC, touching on the principal issues identified by the participants.

At the same time, those meeting in St. Jovite felt that the studies prepared under the auspices of IDRC and reviewed at the meeting were of great potential interest to a wider audience, and therefore it was suggested that a publication should be envisaged with this material. This suggestion was accepted by IDRC and has resulted in the present volume.

THE BOOK

Chapter 1 is an essay on the general question of consulting and engineering in developing countries. The essay draws heavily on conversations with practitioners, users, and researchers; on discussions at international meetings on the subject; and on the growing literature. Some of my previous experiences have also been incorporated.

Chapter 2 reproduces the guidelines that were prepared for the case studies. These guidelines followed from a conceptual framework that has been incorporated in chapter 1.

The case studies are shown in chapters 3 – 6, in edited versions of the original reports. Results of the case studies are reviewed and compared in chapter 7.

Finally, chapter 8 looks into the areas that should be considered in the planning of future research on the subject, which emerge from the previous chapters and from the discussions carried out at the St. Jovite meeting.

CHAPTER 1

CONSULTING AND ENGINEERING DESIGN ORGANIZATIONS IN DEVELOPING COUNTRIES

ALBERTO ARÁOZ

Consulting and engineering design are activities of an intellectual nature, which organize and apply knowledge for purposes of investment and production. They are characterized by certain methods of work, or methodologies, and often by a multidisciplinary approach. The services produced are not just of a technical nature; the economic, environmental, organizational, and training aspects are important for a good formulation and execution of investment projects, as well as for the efficient operation of the resulting installations. There is an accent on professionalism and multidisciplinarity, which distinguishes the best consulting and engineering design organizations.

There are some semantic and definitional problems deriving from the use of different terms for these activities (e.g., consulting, consultancy, industrial consultancy (UNIDO), technical consultancy (India), consulting engineering, etc.) and for those who are engaged in them (often, contractors provide C&E services and on doing so they are acting as consulting engineers, and conversely when consulting engineers construct they act as contractors). Sometimes a certain term is incorporated into legislative texts and adopts a definite meaning in a particular country.

I shall use the set of definitions that were agreed on at the STPI meeting on consulting and engineering services (Caracas 1975), which are of an operational character. C&E services are rendered at different stages of a project (Table 1).

Consulting services comprise the preinvestment services as well as advisory services in the two other categories — project execution and operation maintenance — the rest being engineering services. Therefore, consulting services include preinvestment services (prefeasibility and feasibility), as well as services rendered to a client related to the coordination, control, and supervision of project execution, and to the operation and maintenance of productive installations; and engineering services (or engineering design services) include those related to project engineering (basic engineering, detailed engineering), to product design and engineering, and to other design activities.

Consulting services at the preinvestment stage may involve various disciplines — engineering, architecture, economics, finance, law, ecology, and occasionally even medical, psychological, and educational sciences — the personnel aiming to conceive and appraise a project so that a sound decision may be made. The contributions of professionals from the

Table 1. C&E services at different stages of a project.

Services	Stage of a project
Preinvestment services	Prefeasibility studies (surveys, identification, evaluation); project feasibility study
Project execution services	Project engineering (engineering survey, detailed engineering, product engineering, organization and management, information systems); project implementation (procurement, construction–supervision); commissioning and start-up (includes personnel training)
Services for operation and maintenance	Production and maintenance

disciplines must be integrated so that the result is based on estimates of various parameters, which may later change in value. Thus, there is a degree of uncertainty; input costs may vary, unexpected contingencies such as a geological fault may appear, a new and better technology may be produced, and so on.

Engineering services come into the picture when the main characteristics of the project have been decided upon and a technology has been chosen. They are mainly performed by engineers, collaborating technicians, and draftspersons. Uncertainty of the outcome is much lower than at the preinvestment stage, so that consulting services are "probabilistic," and engineering services are "deterministic."

C&E services may be classified in different ways according to the type of service, the branch of economic activity to which it is rendered, and the type of client. This classification allows a fine division that can be expressed in tabular form; examples are surveys made by UNIDO and OECD.

In developing countries, C&E services are required mostly by users in the public sector (ministries, planning commissions, regional development authorities, public enterprises, development banks, and institutions in charge of promoting industrial development). Private industry is usually a less important client. Small- and medium-scale enterprises are potential clients for a wide variety of C&E services, mostly in the areas of management, technical assistance, and information.

The cost of preinvestment consulting services is only a very small fraction — 1–3% in most cases — of the total investment, but such services are crucial from the technical as well as the economic and social points of view. In a developing country, the intervention of a local consulting organization may mean that the project is conceived with much more relevance to local needs and conditions than it would be if a consultant from an industrialized country were employed. Local engineering may contribute further in maximizing domestic inputs.

I shall use the term consulting and engineering design organization, CEDO, to denote the organization producing C&E services. Several types may be distinguished: private C&E firms, which restrict themselves to rendering C&E services; public C&E firms, which are similar to private CEDOs except that they are state owned; public organizations that supply C&E services in addition to other services — for instance, industrial research institutes, industrial design organizations, technical information centres; captive or in-house organizations in public or private enterprises, which may be called engineering departments, project departments, etc., and may be temporary or permanent; in-house organizations in contractors and in equipment suppliers, which frequently provide C&E services to their clients by formulating projects that will incorporate their goods and services.

C&E activities in developing countries are in general not fully developed. Domestic CEDOs tend to be weak, and demand is geared to a varying but important extent toward foreign CEDOs or their local subsidiaries and joint ventures. At an early stage of development, C&E capabilities tend to be concentrated in construction and civil engineering, as well as in preinvestment services in general. CEDOs devoted to industrial projects appear later on; as industrialization proceeds, the scope of their activities becomes wider, and in some cases basic engineering capabilities are achieved.

If a country does not have the capacity to produce C&E services, projects will be conceived, designed, and executed by foreign-based CEDOs, with the danger of inadequate technological solutions, the need to import capital goods and production inputs that might have been supplied locally, and the continuing dependence on foreign know-how and foreign skills.

CEDOs in developing countries have a wider and deeper role than those in industrialized countries. This is partly due to the more primitive conditions under which they operate, the relative ignorance and unfavourable attitudes of their clients, and other obstacles to their activity. The principal difference, however, lies in the important socioeconomic role they may fulfill by setting up projects that are appropriate to local conditions and by putting in motion a process that may produce significant impacts on development, beyond the contribution of the project itself.

When C&E activities are carried out by competent domestic CEDOs with knowledge of local conditions, the potential benefits for the investor as well as for the whole economy are more adequate technological solutions, clearly delineated investment packages, and efficient absorption of foreign technology and foreign consultancy inputs. There may also be a reduction in the cost of projects and their foreign exchange component, because local consultancy services are often cheaper and there is a higher proportion of local inputs than with foreign-based services.

Perhaps more significant in the long run are the favourable impacts outside the limits of the project itself. Locally designed projects tend to use more local inputs, thus increasing the demand within the country for capital goods, components, technology, services, and professionals. Bargaining power vis-à-vis foreign investors and technology suppliers may be increased. Knowledge may be spread more effectively among firms. New skills, attitudes, and capabilities are bound to be introduced throughout the industrial spectrum as widespread learning takes place. CEDOs may link up local research and development (R&D) institutions with the productive sector, taking charge of the engineering aspects of new technical solutions and providing technical assistance once industrial production has started.

The experience of several developing countries shows that such positive impacts on development have materialized as the management of knowledge by nationals has strengthened.

Some authors — of whom Perrin has been the most persuasive — feel that consulting and engineering play a unique and crucial role in industrial development, being at the crossroads of a flow of information and decisions between productive units, capital goods manufacture, and research and development. C&E activities link these three parts of the economic system and also provide links with the financial system. Through the projects carried out by domestic CEDOs, it is possible to maximize impacts from the productive units to the other two activities, thus promoting the development of an integrated industrial system. Industrial development without employing domestic C&E capabilities would rely indefinitely on imported technical solutions and imported capital goods (Perrin 1971).

C&E activities may, therefore, achieve a high social utility in terms of their impact on development. Two important national objectives would then be the increase in domestic C&E capabilities and their proper utilization so that a high social efficiency will result from the resources allocated to investment.

The public sector may play an important role in this regard. In many developing countries, the state has taken up growing responsibilities in dynamic activities such as petroleum, energy, transport, iron and steel, shipbuilding, heavy chemicals, pulp and paper, cement, etc., and public enterprises have become the main — if not the only — concentrations of economic power under national control able to face foreign-owned firms. They constitute important decision centres with the power to affect profoundly different sectors of national activity. Investment projects in these branches, however, have often been bought from foreign suppliers through turnkey purchases, and the participation of domestic C&E and industry has been limited. A change in traditional patterns of behaviour would have important effects on industrial development. Hence there should be an effort to open and examine investment packages, which often combine financing, technology, capital goods, construction, and technical services, to ensure maximum local participation in the supply of goods and services for the investment project.

A turnkey plant may be said to constitute an unknown package. The investors should be able to carry out their investments in a disaggregated manner, to have control of the technology, put the package together in accordance with the real national needs, and utilize fully intellectual and physical domestic inputs. To go from a turnkey operation to domestic control of technology and inputs, it is necessary to undergo a learning process that can rarely be accomplished in one step; thus, it is necessary to proceed through a series of stages that imply a growing mastery of technology — the development of domestic C&E capabilities and the adequate utilization of such capabilities (Sabato 1973).

There are costs in developing C&E capabilities and in accepting for a period some relative inefficiency, as happens with infant industries. One of the principal obstacles has been the risk to be assumed in entrusting national organizations with complex and exacting tasks. This, however, has generally been exaggerated in the past on account of poor knowledge and underestimation of national capabilities as compared with foreign capabilities that have been taken to be unexcelled.[2] To this is added the frequent attitude of decision-makers in developing countries who look for an immediate effect of their decisions and purchases. They just want to obtain what they urgently need, to "get the job done." By adopting such a short-sighted approach, they may lose important opportunities to improve the efficiency of their own organizations in future and to produce significant long-run effects on development.

There is, therefore, a good deal to be done in educating investors, banks, and governments regarding the key role of consulting and engineering for self-reliant development and the need to support and promote this activity through national policies. Ways and means have to be found in every country to transmit this message to decision-makers, industry, and often the consultants themselves.

Demand for C&E Services

Consulting and engineering services are not products that feed final consumption in a society; they are inputs to other activities — investment principally — and as such their demand largely depends on the volume of those activities, which are themselves related to the extent of actual or planned changes in the country.

A distinction may be made between requirements and demand; the first term is the volume that should be demanded and the second is the actual volume demanded. It may be suggested that the demand for C&E services in a developing country tends to be lower than requirements, because project preparation and design are often made with less depth than would be desirable. If such tendencies were verified, there would be reasons for adopting policies for increasing the demand for C&E services to an adequate level, through persuasion, a decrease in the price of C&E services, or other means.

Sources

The principal sources of demand for C&E services in a developing country are the large investment projects in the public sector, which are carried out by ministries, public enterprises, development corporations, and other agencies. Such projects are usually included in national development plans. Other sources of demand are financial institutions like development banks and small enterprise development funds, which request consulting tasks for studies, programing, and project formulation;

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[2] Foreign consultants have frequently made costly mistakes or recommended inadequate solutions that would have been easily perceived by a local consultant familiar with local conditions. On the other hand, a local firm may contract foreign expertise as and when needed. A more balanced assessment of the worth of local consultancy and a change in risk-avoiding attitudes is needed.

industrial firms carrying out investment projects (new plants or extensions), introducing new products, or adopting new production technologies; and small and medium-sized enterprises needing help for the acquisition of machinery, the improvement of management practices, and the solution of a wide range of technical problems. Demand originating outside the developing country may come from other developing countries, international financial institutions, and occasionally agencies of developed countries that extend bilateral aid usually preceded by extensive preparatory work.

The sources of demand may be classified according to the branch (civil works, mining, food industry, etc.), the type of technical service (building, power and light, water and gas, ventilation and air conditioning, drainage and sanitation, topography, etc.), and the stages of consulting and engineering services for projects (prefeasibility, feasibility, techno-economic work, process design, detailed engineering, procurement, product design, project start-up, project management, etc.). A series of two-way tables using these categories would give a detailed idea of the structure of demand.

This demand may be attended partly by in-house capacity and partly by outside CEDOs. The complexity of demand, to a large extent depending on the country's level of development, will call for more or less complexity in the structure of supply. Of prime importance in the case of semi-industrialized countries are multipurpose CEDOs that may attend the needs of the public sector, financial institutions, and large industrial enterprises. In countries of incipient industrialization, or in those with a very large traditional sector, CEDOs attending the demand of small and medium-sized enterprises would be of prime importance.[3]

Most of the demand for C&E services related to investment projects in the developing countries originates in the public sector. Any policy in favour of building up C&E capabilities and utilizing them adequately would therefore have to rely to a large extent on improving the behaviour of state investors, who should be influenced to adopt enlightened procedures in their investment operations.

ESTIMATIONS

It is not easy to estimate the demand for C&E services. It is probably better to employ as an indicator the volume of business (sales of C&E services) rather than physical indicators such as the number of drawings, personnel, etc. The volume of C&E services may be roughly estimated as a percentage of the expected cost of investment. There are few data on this aspect, but rules of thumb are that the cost of preinvestment studies (consulting) are around 3% of the total project cost in large industry projects and 1–1.5% in large infrastructural investments. The cost of detailed engineering would be between 5% and 9% according to the complexity of the project (Aráoz and Politzer 1975). This calculation is much too rough for reasonably accurate plans for the development and utilization of C&E capabilities, and a first research need comes out clearly:

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[3] A network of consultancy institutions for small and medium-sized enterprises has been established in India, in close liaison with financial institutions for the same sector (Bhatt 1975).

to find out from past experience the value of such percentages for different types and locations of investment projects. This information would make it possible for a country to estimate the requirements for C&E for its main sectors and hence to plan the expansion and use of its C&E capacity.

In the case of preinvestment services, it is probably more difficult to arrive at satisfactory estimates than in the case of engineering and project implementation services. Sometimes investment decisions by the state are taken on political grounds, using a few a-priori elements, and the feasibility study may then become a formal requisite to justify decisions already taken. In other cases, investment decisions respond to one main factor, the availability of finance, and the study once again justifies a decision already taken. Preinvestment studies, then, largely become window-dressing. Similarly, the private sector sometimes justifies decisions in this way, although banking institutions and planning agencies are insisting more and more on the need to carry out careful feasibility assessments as a way to guarantee that good investment decisions will result.

Estimates of demand for C&E services should consider areas in which C&E services are bound to be required in the future and in which there is as yet little or no national C&E capacity. Long-term projections should be useful for identifying such areas. The formation of C&E capacity in them should be undertaken early if complete dependence on foreign CEDOs is to be avoided. Estimates may be made by an official organ, such as a planning authority, or by institutions, like the National Association of Consultants, that can study supply aspects in great detail.

There have been a number of experiences in demand estimation that have underlined the difficulties of the exercise. Demand projections were carried out in Canada, but the experience was not altogether successful, the conclusion being that only short-range predictions could be made because C&E activity is too much affected by the ups and downs of the economy to permit any reliable estimations in the medium or long term.[4] This conclusion applies to a market economy, without explicit national planning; in a mixed economy with central planning, as is the case in many developing countries, it probably makes sense to devote efforts toward estimating the demand for C&E services several years ahead as a basis for programing the development of C&E capabilities.

In Algeria, for example, such estimates were a basis for the training of human resources. A fixed ratio of the principal industrial projects was used as the consulting and engineering input. This gave a good idea about the volume of studies and of detailed engineering needed, and from this figure, the number of working hours was estimated for professionals, such as engineers, technicians, and designers. Thus, it was possible to make rough estimates of the number of people needed by area of specialization.[5]

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[4] This observation was made at the seminar convened by OECD in 1978.

[5] A first conclusion from the exercise was that there were not enough training possibilities in Algeria. Priorities had to be set out, regarding both the engineering field and the phase of the consulting and engineering process, and it was clear that full utilization should be made of the opportunities of repetitive projects (Perrin 1971).

TRENDS

The demand for C&E services is already large in some of the developing countries and may be expected to grow significantly as major investment programs are undertaken. UNIDO estimates that industrial investment in all developing countries is close to U.S. $100 billion;[6] if C&E services represent 5–6%, total annual demand would be in the order of U.S. $5 billion.[7] Opportunities for CEDOs in developing countries would seem to be large, particularly because many projects are to be undertaken by the public sector. In India, for instance, it was estimated for the Fifth Five Year Plan some 25 000 professionals would be needed to handle all the engineering and plan design services, but only 6000 were available at the beginning of the period (Malhotra 1976).

The upward trend is apparently caused by the improvement in the economies of some developing countries, the preparation of more ambitious plans, a more intensive process of programing and implementation, a greater awareness of the role of consulting and engineering, and reorientation based on previous mistakes resulting from insufficiently detailed studies. Another influence is the increase in the share of C&E within total project costs, in part because C&E costs become more visible as the purchase of turnkey projects diminishes and also because there is a tendency to spend more on a wider range of engineering services in an attempt to save on the investment and operating costs of projects.

FOREIGN C&E SERVICES

In many developing countries there is a tendency to channel the demand for C&E services toward foreign CEDOs from industrial countries. If national C&E capacity is to receive proper utilization and thereby produce the social benefits expected from its activities, it is important to identify the reasons for such a preference and to lay down policy that will permit a redress of the situation as far as is convenient. Among the reasons are:

- The relative weakness of domestic CEDOs compared with foreign CEDOs, which principally comes from an inherent inequality in financial means and credentials. Domestic CEDOs are often caught in a vicious circle, which is very difficult to break.
- Attitudes in public and private enterprises that lead to the disparaging of domestic skills, the use of foreign consulting firms, and the turnkey solution. Such attitudes may take a long time to change because confidence in local consulting activity must be developed. In addition, decision-makers — particularly in the state — may have an attitude toward

[6] UNIDO presented this estimate in its document for the UN Conference on Technical Cooperation, Buenos Aires, 1978.

[7] Estimates of the demand for C&E services in Latin America reached U.S. $15 billion for 1976–85. Decisions based on these services would affect U.S. $200 billion of investment and would strongly influence consumption, production, and many other aspects of life in the region (Aráoz and Politzer 1975).

risk that makes them behave on the safety-first principle; this may become an important obstacle to the demand for local C&E services (Aráoz 1977).[8]

- Lack of domestic financing for C&E services; the client then looks for a foreign CEDO able to finance its services on easy terms.
- Lack of local medium- and long-term financing for investments, obliging both public and private investors to turn to foreign sources that finance the complete packages of consulting, engineering, technology, and equipment. This problem is dominant in countries that depend extensively on foreign aid and foreign investment, and the untying of aid has now become an issue in international forums.
- The behaviour of international financial agencies that, despite pronouncements to the contrary, favour the use of established CEDOs from the industrial countries.
- The behaviour of national financial agencies, which tend to copy the "prudent" behaviour of the international banks and, just as the latter, are often in favour of "getting the job done" and not complicating things with relatively untried local CEDOs or local inputs.

There are strong arguments for building up a national capacity in consulting and engineering and achieving import substitution in this field, although too strong a nationalistic attitude may act as a barrier to the flow of technology, it may impose tasks on the local CEDOs that they are not yet ready to discharge, or it may be negated in practice if weak local CEDOs take on foreign CEDOs as partners and leave to them the substantive work and the decisions that go with it. The problem is to use foreign C&E services in such a way as to maximize their positive features and minimize their negative effects.

FLUCTUATIONS

An important characteristic of the demand for C&E services in developing countries is its fluctuating nature. Economic cycles, stop-and-go policies, political changes, lack of long-term public investment programs, etc. are factors that lead to acute ups and downs in demand. There is a need for continuity if CEDOs are to work properly and develop steadily. The drying up of demand has not infrequently meant the disbandment of human groups that had been built up with much effort and the need to turn to foreign CEDOs when demand picks up again. On theoretical grounds, some idle capacity is socially beneficial in the long term in activities where, on the one hand, demand is not constant and, on the other, the length of services demanded is not uniform.[9] Mechanisms must be found to support occasional idle capacity and to avoid disbanding groups when there is no work.

To even out state demand for C&E, first, government can introduce general regulations and carefully draft tenders and specifications. If regulations stipulate that local C&E services be used wherever possible, demand is bound to increase and become relatively more stable. Many influences act on state project owners. They have to decide whether they

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[8] According to an Indian study, no government policy has been effective in forcing clients to use Indian engineering services or indigenously manufactured equipment (Malhotra 1976).

[9] This result is well known in queuing (congestion) theory.

want to pay more to the consultant or to the equipment suppliers. In large package deals there is much C&E work that does not show; if packages are pulled apart, C&E costs increase but the total project cost may diminish. Also, they have to assess their desire to deal with one main engineering supplier, which may minimize complications and risks, and balance it with market conditions. Although it is generally accepted that C&E services should be bought by quality and not by price, sometimes price is considered to be more important than quality. Second, government can stabilize demand by analyzing development plans and by coordinating the different agencies that carry out investments. The latter may be difficult because agencies are often jealous about their autonomy. Third, the government can create demand for CEDOs by ranking projects according to priority and supporting low-priority projects when demand for C&E services is low. This has been successfully done in Brazil through FINEP (Financiadora de Estudos e Projetos), a government agency that funds studies and projects. Fourth, CEDOs themselves may try to adapt to these fluctuations. They can continue to work in spite of recessions by diversifying their activities, working outside the public sector, or exporting their services. In many developing countries, consulting organizations have a small core of highly qualified managers and few stable technical personnel; they rely on a large network of specialists for specific projects. When the work load diminishes, it is the outside collaborators who suffer; the firms continue to survive.

Foreign Demand

Some CEDOs in developing countries have been able to sell their services to other developing countries. This trend is bound to increase in some fields because these CEDOs have advantages over CEDOs from developed countries: they provide services at lower costs; they have an approach that is closer to the philosophy and way of life of the client; their awareness of local problems and local conditions is likely to be greater because of similarities between developing-country economies; and they may draw on technological solutions that have been tested and proved under conditions similar to those of the receiving country.

The export of C&E services is beneficial on several grounds. Foreign exchange is earned; national technology may be exported; and a CEDO may keep up its level of activity when local demand has momentarily dropped. Some developing countries have drafted policies for promoting such exports through tax measures, credits, and other means.

Supply of Consulting and Engineering Services

Types of CEDOs and the Structure of Supply

There is a clear tendency in developing countries — as has been the case in developed countries — toward the separation of C&E functions from other activities, as a consequence of the division of labour in increasingly complex societies.

A CEDO may be independent, producing services for various clients, or it may belong to a larger organization (such as a government agency, productive firm, contractor, or equipment manufacturer). These "captive"

CEDOs, often known as project departments, supply services principally to their parent organizations, but sometimes they do serve outside clients.

CEDOs may be owned by the state or private groups, local or foreign. They vary considerably in size and in the range of services they offer. There is competition between the different producers of C&E services in a country, but there are also relations of complementarity, which a policy for C&E promotion should consider.

In some developing countries, important sectors such as electric power, transport, steel, oil, and petrochemicals are in the hands of the state and carry out a succession of investment projects. They have a steady need for C&E services and tend to have their own C&E capacity; independent local CEDOs are used to supplement this capacity when peaks of activity take place, whereas foreign CEDOs are employed as suppliers of basic engineering and very specialized services.

Unless an enterprise or government agency has a sufficiently steady flow of new investment projects, it does not pay to house C&E staffs and becomes economic instead to contract outside CEDOs for most of these activities. This practice may be socially beneficial, as it allows CEDOs to become larger and acquire a great deal of experience, enabling them to render cheaper and better services to a variety of users, and to disseminate knowledge that otherwise would have profited just one customer.

Countries of incipient industrialization with a small modern sector have a small C&E capacity, mainly in production firms (particularly those of foreign capital), government project offices, and various public-sector institutions, including engineering design centres, industrial research institutes, productivity centres, consultancy units for small and medium-scale enterprises, and occasionally educational and training institutions. It is very important to employ whatever technical capacity is available for tasks of project formulation, design, and technical assistance. Industrial research institutions, in particular, are sometimes the only feasible alternative to import of C&E services.

Private independent CEDOs in developing countries range from very small firms with a high mortality to large, stable, firms. In many developing countries, there are numerous small CEDOs that carry out preinvestment services and a certain amount of engineering. They face a large number of problems, among them the instability of demand, the lack of confidence in the effectiveness of their services, and the fact that their clients often are not exactly aware of what they want and may not be capable of controlling the different stages of execution of a project. Frequently these small CEDOs look for foreign collaboration to increase their chances of landing an assignment. Their role is sometimes that of a commercial and administrative agent or a technical collaborator in peripheral matters. In other cases they carry out a great deal of the work. They are often organized as a small permanent group of able professionals who are joined temporarily by experts for a specific project. In the best firms of this type, those in the permanent staff have acquired a mastery of the technology of consulting,[10] have a good knowledge of local conditions, and keep a

[10] Technology of consulting includes know-how about methods and their use, the utilization of outside expertise, the ways of presenting results and recommendations for different types of clients, etc.

dynamic system of contacts with users in the private and public sectors and with local and foreign sources of technology and equipment.

In some developing countries one also finds relatively large private CEDOs that are able to handle complex projects on their own. Frequently they also operate as contractors and carry out turnkey projects for their clients. Often they are subsidiaries or joint ventures of CEDOs from industrial countries.

India, Brazil, and other developing countries with a relatively important industrial sector show a well-developed C&E capacity in independent and captive CEDOs. In the case of India, Malhotra (1976) has pointed out:

- CEDOs may be classified in two groups according to their ability to provide project consultancy services. Most of the small organizations are in a position to offer only preinvestment or project planning services. It is only the larger organizations that are able to provide comprehensive project consultancy services.
- The small consultancy organizations have been forced to face keen competition from equipment suppliers who provide free consultancy services to the potential investors.
- A review of the activities of consultancy organizations indicates that so far no specific pattern has emerged. Although there are a few organizations (MECONS, Dastur & Co., Engineers India Limited, National Industrial Development Corp., etc.) that were originally established with the intention of specializing in particular industry areas, they have entered other fields as well. This may be due to difficulties in securing continuous business in their specific fields. But this diversification must necessarily reflect the quality of specialization established in highly complex fields.
- There are a fair number of reasonably well-equipped organizations in respect of economic, project, and management consultancy services in India. But not sufficient headway has been made in developing process and technological consultancy services. As a result, India still continues to depend heavily on external sources for the required process know-how and product-designing technology.
- The level of participation of consulting engineering firms in a sector varies according to the industrial sector served. This varying participation, to a very large extent justified by the different rhythms of technical progress observed by each sector, is also determined, to a lesser extent, by factors such as the possibility of access to the sources of know-how, the structure of the sectoral market, the links with groups in other sectors of the economy, and the links with capital goods producers and research institutes in the country.

A more typical situation is found in most Latin American countries, with a proliferation of individual consultants and small CEDOs with ad hoc, fragmentary, and individualistic characteristics, coexisting with some state organizations that produce C&E services and with a few large private CEDOs that often are foreign owned or joint ventures. Except for a few countries, most of the important investment projects are prepared and implemented by foreign CEDOs from the industrialized countries, with marginal participation by local people. The relatively recent emergence of local CEDOs, which did not exist before the early 1960s in most cases, the indifference of governments, the vicious circle, the strong fluctuation of demand, and the lack of financial means have been the main reasons for this situation. Studies undertaken by the Andean Pact Secretariat show that by 1972 there were about 180 independent firms in the Andean subregion, which gave permanent employment to almost 1400 professionals. Most firms were small and were principally dedicated to physical infrastructure projects (transport, power, sanitary engineering, irrigation, telecommunications, urbanization, structures in general). In Chile, around 1974, about 15% of the total national expenditure for engineering was derived from private firms, 25% from foreign firms, and 60% from state organizations. In Venezuela, about 3000 professionals were employed in consulting engineering, but only a small proportion was organized in relatively important firms. Argentina has many small C&E firms, and a few large ones, which have had to cope with low fees, tardy payments, and a very fluctuating demand. The situation is similar in most of the other countries of the region, perhaps with the exception of Brazil, which for years has had a policy in support of domestic C&E.

Some other features of the Latin American situation should be noted. Local C&E capacity for services to industrial investment is much lower than for infrastructural investments. Local CEDOs often associate with CEDOs from industrial countries for a given job, but often there is no real collaboration between them, the local firm undertaking subsidiary responsibilities and sometimes acting as a mere agent. Some large CEDOs are subsidiaries of firms from developed countries or are joint ventures where the local associate is in fact a junior partner. The important C&E assignments tend to be entrusted to foreign CEDOs or to local CEDOs of foreign capital, whereas the locally owned CEDOs are employed in smaller projects or as subcontractors for the simpler tasks of large projects (Aráoz and Politzer 1975).

Some Issues

Imports from Developed Countries

The use of foreign CEDOs is sometimes unavoidable and is often regarded as convenient on grounds of speed, efficiency, and reliability; but there may be serious drawbacks, particularly in the long term. To minimize them, and to heighten the positive effects of employing C&E services from developed countries, certain types of procedures and rules should be applied. The purpose should be to employ foreign C&E as a complement to rather than as a substitute for local C&E, seeking mechanisms of cooperation between both to favour the maximum utilization of local sources and to make full use of foreign consulting as a vehicle for technology transfer and the training of national consulting personnel. Some people feel that the best solution is to employ a local CEDO as the prime contractor and let it determine what foreign collaboration it needs and how the work should be divided, with the proviso that it should establish a "relationship between equals" rather than just offering its letterhead and its offices to the foreign CEDO. This approach, however, finds obstacles in financial institutions and investors on account of their risk-avoiding, efficiency-seeking attitudes and their poor capacity to contract and use C&E services. Local CEDOs, on the other hand, may not feel up to the task in so far as they have become accustomed to a subsidiary role in regard to foreign CEDOs.

PARTICIPATION OF FOREIGN CAPITAL IN DOMESTIC CEDOS

The issues here are similar to those that have been extensively debated in relation to foreign capital participation in manufacturing and other economic activities. There are, however, certain peculiar aspects that have to do with the nature of C&E activities and the role they may fulfill in development. First, the extent to which a local CEDO is dependent on a foreign one is better indicated by the origin of its technology and key personnel than by the percent equity share of the foreign CEDO. Second, whereas foreign capital CEDOs present a number of advantages because of their ready access to the know-how and expertise of the parent organization, there may be disadvantages on account of a tendency to accept uncritically solutions imposed by the parent and to rely on foreign inputs without making a decided effort to use fully what may be procured domestically.

INSTALLED CAPACITY

As with demand, estimations of supply of C&E services are far from easy. Plain inventories of installed capacity on the basis of attainable sales volumes or of human resources available may be misleading. Some participants at a meeting of OECD in 1978 stressed the importance of the type of know-how that depends on the institutional organization; it was pointed out that skills, on the other hand, can be traded among institutions. C&E capacity, it was suggested, may be taken to be the total volume of human resources, economic resources, and technical procedures that are available at a certain moment to carry out C&E services; but these resources must be within certain types of organizations. Two computers and 200 engineers are only meaningful if they are in an efficient organization and have methods that can be used to prepare a project and follow up its execution. Therefore C&E capacity is only significant if there is appropriate capability to manage the organization and the projects it carries out. Hence, estimates of installed capacity are strongly related to the presence of management capabilities.

SPECIFICITY

How can specialized CEDOs be put to work in different areas? Do they have to recruit new people (or teams)? Can existing personnel be retrained in a short time? How can the new know-how be procured efficiently and quickly? Answers to these questions not only would throw light on the chances for survival of a CEDO when demand dries up in its specific field but would be helpful in debates about the establishment of a national C&E capacity when CEDOs have to be set up in several fields, because specific C&E resources may not easily be put to work in a field different from that in which they have specialized.[11]

STATE-OWNED CEDOS AND PRIVATE CEDOS

Private CEDOs in some developing countries have shown great concern about the expansion of state C&E activities, which they feel are encroaching more and more on their market. Although they are not

[11] Recent experience in Argentina has shown that CEDOs engaged in highway projects have found it difficult to switch to hydroelectric projects, even though the fields seem to be closely related.

against public-sector departments for the preparation of general studies and projects, they object to the growth of institutions that "without actually being consulting groups" absorb many resources destined for consulting. They feel that the proper role of state consulting lies in the promotion of expertise in new fields, which once developed should be set up as private CEDOs. They have doubts about the efficiency of state consulting and point out that top personnel are not easily attracted to government employment because of low salaries, that the best technical people move to administrative posts, that the pace of work in state organizations is much slower due to the characteristics of bureaucracy, and that political influences are much more persuasive. They add that private consulting is cheaper, though this fact may be hidden from view because a government organization often does not include in its costs the full amount of overhead items; sometimes only direct costs are charged. A cry of unfair competition comes from private CEDOs, who point out that they are strongly motivated to be efficient because their earnings, and indeed their survival, depend crucially on their efficiency, whereas public-sector CEDOs in general lack such a motivation.[12]

On the other side of the debate, arguments are that the profit-seeking nature of private C&E makes it vulnerable to ties with construction and equipment firms and with foreign CEDOs and that legal and administrative regulations and ethical declarations of principle are largely unsuccessful in curbing such tendencies. Another argument is that the small size of many sectoral markets for C&E services favours monopolistic behaviour by the few CEDOs (sometimes only one) serving a market. Moreover, certain areas of C&E are held to be legitimate interests of the state: such would be the case with industrial sectors like steel, petrochemicals, and mining where the state has a central interest or even a monopoly; with new activities where there is as yet no installed capacity in C&E; and with small and medium-scale industries that cannot meet the fees asked by private CEDOs.

The issue of state versus private C&E probably cannot be solved on rational grounds alone because it depends on contextual factors and on the political style of a country, which may or may not favour private enterprise. Within each country, there should be an attempt to identify the areas in which state-owned or private CEDOs are better qualified and to find out how state and private C&E may collaborate and complement each other. Some people think that the proper areas for the state are those of policy, planning, programing, and preliminary project conception — the strategical decisions — leaving to the private CEDOs the detailed and specialized studies, the preparation of preinvestment studies, and other tasks needed for tactical decisions, as well as engineering design and project implementation activities. Other people believe it is advisable for large public enterprises to develop strong in-house C&E capabilities, coupled with R&D activities, especially when this approach is the only way to acquire the engineering capabilities that are needed for technological autonomy.

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[12] These and other arguments are frequently invoked by national and international consultants' associations in defending the interests of private CEDOs.

C&E Statistics and the Formal Emergence of a C&E Sector

One of the reasons why national policy in many developing countries does not deal explicitly with C&E activities is that the latter do not have a visible existence in the national system of statistics and do not constitute a formal sector or branch. Even though the magnitude of these activities is not large, their importance as organizers and executors of investments, and as suppliers of many different services to production, would justify their constituting a visible aggregate of economic activity to which policy may be applied.

It is possible, and indeed desirable, to measure the production, consumption, import, and export of C&E services, classified according to various criteria, and to relate such data to other economic, educational, and scientific indicators. Such information would help to diagnose the situation at different times and to lay out policies and plans related to C&E.

Although this should eventually be done within the general framework of economic statistics, the characteristics of C&E activities and services are such that it would seem appropriate to start measuring them within the framework of science and technology statistics. Most C&E activities would fall within the category "related scientific and technological activities" of the well-known OECD and UNESCO systems. A subsystem of C&E activities and services could be developed following an effort for drafting and testing operational definitions and classifications, perhaps under the auspices of an international organization.

Employing Domestic C&E

The use of domestic C&E services may produce a number of positive impacts on development beyond those that take place when a foreign CEDO is employed. Most of the effects are medium or long term and are difficult to measure because they are the result of applying certain ways of formulating and executing an investment project rather than other ways that were previously used. They are often social consequences, and they may be obscured by other influences. Some of the variables affected are qualitative, such as technical level, learning, and vulnerability, so that quantification of the effects is not simple and in some cases may be impossible. But it is worthwhile to analyze the different effects and to arrive, at least, at a general appreciation of their magnitude in a particular situation. This will perhaps be sufficient to provide clear guidance for policy decisions if, as would appear from the limited evidence so far, positive effects are high for certain ways of carrying out the investment.

How Decisions in the Project Sequence Are Linked

Certain decisions in the project sequence condition later decisions and markedly affect their relevance to development objectives. During project preparation — the preinvestment stage — the characteristics of the project are defined. Decisions at this stage have strong implications regarding the specifications and the origin of the goods and services that are to be procured in subsequent stages. A number of alternatives are studied as the work proceeds from project identification (when there may be a number of programing studies about the development of the main economic sectors and of specific industrial branches), through prefeasibility (when a preliminary choice is made of the main project parameters, following from studies of markets, technology, location, etc.), and finally to the feasibility report in which more detailed market and location studies, preliminary engineering design, and tentative negotiations with prospective suppliers allow the organization to develop alternative technological solutions, submit them for appraisal, and make recommendations to the project owner, who actually chooses from the alternatives. But the organization doing the preinvestment work will have already taken a large number of preliminary decisions, which are incorporated in the alternatives submitted to the project owner, so that these alternatives may be more or less appropriate to local conditions, or oriented toward the use of local inputs, according to the approach and biases of that organization. Experience seems to show that when a local CEDO is in charge of preinvestment work, a better technological choice may result and more local inputs are likely to be incorporated.

Another important decision has to do with the way in which the investment project is financed. Experience also shows that the local content is highest when the investors use their own funds and lowest when supplier credit is employed.

Once an alternative has been chosen and financing arrangements, government approval, and other necessary preliminaries are ready, the project enters the execution stage, and a number of decisions have to be taken regarding the supply of inputs. The technological solution will have been selected already, and this generally means that a supplier of the basic engineering design will also have been chosen, either the technology owner or a firm that has been licenced by it. In many cases, the technology and the basic engineering design are procured outside developing countries; there is room, however, for detaching certain peripheral technologies from the core and getting them engineered locally. Also, it is sometimes necessary to conduct R&D work to adapt the process or the product to local conditions, and it should sometimes be possible to have this R&D performed locally. The extent to which the work on peripheral basic design and adaptive R&D may be carried out locally varies not only with the level of technical development of the recipient country but also with the attitudes and the efforts of the project owners and their consultant organizations.

The next task is detailed engineering, in which the basic design is converted into a set of detailed drawings and instructions for the purchase and installation of equipment and for the construction activities. At this stage, a number of seemingly minor decisions take place, which when added together may make up important differences regarding the characteristics and sources of the inputs to be employed. The participation of a domestic engineering group is important to ensure that local inputs are incorporated into investment and production as far possible.

It is through a large number of decisions of this nature that a local engineering group can fulfill a socially important role in specifying inputs that can be produced by local suppliers. At the investment stage, this will affect the origins of different capital goods, technical services, construction materials, and construction services. At the operation stage, previous design engineering decisions will influence the nature and source of raw materials, basic inputs, components, parts, spares, technical services, and administrative services.[13]

One can easily see how important it is to have domestic control of the preinvestment and the design engineering activities if full use is to be made of potential domestic supply at the investment and the production stages of the new installations. Consulting and engineering organizations in charge of those activities should be well aware of the possibilities of local supply and should have the right attitudes regarding modifications in process and product design, specifications, standards, and delivery dates. They should appraise the risks and the extra cost — if any — in each local purchase and advise the project owner regarding the decision that is best in the long run. In this way they may have a decisive role in increasing significantly the social efficiency of the investment process.

PROJECT PARTICIPANTS

THE INVESTOR

By using local C&E services and by opening up the technological package, the investor may benefit in the short run from a reduction in the costs of purchases, as efforts are applied to certain activities that may have been disregarded before, such as more appropriate specifications, better quality control, and the search for new sources of supply. In a longer time span, the investor may be able to choose a better-adapted technology, lower the cost of many items, supervise closely the construction of equipment and fixed installations, and decrease vulnerability in future operations as a consequence of a higher proportion of local inputs. This may cause substantial savings in investment costs, as well as in operating costs later on. But, more importantly, the investor and the local CEDO it employs undergo a learning process that is bound to increase the efficiency of production and maintenance operations, permit better investments to be made in the future, and help incorporate a stream of product and process improvements, some of which may originate locally. The cumulative effect of this learning process, and of a similar learning process in the investor's local suppliers, may be very important.

There are, naturally, some drawbacks. The investors have to bear the costs of building up their internal technical capabilities and may also have to face extra costs on account of higher prices, poorer quality, and dearer financing of local supplies. There are also the risks of technical failure and late deliveries, which often deter users from opening up packages, relying on local engineering, and buying from local suppliers; however, it is likely

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[13] For example, in a Latin American country some years ago, a number of simple industrial buildings had to be built. Some of them were designed by local engineers, and these used 75% of domestically produced steel; others, designed by foreign engineers, imported 75% of the steel required. The large difference did not result from different characteristics of the buildings, which were alike, but from the approach of the designers. Foreign engineers were not familiar with local steel and would only employ it when they were sure it would not endanger the structure. Local engineers knew well the local steel and employed it unless they were sure it would not be appropriate. The "safety-first" attitude of the foreigners, added to their imperfect knowledge of the local product, unnecessarily multiplied by three the steel imports.

that such risks have been exaggerated in the past and have resulted in the continuation of poor practices for too long.

Changes in project formulation and implementation to produce the benefits should be carried out with caution. There should be a careful realistic appraisal of how far it is possible to proceed with forward-looking practices on a given occasion, on the understanding that another step ahead can be taken at a later date. By following a stepwise process of change, the investors can build up solidly their technical competence and that of their CEDOs and can develop a network of reliable suppliers. Some risks, however, are unavoidable, particularly when suppliers are given a chance to produce something they have not produced before. But risks are a part of economic life, and those who do not risk do not gain.

Local Suppliers

Improved investment practices, particularly if they involve purchasing programs for some time in the future, are bound to benefit local suppliers through an increase and stabilization of demand that encourages application of resources and efforts for technological improvement, productivity increases, personnel training, and expansion of plant. Additional inducements for technical progress are the introduction of specifications that demand a higher level of accomplishment.

One of the results may be that suppliers improve their technological levels and learn to do new things, thus enlarging their markets. Such a consequence is well known in developed countries, where many technical innovations resulting from work for the government in aerospace, defence, and other areas have found their way into civilian applications. The suppliers are allowed and even encouraged to apply the know-how they have gained to new products in other markets. In developing countries, the industrial branches are less sophisticated, and the know-how does not usually come from original R&D but rather from technology imports, personnel training, engineering efforts, and a sequence of minor changes and innovations. But the phenomenon is essentially similar; it can be clearly observed in mechanical industries supplying parts to manufacturers of automobiles, ships, and other complex products, which have shown remarkable technical progress in some developing countries. It is possible through adequate purchasing policies to accelerate and orient the learning process; a good example is the role that French public enterprises played through their procurement policies in developing the capital goods industry in France in the early postwar period.

Suppliers may find some problems in going along with purchasing policies that are aimed at them by just one or a few customers. They may have to accept stiff conditions and face continuously the possibility of a sudden drop or cancellation of orders on account of a change in policy, a not infrequent occurrence in some developing countries.

Other Participants

When purchases are made from local suppliers, they may produce effects on other parts of the economic system through market and nonmarket mechanisms.

A rise in the output of suppliers produces demand increases elsewhere through the "multiplier mechanism," and if there is not enough idle capacity in personnel and equipment to allow a corresponding increase in output, new investment may be needed (the "accelerator"). In addition, there may be significant "linkage effects," through which important changes in the industrial structure of the country result.

The magnitude of the multiplier, accelerator, and linkage effects would reflect the orientation and magnitude of the investor's demand, at the investment and operation stages, and could be significant when large investments are carried out, such as happened last century with railways and is taking place today in certain developing countries that have ambitious plans for expanding their petrochemical industry.

There are other effects, or externalities, that are not transmitted through the market and are, thus, less quantifiable but that may prove to be even more important for industrial development in the long run. They should be explicitly considered and their magnitude appraised, if only by means of qualitative judgments, when investment programs are being formulated. Among them are the favourable psychologic impacts of successfully employing local consulting engineers, disaggregating complex investments, relying on local technological developments, and utilizing local capital goods and other inputs in investment and production. This "demonstration effect" is potentially so important that a strategy for building up C&E capabilities and utilizing them for maximum impacts on development should carefully select its initial activities so that the chances of success are maximized and it should devote efforts to propaganda on the achievements.

But, more importantly, a number of technologic effects occur as human resources are trained, researchers' attitudes are improved, technical knowledge is diffused, and capabilities for problem-solving and for the improvement and generation of technology are reinforced throughout the industrial system — a learning process sparked by forward-looking investment activities and the backbone for technological self-reliance. CEDOs fulfill a crucial role in this process by applying new know-how when approached by different clients. In this sense, independent CEDOs help in the "socialization" of knowledge otherwise locked within enterprises.

Impacts on Development

Governments can direct impacts so that they promote the development of a certain branch of industry (say, electric motors of 10 horsepower) or type of producer (small firms in a particular region) by explicitly using as a policy instrument the considerable purchasing power of the public sector resulting from its investment activities.

Other impacts will be transmitted throughout the industrial spectrum by market and nonmarket mechanisms; perhaps the most interesting outcome is a widespread learning process that results in an increase in productive efficiency, a reduction in costs, and a technological progress that may allow new productive activities. It is suggested that investment projects should be designed and conducted so that they have strong positive effects on learning.[14]

[14] The importance of the learning process was pointed out to me by R. Carranza in a private communication.

Impacts on R&D activities, and on the utilization of R&D results, are also very important. In fact, the results of R&D in specialized institutions have little chance of being employed optimally if C&E expertise is not applied to evaluating them, finding possible uses, identifying clients and users, developing product and process designs that can be applied commercially, and in general carrying out the activities needed to transform a technical advance into a commercially successful innovation. Some R&D institutions have their own C&E departments — "technoeconomic services," "sales," "consultancy," etc. — whose job is to link R&D activities with prospective users. In other cases, the task is done by an independent CEDO. In some large public enterprises in developing countries (oil, iron and steel, power) in-house R&D and engineering departments work hand in hand to develop and apply new technology and may enable new investment projects with basic engineering of their own. At this stage a very high degree of mastery of technology will have been obtained.[15]

The final impacts on development are expressed in a change of structures and a modification in the values of macro variables such as employment, productivity, imports, qualified personnel, etc. Other influences are at work so that the contribution of local C&E in investment projects may not be easy to ascertain. The stage of development of the country is an important factor. In a relatively advanced developing country, the impacts are probably much more important than in a country of incipient industrialization. In fact, they may even help to overcome the blocking of industrial development at the end of the easy import-substitution stage, through substantial purchases of industrial products from the enterprises that are receptive to innovation and able to profit from it. The impacts result from a conscious effort to manage investment projects in such a way that demand is generated for those enterprises, purchase specifications are carefully drafted, adequate prices are agreed, flexible contracts are signed, and financial and technical support is provided. The positive effects not only come from the increase in demand and its repercussions throughout the economy, but also derive from the technical progress that suppliers are induced to make to respond to increasing technological requirements, from the widespread learning process that such technical progress causes in other parts of the industrial system, and from the restructuring of relations between public enterprises, foreign and national private enterprises, R&D, financing organizations, and the government (Sabato and Martin 1967).

The benefits may be partially offset by the costs implied in inefficiencies and failures of local producers, retaliation by countries that face a drop in their exports, monopoly situations, etc. Policymakers have frequently magnified these drawbacks and often have not been fully aware of the potential benefits.

Procedures and Decision Models

To achieve maximum impacts, projects should be disaggregated, local supply possibilities studied, and purchases carefully programed, prefera-

[15] The CEDO analyzed in the Brazilian case study in this volume is a good example of how this mastery is achieved. See also Malhotra (1979).

bly in concert with the supplier branches. A procedure employed in Argentina classifies items into a "positive" list (the items are already being produced with the required quality at acceptable prices), a "negative" list (it is not possible to produce them locally), and a "probable" list (production may take place if several problems are overcome, such as small local market, quality, safety). Efforts toward supplier development are concentrated on the "probable" list. This approach may be used also for technological inputs; action would be taken not for productive firms but for consulting and engineering organizations, research institutes, and other organizations of the science and technology system (Sabato 1973).

Similar procedures may be used in the stage of operation of productive units, but the difficulties are increased because the project owners, functioning enterprises, deal with many supplier units. There must be a development of adequate administrative procedures to construct an effective purchasing policy including technical, financial, and training assistance to the suppliers.[16]

Regarding decision models for local procurement, there have been in France some interesting attempts at constructing formulas for the pricing of local inputs under different conditions, and it would be useful to analyze such solutions in detail. In Argentina, G. Gargiulo has analyzed the acceptability of higher prices for local components of atomic power plants. Local production of components has microeconomic, macroeconomic, social, and technological effects that should be identified. If the component is already being produced locally, with sufficient quality, the purchasing decision is based on a comparison of the local and the import costs, with due regard to existing incentives and protective tariffs for local production. If the component is made locally but not with enough quality, or if it is not yet made but could be manufactured, the indirect benefits brought about by local production should be taken into account. To produce the component, the suppliers need to increase their technical capabilities, in equipment, technology, and training. This step produces extra benefits to the firm, which otherwise experiences a slower rate of technical development. There are, however, extra costs occasioned by the rapid increase in technical capability. The valuation of costs and benefits requires the definition of quantifiable indicators and the solution of the price system that should be applied. This line of analysis has not been developed (Comisión Nacional de Energía Atómica 1974).

Far too little is known about the practical aspects of heightening and transmitting the impacts of investment activity. Many positive experiences have taken place in developing countries, and no doubt the practices currently employed in some industrial countries may also be valuable as examples. There is a clear research need to identify and analyze successful cases and evaluate the procedures and decision rules employed, from which guidelines may be prepared for the benefit of developing countries.

[16] An example is the "ancillary industries program" carried out by public enterprises in India.

Efficiency of Investment Activity

Investors are expected to maximize the efficiency of their investment activity, i.e., the relation of benefits to costs. How far is this achieved in the developing countries? Partial evidence shows that frequently investors respond to limited, short-run objectives and are up against limitations and constraints such as the unwillingness to assume risks, the lack of qualified technical advice, imperfect information about alternatives, restrictions imposed by outside finance so that they employ foreign CEDOs and the project is carried out in a turnkey manner.

It is likely that if a long-term outlook were adopted, internal limitations eased, and a certain amount of effort applied — in other words, if improved procedures were employed for project formulation, design, and execution, involving a domestic CEDO at all stages in a responsible role — more efficiency would be possible.

Extra efforts applied by the investors and their CEDOs to the investment activity produce an increase in the private efficiency of the activity, that is, in the relation of the benefit reaped by the investors to the extra costs they must bear. The efforts have a more than proportional return until an optimum is reached, when more efforts do not pay. The investors may get to a new optimum in a reasonably short time, by acting on aspects that can be modified rather quickly. Over a longer period, they may build up their internal capability, undergo a learning process, improve their purchasing procedures, set up a network of reliable suppliers, etc., and, particularly if during this period there is an adequate development of one or more domestic CEDOs on which the investor may rely, further improvement may take place as a succession of investments is carried out.

In employing turnkey operations, investors apply a moderate effort and obtain an efficiency that they regard as maximal (Fig. 1), feeling that extra efforts are not warranted and may even be counterproductive. But changes in attitudes, a more long-term view, the increasing use of local CEDOs, and improved purchasing procedures may allow them to reach a higher maximum of efficiency in a relatively short time and an even higher maximum in the long run. The differences in short- and long-term maximums are attained through successive investments, as learning proceeds and various effects are worked out. The long-term maximum would be the optimum from the private point of view in the case of investors' making their decisions according to long-run considerations. But an additional increase in efficiency may result if efforts are joined with other investors — this is a distinct possibility in the case of public enterprises — so that CEDOs can accelerate their learning process, specifications can be unified (particularly in the design of peripheral installations), product varieties reduced, and larger consolidated purchases carried out at lower prices (Fig. 2). However, in practice, it does not appear easy to coordinate investors' activities and unify their criteria and purchasing mechanisms.

Private efficiency takes into account only the costs that investors must bear and the benefits they reap. Meanwhile, what is happening to social efficiency — the benefits versus the costs to the suppliers and other participants? Reaching a social optimum may require greater efforts than are required in reaching an optimal private efficiency. Thus, incentive

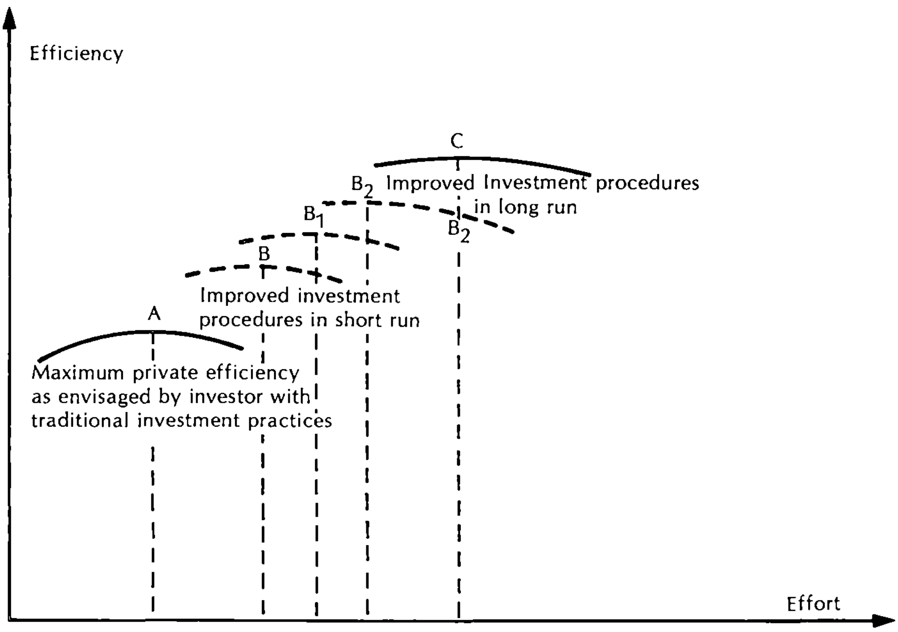

Fig. 1. Efficiency in relation to effort spent by investors and their CEDOs on investment activities.

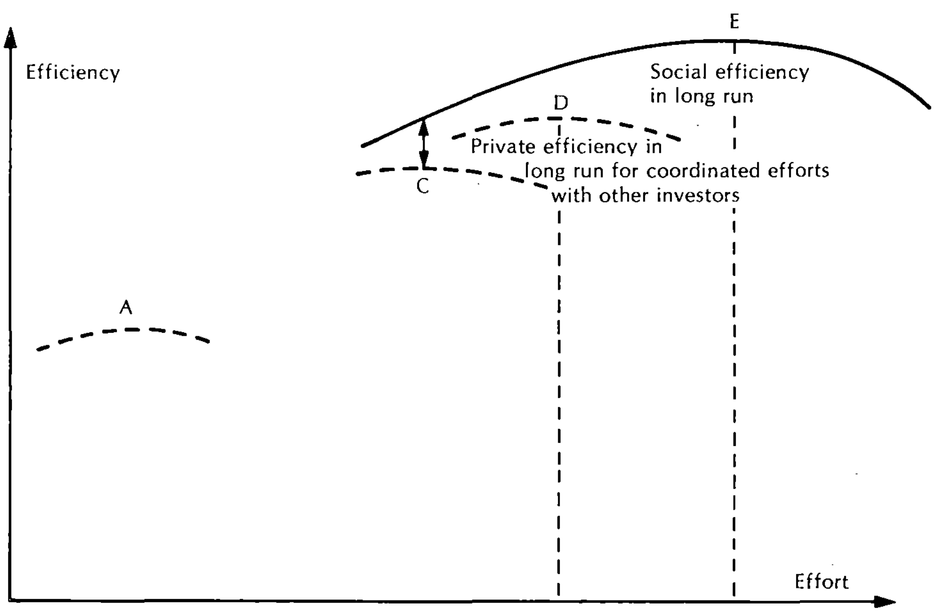

Fig. 2. Efficiency in relation to effort if investors operate jointly with other investors.

mechanisms of various types must be introduced so that the costs will be borne by the community rather than by the investors.

The model of analysis I am suggesting is conceptual and qualitative, and it would not be easy to express quantitatively. However, a first observation that has strong policy implications is that the point of maximum private efficiency may be reached by the investors without any incentive other than their self-interest. It pays them to increase efforts up to that point. Now, if the increase in social efficiency from the original position (turnkey operation) to that corresponding to optimum private efficiency is very high, a great deal would have been accomplished already, without a special incentive policy because the investors should have learned how to improve their practices.[17]

The maximum private efficiency that can be attained partly depends on internal factors — for instance, the technical and managerial level, the correct appraisal of real risks — and partly on factors of the environment, among them, coherence of policy, stability, etc. Higher levels of private efficiency in investment activities will be reached when policy and institutions are stable and when public-sector investors follow a common rationale.

A further increase in social efficiency may follow from the application of measures to encourage investors to apply more efforts than strictly warranted on private efficiency grounds. Such measures depend on the particular circumstances: they may take the form of a subsidy to the investors to compensate them for the extra effort with its accompanying costs and risks; or they may be directed to suppliers to lower their costs through special credit lines, training schemes, technical services at low cost, tariff protection, etc.

There is at times a tendency to rush things, without adequate preparation, in an attempt to achieve too soon a high level of incorporation of domestic technology, services, and inputs. It is necessary to understand the limitations that exist: learning to produce results that can be incorporated in successive investment projects takes time, and progress is achieved by stages. An important question is how far to go in each stage. In other words, what percentage of local participation may be sought in successive investment projects?

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[17] For instance, the investors may have had to modify their previous attitudes; plan their strategy for carrying out future investments; study the possibility of using local technology, engineering, capital goods, and inputs; improve their technical and management structures to make them able to carry out the expanded tasks involved in opening up a package and dealing with local CEDOs; perhaps develop their own project formulation and engineering departments ("captive" CEDO) and R&D groups; develop and adopt adequate methods of analysis and decision rules to deal with the various activities involved in an investment project, particularly in regard to purchasing decisions; externally, assist their domestic suppliers financially and technically so that their efficiency and technical level may increase; schedule purchases far in advance and make this known so that suppliers will have expectations regarding the type of purchases and their timing, a fact that will reduce uncertainty and induce investments in physical facilities, training, technological improvements, new technology, etc.

CEDOs

CEDOs can be very different, and it is not easy to make general statements about them. For instance, they differ in the way they originate, and this fact may significantly affect their later development and characteristics.[18] What makes them comparable is that they have to carry out certain activities concerned with the organization and application of knowledge, and they have to acquire the resources and abilities to perform those activities in an efficient way.

CEDOs, like other institutions, develop until they reach maturity when they are reasonably well equipped with human, physical, and intellectual assets; are large enough to perform efficiently; have stable relationships with their environment — clients, suppliers, government, banks, local and foreign CEDOs — and are able to fulfill efficiently their social role.

The problems of a mature CEDO are somewhat different from those of a CEDO in its developing stage, because one of the main imperatives of the latter is to achieve maturity. To do this, it may need special measures of support from the public authorities. This is why both stages are considered separately here. Policy issues in sectors where mature CEDOs exist are different from those where CEDOs are developing. International cooperation between CEDOs also acquires different characteristics according to the maturity of the weaker party.

Mature CEDOs

I suggest that the performance of a CEDO should be appraised by its social efficiency (SE) — the impact of the CEDO on national development in regard to the resources it employs.[19] The concept is related to that of social efficiency of the expenditure on an investment project and is not easy to quantify (Fig. 3). However, qualitative comparisons may be made of the SE of a CEDO at different times, and also between two different CEDOs of similar overall characteristics.

What influences social efficiency? SE seems to depend on the adequate performance of CEDO activities; grouped into three main categories, these are determination of the "products" to be produced; production; and distribution. Maximum social efficiency in these activities would be, respectively, a maximum social utility of the products, a maximum productive efficiency, and a maximum distribution efficiency. The better a CEDO performs in these respects then; the better its SE.

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[18] This was discussed extensively at the meeting sponsored by IDRC in 1976, where a typology of "emergence patterns" was considered, ranging from professionals getting together and looking for clients, through a building firm that branches into C&E services, to the carefully planned creation of a large C&E department by a large production enterprise.

[19] The indicators of "success" that are sometimes applied to a CEDO may not adequately reflect SE; for instance, the fact that a CEDO is profitable, or shows a good rate of growth, is a good measure of its commercial success but only a partial indicator of its social efficiency. To give extreme examples, the Red Cross probably has a large SE but is not profitable, whereas exactly the opposite happens with the Mafia.

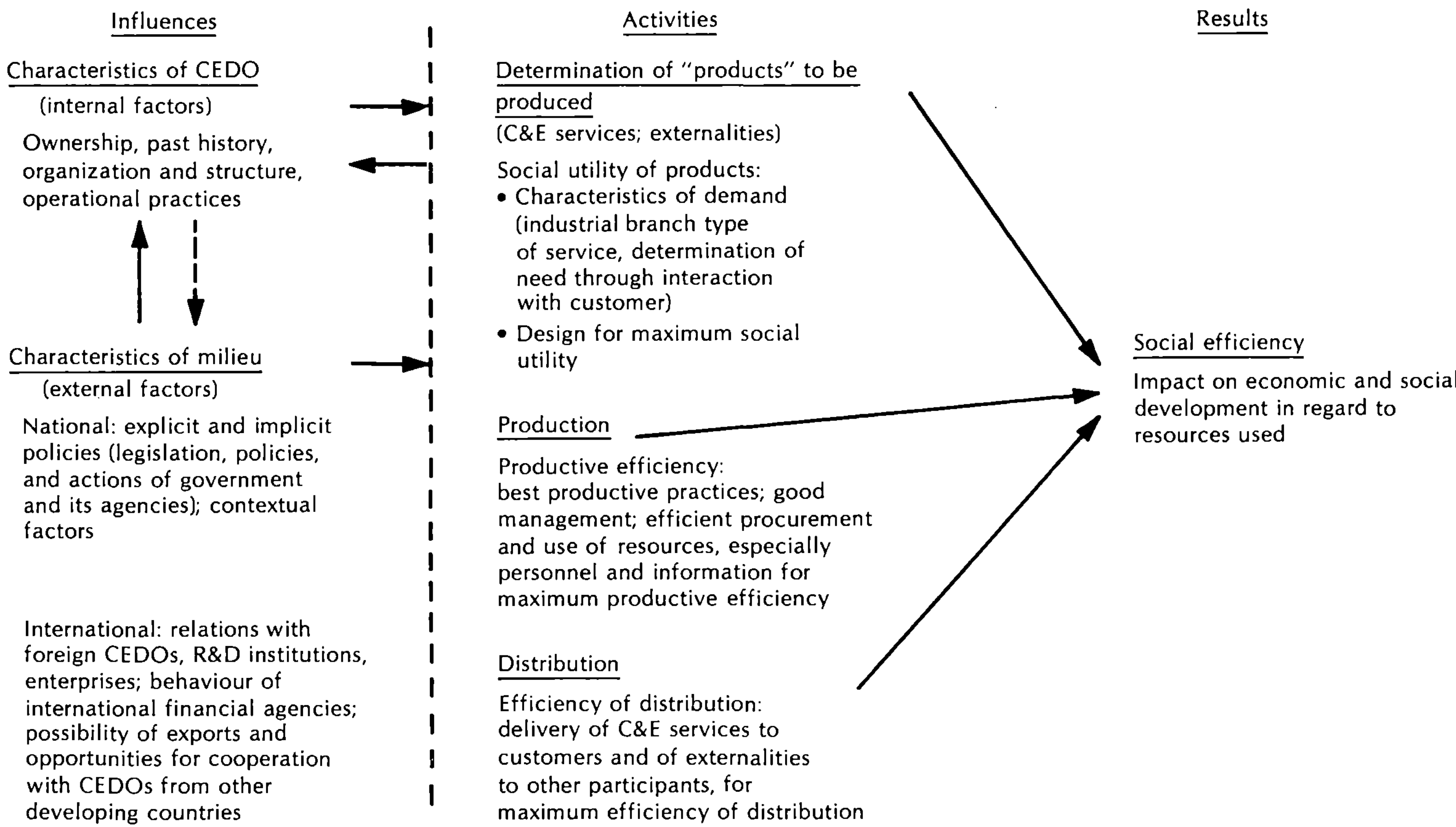

Fig. 3. The CEDO in its mature state.

These activities themselves are influenced by internal factors that derive from the characteristics of the CEDO. Such characteristics have probably evolved in response to needs posed by the activities carried out by the CEDO and have also been influenced by the environment in which it performs.

Determination of "Products" to be Produced

The rule for determination of products would be that, within its field of work, the demands of its clientele, and its production possibilities, the CEDO should aim at selecting its "products," and "designing" them, in such a way that their social utility is highest. A CEDO produces consulting and engineering services that have a certain value for the client, but the utility for society may be different, because the prices that are relevant socially may be different from those that are relevant privately, and other costs and benefits may accrue to society on account of the impacts associated with the rendering of C&E services. The CEDO not only should do a good technical job but should carry it out in such a way as to produce long-run favourable impacts on the investor and also on other social participants, so that maximum social benefits are derived from the task. In the design of products, therefore, the CEDO must consider both the strict needs of the project and long-run impacts on the client and on other participants.

The problem, of course, is that the extra costs and risks of designing for maximum social impacts are to be borne by the clients, whereas the benefits brought about by those impacts may be capitalized by them only in part. Thus, it may be necessary to instill motivation and to provide incentives that will induce a socially desirable course of action.

A number of issues may be brought up regarding the social utility of the CEDO products. The first one is how to appreciate (let alone measure) this variable. What weight should be given to long-term impacts compared with short-term ones? It is likely that this matter can only be discussed properly within the framework of a development plan. Other issues have a more operative content. Can certain practices be applied for maximizing expected social utility? What internal characteristics (for instance, national or foreign ownership of the CEDO) help or hinder a high social utility? What policy instruments are best to promote maximum social utility? Research is needed to answer such questions.

Production

One important objective for every CEDO is to attain maximum production efficiency; the production program should be executed in minimum time and cost, with adequate quality and reliability. This objective is a necessary although not sufficient condition for maximum SE.

There is much diffused knowledge about CEDO production, but little has been written about it in the case of developing countries. Here is an important field for research, which goes well beyond normal management problems on account of the peculiarities of a CEDO. One of these peculiarities is the nature of the principal inputs used by a CEDO: high-level human resources; and knowledge, technical know-how, and information of many kinds. The management of these resources is not simple, and current management literature is of limited value. Questions are numerous: What sort of professionals should a CEDO employ? How should they be trained and kept up to date? How can they be integrated into an efficient team? What are the best methods of work? How is information to be procured, stored, employed? What links should be formed with local and foreign suppliers of technology and information? When is an association with a foreign CEDO useful?

The experience of CEDOs of industrial countries is more pertinent to questions of productive efficiency than to questions about the determination of products, and about their distribution, where peculiar conditions in developing countries and the nature and role of their CEDOs would seem to call for fresh approaches. Whereas in the industrial countries the well-structured socioeconomic context largely reduces the problem of a CEDO to that of attending the expressed needs of the client and attaining a high productive efficiency, in a developing country the situation is much more complex and the optimum social efficiency cannot be reached by acting only on production. The two other groups of activities require much attention, and often the CEDO will have to surmount adverse characteristics of the milieu.

DISTRIBUTION

It is not enough for a CEDO's products to possess a high social utility. The products must reach users at the appropriate moment in a form that will respond to their needs. In this way the CEDO makes sure that the results of its production activity receive proper utilization and hence that the promise of social utility is realized. This is the problem facing those involved in distribution.

In a highly industrialized country the problem is not acute. Clients are able to state very precisely their needs for C&E services, and they have technical structures to absorb what consultants give them; the market mechanism takes care of most if not all the impacts on development of C&E services, the importance of external benefits being probably of small magnitude.

In a developing country there is a danger that the clients will not ask for the type of C&E services they need, that they will not absorb well the C&E services for want of a technical capability of their own, and that the potential external benefits of a CEDO's work will not materialize because the participants are not aware of opportunities or are not capable of seizing them. To avoid such outcomes, every CEDO needs a good "delivery system." This requires strong links with clients and receivers of impacts. The CEDO has to devote efforts to overcoming barriers such as unfavourable client attitudes, lack of a common language, lack of economic incentives for clients to contract local inputs, etc. The CEDO may even have to educate the clients and help them consolidate a technical group of their own.

The CEDO should ideally go beyond its strict duty of providing C&E services and engage itself in a larger task of identifying and educating other groups that may profit from the opportunities opened up by its activities. For instance, the CEDO may look for research centres and capital goods producers that could supply needed inputs, encourage them to bid, pass on to them relevant information, and so on. In this way the CEDO may perform its social task. This activity is costly and time-consuming and would have to be supported explicitly by the investor and possibly by public policy.

CHARACTERISTICS OF THE ENVIRONMENT

The national and international environments affect significantly a CEDO's internal characteristics as well as its activities. Major influences in the national environment may be divided into two groups, according to the degree of control that may be exerted over them. The first includes legislation, policies, and actions of government, its agencies, and enterprises. Within this group, there are explicit policies that are expressly designed to affect CEDOs and their activities and implicit policies that are directed to other institutions and activities but produce side effects on CEDOs. Among the problems hindering CEDO activity are the instability of demand, the lack of financial strength, and the competition from foreign CEDOs; if conditions are to be improved, implicit policies may have to be changed and explicit policies formulated and implemented. For instance, the implicit policies contained in the growth and pattern of public investment should be examined, because slight changes in timing may mean survival for some CEDOs; the establishment of a fund to permit a countercyclical policy such that contracts can be awarded to CEDOs for long-term studies when project work slackens may be all that is needed to stabilize demand.

The second group comprises contextual factors that cannot be quickly changed by modifying legislation, policy, procedures, or decision rules. Perhaps the most serious obstacle to CEDO development resides in the cautious, risk-averting attitudes of decision-makers, which make them opt for foreign suppliers. Other contextual factors relate to the administrative practices in government procurement, which are often heavy and cumbersome; the technical capabilities of clients, which are often low; the frequent lack of understanding in government and political circles of the importance of having strong domestic and engineering capacity and using it; the quality of university graduates that a CEDO recruits, etc.

CEDOs need not accept these limitations; they may try to modify conditions in their favour, influencing their national environment in different ways: seeking changes in legislation and practices, suggesting new measures, building up a favourable image, helping clients to create an internal technical capability of their own, etc. Some of these actions may be done by individual CEDOs, others by CEDO associations at a national or even international level.

In the international environment, two aspects are noteworthy. The first one has to do with the outside organizations that may affect the performance of domestic CEDOs, by influencing their characteristics and their behaviour: foreign CEDOs, as competitors; financial agencies; and suppliers of different inputs.

Foreign CEDOs may be strong competitors in the national markets, and the local CEDOs, by virtue of the usual selection procedures applied by clients, may find themselves unable to break a vicious circle in which lack of previous experience precludes them from getting contracts that may give them experience. This subject properly belongs to the developmental and not the mature stage of a CEDO; but it is likely that a certain measure of protection may have to be extended for some time to CEDOs that have recently achieved maturity, because foreign CEDOs may have strong advantages from the financial backing and export subsidies of their countries and from their proximity to and familiarity with owners of technology and producers of capital goods. Foreign CEDOs often associate with local CEDOs for certain assignments. In such cases, there is the danger that the local CEDO will remain the junior partner, without participating in the main decisions; this should be avoided. In fact, associations with foreign CEDOs should be employed for gaining experience, training staff, and obtaining information.

Regional and international financial agencies often fund large development projects, and therefore their policies and practices have an influence on domestic CEDOs. The record shows that these agencies have principally wanted to "get the job done," although recently some of them have shown interest in using their loan operations to foster the development of national C&E capabilities. The behaviour of international banks is often imitated by domestic banks, and this gives more urgency to the redressing measures that can be taken.

A number of foreign organizations may be the source of important inputs — for instance, R&D centres, information systems, capital goods manufacturers, manufacturing firms, etc. The CEDO should maintain a network of relationships to have "on tap" information, experts, and other critical inputs.

The other aspect of the international environment has to do with the export of C&E services to other developing countries. Such exports have been taking place for some time, and it is likely that they will expand in the future for reasons already reviewed (lower costs, more appropriate technical solutions, a better understanding of conditions in the recipient countries, etc.). One of the principal issues is whether such operations of technology commerce can be kept free from the drawbacks that similar operations between developed and developing countries have had in the past and, furthermore, whether they may be endowed with characteristics that would give them positive social impacts in the receiving country, creating domestic demands for goods and services, contributing to the domestic development of skills and technical capabilities, and producing other desirable effects. This technical cooperation among developing countries (TCDC) may require positive guidelines expressed in international agreements, and incentives for operations that comply with them.

CHARACTERISTICS OF THE CEDO

A mature CEDO should have a mastery of the technology of consulting and engineering and a reasonable degree of competence in the technology of the area or areas it attends. For this it needs qualified, experienced personnel; good management procedures; organizational know-how; and other characteristics favourable to its efficiency.[20]

The characteristics of a CEDO will be influenced by its environment, the origin of its capital, its degree of autonomy, its past history, and the

[20] Malhotra (1976) points out that successful CEDOs in India show characteristics such as good management; tendency to recruit the best people and pay them well; acceptance of risks; good marketing; support from government or political sectors to obtain key contracts during their first few years of life; flexibility and willingness to go into new fields; agreements with foreign CEDOs; disaggregation of C&E services until only basic engineering is purchased outside; ability to offer the local investor a complete package from conception to start-up as well as technical services at the operating stage.

sector it attends; they will also be shaped by the policies and practices adopted by managers and senior staff members, volitional factors that find expression in the choice of the role, structure, strategies, etc.

CEDOs in developing countries often attempt to modify external factors in their favour. This action is an important departure from the practices of CEDOs in developed countries where the environment is favourable, or at worst neutral, rather than hostile.

Some underlying research questions are: How are stable and useful links forged with the various social participants? What role can the CEDO have in the formulation of sectoral development plans? What is the minimum size of an efficient CEDO in different fields, from heavy chemistry to small mechanical industry? How should it be organized to withstand the ups and downs of demand so common for C&E work in developing countries (for instance, a relatively small stable staff and an ample list of collaborators that can be drawn into projects as and when necessary)?

The Development of a CEDO

CEDOs show different characteristics in their development over time, according to their origin, ownership, degree of autonomy, and sector of activity; but certain aspects and issues are relevant for many different types of CEDO.

The development of a CEDO to maturity is bound to be gradual, with, ideally, an increase in social efficiency as a function of time. The final goal is the mature CEDO functioning at a reasonable level of social efficiency, its action being guided by long-term objectives.

During the developing stage the CEDO principally guides its actions according to concrete, short-term objectives, the main purpose being to get to the mature stage. Ad hoc government policies may be required for the promotion and support of this process. The time needed to complete the process and reach maturity will be variable and will very much depend on the support received by the CEDO and on the characteristics of its environment (Fig. 4).[21]

An independent CEDO in a developing country faces many obstacles, due to the nature of its activities and to the environment in which it acts. Equity capital is scarce for C&E activities, and financing is scarce and expensive. Tardy payments when a job is done for the state put a strain on finances; competition and fluctuations in demand result in a high death rate. A small CEDO may be caught in a vicious circle; it cannot get the large assignments it needs to grow because it cannot show qualifications, never having undertaken large assignments before. Even when experience has been acquired, for instance through work as a subcontractor to a large local or foreign CEDO, other obstacles persist in the shape of legal and administrative requirements such as the need for offering financial guarantees.

It is no wonder then that many important CEDOs in developing countries are subsidiaries or joint ventures of foreign CEDOs. However good this may be from the point of view of survival and of productive

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[21] Some CEDOs will never reach maturity, will remain at a low level of social efficiency, or will even disappear.

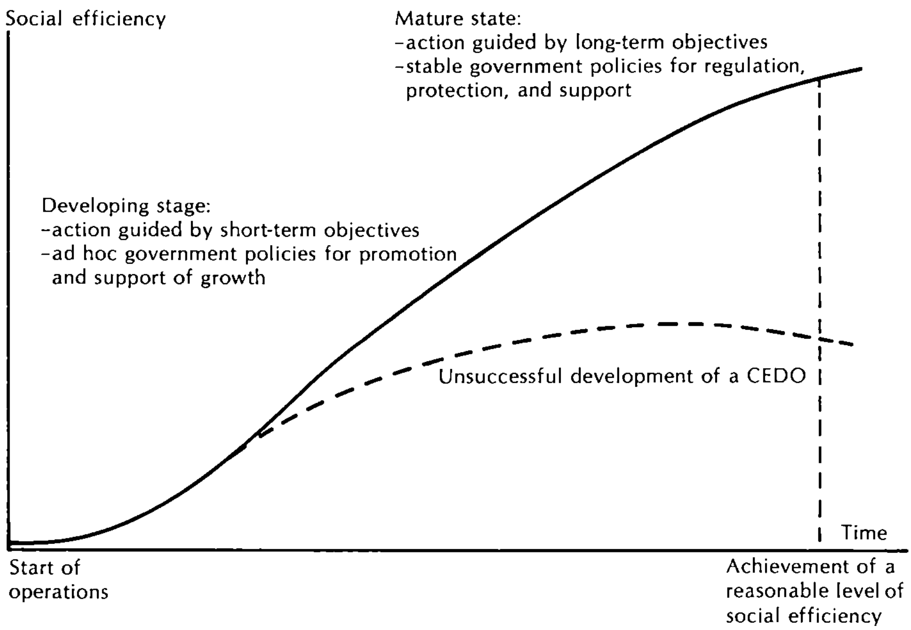

Fig. 4. The CEDO in its developing stage.

efficiency, it is often not good from the point of view of social efficiency. A country cannot depend permanently on foreign sources for the greater part of the work involved in organizing and carrying out investment projects, and sooner or later it will have to develop its own C&E capabilities.

State support is required for this. In some countries the tendency is toward public-sector CEDOs, in others toward independent private CEDOs. The principal role of the state regarding the development of a CEDO is to ensure it an expanding and stable demand; extend to it a measure of protection; make available sufficient credit; and help it acquire technology, experience, and a good human team.

There is not a unique model for CEDO development. The way the organization develops depends on circumstances. Paths and strategies are dictated by the concrete objectives to be achieved, but the process is gradual and relies on the acquisition of expertise and credibility in successive stages.[22]

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[22] The experience of successful CEDOs in developing countries should be examined. A first step has already been taken with the four case studies included in this volume. There is also a wealth of experience about CEDO development in industrial countries that should be examined critically for its relevance for developing countries. For instance, the OECD (Organization for Economic Cooperation and Development) studies have indicated that in the USA, CEDOs showed no established historic pattern of growth, many of them having started as boilermakers, mechanical or electrical designers, civil engineering contractors, or even construction material suppliers. Continuity of demand was extremely important. The early CEDOs gained diversification by accommodating a range of tasks along the specialties that made them leaders in particular fields (Brown 1978).

A developing CEDO should pay attention to a number of aspects, some of which have to do with its internal functions and others with its relations with clients and other participants:

- Paths of development — the areas in which the CEDO is to work; they come up as a result of an interplay between immediate market opportunities and long-term objectives. There is a danger of growing along an "easy" line, as market opportunities appear and clients "overburden" the CEDO, making for imbalances, too much specialization, and possibly shallow technical development. Thus the CEDO may find itself expanding greatly its economic analysis capabilities or its structural design activity, while subcontracting other areas of work. Or the CEDO may diversify too much through accepting all customers, stunting its technological capabilities. The CEDO should lay out its long-term objectives and develop fully one or two technological areas that show good promise; once mastery has been acquired in one area, the CEDO may move into a new one.
- Acquisition of know-how and expertise — the key to CEDO development; it may be said to comprise three interrelated aspects: human resources development, technology acquisition, and the development of management capabilities.
- Cultivation of clients in a widening circle — life insurance; it may mean a CEDO must help clients to acquire sufficient capabilities to deal efficiently with tasks such as the preparation of terms of reference, drafting of tenders, evaluation of bids, control of progress, etc. The clients or users must have their own technoeconomic capabilities and procedures that will guide their dealings with CEDOs and other suppliers.
- Design of contracts favourable to CEDO development; lump-sum contracts are usually preferred by clients, but CEDOs favour cost-plus-fees, as they often find it difficult to make accurate cost estimates because of unstable conditions in a developing country. A small CEDO may not be able to absorb the losses of a single contract, so this is a critical point.
- Pricing policy; many prospective C&E clients in a developing country, principally the medium- and small-scale enterprises, are not in a position to pay fully for the services they need. Sometimes such services are provided at a loss by special state institutions. At the other end of the scale, large state investors may give opportunities to developing CEDOs to bid for a large C&E task, for which a developing CEDO may have to charge more than usual because of high indirect costs such as employment of new management resources. This could perhaps be interpreted economically as a firm working on the rising part of its cost curve. The state client would be footing part of the costs of CEDO development; if it did not accept this, it is possible that the CEDO would be deprived of an opportunity to expand and to acquire more know-how.
- Development of network of contacts; the developing CEDO will need to devote efforts to develop a network of contacts internationally so that it may have good and prompt access to information, technology, equipment makers, and other suppliers of inputs for its work. It should also build up its relations with local research institutions and manufacturers, which should be close enough to permit it to discharge a socially important role as a link between domestic producers and users of technology and capital goods.

The Acquisition of Know-How and Expertise

The building up of a good human team, the acquisition of technological knowledge, and the development of management capabilities are interrelated. The development of human resources cannot be separated from the acquisition of know-how; and in particular the development of management requires it to absorb key technical knowledge.

The development of human resources should be in step with demand, or possibly somewhat ahead of it, if those resources are to be prepared for the tasks to be carried out. Ideally the CEDO should formulate a personnel development program. The recruitment and training of stable personnel are two factors that interplay. What type of recruits should be had and what training they should be given will very much depend on circumstances and opportunities; there seems to be no agreed procedure, and practices differ from firm to firm. Recruits may be fresh graduates, persons with 3 or 4 years' experience in technical work, or experienced professionals. In regard to training, two important elements are academic training at home or overseas and on-the-job training while assignments are carried out, particularly when this is done in association with a more experienced CEDO. It is important to use the training opportunities when there is collaboration with a foreign CEDO, but this may not be easy if the latter believes that it will raise costs or lengthen the job or if it is wary of helping the development of a potential competitor. These are aspects where explicit policy may greatly help, by inducing the local CEDO to maximize the use of training opportunities and the foreign CEDO to conduct the training.

The efficient operation of a CEDO requires the use of modern management techniques and needs the acquisition of expertise in handling complex tasks that are carried out by persons from different backgrounds. In organizing its program of work, the CEDO has to pay particular attention to the allocation of its resources to the best effect. It should operate in a businesslike manner, if it is to become cost-conscious and efficient; this should apply too in public-sector CEDOs. In this sense a cost-plus type of contract is not too effective. Attention should be paid to the setting of standards for executing consultancy projects, the control of costs, schedules, the quality of work, etc. All this may be embodied in standard procedures.

The acquisition of technology and expertise by the CEDO implies a lengthy learning process about which little hard data exist so far. In the first place, the technology of consulting and engineering should be mastered, including techniques such as demand analysis, project evaluation, mathematical model-making, electronic data processing, scheduling, design routines, drafting techniques, preparation of reports, etc.

Second, the technology of the sector to which services are rendered should also be mastered. This brings up some interesting issues:

- The technology should not only be in the minds of the CEDO's staff but should somehow be incorporated in the organization itself, through specialized routines, computer programs, technical files, lists of technology, equipment suppliers, etc. This "firm-embodied" know-how may reinforce the aggregate knowledge of the staff, improve their efficiency, and allow a departing staff member to be replaced by a new recruit with little disruption.

- Technology acquisition may reach different levels of depth and complexity. The mastery of basic engineering design would be an appropriate goal in the long run; other more accessible goals may be formulated for different times as a guide to the CEDO's technical development.
- Noteworthy among the forms of technology acquisition and learning are the recruitment of experienced personnel; the repetition work that may be carried out for successive clients; the establishment of feedbacks from clients once assignments are completed (possibly through follow-up visits and meetings); the close interaction with R&D institutions, technology owners, and equipment makers; the further training of staff members through special programs; the formation of a special group to master a certain technology (such as a "process group" that can carry out development and pilot plant work); and very importantly the association, permanent or temporary, with an experienced foreign CEDO. It may be desirable for the CEDO to establish links, or even associate itself, with a foreign CEDO, either indefinitely or for the duration of a project. In the best of cases this may mean a quick way to acquire know-how, but there is a danger that a developing CEDO will remain a junior partner. Experience shows that the local CEDO usually has problems in gaining access to crucial data, obtaining manuals and operating instructions, and in general procuring written documents that collect and summarize years of experience. The CEDO should negotiate access to such information,[23] which is vitally needed if there is to be an effective transfer of corporate knowledge. Government policy should support this, for instance, by requiring that the local CEDO should lead the project with the foreign firm helping to carry it out: the project director can then have direct access to the top personnel at the foreign CEDO's headquarters instead of having to go through the foreign personnel who happen to work on the spot. Training may also become one of the items of cost in a contract between a government and a foreign CEDO. There are several interesting experiences in the developing countries that are worth analysis for the types of agreements and the operating procedures that are best for technology transfer from a foreign to a local CEDO (see Perrin 1971).

Building Up a National Consulting and Engineering Capacity

Developing countries need to build up a national C&E capacity and put it to good use if they are to have control of decisions that are important for their development, employ their intellectual resources well, carry out optimal investment projects, and achieve a harmonious growth of their industrial sector. This is not likely to happen spontaneously; it requires promotion policies that aim to produce a set of CEDOs able to provide C&E services with efficiency and reliability. As benefits to the country as a whole are bound to be significantly larger than those accruing to the users of C&E services, it is logical that the costs of developing C&E should be shared by the country through appropriate government action.

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[23] For instance, through a full-disclosure clause in an agreement for collaboration on a specific project.

Obstacles

Certain obstacles in developing a domestic C&E capacity and using it efficiently are a result of the characteristics of investors, CEDOs, and other participants; other obstacles are a result of the local or the international environment. A study of them suggests some policies to eliminate them.

Small countries can only hope to install adequate C&E capability in a few fields, if at all. Policymakers are often not aware of the key role of C&E in carrying out better investments and contributing to self-reliant development; and frequently there is not the necessary political will to change things for the better in these matters. Public investment programs often lack continuity, and decision-makers tend to be too cautious, not fully trusting local CEDOs and suppliers and wishing to avoid any complications that may imply delays and costs in the short run. Besides, they are hampered by the usual systems of selection and contracting of suppliers, established by law or traditional administrative practices, which are not adequate for promoting technical development; thus, it is not easy for them to support tasks that go beyond immediate requirements. In addition, investors often have a limited technical capability to deal with CEDOs, negotiate technology purchases, and identify technical requirements of production problems.

External forces such as supplier financing and tied loans greatly reduce the investor's scope of decision; there is more latitude when financing comes from international agencies, although insistence on "getting the job done" puts the focus on short-term efficiency aspects rather than long-term ones. Domestic investment banks tend to behave like international banks and are not willing to take what they consider to be high risks. Self-financing allows the highest latitude for choice of CEDO, technology, and equipment; but few investors have it.

Domestic CEDOs face strong competition from industrial countries' CEDOs, which may show much more impressive credentials, promise better guarantees, and provide more favourable financial terms. Faced with the choice, real or imagined, between delays, uncertainty, and few guarantees, on the one hand, and speed and efficiency, on the other, investors frequently select a foreign CEDO. Short-term considerations prevail, and long-term ones, which might help in the reduction of technological dependence, are not considered.

Internal characteristics of clients, CEDOs, and other participants may change in time as development proceeds and learning takes place. Unfavourable government policies may be changed once identified. But many contextual factors are difficult to modify; although some of them may be overcome through persuasion and strong incentives, others have to be accepted as part of the environment. As to the obstacles that originate in foreign participants, the country may adopt defensive policies and also join other developing countries in a united front to bring about changes in the international environment.

Strategy

An efficient approach to the building up of domestic C&E capacity should not just rely on policies "from the top." It should seek to promote actions from the participants themselves so as to put in motion a cumulative and expanding process that will overcome obstacles, change attitudes, and bring about CEDO development and utilization as a consequence of the interest and efforts of those involved, complementing this with adequate policy measures at the right moments. Persuasion, the diffusion of experiences from home and abroad, and the training of responsible officials in investing enterprises are general measures that can be taken early. As the process gets going, a number of general or sectoral policies may be adopted to support it, and at the same time existing policies may be revised when they have a negative influence on the development and use of C&E capacity.

Within this general strategy, many specific actions may be taken. Which ones, and in what order, will depend on the context, the opportunities, and the interest and eagerness of the participants. It is possible, for instance, that major advances can only take place when there is a balance of payments, and investors — particularly public enterprises — have to turn, faute de mieux, to local CEDOs and local suppliers. If things turn out well, the terrain that has been gained may be kept. It is likely that the process cannot be planned in detail and that it is rather a case of "disjointed incrementalism" as outlined by Lindblom and Hirschman, the pursuit of an objective when there is only a general idea of where it lies and little knowledge of the obstacles, like crossing a minefield with the help of a mine detector.

The way in which a national C&E capacity is organized will be different for different countries and for different fields where C&E services are needed. Certain strategic choices must be made so as to define objectives that will guide policymaking and action. These choices must address:

- The problem of priorities regarding the type of service and the industrial branch in which C&E capacity should be established first. It has been suggested that priority should be given to preinvestment studies first because these are required for principal decisions that shape the way investment projects are engineered and implemented. After preinvestment, a second priority would be detailed engineering, an activity that allows the links with the capital goods industry. Priority should probably be given to the branches in which there are possibilities for repetitive investments that will maintain a demand and allow experience to be gained in successive tasks. Repetition possibilities for engineering are present in peripheral technologies used by many different investment projects; to make use of them it is necessary to disaggregate investment packages and parcel out contracts.
- Degree of autonomy and specialization. Which combination should be favoured — private or state-owned CEDOs, independent or captive, specialized or multipurpose? Much will depend on the prevailing opinion and the "style" of the country concerned.[24] State-owned CEDOs, however, would seem to be a necessity to serve small and medium industries, which cannot pay fully for the services they require. Independent CEDOs may sometimes offer advantages over captive ones both from the private

[24] One country, through its National Development Bank, has created technical groups in areas like forestry and has made them private after some time, continuing with its support in the shape of assignments and credit. In India, the government has tended to build up its own C&E capacity; government CEDOs act as prime contractors in large projects and subcontract certain parts to private CEDOs.

and from the social points of view: clients would not be saddled with project offices that are active only part of the time, and such CEDOs probably have a stronger impact on the diffusion of knowledge by virtue of the many clients for which they perform assignments. But large enterprises may prefer to have their own captive capacity, which allows them a high degree of mastery of the technology in their branch, particularly if R&D activities are also carried out and secrecy is a consideration. Multipurpose CEDOs have fewer problems associated with demand fluctuations, but this approach tends to disperse efforts, particularly of key management personnel. However, in small countries diversified CEDOs may be unavoidable. A closely related question is whether CEDOs should be totally independent of ties to technology owners, contractors, capital goods producers, and other commercial interests. This issue has been debated for a long time. National and international CEDO associations maintain that the clients can only get proper and unbiased advice if the organization they retain is not tied to any other interests, and they have incorporated this principle in their codes of conduct. However, international banks allow CEDOs related to such interests to participate in the formulation, engineering, and supervision of investment projects provided that their associates do not supply any inputs. In a developing country there are reasons that the principle should not be absolutely upheld: for instance, a captive organization belonging to a contractor may sometimes represent the best domestic source of C&E; the volume of business and particularly the profits will be much larger for a CEDO that is integrated within a larger commercial operation, such as a contractor, significantly increasing the chances of development of the CEDO; this argument is important from the point of view of developing an indigenous CEDO capacity; in any case, many developing country CEDOs have originated in civil constructors and other enterprises that established an engineering department that later became large and went on to supply services to other customers. In certain sectors of some countries — for example, CEDOs in the process engineering branch in Argentina and Mexico — C&E capacity is already extensively tied up with commercial interests.

- The organization of CEDOs nationally and sectorally. In some areas the expected work load may not justify more than one or two large CEDOs; the danger is that there would exist strong competition and a high death rate among many small CEDOs, none of which could aspire to become large enough to carry out an efficient task, so that foreign CEDOs would continue to be employed indefinitely in key assignments. A monopolistic situation may be the only alternative to such foreign domination, contracting and pricing procedures being negotiated and agreed.
- Relations with foreign CEDOs. A position should be taken regarding the place of foreign-controlled and joint venture CEDOs.

The support awarded to developing CEDOs is essential if they are to reach maturity. The main questions are: How much support should be given to private CEDOs (a) directly through fiscal incentives, loans, and other means, and (b) through contracts for which relatively high rates are paid? How much should be invested to create and develop state-owned CEDOs in certain key areas and branches? What amount of subsidy should be given to the C&E services rendered to small and medium industry by information centres, industrial research institutes, and other organizations catering to that sector?

Policy

Some policy measures and actions can be taken by users and producers of C&E services, and by the government, to help the development of national C&E capabilities. Most have been discussed elsewhere in the literature; others have been put forth in conferences on C&E or have derived from personal conversations with different people. In some cases they are being applied in developing countries, as shown in the case studies included in this volume.

Users

Measures and actions by the users of C&E services include:

- Careful appraisal in selection of a CEDO based on expected performance. Selection should not be influenced by price considerations; or by financial facilities; risk-avoiding attitudes; too much reliance on credentials, especially those of a foreign CEDO. Methods of selection should give domestic CEDOs the possibility to overcome the "inherent inequality" they suffer in regard to foreign CEDOs.
- Use of enlightened practices in the preparation and implementation of investment projects. Local CEDOs should be given significant responsibilities as well as opportunities to train their personnel and acquire know-how even though this may signify a cost.
- Development of their own technical staff to deal with suppliers. It will often be convenient to build up a true technical and engineering capability. The process of creating this internal capability is not simple; it is not enough to hire professionals; a team should be formed.
- Careful handling of relations with CEDOs. Terms of reference should be precise but flexible. The users should control carefully the work of CEDOs and other suppliers. They should integrate their own personnel into the CEDO's technical teams for a better overseeing of the work and as a means to train people who will later be engaged in operation and maintenance. They should provide the necessary feedback information to allow the CEDO to learn from its past work.

CEDOs

CEDOs in developing countries can do much by themselves to increase the quality and scope of their activities:

- They should program their development, establishing concrete objectives over time and marshaling the means to achieve them.
- They should attempt to utilize fully the resources and skills available in the country, establishing strong ties with various institutions — universities, research institutes, development agencies, banks, equipment makers — and at the same time creating links between them for the benefit of an integrated industrial development.
- They may pool resources to carry out large assignments. This does not exclude foreign inputs through joint ventures or individual consultants to carry out specialized tasks.
- They should form or strengthen professional associations of consultancy organizations, which can be useful in raising professional standards

through registration, establishment of codes of conduct, exchange of experience, and improved communication channels.

- They should develop quality assurance mechanisms so that a solid and reliable structure of C&E services is created. In developed countries, the profession of consulting engineering usually has a self-policing mechanism, such as the periodic renewal of a qualification, which gives the user some guarantee as to quality. In addition, large CEDOs continuously check the quality of the work in their various projects and can change the project managers and their professional staff if necessary. But CEDOs in developing countries may have just one or two projects that are managed by the principals of the firm. This fact points to the need for a central organization, possibly set up by a CEDO association, that supplies reliable information to prospective clients, helps in drafting guarantee and bonding clauses, and carries out a control of the quality of services rendered.

GOVERNMENTS

Governments should ideally define a long-term program for the development of C&E capacity at national and sectoral levels, with clear objectives according to the choices made on several aspects of strategy. Within the program, specific policy measures may be adopted at the appropriate times.

Government policies on the demand for C&E services include:

- Adoption of political support and the right attitudes, which may vary from branch to branch. For instance, atomic power development in Argentina and India relied from the beginning on domestic C&E efforts, disaggregation of packages, increases in local inputs, etc., whereas steel and other industries in the same countries relied on turnkey projects for a long time. The government may influence attitudes and behaviours through persuasion and other means.
- Awarding of contracts directly to local CEDOs. The government can adopt legislation favouring the use of local (in preference to foreign) C&E in public investments, although in practice this may not work too well as decision-makers invoke urgency, safety, etc., in their justifications for using foreign sources.
- The protection of domestic C&E production through a system of preferences. The usual tariff mechanisms do not appear to be effective because of operatives peculiar to C&E activity. C&E services are bought — or should be bought — on grounds of quality rather than price, and, in this regard, there usually is a bias in favour of what comes from an industrial country; price incentives are largely inoperative because the customer prefers to pay more if necessary — this is only a small part of the investment cost — and to feel confident that the most reliable and best quality services have been acquired. The application of regimens for the control of technology imports, foreign investment, and industrial property rights does not provide enough inducement to select local C&E services. There are many factors in technology choice that escape those regimens; some of them are subjective; others depend on how activities that demand technology are organized, who takes the decisions, and what decision rules are applied. To act on these factors and favour the contracting of domestic C&E services, governments may use preference systems of a qualitative nature. Domestic CEDOs face stiff competition from foreign

firms and are at a disadvantage on account of an inherent inequality in financial means and credentials. To eliminate this disadvantage and, further, to tip the balance in favour of local CEDOs, governments need to do two things: first, to devise financial mechanisms that would grant adequate credits to CEDOs (for their capital requirements and the preparation of proposals) and to their clients (so that consulting and engineering services may be had on favourable terms); second, to devise a method of selection on the part of the client in which the sheer volume of background experience and the renown of professionals do not automatically determine who is to be awarded a contract. Such a method would include the development of a point system with standard procedures for the assessment of the quality of a firm and of its proposal without undue emphasis on the volume of background experience and the awarding of extra points if the firm is local.

- Regulation of demand in the public sector so that CEDOs are not exposed to great fluctuations in the work load.
- Promotion of exports of C&E services through identification of likely foreign customers, use of embassies and missions overseas to assist local CEDOs, provision of tax rebates and subsidies for the export of C&E services, etc. In some countries a special trading company has been jointly founded by the government and exporters of technological services.

Policies on the supply of C&E services include:

- Establishment of state CEDOs in certain areas of the economy. In some cases these may be captive groups that are pulled outside their parent organizations and given a wider role.
- Preferential tax treatment to CEDOs for activities such as the export of services.
- Creation of credit facilities from which CEDOs may obtain working capital, training, research, technology, etc.
- Support for the establishment and functioning of consultants' associations.

Policies on the activities of CEDOs should aim to improve the social efficiency of CEDOs and that of the investments they serve. Examples are:

- Support for improved, enlightened practices that mean high social efficiency. This will require persuasion and, perhaps, the teaching of such practices to investors and CEDOs.
- Adoption of legislation compelling investors to acquire a percentage of their inputs from domestic CEDOs and local suppliers. This type of action has been very effective in the case of inputs for automobile production, where local subsidiaries have been forced to "integrate" their production. In the case of C&E services, success is less likely. Experience in Argentina and other countries shows that such legislation is frequently bypassed by public enterprises. It is possible, however, to establish a control mechanism, as has been done in Brazil and in India.
- Introduction of regulations that use foreign CEDOs positively for technology transfer and training. Such regulations may be implemented, for instance, by a technology registry that approves all technology agreements.
- Promotion of relations between CEDOs on the one hand, and R&D organizations, equipment makers, and input suppliers, on the other. The government may play an important part in this through its financial,

administrative, and technical units, acting in accordance with a central policy.

INTERNATIONAL COOPERATION

Positive policies, especially by governments, will encourage appropriate international cooperation with both developing and developed countries. Cooperative efforts among developing countries in technical matters are especially important not only in the sharing of technology but also in the reorienting of conditions now permeating operations of technology transfer, foreign investment, etc.

Technology may be shared through traditional channels (bilateral and multilateral cooperation) and through commercial channels (operations of technology commerce between a supplier in one developing country and a client in another). Technical cooperation through commercial channels offers great promise of expansion. The operations may be of benefit to the exporting country in terms of a greater mobilization of its C&E potential and the expansion of markets for its CEDOs. The receiving country may benefit through lower costs, the possibilities of obtaining more appropriate technologies,[25] and the likelihood that such transactions will create much weaker links of dependence and will be endowed with characteristics that make them socially useful for the receiving country, helping the latter to build up its own C&E capacity. Cooperation of this sort may lead to the creation of large technology markets, the establishment of joint programs and joint institutions in certain fields, and eventually the achievement of technological integration between two or more countries. A small country may not find it easy to develop independent C&E capacity in certain fields, and cooperation with other countries may be the only way to obtain a C&E capacity that responds to its interests. Examples may be found in the Andean, the Central American, and the Caribbean subregions in the Americas.

The developing countries should cooperate to carry out a "technological diplomacy" to improve the conditions now ruling in operations of technology transfer, direct foreign investment, and others that may influence their technological development. The negotiations being carried on in UNCTAD (United Nations Conference on Trade and Development) and other international forums on "codes of conduct" for technology transfer and multinational corporations should be continued

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[25] A large part of the technologies needed by developing countries are already used by other developing countries and have been mastered by them; the "technology gap" between developing and developed countries as a whole is significant only in certain areas and branches, mainly the "science-based"type. Also, adaptive efforts, innovations, and cumulative production experience have produced "appropriate" technical solutions in many fields. Such solutions constitute "technological assets" that in many cases are implicit in existing plant and operating practices. To transfer such technological assets, it is necessary to make them explicit, i.e., to derive a "conceptual engineering" from existing practice. This needs technical efforts of the "reverse-engineering" type, which may be forthcoming if there is a market for such technological assets. With the conceptual engineering in hand, a proposal may be prepared in such a way that it incorporates the "basic engineering" of a project that fits the clients' needs and contemplates the local conditions under which they operate.

actively, and it would be convenient to start other actions to change the behaviour of various participants such as international and regional development banks, productive enterprises, CEDOs, donor agencies, and banks of the industrial countries.

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Chapter 2

Guidelines for a Case Study of Consulting and Engineering Design Organizations

Alberto Aráoz

Case studies are useful for researchers just beginning to analyze complex situations where many variables and decision centres are present. They detail individual situations that incorporate the complexity, and they provide insights into the interrelations among all the elements. They rely on inductive reasoning and do not imply the collection of data for testing conjectures and hypotheses. Although they are not a basis for conclusions of general validity, they do provide a basis for conceptual interpretations and hypotheses that may be submitted to corroboration by statistical evidence.

The CEDO case studies were not carried out with the purpose of giving answers to a list of carefully formulated questions. Although many useful insights and some preliminary conclusions were obtained, the principal aims were to identify the different instances of decision, the participants and the problems they faced, and the influences at work; to define hypotheses that may be subjected to verification; and in general to contribute to a better formulation of the CEDO project. At the same time, the task allowed national teams to get acquainted with research on CEDOs and to train their personnel on the subject.

There is, therefore, a strong exploratory flavour in the case studies. The methods were flexible; there were suggestions on the scope and content but even these were regarded as guidelines, not compulsory procedures, because the output was to be questions rather than answers.

Subject and Structure

It was suggested that the case studies be of a reasonably mature, locally owned, independent CEDO, private or public, and that they include the CEDO's past development and present functioning, with an example of a recent investment project in which the CEDO played a major role, especially in formulation and execution. Such information was sought so that a close look could be taken at aspects of the CEDO's developing stage and of its mature state so that hypotheses about some of the issues could be made and, later, researched. It was believed that, by studying a particular investment project, one could identify the principal participants and pose questions to them about alternative courses of action.

The investment project was to be medium sized — U.S. $10–50 million — anything smaller lacks complexity and larger projects are likely to be too complicated for adequate analysis. The client was to be a private investor or a public enterprise or agency. To facilitate cross-country comparisons, it was suggested that the project be in the chemical process industry and that the project be completed recently so that relevant information would be relatively easy to obtain.

A brief examination of, perhaps, six investment projects, and the CEDOs participating in them, was suggested as a means for choosing the subject of the in-depth case study. The preliminary study was to be an abbreviated form of what was to be done later and was to be conducted along the same lines, key participants being interviewed about the CEDO's development and operations. The result was to be very sketchy case studies that would be useful indicators of relevant issues and hypotheses. Once the main case study was made, the next step suggested was that the results be discussed with those who had been interviewed in the first round, so that the findings could be contrasted with other cases and experiences, and the final report enriched thereby.

The empirical information for the in-depth study was to be collected through interviews with key informants and through the study of reports, records, and other documents. A tentative timetable was $18^1/_2$ weeks — 2 weeks for the preliminary analysis, 6 weeks for accumulation of details on the CEDO's development, 6 weeks for examination of a recent investment project, $^1/_2$ week for discussions with key personnel of other investment projects, and 4 weeks for the preparation of a report. A minimum staff was considered to be one researcher with the aid of one research assistant for at least 12 weeks. For a more complete work, and for training purposes, a larger team was recommended.

The CEDO and Its Development

The first step was to characterize and describe the CEDO as it is — the principal aspects of its "anatomy," its "physiology," and the relations with its environment. (This examination would be considerably expanded during the second part of the case study.) The following step was to analyze the main features in the CEDO's development, from its beginnings, to find out about the principal decisions, the most influential factors, the relative success of strategies employed, etc. It was hoped that the information derived would indicate the salient questions and issues related to development so that they could be subjected to research later on. The conceptual framework in the previous chapter details the types of issues that might be identified.

Some of the principal points to be covered in the first step were:

- Characteristics: ownership; dependence on other firms or agencies; parameters of size: capital, stable personnel, person-hours per year, number of projects handled and their value, sales; branch or branches it attends and their main characteristics; type of clientele;
- Output: structure of the services produced; approximate proportion of effort in preinvestment, design, construction, and supervision; other services (see Malhotra's classification); degree of specialization of the CEDO; the way in which it envisages and accomplishes the functions that

make up its social role, such as formulating appropriate investment projects, opening technology packages, seeking appropriate technology, adapting foreign technology, acting as a link between local R&D and industrial users of technology, acting as a link between industrial investors and the capital goods producers, contributing to technology diffusion, etc.;

- Market and clients: characteristics of demand, in size, diversity, growth, fluctuations, and discontinuities; characteristics of clients in nationality, ownership, size, technical level, etc.; attitudes and biases of clients; relations with clients through marketing practices and other means; types of contracts, bid presentations, formal and legal practices in this respect; commercial relations with other CEDOs as collaborators or subcontractors to them; exports of services;

- Structure, operating procedures, management: physical resources (buildings, equipment, instruments, etc.); information resources (books and periodicals, special technical files, etc.); human resources (structure of staff, qualifications); stable and temporary employees; turnover of personnel; seniority of present employees; salary levels and salary structure; organizational structure (has a foreign model been adopted?); capabilities; range of skills; internal procedures and production techniques compared with those employed in top foreign CEDOs (for instance, planning and programing; use of computers for calculations and for drafting; use of advanced quantitative methods for simulation, analysis of data, design, scheduling); structure of costs (labour, support services, overheads, etc.); structure of finance; management methods employed (and opinions of how far usual management methods for normal enterprises apply to a CEDO in a developing country); internal communications, motivation of personnel, promotion of creativity; critical resources: human resources — patterns of recruitment of personnel; training of human resources (academic, on the job, with foreign associates; problems in this training); technology and information resources — patterns of access to technology and to specialized expertise; links with foreign CEDOs and foreign technology owners; identification and procurement of domestic technology; setup for feedback from clients; access to economic and technical information through literature, documentation centres, trips, meetings, contacts with universities and research centres, etc.; storage, internal distribution, and utilization of information;

- Environment, influences received: local institutions and type of relations maintained — government ministries and agencies, universities, professional associations, financial institutions, CEDOs, equipment makers; contextual factors, implicit policies, and explicit policies that have a bearing on the CEDO's performance and on its current development; efforts of the CEDO to change in its favour its domestic environment by itself or through associations with other CEDOs; characteristics of and relations with foreign CEDOs (collaboration/competition), experts, equipment makers, technology owners; influence of foreign and international banks; relations with CEDOs and other institutions in developing countries; and

- Problems, obstacles, opportunities — the main factors contributing to the CEDO's success, such as a monopolistic situation in the local market, special relationships, dynamic management, continued access to know-how, etc.; the main obstacles and problems to be overcome to improve further the social efficiency of the CEDO (in its three components, see conceptual framework), and what government policy can do to help; the opportunities the CEDO perceives in the near future and how it can profit from them.

These facts about the mature CEDO were to serve as a point of departure for the second step — study of the past development. They would provide a basis for questions such as how each main characteristic has evolved, how the critical resources have been procured, what opportunities have been used, how obstacles have been overcome, etc. They needed to be supplemented by questions on:

- Origin: Was it a new firm and, if so, what was the previous experience of the founders? Was it a spin-off from a government agency or a manufacturing firm? Why were a particular technical field and technical services chosen? What were the main characteristics of the CEDO in its very beginnings? What were the initial assignments?
- Paths of growth: What were the industrial branches and other customers served, and types of services rendered? Were there trends toward diversification or specialization? What quantitative indicators evolved? What influenced the gaining of expertise, or learning process — repetitive work, collaboration with foreign CEDOs, recruitment of new, specialized personnel, training of staff? When did access to technology increase? How did the CEDO's own technology or production procedures evolve? How did it establish an image, create confidence among clients and other participants, develop clientele?
- Strategies and policies for development: What was the model for the type of institution the CEDO aspired to become? What were its objectives at different times? What were the principal obstacles, critical problems, and key opportunities in the development process? What were the solutions in terms of strategies and policies?[26]
- Support received from the government and other participants: Which government policies have helped? (The policies that have hindered development will have been examined as obstacles.) Have government-awarded contracts been key inputs in the CEDO's development? What role has political support played? What support has come from financial institutions and from industry? What other help would have been useful in hastening and improving the development process?

Analysis of an Investment Project

The main purpose of analysis of an investment project is to obtain detailed knowledge about how a mature CEDO performs in a particular

[26] One strategy merits special analysis: a developing CEDO in association with a foreign CEDO. This has been characterized by K. Mariwalla as having three phases: (1) a division of activities between foreign and local CEDOs, and supervision by the former of the latter's work; (2) most work carried out by the local CEDO, but the highly specialized work done by the foreign CEDO, which also oversees the complex work done by the local CEDO; (3) responsibility with the local CEDO, which may consult occasionally with the foreign CEDO.

instance, how it relates to other participants, and what influences it so that the principal questions and policy issues will emerge and shape further research on the performance of a mature CEDO and the conditions it needs to achieve a high social efficiency.

The questions to be asked related to the aspects identified in the conceptual framework presented in the previous chapter: determination of the "products" to be produced, production, distribution, characteristics of the environment, and internal characteristics of the CEDO. Some sort of judgment should have been passed by the research team about the social efficiency of the CEDO in the particular investment project, the components of that parameter (social utility, productive efficiency, distribution efficiency), the influence of external factors, particularly explicit policies, implicit policies, and contextual factors, and the adequacy of the salient internal characteristics of the CEDO.

Alternative courses of action at different points in the investment project sequence were to be identified and questions asked about the reasons that they were not chosen. A further question was how far work on the project had meant a significant learning experience for the CEDO, had allowed it to increase its expertise, improve its organization, made it able to offer a wider range of services; and in how far such ameliorations had permitted the CEDO to tackle successfully more complex assignments.

The characteristics of other participants and the relations of the CEDO with them were also to be studied, particularly in the case of the client; other CEDOs, local and foreign; technology owners; the local R&D institutions. The client was to be examined from the point of view of its technical capabilities, past record on technical matters, and the effect of the project in increasing its skills and organizational capacity. Another important aspect was the utilization by the CEDO of local R&D organizations; in many developing countries this utilization is very meagre, and the reasons for this should be tentatively explored.

To take these aspects into account in an orderly manner, the first step suggested was to identify and describe carefully the "decision chain" of the investment project, i.e., the series of points where critical decisions were made from the moment the project was identified until the resulting installations were operating to specifications. At each point in the decision chain, various elements would be identified: the participants involved; the alternatives considered at the time of decision and how they were identified and formulated; the alternatives not considered and the reasons; the decision method employed, explicit or not; the information used for decision-making; and the principal influences at work — explicit and implicit policy, contextual factors, motivation and attitudes of the participants, characteristics of the production branch, etc. — that have operated directly (i.e., through the information employed for decision-making) or through the participants (i.e., affecting their behaviour).

It was suggested that the resulting descriptions be summarized in a table that would permit fruitful discussions with the participants themselves and with other national teams (Table 2). This description was to be used as the starting point of an analysis aimed at understanding the influences on the outcome of decisions along the investment project, which may be related to an appraisal of the relative success or failure of the project to comply with private goals (getting the job done quickly and

Table 2. Analysis of an investment project.

Critical decision	Decision adopted	Participants present	Participants that might have been present	Alternatives considered	Alternatives not considered	Methodology of decision	Information for decision	Influences at work	Observations regarding CEDO role	Other observations
Conception and identification										
Preinvestment work: whether to do it; choice of who will; depth and scope of work										
Guarantees asked of the CEDO selected										
Choice of technology and how to obtain it										
Size, location, product mix, and other parameters										
Structure and sources of financing										
Detailed engineering and who will do it										
Where the equipment is to be procured and how										
How the equipment will be inspected: (a) while being manufactured, (b) upon delivery										
How the construction and assembly will be done and by whom										
How personnel will be recruited and trained										
How to carry out the commissioning										
How to supply follow-up technical services										
How to carry out feedback from operations to designer/engineer										

efficiently) and social objectives (keeping decisions in national hands, using more adequate technology, maximizing favourable impacts on local production and engineering, etc.). Of particular interest are the limits imposed by various circumstances (explicit and implicit policies, contextual factors, characteristics of the branch, etc.) on the action of local participants. Another interesting point is the relations between participants; for instance, CEDO–client, CEDO–foreign CEDO, CEDO–R&D system, etc.

In some cases, it was possible to suggest alternative decisions and actions that could have been taken to improve the project's success. This aspect comes out more clearly when several national case studies are analyzed side by side.

The set of all possible decisions may be said to make up a "decision tree." To examine the alternatives, one must start at the first point in the chain and identify alternative decisions that may be taken — those explicitly considered by the participants as well as those not considered but possible. Each outcome branches out into two or more possibilities, and so on. The usefulness of this representation may be improved if alternatives are qualified and ranked according to the degree to which they are expected to enhance the social efficiency of the investment activity (Fig. 5).

This decision tree cannot in practice be constructed except in very simple cases because of the large number of links in the decision chain; the possibility that one must go back and change decisions; and the likelihood that social efficiency is to be measured ordinally rather than cardinally. However, the concept of a decision tree of this nature allows interesting discussions to take place with the key informants. For instance, it would be possible to specify a "best" chain of decisions in the sense that at each point an alternative is chosen that will mean maximum social efficiency (Fig. 6).

In practice an optimal sequence may not be feasible, and the reasons for not adopting the "best" decisions should be examined. Some people feel that one of the main influences behind a near-optimal decision sequence is the positive attitude of the main participants — principally the client and the CEDO — and that without a favourable philosophy on their part it is easy to fall back on decisions that maximize private but not social efficiency.

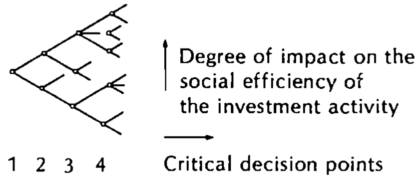

Fig. 5. Decision tree — ideal representation.

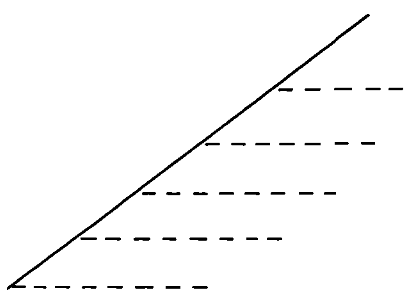

Fig. 6. Decision tree — optimal sequence.

It is easier to achieve a high overall efficiency of the complete investment project (once the decision chain has been gone through) when the first few decisions are optimal. This is in line with the proposition in the literature that decisions taken during the preinvestment period largely set the stage for later decisions — the choice of a local consultant, for instance, would make it much more probable that the technology chosen will be more adequate, that local capital goods and other inputs are fully employed, etc.

At some decision points, the outcome of certain alternatives may limit the choices in later decisions and be strongly negative for social efficiency. This would particularly be the case with the election of the source of finance. A decision to accept supplier credit, for instance, would throw the sequence into a tailspin.

CHAPTER 3

DEVELOPMENT OF ENGINEERING CONSULTANCY AND DESIGN CAPABILITY IN KOREA

JINJOO LEE

SUMMARY

The Korea Engineering Co. Ltd (KECL) was founded in 1970 as a joint venture of the government with the Lummus Co. (USA), with equity participation by several leading Korean enterprises. In 1973, Lummus was replaced by the Toyo Engineering Co. of Japan as the KECL partner, and in 1978 the Korean Development Bank sold its stock, 50% of the Korean share, to the Sam Sung Co., which now has the control of KECL.

KECL is a multipurpose engineering company, making available all major services in the areas of plant and water resource engineering, harbour and coastal engineering, irrigation, sewerage, and agricultural engineering, collaborating whenever needed with competent foreign CEDOs.

In its first year, KECL had a large volume of work from the government, but this decreased in the second and third years, causing Lummus to retire. Contract amounts increased notably after 1976, and the company has now accumulated good experience and technical expertise. KECL is expected to grow rapidly after its transfer to private enterprise. Personnel went up from 66 in 1971–73 to 129 in 1974, and it doubled again to 238 in 1975. In 1978 it was expected to reach 500.

Most clients have been Korean enterprises. Some subcontracted projects have been made for foreign ones. Services have covered feasibility studies (15 projects), detailed engineering including procurement and construction management (45 projects), and detailed engineering including start-up (two projects). No basic engineering projects have been carried out: the firm's technical capability and expertise has not yet reached a sufficient level for this.

Among the problems faced by KECL, a crucial one is the scarcity of competent, experienced engineering and technical personnel, especially piping and instrument engineers with plant design expertise. KECL's growth, despite support by the government, has not been easy. This experience shows that the engineering industry cannot be fostered only with direct government support. Incentives are needed to enhance engineering capabilities and to create a demand, overcoming the hesitation of most entrepreneurs to use domestic engineering firms on account of supposed shortcomings in quality and efficiency.

KECL has steadily developed its technical capability to handle detailed engineering services. The 1960s were a period of foreign dependency for engineering services, with almost no Korean contribution. Partial localization of such services took place in the 1970s, KECL taking a leading role in this. However, no basic design and engineering service projects have been carried out as yet by domestic engineering firms using only their own capabilities. Perhaps this will be possible in the 1980s if high-risk entrepreneurship is forthcoming on the part of clients.

This case study analyzes two investment projects where KECL has had a major role. Both have been successful — as indeed have been all of KECL's projects to date.

One of the projects studied was a styrene monomer plant. The client was a company backed by the Korean Development Bank. A preinvestment study made by the client led to the choice of the Monsanto process. The Toyo Engineering Co. of Japan was chosen as the CEDO, because its parent company, the Mitsui Corp., was able to finance the project. The total cost was about U.S.$17 million, of which $2 million (12%) accounted for the engineering fee. KECL provided two types of engineering services: detailed engineering and plant construction management, through a subcontract with Toyo, and all engineering services for an off-site building through a direct contract with the client. The latter amounted to U.S.$600 000.

There were few alternatives regarding size, location, and product mix of the plant because there was a long-term government plan for petrochemical development. Because of the extent of the investment, which could not be funded solely by the government, decisions on technical matters were not made prior to financing decisions: financing and loans took priority over all other problems, and any alternative technological choices had to be made in accordance with financing possibilities.

The government required a breakdown of foreign and local procurement, the latter amounting to U.S.$4 million. KECL's role in procurement was the evaluation and recommendation of local vendors, supervision of vendor drawing, expediting of deliveries, etc. The project gave KECL a good opportunity to acquire expertise in activities where it had little previous experience. KECL's efficiency was satisfactory: the project was completed by the target date, there were no cost overruns, and the cost of the plant was evaluated as reasonable or even lower than expected. The quality of the engineering services was said to be good according to clients.

The other project studied was a resin plant. The client was a private company. KECL's services included planning and preinvestment analysis in collaboration with the client, detailed design and engineering, procurement services, and construction supervision. Basic design and engineering were provided by the Japan Synthetic Rubber Co., which was the ABS resin process licencer. The project cost about U.S.$10 million; KECL's engineering fee was about $400 000 (4%). In addition there was an undisclosed amount for basic design and engineering.

KECL made great efforts to localize plant facilities and equipment; only items such as high-precision equipment (process, control, and electrical) were imported. This high level of local purchasing was possible because the client itself financed the project.

The plant was completed on time and without cost overruns, and it is now in good operational condition, showing the satisfactory quality of the engineering services.

For comparison purposes, the case of a very large fertilizer project that was handled by a foreign CEDO is mentioned in the study. Investment was U.S.$419 million, most of which came from foreign loans. The general contractor was a large U.S. engineering firm, which was paid $42 million (10%) for the engineering services for basic design, procurement, guarantee of the start-up and operation, and construction. This amount surpasses the total amount spent on engineering services by all companies in Korea in 1977. Total plant facilities and equipment amounted to $219 million, of which only 27% was locally procured, i.e., about $60 million. The localization rate would have been higher if local engineering firms had taken responsibility for engineering services. It should be noted that three domestic engineering firms, including KECL, participated in the project through subcontracts.

The emergence of engineering design and consultancy organizations in developing countries has been stimulated by the increase and diversification of industrial projects. These organizations play an important part in economic and technological development, frequently providing a channel through which industrial technology is transferred from advanced countries to developing countries and performing a crucial role by linking four systems that need to be integrated for efficient industrial development: the finance system, which makes it possible to start a project; the engineering design system, which organizes the necessary resources, personnel, facilities, money, and skills to implement the project; the production system, which applies a specific set of techniques to the project; and the science and technology system, which creates/supplies the technology required.

Engineering and consultancy are therefore related to several issues of industrial development, such as technology transfer, production efficiency, local engineering capability, product and process improvement, etc. They are essential for fast industrial development and technological self-reliance. The important benefits from the development of reliable and competent engineering services can be realized through reduced engineering fees, localization of plant facilities and equipment, reduced plant construction costs, development and localization of technology, promotion of related technology especially for the machinery industry, personnel development, machinery exports, etc.

Few systematic studies have been carried out to analyze the factors in the evolution and the practices of engineering design and consulting organizations. Knowledge of engineering activities in developed countries is fragmentary and embedded in trade secrets, so that any systematic understanding of CEDO practice and behaviour is difficult to achieve. According to Machlup (1962), engineering services make up a typical subsector of the knowledge industry.[27] Engineering services apply scientific principles and knowledge to the planning, design, development, construction, operation, testing, and inspection of plants or facilities, which are an integration of machines, structure, and equipment for a manufacturing process. Table 3 specifies the activities needed for a number of main engineering functions and the organizations carrying out those activities.

This chapter will describe and analyze the development of engineering consultancy and design capability in Korea in the light of the knowledge industry, with special reference to Table 3. The levels of the analysis are three: national, i.e., Korean engineering service industry as a whole; company, i.e., a specific engineering firm, Korea Engineering Co. Ltd; and project, i.e., a few engineering projects.

Before 1961 almost no investment in engineering services took place in Korea. During the Five Year Economic Development Plan (1962–67), plants for fertilizer production and petroleum refining were built on a

[27] Machlup distinguishes five types of knowledge industry: education, research and development, communications media, information machines, and information services. CEDOs are concerned with certain kinds of information services, especially engineering and architectural services, business services, and services rendered to government.

turnkey basis, which resulted in little impact on indigenous engineering capabilities. Some pioneering efforts to establish integrated engineering firms by technical entrepreneurs in the 1960s were not successful due to restricted domestic demand and lack of technical capabilities. Only

Table 3. Activities in main engineering functions.

Engineering functions	Activities	Organization in charge
Consulting prior to design	Resource survey; labour study; market analysis; environmental study	Integrated engineering firm; resource development corporation; general trading company; survey and consultant organizations; industrial firm; project end-user
System design and basic engineering	Master plan for installation; urban planning feasibility study; technical feasibility; overall evaluation	General trading company; integrated R&D institute; specialized survey team or firm; integrated engineering firm; plant equipment manufacturer; industrial firm
Detailed engineering and design	Total system design; subsystem design; system element design; other design; technical evaluation	Integrated engineering firm; plant equipment manufacturer; specialized design company; technology-based venture business
Procurement	Preliminary procurement study; market survey; procurement; provision of loan	Integrated engineering firm; general trading company; construction company; plant equipment manufacturer
Construction and maintenance	Plant construction; installation of equipment; various civil engineering tasks	Integrated engineering firm; construction company; plant equipment manufacturer
Project management	Project control; inventory control; engineering cost analysis; supervision	Prime contractor; construction company; equipment manufacturer

Table 4. Status of engineering firms in Korea, March 1978.

Type of firm	Number of firms	Professional engineers	Engineers
Plant engineering	6	129	1254
Specialized services			
Integrated	9	59	419
Mechanical	6	8	441
Metallurgical	–	–	–
Chemical	2	2	11
Electrical	16	58	159
Electronics	–	–	–
Communications	2	2	84
Shipbuilding	2	4	181
Construction	35	68	714
Construction equipment	2	3	8
Mining	5	9	21
Textiles	2	2	222
Nuclear	1	11	78
Production	–	–	–
Geology	17	21	245
Information processing	–	–	–

construction and architectural design services maintained their operations.

In the late 1960s, a partial localization of engineering services was accomplished in the construction of several chemical plants by a fertilizer company's technical team. In the early 1970s the first integrated engineering firm, Korea Engineering Co. Ltd, was created under the auspices of the Korean government, as a joint venture with Lummus Co. of the U.S. The company participated in a few engineering projects, but Lummus withdrew owing to the lack of a market for engineering services, being replaced in the partnership by Toyo Engineering of Japan.

The government influenced the engineering industry through the Professional Engineers Law before 1973 and, thereafter, through the Engineering Services Promotion Law. The latter stipulated that a domestic engineering company should be the prime contractor for engineering services except when not feasible, and it required registration of engineering firms and an annual report of their activities.

Engineering firms registered in Korea[28] in 1978 comprised 6 plant engineering, 9 integrated engineering, 25 specialized, and 65 individual firms (Table 4). They employed 4213 engineering personnel. The value of engineering services was estimated at about 1 billion won[29] in the late 1960s, 2.1 billion won for 632 project contracts in 1973, 5 billion won for 1092 projects in 1974, 8.6 billion won for 1738 projects in 1975, 20 billion won for 2403 projects in 1976, and 24.6 billion won for 3031 projects in 1977.

[28] A registered engineering firm is required to have at least one professional engineer and four registered engineers.

[29] One U.S. dollar was worth 275 won in the late 1960s and 485 won after 1973.

Table 5. Size of Korean engineering firms.

	1975	1976	1977
Professional engineers			
1	58	80	65
2–4	26	29	23
5–9	7	10	8
10–19	7	7	6
>20	0	1	3
Engineers			
1–4	45	72	0
5–9	25	27	48
10–19	14	12	20
20–49	6	12	16
50–99	6	4	12
>100	2	0	9
Contract amount			
<W10 million ($20 000)	28	26	13
W10–50 million ($100 000)	20	29	24
W50–100 million ($200 000)	18	14	19
W100–500 million ($1 million)	18	25	33
W500–1 billion ($2 million)	3	3	3
>W1 billion (>$2 million)	1	4	13

Contract amounts have increased sharply since 1976 due to plant exports as well as the localization of power plants. Yet the engineering service industry is not mature (Table 5). Perhaps less than a dozen firms are true engineering firms. Most have only one professional engineer. Of the 105 registered engineering firms, 35 architectural service companies, 16 electrical service companies, and 17 geological service companies can hardly be considered integrated engineering firms. Contract amounts represent only about 10% of the potential market for engineering services (estimated as one-tenth of total capital investment in industrial plants). The potential market for 1977–81 is estimated at $1.6 billion, or more than $300 million annually.

Korean engineering services have passed through three developmental stages (Fig. 7). The first stage was a period of foreign dependence in the 1960s, with package-type foreign investment and engineering services; local participation was restricted to some construction activities. The second stage in the early 1970s was characterized by the birth of domestic engineering services, helped by an accumulation of technical experience, the enactment of a promotion law, and an increase in plant construction. Some development was achieved in the areas of detailed engineering, procurement, supervision of construction, and project management. Construction technology was enhanced significantly. During the second half of the 1970s the foreign construction boom (especially in the Middle East) spurred the further development of domestic engineering services. Turnkey engineering services and plant construction by domestic firms became feasible, and some plant exports were achieved. Government

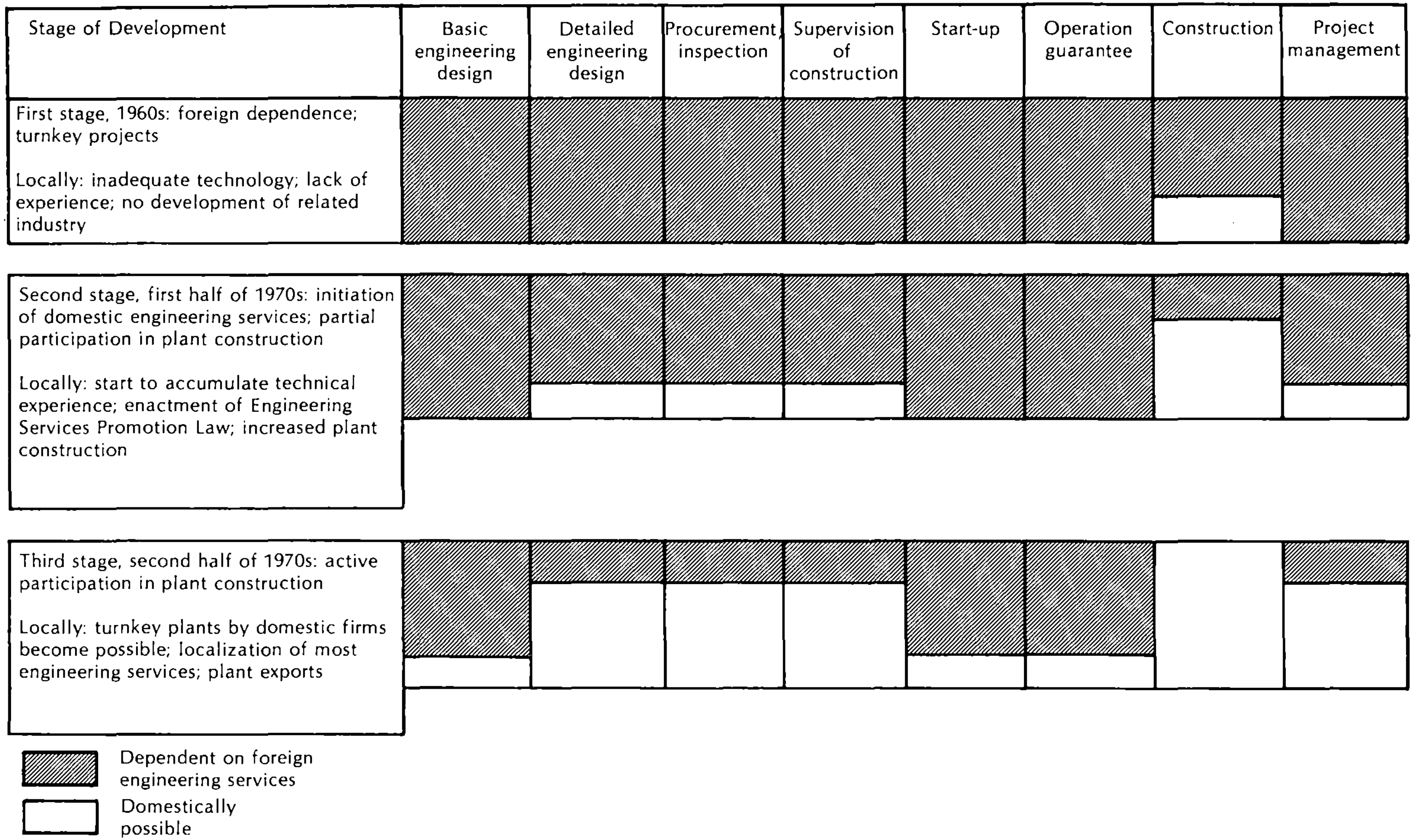

Fig. 7. Stages of development of engineering services in Korea.

intervention caused the localization of most engineering services, especially for power plant construction. A remarkable upgrading of domestic engineering services was, therefore, achieved except for basic engineering, start-up, and operation guarantee.

It is not yet feasible, however, for Korean engineering firms to construct various types of plants independently with only their own technical capabilities. A recent survey shows that plant construction capability is best for viscose textile plants, with 78.9 points out of a maximum 100, and worst for nuclear power plants with 28.9 points. Management and technical capabilities were examined for plant construction for 311 types of Korean industries and plants in terms of 33 factors such as R&D, plant operation, safety, planning, design, training, funding, machinery, start-up, construction, etc.

The future of Korean engineering is bound to be greatly influenced by plant exports tied to construction exports, which have grown steeply in recent years ($27 million in 1976, $400 million in 1977, and $800 million in 1978). Plant exports are bound to lead to the accelerated growth of the engineering services industry, and because of the low labour costs for engineers in Korea, it will be possible to compete internationally for engineering contracts.

Government Policy and Strategy

The profitability of the engineering services industry is very poor, mainly due to the uncertainty of demand. Government policy and strategy should focus on three issues to achieve the likely benefits and links from an expansion of this industry:

- The creation of demand for domestic engineering services and the guarantee of minimum profitability;
- The promotion and enhancement of engineering service, technical ability, and competence; and
- Balance of development with other related industries and realignment of environmental factors to promote domestic engineering services.

There are several causes for the slow development of domestic engineering services. An important one is the lack of demand resulting from the turnkey basis of plant construction. Other causes are the lack of capability for planning and feasibility study on the part of investors; the shortcomings of the domestic engineering firms themselves (lack of specialization, inadequate financing, poor knowledge of management techniques, small size, lack of credibility, and low engineering fees due to the excessive competition); the underdevelopment of related industries, especially the machinery industry, which is weak both in the quality of the products and in financing, i.e., provision of long-term loans especially for plant facilities. The competitiveness of the Korean engineering services industry is, therefore, far below the international level. It is difficult to solve these problems independently because they are interrelated and they overlap. This means that an action program should solve several problems at once. A systems approach is essential in analysis and promotion of the industry.

The Engineering Services Promotion Law, enacted in 1973 to promote the domestic engineering services industry, has two important features. First, it prescribes domestic engineering firms as prime contractors for domestic plant construction, except when there is technical inadequacy. This policy, aimed at creating a demand for engineering services, has not been effective in practice.[30] A second feature is that it encourages the undersized engineering firms to become large scale, specialized, and integrated organizations. The law sets minimum qualifications for registration: one professional engineer for a designated specialization, four registered engineers, and a set amount of capital or assets, now $40 000. These stipulations have contributed to the expansion of firms, but there may well be some adverse effects. Korea is now experiencing a severe shortage of high-quality personnel. For example, there are only about 600 professional engineers, and this number is far below present demand. Massive training programs such as in-house training, commissioned education at universities, and on-the-job or academic training abroad are urgently needed. Technical collaboration with engineering firms in advanced countries also seems necessary. Actually, several domestic engineering firms have joint ventures, and others have established a network for technical assistance.

Other policy instruments that might help the development of the engineering services industry in Korea are a fund for supporting domestic engineering services; tax incentives; credit incentives; creation of a trade association to support common interests and activities such as training, publications, etc.; drafting of a standard code for parts and plant facilities; support of exports of plants and engineering services, and development of personnel required for efficient engineering services. Basic to these is the voluntary participation by the engineering services industry as opposed to compulsory mandates by government.

ANALYSIS OF KOREA ENGINEERING COMPANY LTD

Although there are more than 100 engineering service firms in Korea, only 12 can provide authentic engineering services. One of the most important is the Korea Engineering Company Ltd (KECL), which was founded in January 1970 with the positive support of the Korean government, as an equal partnership, joint venture between the Han Kook Engineering Company Ltd of Korea and the Lummus Company of the United States. KECL is an integrated engineering and contracting company established in Korea to engage in plant design, engineering, water resource studies, etc. Whereas one of the original partners in the joint venture, the Lummus Company, is an engineering firm of world repute, the Han Kook Engineering Company was organized solely to serve as a holding company for KECL, with capital from the Korea Development Bank

[30] To help increase demand, the government is considering amending the foreign investment law to make it possible to separate capital investment and the engineering services embedded in the investment loan. Another policy alternative is to create a fund to support the preinvestment feasibility study or localization of plant facilities. It is reported that such a policy program has been successfully adopted in Brazil. The Korean government also has a program to promote the exports of plant engineering services and of complete plants.

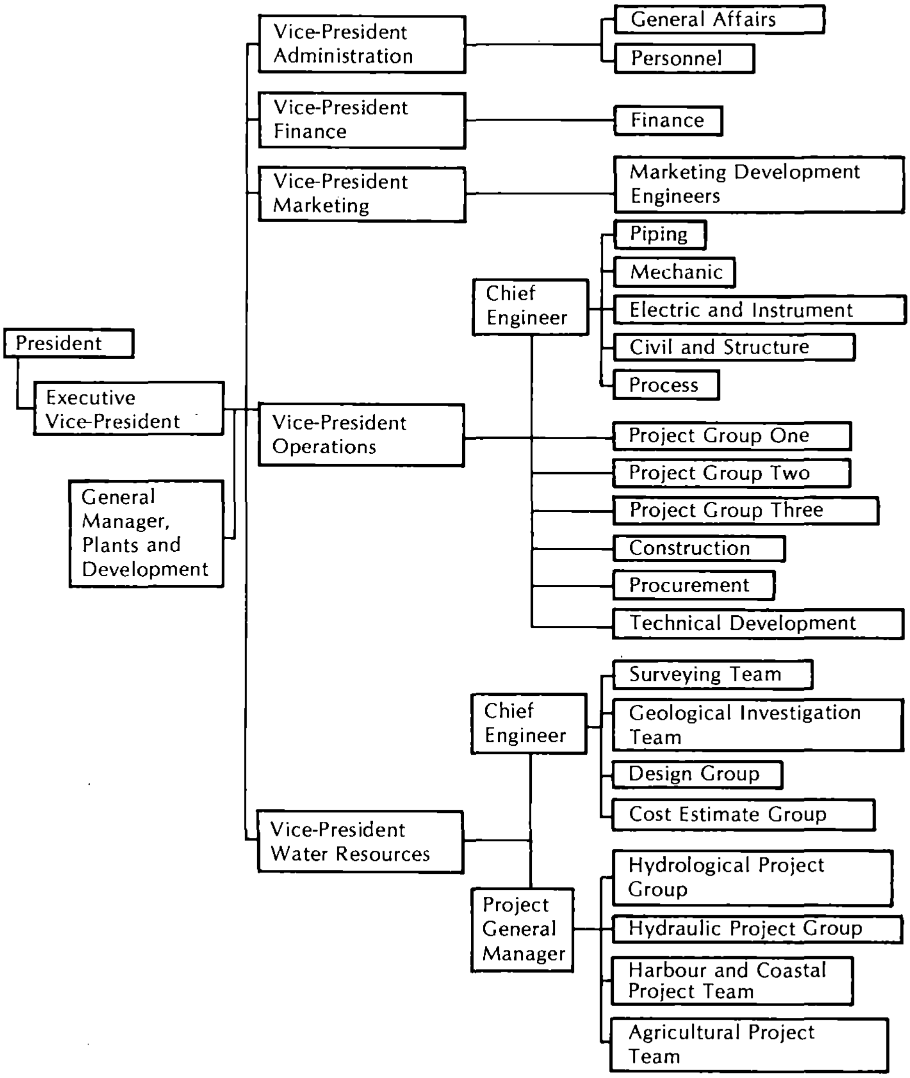

Fig. 8. Organization of KECL, 1978.

and from leading Korean enterprises such as the Sam Sung Company Ltd, Dae Woo Industries, and the Korea Institute of Science and Technology.

In September 1973 the Toyo Engineering Company (TEC) of Japan succeeded the Lummus Company as the KECL partner. TEC is also a world-renowned engineering company and has provided KECL with all available technical assistance. In April 1978 the Korea Development Bank sold its stock, 50% of the Han Kook Engineering Company's capital, to the Sam Sung Company, which has now become the majority owner of KECL. As a result, all of the large conglomerates in Korea now have engineering firms under their control.

KECL's organization chart is shown in Fig. 8. The firm has made available to its clients major services in the areas of plant and water

Table 6. KECL contract amounts in million won ($2000).

	1971	1972	1973	1974	1975	1976	1977
Contracted projects	5	3	6	27	6	17	20
Contract amounts	770	80	90	1622	390	1602	2330
Completion amounts	467	336	96	368	778	1490	2096

resource engineering, harbour and coastal engineering, irrigation, sewerage, and agricultural engineering in a reliable and expeditious manner, sometimes in collaboration with foreign CEDOs.

Because KECL was established in accordance with government policy and strategy, the government contracted actively with it during the first year. But in 1972 and 1973 the government offered no strong support, the contract amounts dropping to about one-tenth (Table 6). As a result, Lummus decided to withdraw, and Toyo Engineering Company became the substitute partner. Since 1976, KECL has performed at a reasonable level of activity because of the economic recovery and of its accumulation of experience and technical expertise. KECL is expected to grow rapidly now that a private enterprise, the Sam Sung Group, has assumed jurisdiction over it.

KECL's clients have mostly been Korean enterprises; a number of subcontracted projects have also been undertaken for foreign clients (Table 7).

One-fourth of the projects were feasibility studies and the rest, detailed design and engineering jobs. This means that KECL's technical capability and expertise have not yet reached the level of full-fledged engineering services. The number of engineering projects carried out by KECL is minimal compared with the total plant construction and engineering projects in Korea. Hence, KECL has contributed to the development of

Table 7. Breakdown of KECL engineering projects, 1971–78.

Type	1971	1972	1973	1974	1975	1976	1977	1978
Feasibility study	3	1	2	3	1	1	1	3
Detailed engineering including procurement and construction management	1		4	6	7	10	7	6
Detailed engineering including start-up	–	–	–	1	–	1	–	–
Basic engineering	–	–	–	–	–	–	–	–

Table 8. Distribution of KECL employees in mid-1978.

	Engineering and drafting		
	Permanent	Semipermanent	Administrative
Head office	247	125	32
Water resources office	28	25	3

the engineering industry as a pioneer, but its contribution to the development of Korean industry as a whole has not been high.

From 1971 to 1973 KECL had 66 employees. The number doubled in 1974 and doubled again in 1975, when it reached 238. Growth has continued at a slower pace, and in mid-1978 total staff was 460 (Table 8 and 9).

As KECL was founded by the Korean government, its marketing was done largely by the government at first. Despite strong government support, KECL experienced severe difficulties from the first moment. Its growth and development were hampered by the economic recession after the energy crisis. The path of KECL's development suggests that the engineering industry cannot be fostered only with direct government support. Indirect support or incentives to create a demand for domestic engineering services and to enhance engineering capability are almost essential. Because the quality and the efficiency of engineering services are crucial for plant production, most entrepreneurs still hesitate to use domestic engineering firms.

Table 9. Breakdown of personnel specialization in KECL, 1978.

	KECL staff	Semipermanent subcontractors
Project managers and engineers	24	1
Process engineers	10	–
Plant layout and piping engineers	20	–
Electrical/instrument engineers	23	–
Civil/structural engineers	26	–
Mechanical engineers	13	–
Agro-engineers	2	1
River engineers	11	2
Harbour engineers	1	2
Hydroelectric engineers	9	3
Water supply engineers	2	3
Plant facilities engineers	2	–
Procurement and inspection	5	1
Construction engineers/supervisors	14	–
Surveyors	3	14
Cost estimates and scheduling	10	–
Project control	6	–
Scale model engineers	6	–
Drafting personnel	88	123

Although KECL rates as one of the most capable engineering firms in Korea, it has many problems. A crucial one is a shortage of engineering and technical personnel. There are few qualified, experienced engineers, especially plant engineers; moreover, engineering colleges cannot completely prepare qualified piping and instrument engineers. Most engineers in KECL have come from chemical plants, especially fertilizer or petroleum refining. They lack plant design expertise like piping and instrument engineering, which is not usually taught in universities. The available electrical engineers are relatively competent and mechanical engineering can be done if appropriate blueprints are supplied. Most important, master planning for plant construction should be done locally, but the ability to carry out such an engineering service has not yet been developed. More effort should be put into providing internal as well as on-the-job training domestically or abroad. Culturally, knowledge such as engineering expertise has been regarded as private property in Korea. As a result, most Korean engineers are unwilling to exchange technical information or accumulate it systematically.

The future of KECL is uncertain, as is the future of the engineering industry in Korea, even though its growth potential is great. Now KECL has been transferred from direct government control to a renowned private conglomerate, the Sam Sung Group, its development seems promising, especially with the huge demand for domestic investment projects and great possibilities for plant exports.

PROJECTS

KECL carried out more than 60 engineering projects during 1971–77. Most were detailed design and engineering projects, which were difficult to execute in the early period but are now handled without difficulty. However, no basic design and engineering service projects have been carried out by KECL or other domestic engineering firms using only their own capabilities. Perhaps such a capability upgrading will be possible in the 1980s through collaborative efforts with high-risk entrepreneurship on the part of clients.

KECL has not failed in the execution of its engineering projects, so the two projects presented here have been successfully executed. The first deals with the construction of a styrene monomer plant and the other with the construction of an ABS resin plant. For comparison purposes, efforts were made to identify unsuccessful engineering service cases carried out by domestic or foreign engineering companies, but no data other than rumour regarding such failures were collected. As a compromise, a brief case study of a successful engineering project by a foreign engineering firm has been added for comparison.

CONSTRUCTION OF A STYRENE MONOMER PLANT

The styrene monomer plant project was initiated by the Niwon Company, which for various reasons could not carry on with it. Following government instructions, the project was taken over by the Korea Development Bank, which arranged to establish a firm, the Ulsan Petrochemical Company, with 75% of the investment made by the Korea Fertilizer Company and 25% by Niwon. The original idea was to obtain engineering services from Lummus using Monsanto's new process, but a shift was made to the Toyo Engineering Company of Japan because Lummus could not provide a suitable loan arrangement. Mitsui Company of Japan financed the project. As Toyo was a Mitsui subsidiary company, it was natural that Toyo should take the project's engineering services. As this was a lump-sum contract between Ulsan Petrochemical and Toyo, information concerning the specific amount allocated for engineering services is not available, but the total payment including foreign procurement and the engineering fee was $17 million. According to an informal source, the engineering fee was around $2 million (Table 10).

KECL provided two kinds of engineering services through two channels. One type was detailed design engineering, through a subcontract with Toyo Engineering, and the other was construction management, supervision of local procurement, and all the engineering services for the construction of an off-site building, via a direct contract with the client, Ulsan Petrochemical. The amount of the subcontract is not known, but the amount of the direct contract was around $600 000. KECL has a special relationship with both Toyo and Lummus, so it was not difficult for it to contract successfully. Also, KECL is in a good position for contracting for the engineering services on government-investment projects.

The preinvestment analysis for this project was prepared by Niwon. It was decided to entrust the engineering services to the Japanese company, Toyo, because of its capacity to provide financing. The choice of technology and equipment was thus naturally determined. Although Monsanto's new process was chosen as the basic process technology, Toyo exercised great influence on the foreign procurement, which is closely related to the choice of technology as well as to the localization of process equipment. It should be added that there were few alternatives regarding size, location, and product mix of the plant, because the Korean government already had an integrated long-term plan for the promotion of the petrochemical industry. Because of the extent of the investment, which could not be supported solely by the government, decisions on technical matters were not made prior to financing decisions. In other words, financing and loans took priority over all other problems. Thus, the technological choice had to be in accordance with financing or loan possibilities.

Because of government intervention in the procurement of process equipment, a breakdown into foreign and local sources was carefully made. As a result, Toyo was in charge of $17 million of foreign procurement, whereas KECL was responsible for $4 million of local procurement. Procurement services may be regarded as an advance in engineering services as compared with mere detailed design engineering, and they are closely related to the social efficiency of engineering services, i.e., contribution to the localization of equipment and machinery, balance of payments, employment, etc. KECL's role in procurement was the evaluation and recommendation of local vendors, supervision of vendor drawings, expediting of deliveries, etc. Actual procurement was made by the client, i.e., the owner of the plant, through direct contracts.

In addition to procurement services, KECL was responsible for plant construction management as well as the construction of an off-site building. KECL recommended the builders, supervised the progress and

Table 10. Data on engineering services for styrene monomer plant by KECL.

Project	
Client: Ulsan Petrochemical Int. Ltd	
Product: Styrene monomer	
Capacity: 60 000 t/year	
Location: Ulsan, Korea	
Period of services	
June 1976 – February 1978	
Scope of services	%
Basic design	–
Detailed design	70
Progress	100
Process design	–
Equipment design	5
Piping design	35
Civil/struc. design	30
Inst./elec. design	15
Project management	15
Procurement and progress: requisition, bid evaluation, vendor recommendation, expediting, inspection	100
Construction and progress: supervision, management	100
Foreign collaborators	
Process licencer: Monsanto	
Design collaborators: Lummus and Toyo engineering corporations	

Table 11. Data on engineering services for ABS resin plant by KECL.

Project	
Client: Lucky Co. Ltd	
Product: ABS resin	
Capacity: 6000	
Location: Yeosu, Korea	
Period of services	
September 1976 – October 1977	
Scope of services	%
Basic design	–
Detailed design and progress	100
Process design	5
Equipment design	12
Piping design	38
Civil/struc. design	20
Inst./elec. design	15
Project management	10
Procurement and progress: requisition, bid evaluation, vendor recommendation, expediting, inspection	100
Construction and progress: supervision, management	100
Foreign collaborator	
Process licencer: Japan Synthetic Rubber Co. Ltd	

completion of the building and plant, etc. It had little previous experience in construction supervision services, and this assignment allowed it to accumulate a significant amount of expertise.

As far as the efficiency of KECL in the production of engineering services was concerned, the project was completed within the target date, there was no cost overrun, and the cost of the styrene monomer plant was evaluated as reasonable or even lower than expected. The quality of the engineering services was considered to be good by the clients. Even though KECL thought the engineering fee was not sufficient, it did its best to build a good reputation, which would be helpful for long-term marketing.

ABS Resin Plant Construction

Whereas the styrene monomer project client was a government-owned company, the ABS (acrylonitrile butadiene styrene) resin project client was a private company, the Lucky Company for which KECL had earlier provided engineering services (the construction of a paste PVC resin plant). Because of KECL's good performance, Lucky decided to use

KECL's engineering services again. Like the Ulsan Petrochemical Complex located on the southeastern coast of Korea, the Yeosu Petrochemical Complex on the south coast of Korea was an offspring of Korea's industrial development plan. As Lucky is an integrated chemical firm and produces various types of resin products, the company decided to establish an ABS resin plant for high-quality resin products.

The KECL engineering services included planning and preinvestment analysis with the collaboration of the Lucky Company, detailed design and engineering, procurement services, and construction supervision. Basic design and engineering were provided by the Japan Synthetic Rubber Company, which was the ABS resin process licencer. Project investment was about $10 million, and the engineering fee for KECL was around $400 000. The engineering fee for basic design and engineering is not known (Table 11).

Japan was thought to be the best source of the technology because its resin technology was advanced, the language does not present a communication barrier, and it is geographically close to Korea. As the decisions on size, location, and product specifications had almost all been taken in advance by the Korean government, there were no alternatives on these aspects.

The level of technical sophistication for an ABS plant is lower than that for a styrene monomer plant. KECL was in charge of procurement services and detailed design and made great efforts to localize plant facilities and equipment. As a result, most items were obtained through local vendors, the exceptions being high-precision process, control, and electrical equipment that could not be produced domestically. Another reason for the high rate of localization was that the client financed the project itself, so fund utilization was not tied up. Although the basic design was done by the licencer, the Japan Synthetic Rubber Company, KECL made slight adjustments in the layout of the process and also provided detailed design and engineering, construction supervision, and the construction of utility facilities. KECL executed complete engineering services for the utility facilities from the basic design to guarantee operation and performance.

The construction of the plant was supervised carefully by KECL according to the engineering services contract. Because the technical level of the client firm's personnel was the best among Korean firms, there were no serious problems in the technical follow-up services. The completion target for the plant was easily met, and there was no cost overrun. The ABS resin plant is in good operational condition, an indication that the quality of the engineering services was excellent.

Construction of a Fertilizer Plant

A case where engineering services were provided by a foreign firm is noteworthy for comparison purposes. The Nam Hae Chemical Company procured the services for the construction of a fertilizer plant, one of the largest in the world, from the following sources: $52.5 million from the Korea Integrated Chemical Company, $17.5 million from Agrico of the USA, a loan of $103 million from the national investment fund, and $246 million in foreign loans. The general contractor for the engineering

Table 12. Data on plants of the fertilizer complex.

Plant name	Size	Process licencer
Ammonia	907 t/2 days	Kellogg, USA
Urea	1000 t/day	Toyo Engineering Co., Japan
Composite fertilizer	1080 t/2 days	Davy Powergas, USA
Phosphoric acid	660 t/day	Davy Powergas, USA
Sulfuric acid	1050 t/2 days	Chemico, USA
Nitric acid	180 t/day	Chemico, USA
Nitric acid (concentrate)	100 t/day	Chemico, USA
Nitrate	50 t/day	Chemico, USA

services was Fluor Engineers & Constructors, Inc., of the U.S. The main facilities of the fertilizer complex were eight plants (Table 12).

The Fluor Company was paid $42 million for the engineering services for the basic design, procurement, and guarantee of the start-up, operation, and construction. The contract was based on a fixed-fee-plus-cost method, i.e., a fixed fee of $42 million for engineering services including licence fees and construction costs and procurement costs as they occurred. The amount of $42 million for engineering services surpasses the total amount spent on engineering services by all companies in Korea in 1977. This does not mean that the engineering fee was outlandish; on the contrary, Nam Hae Chemical invited bids from all major international engineering firms. It does imply, however, that engineering services are important not only to the engineering service industry but also to industrial development as a whole. For example, total plant facilities and equipment amounted to $219 million, and only 27% of the total facilities and equipment were localized. In other words, foreign procurement amounted to $159 million, and the amount of local procurement was only $60 million. Although such a low percentage of localization might be attributed to the Korean manufacturers' lack of technical capability in the production of capital goods, the localization rate would have been higher if local engineering firms had taken the responsibility for engineering services. The project lasted 36 months, from February 1974 to February 1977. Three domestic engineering firms including KECL, as well as several construction companies, participated in the project through subcontracts. The quality of the engineering services, including duration and cost targets, was assessed as excellent.

Concluding Remarks

One crucial problem in studies of engineering services and engineering firms is the difficulty in hypothesis formulation. As suggested by Aráoz (1977), one must focus on the social efficiency of the engineering firm and its services as well as the productive efficiency of the firm. Finally, he suggests that the efficiency of engineering services distribution be considered. None of these criteria—variables are easily measurable, either qualitatively or quantitatively. One indicator or measure of social efficiency or utility is the contribution to industrial development. It is extremely difficult, however, to ascertain the effects of the engineering service separately from those of the investment project. If the engineering firm is involved in the project from the first moment of planning or preinvestment analysis, the effect of engineering services from the point of view of social efficiency would be large. If not, the effect would be minimal and could be adverse if there were failure in engineering services. To measure such effects is extremely difficult.

Productive efficiency is also difficult to assess, although less so than social efficiency. Productive efficiency should be considered in terms of both the engineering firm and the engineering services. The latter can be measured by cost target, duration target, and engineering service quality. Again, it is difficult to measure engineering service quality. The productive efficiency of the engineering firm as a whole must be gleaned from a general evaluation of the firm. One must borrow various evaluation tools for the purpose.

There are many factors or independent variables that influence the criteria–variables. The variables may be divided into uncontrollable (parameters or environmental variables), semicontrollable (policy variables or macrovariables), and controllable (project level variables or microvariables). It is best to develop a model that delineates all the interrelationships among the variables. Thus one can derive hypotheses regarding the engineering services and firms. Some basic data may be obtained through case studies. Without a set of such specific hypotheses, the subject can hardly be analyzed systematically. A comparative study for each variable or hypothesis is desirable. Without proper comparison, the result of research is mainly descriptive and not too helpful in the search for conclusions and implications.

The next important issue for the study of engineering services and firms in the developing countries is the analysis of the impact of engineering services at the project level. Emphasis should be put on the execution of the project, with a focus on the role of engineering services. Thus, it is useful to compare similar projects to distinguish various ways of using engineering services, and their effects. For example, the portion of in-house engineering services is probably more significant than that of engineering services supplied by independent specialized firms.

Finally, a longitudinal analysis of a specific industry with a focus on the role of engineering services is recommended as a research tool. The analysis of an engineering project across various industries seems to give less useful information than a longitudinal analysis. A combination of longitudinal and cross analysis is ideal. The longitudinal analysis, however, should be adopted only in the case of relatively mature industries; otherwise little information will result.

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CHAPTER 4

BUILDING NATIONAL CONSULTING ENGINEERING IN THE CHEMICAL INDUSTRY: A CASE STUDY IN BRAZIL

SERGIO ALVES AND RICARDO BIELSCHOWSKY

SUMMARY

Brazil is building up technical capabilities in areas of modern technology such as petrochemicals. This case study deals with NATRON, a private CEDO in this field, and focuses on the process technology acquisition and the state support for it. NATRON was founded in 1967 by a group of chemical engineers from PETROBRAS, the state petroleum company. It started life, therefore, with a set of highly qualified professionals, who had good connections with the expected main client, PETROBRAS. An explicit strategy was adopted regarding the areas to be covered, the types of services, and the technology to be acquired. The two principal areas were petroleum refining and phosphate fertilizers. The first one had to be left aside because PETROBRAS founded its own captive C&E capacity.

Three stages are shown in NATRON's development: (1) 1967–71: rapid growth; many small projects; peripheral installations. The staff grew to 172. In terms of technological learning, little progress was made in sulfuric acid; NATRON had a full-disclosure licencing agreement with a U.S. producer, and it undertook two turnkey sulfuric acid projects. (2) 1972–75: sales multiplied by five, staff by three. Contracts became larger. In 1975 NATRON took up a sulfuric acid project for SULFAB, a firm controlled by NATRON itself. Technologically, in this period it consolidated its sulfuric acid know-how by working on three projects and particularly through the creation of its Department of Industrial Processes (DIP). This is seen as an important step toward acquiring the know-how of the phosphate fertilizers complex. The main clients were two large state enterprises, which chose NATRON because they considered it as a technically capable firm. Although the rate of expansion was high, there were limitations to technological progress. There was not enough repetitive work, and more importantly, NATRON mainly worked as a subcontractor to foreign CEDOs, which gave it little bargaining power and did not allow it to obtain the full-disclosure clause that was needed to fuel a learning process in basic engineering. (3) 1976–present: a new stage has been entered, with a few large projects, of higher technical sophistication. There has been a concentration in the phosphate fertilizers area and a beginning in chlorine–soda production as a first step in the pulp and paper area. The staff increased from 583 in 1975 to 1184 in 1977, and the firm now feels it is able to "carry out all stages of engineering for productive units related to phosphate fertilizers."

Two important policies of NATRON were to retain its personnel, thus minimizing turnover, and to apply regularly a good part of its profits for the expansion of technical staff ahead of new tasks. The major investment in technology has been in phosphate fertilizers. The efforts have been successful, as shown by the prestige obtained and the recent contracts awarded. The firm has a clear determination about technological learning and a good sense of entrepreneurial opportunities. It chose an area of rapid growth where technological

autonomy was within reach of a medium-sized CEDO and adopted an adequate path for technological learning, from the simple to the complex. It started with sulfuric acid and should have gone on to phosphate fertilizers but a good opportunity was seized for mastering "ahead of time" the technology of phosphoric acid. By mid-1978 the firm was doing well in both phosphate fertilizers and phosphoric acid, with a group on each in its Department of Industrial Processes.

This report analyzes the successive steps in the mastery of sulfuric acid, which shows the gradual learning process: 1967: technology contract with U.S. firm, with full disclosure; 1968–70: two turnkey projects with the simple-absorption process; 1972: participation in large plant with the double-absorption process; 1973: creation of DIP; technological research program on phosphate fertilizers cycle; by 1975 the double-absorption process mastered; and 1973–75: turnkey project for simple-absorption process; 1975 to present: turnkey project for SULFAB, using the simple-absorption process with provisions for conversion to the double-absorption process; prime contractor for large sulfuric acid plant with German basic engineering; basic engineering, detailed engineering, and management services for a small plant with the double-absorption process; in 1977, same for a large project; in mid-1977 SULFAB started production and provided NATRON with a "permanent laboratory."

The sequence for the mastery of phosphoric acid technology started in 1973 with participation in a project. In 1976, NATRON was prime contractor of a large phosphoric acid project and could open up the package to a considerable extent. In 1977, it was prime contractor in another project, and with the full support of a forward-looking client, it chose a technology that allowed it to have full disclosure.

In the case of phosphate fertilizers, DIP has a unit devoted to study and to the acquisition of experience through reading, visiting plants, analyzing projects, and interacting with foreign experts. The lack of projects has been a retarding factor; however, NATRON has announced it is able to undertake complete phosphate fertilizers projects, including basic engineering.

This report describes the SULFAB project. In line with a clear policy to support and strengthen C&E in this area, NATRON was given a turnkey contract for setting up the plant. Its performance was good: the project was finished on time, almost within the budget, and the operating performance has been good. The participation of local industry, however, was not higher than the usual 25% of the total equipment that is normal in similar projects.

NATRON was helped financially to gain control of SULFAB, and this has meant a strengthening of NATRON and has given it the opportunity to expand C&E activities, draw on its permanent access to production facilities, carry out tests and research, and demonstrate its capacity to prospective customers.

This report underlines the key role of government through its purchasing policy and its financial support policies. This and NATRON's strategy of specializing in technologies that could be absorbed were the principal factors in NATRON's success.

The subject of this case study is NATRON in Brazil, the most important national CEDO specializing in chemical processes. Among the projects it has undertaken, one has been singled out for analysis: the complete design of a sulfuric acid plant for SULFAB, where NATRON saw the successful culmination of its efforts to master all stages of project design in sulfuric acid, which had been one of the principal strategic decisions taken at the time the firm was founded in 1967.

The study examines the steps followed by NATRON to achieve its present stage of development and attempts to identify through the examination of the SULFAB project what is the technical and entrepreneurial level effectively reached at present. It traces NATRON's evolution over the past 11 years regarding its expansion and the services it renders and appraises the strategy of expansion in its chosen field of phosphate fertilizers. Finally, the SULFAB project is analyzed.

BASIC ENGINEERING IN BRAZIL

The mastery of project engineering, and particularly its basic engineering component, seems to be affected by three groups of factors:

- The technological characteristics of the sector served — the universality and complexity of techniques, the technological dynamism, and the importance of technology as a marketing instrument (it is more difficult to attain mastery in techniques that are complex, known by few, highly dynamic, and a key to market control);
- The behaviour of public enterprise on questions of national technological autonomy; and
- The continuity of investments in the sector, the source of funds for expansion, and the level of the capital goods industry in the country.

These basic influences have combined in Brazil in recent years in such a way as to help it attain a good level of technical capability in two sectors, hydroelectricity and railways; in other sectors such as iron and steel, petroleum refining, and petrochemicals, the level is still low.

In hydroelectricity, roads, and railways, technology is largely traditional, and technical information is easily obtained. Local CEDOs predominate and are able to assume global responsibility for a project. In fact, projects have been exported in recent years. Public enterprises have generally adopted a policy of preferring local CEDOs, and in practice this has almost eliminated the presence of foreign-owned CEDOs.

In iron and steel, petroleum refining, chemicals, and petrochemicals, the technology is almost always under foreign control. Foreigners prepare the "basic" project even when a local firm is the prime contractor; the latter, in such a case, will only have — in addition to the opportunity of carrying out detailed engineering design — a better "post of observation" of the basic engineering tasks entrusted to the foreign CEDO. In iron and steel, where technology evolves slowly, the participation of local consulting and engineering in the main units, or the core processes, is usually confined to detailed engineering. The same is true in petroleum refining, chemicals, and petrochemicals, where dependence on foreign process engineering and basic engineering is even greater. In addition, technology in these sectors is highly dynamic, and it is a basic instrument for market control. This fact further restricts the possibility of achieving local mastery of technology.

The building of a national engineering capability in these sectors is of fundamental importance, but the necessary teams have been formed only recently. The most important one is CENPES, within PETROBRAS, the Brazilian state petroleum company. At present, CENPES is concentrating efforts on basic and intermediate units in petroleum refining, ammonia and urea for fertilizers, and petrochemicals. Among the private CEDOs, NATRON emerges as one of the three or four that are potentially capable of advancing into the areas of process and basic engineering. Its efforts are concentrated in the important field of phosphate fertilizers and their basic inputs, sulfuric acid and phosphoric acid.

EVOLUTION OF NATRON, 1967–78

NATRON was founded in 1967 by a group of chemical engineers from PETROBRAS; 11 years later it had grown into a solid and profitable chemical engineering enterprise, with almost 1300 employees. Three periods may be distinguished in NATRON's evolution: 1967–71, the initial period; 1972–75, when NATRON became medium-sized; and the period starting in 1976, when it became one of the largest CEDOs in the country.

Until 1971 there was a rapid growth, which took place through a succession of small projects. By that year the staff numbered 172. In 1972 sales grew sharply and were multiplied by five in 1975 in comparison with 1971, while staff tripled. The firm was able to create a technical nonoperational group, the Department of Industrial Processes (DIP), which would later show a high indirect profitability. Contracts became larger, and in 1975 participation in SULFAB was assured.

In 1976 a new stage started. The firm went on to work in a small number of large projects. Sales grew 113% in 1977. Staff grew from 583 in 1975 to 1184 in 1977; within this expansion, the highly qualified staff grew more than proportionally, showing a growing technical sophistication of the services rendered. The firm announced that it was able to develop all stages of the engineering services needed for various productive units in its priority sector, the phosphate fertilizers market.

Two more observations may be made. First, an explicit policy of NATRON was to retain personnel and minimize turnover. This policy, which was different from that of other CEDOs in Brazil, contributed to building its technological strength. Second, profits were regularly applied to a selective expansion of the technical staff ahead of new commitments. Whereas at first glance this gives the impression of an increase in current expenditure, it is to a large extent an investment in the most important asset of a CEDO. Finally, there has been a high rate of profit in the most recent contracts, and this, compounded by higher sales, has allowed the firm to invest heavily in human and technological capital.

MARKETS AND TECHNOLOGY

The firm's "project book" gives information on 49 projects, 12 of them still in progress. Only small consulting services are left out. The firm's markets are state petroleum and petrochemical enterprises (PETROBRAS/PETROQUISA); users of phosphate fertilizers including sulfuric acid, chlorine and soda, and others. No data were obtained on the value of the projects, but it is clear from general sales information that 1967 projects were small and grew in size over the years.

In 1967–71, there were many small projects for the state firms and "other" markets, covering many types of engineering services for "off-site battery limit." In terms of technological learning, not much progress was made toward basic engineering and process engineering in these various segments, because such progress would have required continuity in the same or similar tasks for the same process. But there was an exception: the preparation in 1968–69 of two turnkey projects for sulfuric acid units, for which NATRON had a licence agreement (1967–77) with a major foreign producer.

In 1972–75, NATRON consolidated its know-how in sulfuric acid production, with the development of the double-absorption process that had been introduced in the U.S. and Europe in the 1960s. For this it counted on DIP, and the opportunity of working almost simultaneously on three sulfuric acid projects. NATRON was starting to specialize, which it considered to be an essential step toward entrance into the phosphate fertilizers industry as a whole, and in fact the creation of DIP corresponded to the decision of advancing in technical knowledge in two basic areas, fertilizers (including sulfuric acid) and petroleum refining.

The latter area, however, was abandoned when it became clear that PETROBRAS would get directly involved in it. After the 1975 creation of CENPES, NATRON decided to concentrate its technological learning efforts in the fertilizer area.

The two state enterprises, PETROBRAS and PETROQUISA, were NATRON's main clients and accounted for 11 of the 17 projects contracted during this period. NATRON was frequently chosen by those clients because it was considered to be one of the two main national firms in the engineering of industrial processes (among some 20 CEDOs, of which several were foreign owned), on account of previous experience, technological level, financial solidity, and adequate prices.

NATRON had to expand continuously during its first 8–9 years, but there were limitations to its technological progress. These were partly a result of the variety of tasks undertaken, which involved little repetition; but they were principally because in most of the important, relevant projects, it acted as a subcontractor to foreign CEDOs, which were engaged as prime contractors by PETROBRAS as a consequence of a safety-first policy of this state firm. The policy greatly limited the possibility of transfer of foreign know-how to NATRON, which was left with little bargaining power and could not ask for a full disclosure that would allow a learning process in basic engineering.

From 1976 onward, NATRON's concentration in the phosphate fertilizer area has resulted in success. In 1976 and 1977, four of the seven contracted projects were in this market, and NATRON has had to double its staff. Also in 1977 production started in SULFAB, the sulfuric acid unit controlled by NATRON itself. Moreover, NATRON has become increasingly less dependent on the two state enterprises, as it has expanded into phosphate fertilizers and chlorine–soda.

Recently, NATRON has undertaken two contracts for chlorine–soda plants, products that are essential for the pulp and paper industry. It is likely that the firm will use these as a way to enter the pulp and paper industry market, where there is place for a local CEDO (most pulp and paper projects are now being absorbed by one CEDO of Finnish origin). The recent succession of detailed engineering projects, and the ability already shown by NATRON to absorb basic engineering know-how are favourable signs.

NATRON's main line of work is in phosphate fertilizer production, where it competes with subsidiaries of large foreign chemical engineering firms (Lurgi, Davy Gas Power) and with another local CEDO (EIM).

Strategy of Expansion and Technological Learning

The firm's founders envisaged two areas of expansion: one was in petroleum refining, a natural area for former employees of PETROBRAS, the state petroleum firm; the other was in chemical products related to the agricultural sector, especially pulp and fertilizers. The first area has been left aside, at least for the time being. The pulp area has not yet been properly explored, although a beginning has been made through the taking up of detailed engineering projects in chlorine and sodium. The major investment in technology of the firm has been in phosphate fertilizers, a successful venture as evidenced by the prestige acquired by the firm and the recent contracts awarded to it.

Looking back on NATRON's policy toward this sector, we note a clear determination regarding technological learning and a sense of entrepreneurial opportunity, shown whenever there was the possibility of an important qualitative jump. The firm made a good choice of its client sector, which grew rapidly during the last 10 years (about 25% a year in 1967–76), capitalizing on the expectations held in 1967 that large investments were soon to be made in phosphate fertilizer plants. So the market for NATRON's services could have reasonably been expected to be there, but there is another important dimension in the decision: the feasibility of technological learning by the firm.

To master a technology, one must make an investment. NATRON's choice of sector was adequate. The technology of sulfuric acid production is not too complex and is well known; it is therefore accessible to a local CEDO. Phosphoric acid production technology is also accessible, particularly if the purchasing power of state enterprises is properly used to support good procedures of technology acquisition. NATRON chose a sector where technological autonomy was within reach of a medium-sized CEDO, contrary to, say, ammonia, urea, or the FCC process, where mastery of basic engineering would have been hardly possible.

NATRON was also able to outline an adequate path for its technological learning. The strategy was to proceed from simple to complex — in this case, sulfuric acid to phosphate fertilizers to phosphoric acid. Good advance in sulfuric acid was made in 1967–76, and the next step would have been to initiate efforts in the second area. However, a very good opportunity came up for mastering the technology of phosphoric acid, and this altered the expected sequence. By mid-1978 the firm was making good progress in its technological learning in both fields and had two working groups in its DIP, one for phosphoric acid and the other for phosphate fertilizers.

A number of steps can be identified in the process of acquiring expertise in the sulfuric acid technology. It all started with a 10-year technology contract signed in 1967 with a U.S. firm, which included a full-disclosure clause. Two turnkey projects were carried out in 1968–70 with the simple-absorption process. After 1972, NATRON took part in a project for a large unit using the double-absorption process, where it undertook the general administration, including the coordination of foreign contractors, and carried out the detailed engineering of utilities and peripheral facilities. In 1973 it created its Department of Industrial Processes, which started a technology research program. In 1973–75, NATRON carried out a turnkey project for a medium-sized sulfuric acid plant with the simple-absorption process, and in 1974–75, DIP mastered successfully the double-absorption process.

In a final stage of technological learning, from 1975 onward, NATRON executed a complete project for a medium-sized plant for SULFAB (simple-absorption process to be later adapted to double-absorption). Starting in 1976, NATRON became the prime contractor for all engineering and project management services for a large plant with German basic engineering, which will enable it to absorb German sulfuric acid know-how. In December 1976 NATRON undertook all engineering and management services for a small plant using the double-absorption process, including for the first time the basic engineering. Since March 1977 NATRON has been performing management and engineering services, including the basic project, for a large sulfuric acid unit with the double-absorption process. Here a foreign expert was brought in because sulfur was being reclaimed from residual gases from copper refining. In the second half of 1977 SULFAB (where NATRON has equity control) started to produce sulfuric acid and thus became a "permanent laboratory" for the study of the process.

In sum, NATRON was able to make good use of technical and commercial opportunities. It was able right from the start to negotiate efficiently foreign technology, which it could absorb as it applied it in two projects. At the appropriate moment it created its own department for the study of processes, which allowed it to systematize the accumulated knowledge and provide a backing to the technological competence of the firm. In little more than 5 years it signed contracts for six projects, of which four were large; in two of these large projects, it carried out the basic engineering; in one it became the prime contractor, and in the remaining one it coordinated the foreign process. In the two smaller projects it undertook all engineering steps and also the project management.

With its last two projects, NATRON can be said to have completed its cycle of technological learning in sulfuric acid. At the same time it carried out a first phase of learning in the other products of the phosphate fertilizers industrial complex. In fact, technology absorption in phosphoric acid started in 1973 with the participation in a unit for sulfuric and phosphoric acid, where NATRON was coordinator of foreign contractors. Contact with the same foreign technology was repeated after 1976 through NATRON's participation in a project for a large phosphoric acid unit, as the prime contractor, and in this capacity it obtained a larger opening of the technological package.

A most significant step toward the learning of the basic engineering in phosphoric acid production was taken in 1977, with a contract that gave NATRON the responsibility for choosing the technology for a new unit and that would appoint it as prime contractor for the later steps of the project. This opened an opportunity that was efficiently used. NATRON's purpose was to choose a technology supplier, from the four principal companies in the international market, that gave the new unit a technology transfer contract with a full-disclosure clause, even though this technology had less tradition at an international level. The client, a state enterprise, went along with NATRON in this trade-off, as it had done in the case of a sulfuric acid project where the risk was smaller. The conscious position here was to enable the technological strengthening of national consultancy. (This enlightened attitude contrasts with that of another state client, which in a sulfuric acid project argued that NATRON did not have sufficient technical capability to undertake the basic engineering design and gave this to a foreign firm at three times the price.)

It can be said that by 1978, when this case study was made, NATRON was learning fast regarding phosphoric acid production, and in fact one of the two teams at DIP was devoted to this technical area. The other team was engaged in phosphate fertilizers, where there had been few opportunities to acquire experience; know-how was being gathered from the literature, visits to factories, analyses of projects to which access was obtained, and interactions with some foreign experts. Although the lack of projects has been a negative factor, NATRON has announced it is in a position to develop basic engineering in this area too.

THE SULFAB PROJECT

The SULFAB plant started operating in October 1977. NATRON's performance in engineering and managing the project has been very good, as measured by several indicators: work was finished on time and practically within the expected budget (other neighbouring chemical units built at the same time at the North East Petrochemical Pole were different in these respects) and has shown a satisfactory performance with hardly any technical problems. The project did not imply a higher than usual participation by local industry; the usual types of equipment were imported, amounting to about 25% of all equipment. The interest of the case study resides in the significance of the SULFAB project as a demonstration of the entrepreneurial capacity of NATRON.

COPENE, the North East Petrochemical Company, invited NATRON to take total responsibility for a sulfuric acid plant, including control of equity. This was a very good opportunity, technically and commercially. The participation of NATRON meant its strengthening as an enterprise, and a valuable economic support for the expansion and concentration of its consulting and engineering activities, which were subjected to the usual ups and downs of the trade. Strong financial incentives were offered. NATRON negotiated very well and got good support from industrial policy organs and from the government financial institutions. It argued that it would be strengthened as a firm, that through having permanent access to industrial facilities it would acquire a complete mastery of acid production from elementary sulfur, and that the plant would serve as a demonstration of NATRON's technical achievements, thus reinforcing the chances of obtaining new clients at home and abroad. NATRON's equity participation came from the engineering services it rendered and from an important loan by FINEP, which also participated in the equity along with other government financial agencies.

The 400 t/day plant employs the traditional simple-absorption process but is sufficiently flexible to be adapted to the more modern double-absorption process. NATRON took complete responsibility for the project, which was turnkey. This, plus its equity control, gave it permanent access to the plant, from which several advantages follow: a demonstration effect on possible clients (this has become the main advantage); a continuous optimizing and feedback of process data; the possibility of verifying in practice equipment, materials, operating costs, etc; the constitution of a permanent team to render start-up services to other sulfuric acid units.

Recognition of the experience acquired by NATRON was a decisive factor in its being chosen more recently to carry out two new sulfuric acid projects, in competition with well-known foreign suppliers. In fact, it is possible to perceive a clear favouritism toward NATRON by the state policy and financial organizations, an attitude that will no doubt be a constraint on enterprises that favour foreign firms for the work on new sulfuric acid units.

The SULFAB plant will be employed by SULFAB and NATRON for R&D programs, for optimization of processes, and in particular for the development of know-how that may allow local production of the catalyst. For such purposes, 10% of SULFAB's net earnings will be allocated to a "technical fund." The incentives granted to NATRON for participating in SULFAB were not dissimilar to those granted to other investors in the petrochemical complex being built. There was, however, an important aspect that merited state support, i.e., the strengthening of national engineering capabilities.

CONCLUDING REMARKS

The case of NATRON is of great interest as an example of concentration of efforts to achieve the mastery of process engineering in certain areas. It also shows the key role of government through its purchasing power and its financial support policies in favour of technological development. These instruments, appropriately used, did bring about favourable conditions for the advance of basic engineering capabilities. NATRON's success is based not only on its strategy of specializing in technologies that can be absorbed, a strategy that was favoured by a succession of similar projects, but also on the support it was able to obtain within government organizations, notably financial agencies.

CHAPTER 5

CONSULTING AND ENGINEERING DESIGN CAPABILITY IN THE PHILIPPINES

ECONOMIC DEVELOPMENT FOUNDATION (PHILIPPINES)

SUMMARY

The Philippines project was for the production of caustic soda and vinyl chloride monomer (VCM), owned by the MVC company (of 100% local capital). MVC had installed a small plant in 1965 and later expanded in 1970 and 1972. Its Planning and Projects Department (P&PD) outlined three alternative projects for a new VCM plant: petrochemical-based, petrochemical-cum-carbide, and carbide-based; the last was chosen, even though it was considered obsolete internationally, because it required a lower investment and used locally available raw materials (principally limestone and charcoal, the latter a labour-intensive product and thus socially desirable).

The company decided to undertake the project with in-house capacity, disaggregate it into core and peripheral technology, acquire the components from different sources, and use local consultants, equipment suppliers, and constructors where possible. This decision was justified by the past experience of the firm, the high cost of foreign C&E services, the many possibilities to procure local equipment of adequate quality and cost, and the access to extra tax incentives.

The main point was whether MVC could use its in-house capacity of P&PD plus plant engineers to manage the whole project. There was experience in soda–chlorine, acquired through former expansion projects, on aspects of basic flow process design, detailed engineering, bidding for suppliers and equipment, bid evaluation, installation, and construction management. Furthermore, P&PD had carried out a desk research program, exhibits had been regularly attended, and its members had been exposed to the latest technology and equipment. As a result, management was confident that the project could be undertaken solely with in-house resources.

P&PD prepared the basic engineering of the project, and a technology survey was started. Lists of equipment were prepared, and lists of suppliers were drawn up from catalogues, referrals, publications, and information gathered at international exhibitions. A team was organized to survey and choose equipment by visiting manufacturers and users in several countries. These activities took 3 months, and a bankable feasibility study was prepared during February–March 1974. By August 1974, this had been registered by the Board of Investments and the project was then eligible for a number of incentives.

The cost of the project was about U.S.$30 million, of which one-half was available locally. A loan was requested from the International Finance Corporation, which required that the company should have an accredited foreign CEDO to undertake the management of the project, a condition that was not accepted by the company. Putting together the financial package was lengthy, because several different sources had to be used. This took from February 1974 to August 1976.

Some comments may be made on the contracting and unpackaging of technology. Detailed engineering was subcontracted, so that the company could avoid hiring people expressly for the task, only to be dismissed afterward. A local CEDO, TECHSERVE, was engaged. This firm had extensive experience in the petrochemical field, and MVC had already used its services. MVC used the bidding process of the Philippines Development Bank, which strengthened its negotiating power. Most standard items of equipment were locally supplied. Local contractors carried out the civil works, some peripheral installations, and instrumentation. Construction management was undertaken by SERETE, a French firm, as required by one of the funding sources.

In 1977, MVC was asked by the government to reduce the output of its projected plant to one-third the original capacity. VCM production was thus made uneconomic, and the VCM plant was postponed. The company decided to concentrate its project in chlorine–soda production. It became necessary to reformulate the project accordingly.

P&PD was responsible for overall project management. SERETE got four expatriates to supervise and inspect construction activities, affording a good training opportunity for the 10 MVC engineers who worked with them. Installation of equipment and the construction activities were carried out by a local firm. Some MVC engineers went overseas for training. It was expected that the new plant would be commissioned in early 1979.

The local CEDO engaged in the project, TECHSERVE, was founded in 1970 by two recently retired professionals with 15 years' experience in Caltex and Union Carbide; the idea was that these partners would work as subcontractors for Caltex projects. TECHSERVE's technical capability is based principally on the know-how and experience of the founders, who have acquired their expertise in the petrochemical industry — a good basis for work on any chemically based process industry. The firm has no links with foreign CEDOs.

By 1973, the staff had grown to some 30 engineers, the present complement. The firm has hired fresh college graduates and has trained them on the job for periods of 3–4 years. The turnover, however, has been high, perhaps because of moderate salaries and distant work locations. Most of the staff members have specialized in three areas: mechanical engineering/piping/equipment; chemical process engineering; and electrical/instrumentation. A few of them are in civil/structural/materials. Very specialized skills have been obtained from consultants.

Services rendered range from chemical process flow design to detailed engineering work. The main service lines are detailed engineering and project management. About 30 major projects have been carried out since 1970. Services usually start with detailed engineering, go through the preparation of bid documents, and include advice on the evaluation and selection of suppliers and contractors — in particular, the identification of local ones, which usually results in lower investment costs — as well as assistance in project management.

The firm gives on-the-job training to its clients' engineering staff — this was notable in the case of MVC — including the transmission to them of engineering standards and formulas.

Among the constraints on growth are a limited market, the lack of senior qualified staff, and the fast turnover of trained staff engineers. The principal market is Caltex, which has confidence in the two partners, but market expansion is difficult because of limited acceptance of local CEDOs. This is a reflection of two extreme attitudes: risk aversion (little confidence in local CEDOs — foreign ones are employed even though they cost four to eight times as much), or risk taking (many enterprises do not spend on C&E services, feeling they are unnecessary or too expensive).

This study examines the development of a well-established CEDO in the Philippines, its characteristics and activities, and the environmental influences on it. As a corollary to this, an analysis of an industrial investment project in which the CEDO had a significant participation is presented. Essentially, the case study focuses on the analysis of the cause-to-effect relationships as they influenced the decisions affecting the characteristics of the CEDO and the development of an industrial project. The research work itself was useful as a learning process and provided a tentative framework for a full-scale study of CEDOs.

The major sources for data and information were documents, reports, and personal interviews. Four sets of questionnaires were employed, dealing with characteristics and operations of CEDOs, development and implementation of industrial projects, impact areas of CEDOs, and impact areas of industrial projects. Five business firms were selected as prospects for the CEDO case study. Three of them were CEDOs involved in civil, mechanical, and electrical work, and the other two were primarily civil construction companies. The research team gathered knowledge about these firms and conducted preliminary interviews with their principal officers.

The search for a suitable investment project to be studied required interviews with officers of three chemical processing firms. The integrated caustic soda and vinyl chloride monomer (NaOH-VCM) project of Mabuhay Vinyl Corporation (MVC) was chosen as the subject of the project case study. Major factors considered in the choice of MVC were: access to and cooperation of MVC's top management; its being an ongoing project, which was not turnkey; this meant that decision points were significant and researchable.

It was then decided that the subject of the CEDO case study should be Technical Services Philippines (TECHSERVE), a small group of professional engineers that undertook the process detailed engineering of the MVC project. Extensive interviews were conducted with the top executives and project staff of MVC regarding the caustic soda-VCM project, and with the head of TECHSERVE. Interviews were also conducted with other units, principally the Board of Investments, the Central Bank, the Development Bank of the Philippines, the Private Development Corporation of the Philippines, and SERETE Consultants. These were to verify information because each source was prone to bias to protect its own interest.

The results of the interviews and research of TECHSERVE and MVC were synthesized, analyzed, and documented as case studies. These case studies included not only factual narration but also integration of opinions and analysis of the interviews, particularly regarding the decision points and their influences. Validation interviews were then conducted with MVC and TECHSERVE, based on the draft case studies, to verify case contents, incorporate additional feedback, and finalize the case studies.

Moreover, the results of interviews with the DCCD Engineering Company and with LMG Chemicals were written up as preliminary case studies, because it was felt that they provided information regarding other modes of technological activities; that is, DCCD exemplifies a typical CEDO in the fast-growing construction sector, whereas LMG's project represents a typical case of turnkey technology importation.

Based on the analysis of the four cases, we identified important research issues regarding CEDOs, and the extent of their influences and implications is briefly described in the last section of this chapter. It was concluded that none of the government policy instruments had any significant influence on the development and operation of CEDOs, except for the Oversea Construction Act. The only notable effect of government policies has been to induce development in the production sector, which in turn would have enhanced the engagement of CEDO services. Nevertheless, some policy instruments that may have had an indirect effect were:

- Investment Incentives Act, 1967 (RA 5168). To encourage Filipino and foreign investments (that are in line with development policy), with various incentives for registered enterprises and "pioneer" enterprises (tax exemptions, accelerated depreciation, antidumping protection, loan facilities, tariff protection for pioneer industries, etc.). It is administered by the Board of Investments (BOI).
- Foreign Investments Act, 1968 (RA 5455). To regulate entry of foreign investments greater than 30% of stock; BOI evaluates proposals in accordance with the existing laws and national economic goals.
- Export Incentive Act, 1970 (RA 6135). To promote exports of services and manufactures using domestic raw materials to the maximum extent. 60% of capital should be Filipino and 50% of sales should be export sales. Tax benefits and increased deductions over those of the Investment Incentives Act.
- Developing and Regulating the Overseas Construction Industry, 1977 (PD 1167). To provide opportunities to export materials, labour skills, technical and managerial expertise in the construction sector, with incentives to Filipino overseas contractors: foreign tax refund, accelerated depreciation, tax benefits for labour training, net operating loss carryover for 3 years.
- Amendment to Patent Law, 1977 (PD 1263). To meet the demands of national development, establishing approval of licence contracts by the Technology Resource Center, a limit of 5% royalties on sales, nullifying restrictive clauses, and establishing the possibility of compulsory licencing.
- Central Bank Circulars 365 and 393, 1973. To regulate, respectively, repatriation of foreign investments and remittance of profits and dividends, and approval of royalty/rental contracts and remittances of royalties/rentals.

AN INVESTMENT PROJECT OF MABUHAY VINYL CORPORATION

Mabuhay Vinyl Corporation is a Filipino-owned firm, producing since 1961 PVC resins, vinyl chloride monomer, hydrochloric acid, caustic soda, and PVC compounds. MVC's first PVC and caustic soda project was financed by a $2.1 million loan from the Philippine War Reparations Commission. The plant, located in Iligan City, was completed in late 1965. It was designed to produce 6000 t/year of PVC resins and 5000 t/year of caustic soda. In 1970, the firm undertook a ₱2 million expansion, which increased the plant's capacity by 60%, followed by a bigger expansion in 1972 involving a capital outlay of ₱12 million, increasing capacity to 9000 t/year of vinyl chloride monomer (VCM). In that same year, MVC's Planning and Projects Department (P&PD) further increased PVC capacity to 28 000 t/year through infusion of technology and other innovations with minimal investments.

Project Conceptualization

Vinyl chloride monomer is the major raw material in PVC resins. With the PVC expansion in 1972, the plant operating at full capacity required around 30 000 t of VCM; as only 10 000 t were being produced by Mabuhay, the company's Management Committee directed its Planning and Projects Department to study the different processes of producing VCM and to compare their financial viability against that of importation, taking into consideration other factors such as the reliability of world supply and the inevitable price increase of VCM on account of the oil crisis.

P&PD developed three alternatives, which employed respectively the petrochemical-based process, the petrochemical–carbide-based process, and the carbide-based process.

The carbide-based VCM process was chosen because, although considered obsolete internationally in view of advanced developments in petro-based technologies, it required a lower investment and used major raw materials (charcoal and limestone) that were available locally. This choice was supported by the Development Bank of the Philippines, which noted that the production of charcoal would require considerable land and labour in the agricultural sector, the use of which was in line with one of the major developmental thrusts of the government.

Project Planning

Several questions were raised by MVC's management regarding the source of consulting and engineering services and the way in which technology would be acquired. MVC's past experiences with its initial PVC plant and subsequent expansions had implications for decisions in four areas:

- Turnkey or unpackaged technology. MVC's first PVC plant, acquired on a turnkey basis, encountered numerous problems, especially when an attempt was made to increase the normal capacity level. Debugging activities of MVC's engineers revealed that the unbalanced design of the whole production system permitted production only at a normal level. Any further increase within its rated or maximum allowable level would subsequently produce overflows or bottlenecks. Furthermore, MVC's engineers in the process of debugging and dismantling certain subsystems of the PVC plant discovered that certain equipment and materials were either locally available or could easily be made locally.
- Use of expatriates. Expatriates' professional fees are normally eight times higher than local consultants' fees — an amount that excludes incidental charges such as overseas travel costs, living expenses, and others. These usually total a large amount of money, usually in foreign currencies and add greatly to the project cost.
- Locally available equipment and materials. Through MVC's exposure in the initial plant installation and expansion programs, MVC found that

locally fabricated items were comparable to imported ones, with the former having an added feature of shorter delivery time. More important is the lower cost of locally manufactured equipment plus the tax credit incentives provided under existing legislation.

- In-house technical capability. The final area was whether or not the Planning and Projects Department together with the line engineers could manage the total project from planning (front and tail engineering) to project management, implementation, and control. P&PD's experience was basically in MVC's earlier expansion, covering the front and tail engineering, which included basic flow process design and detailed engineering, suppliers and equipment bidding and evaluation, and actual installation and construction management. P&PD also conducted continuing research of journals, periodicals, and other technical publications. Regular attendance at international science and suppliers' fairs by P&PD and line engineers had exposed them to the latest technologies and equipment.

With these experiences, MVC's management was confident that it could undertake the project solely with in-house resources and decided that the VCM project should be undertaken by its own P&PD and line engineers; that the entire VCM expansion project should be disaggregated into its core and peripheral technology components, for acquisition from different sources depending on their quality and reliability; and that use of local consultants, equipment suppliers, and constructors should be the first consideration before use of foreign expatriates and imported equipment.

PROJECT OPERATIONALIZATION

The front engineering, which entailed the design of the basic flow processes, was prepared by P&PD. The basic engineering process included the materials and energy balances and required quality and specifications of process outputs including general instrumentations.

The items of equipment came out of the basic engineering flow process designs, and a listing of respective suppliers (local and foreign) was prepared. The listing was based on publications, suppliers' catalogues, referrals, and information acquired in international fairs.

A five-person team was organized to survey and inspect needed equipment and to negotiate with suppliers for acceptable terms and conditions. The members of the team included the firm's president and vice-president, one of the directors, the construction superintendent, and a senior project engineer. The team started its work in November 1973 and visited India, Japan, the U.S., Germany, and France. The team was guided mainly by three factors: guarantees on reliability of equipment; equipment costs, financial terms, and conditions; and delivery date. The team traveled extensively and inspected equipment in actual operations, inquiring from users about the reliability (quality and specifications of outputs) of such equipment. In early 1974, the team arrived back in the Philippines.

With relevant information on equipment price, terms, and payments serving as background, a bankable feasibility study was prepared. The marketing group of MVC together with P&PD prepared the market study, which showed basically the demand–supply forecast and analysis of VCM, caustic soda, HCl, chlorine gas, and liquid chlorine. P&PD prepared the technical aspects, which involved the basic flow process and the equipment requirements. The financial study was prepared by P&PD, with assistance from MVC's finance group, and included financial statements with financial and ratio analyses.

Registration was applied for in March 1974, and the project was approved by BOI in August 1974. After being registered, the project could apply for fiscal and other incentives, which often determine whether a project is financially viable. The incentives awarded to MVC as provided by BOI's Incentive Act (RA 5156) were tax credits on domestic capital equipment and withholding tax interest; tariff exemptions on imported equipment; tax deductions for capital reinvestment and net loss carryover; accelerated depreciation; and double deduction of preoperating expenses.

Total funds required for the project were ₱260 million, which included a foreign currency (U.S. dollars) requirement amounting to $14.2 million or just under 40% (in 1974, U.S. $1 was equal to ₱7.15). The finance group of MVC took charge of securing the necessary funds from all sources available at reasonable rates and conditions. It eyed the World Bank–IFC as one source, thinking that with IFC's approval of a loan, it would be easier to secure other funds. However, IFC insisted that MVC have an accredited foreign CEDO to undertake project management of the VCM project; its unwillingness to fund the project, according to one of MVC's key officers, was a result of its previous experience with a local construction/consulting firm that bungled an industrial project.

In the end, the ₱260 million was secured from the Development Bank of the Philippines, $6.6 million; Private Development Corporation of the Philippines, ₱19.0 million; Trident International Finance Ltd, $2.2 million; Bank Dreyfus, $3.5 million; Manila Banking Corporation, ₱10.0 million; City Corporation, ₱15.0 million; and the balance from cash generated by MVC's operations. The syndication of loans started in February 1974 and was completed in August 1976. The Private Development Corporation of the Philippines (PDCP), a private financing institution with its main thrust in financing development-oriented projects, offered its services to package the loan for MVC as early as April 1974. MVC declined because of the high service charges involved. There was a 2-year delay in completing the total loan package, and a consequence of this delay, according to PDCP, was opportunity costs that MVC incurred in its inability to cash in on the VCM market as programed.

The French financial package extended by Bank Dreyfus required that 85% of the loan should be used for French equipment and services.

Contracting and Unpackaging Technology

Additional technical personnel were needed for detailed engineering. The option of hiring technical people just for this aspect of the project and maintaining them after the work had been completed was deemed too costly; hiring foreign consultants likewise was considered too great a burden on project funds and was in conflict with the management policy of using local expertise whenever possible. TECHSERVE, a local consulting and engineering design organization, was contracted by MVC to do detailed engineering for the brine purification, power substations, refrigeration plant, air compressor plant, instrumentation, electrical works, civil works, and hydrochloric acid plant (this last, in collaboration with a foreign company). Detailed engineering for the electrolysis, evaporation, and liquid chlorine plants was performed by foreign firms, but TECHSERVE took charge of equipment and instrumentation installation and supervised local equipment fabrication. MVC hired TECHSERVE's services, considering the latter's extensive experience in the process and detailed engineering in the petrochemical industry. TECHSERVE had previously been hired by MVC to undertake the basic process design and detailed engineering for the manufacture of acetylene black.

MVC decided to accept bids for the supply of all equipment (local and foreign) in compliance with the requirements of the Development Bank of the Philippines. Equipment bidding enabled MVC to attain the most advantageous prices and terms of payments, early delivery dates, and better guarantees on quality and service features.

Local fabricators supplied most of the standard equipment such as atmospheric and pressure tanks, stainless and mild steel, heat exchangers, distillation columns, flow reactors, filters, strainers, water-softening equipment, and rubber linings. Use of local fabricators enabled MVC and the local suppliers to acquire tax credits as specified in BOI's incentive program. MVC decided to handle directly the importation of certain construction materials, such as special pipings, valves, and fittings, even though they were available locally through trading companies. This decision meant MVC could take advantage of BOI tax incentives on imported materials and equipment, but it also entailed hidden costs because the VCM plant construction schedule was delayed by 3 months due to the delay in the release of the imported materials from the Bureau of Customs.

All civil works jobs were awarded to local contractors. Engineering Equipment Incorporated (EEI), a local construction and fabrication firm, won most of the contracts of the VCM project and supplied all the necessary local construction materials. Contracts included the electrolysis and evaporator structure, HCl substation, refrigeration, air compressor, pipe racks and foundations, installation of all piping, equipment and wiring, distribution transformers, and motor control centres. Minor civil works contracts were awarded to contractors close to the plant site.

Site grading and development were awarded by MVC and P&PD to the lowest bidder, F.F. Cruz; this work included relocation of existing pipelines and provisions for a new water supply line from Mimbalut Creek. Instrumentation was awarded to a local firm — Process Instruments Designers (PID) Inc.

SERETE S.A. of France was contracted to handle the construction management of this project. SERETE introduced MVC to French financing firms — an act that eventually led to the securing of a $3.5 million loan from Bank Dreyfus in 1976. Although local construction management and engineering firms were available, SERETE's services were secured primarily due to the French loan requirement.

Project Replanning

In 1976 the Board of Investments sent a letter to Mabuhay Vinyl Corporation reducing VCM production from 30 000 t to 10 000 t on account of a government-supported project (Asian Petrochemical Development Corporation — Hooker) establishing a petrochemical complex with 150 000 t VCM as one of its product lines. In April 1977 BOI formally amended MVC's registration to produce 10 000 t VCM and 6000 t liquid chlorine. Some equipment items had already arrived, with others in transit; most of these items were not standard but were built to MVC's earlier specifications. This move placed MVC in a quandary.

The Planning and Projects Department immediately undertook studies and came up with two alternatives: to continue with the VCM project with a 10 000 t/year capacity or to establish a caustic soda (NaOH) plant, which was a subsystem of the total VCM plant. P&PD studies showed that it would be highly uneconomic for MVC to produce 10 000 t VCM with a plant designed for 30 000 t/year. Thus, the NaOH plant was considered to be the best option. This plant would produce concentrated hydrogen chloride, liquid chlorine, chlorine gas, and caustic soda. Furthermore, the other two firms in the country producing caustic soda, with locations within Metro Manila, were faced with possible closure or complete relocation as a result of new government pollution regulations.

The NaOH plant would include the following subplants: 23 500 t/year caustic soda plant using the diaphragm process; 20 500 t/year HCl synthesis plant; 6000 t/year chlorine liquefaction plant; and 10 000 t/year VCM plant using the conventional carbide route process (this phase was deferred). P&PD recommended a diaphragm-type cell instead of a mercury cell for its electrolytic plant because of a possible mercury pollution problem.

The NaOH project involved a total cash outlay of ₱170 821 million, with a revised financing scheme: Trident, $2.0 million; DBP, $5.0 million, ₱19.0 million; Dreyfus Coface, $3.5 million; PDCP, $1.8 million; Citibank/FEATI, ₱10.0 million; new equity, ₱30.0 million; and internally generated funds, ₱19.8 million.

VCM's Board decided, in line with P&PD's recommendation, to postpone the VCM plant and instead to continue with the caustic soda plant. In fact, the decision proved favourable to the company, for in the latter part of 1977, the world price of VCM declined due to the dumping of chemicals by the developed countries.

Project Implementation

This responsibility was entrusted to P&PD, which worked partly from the Manila headquarters (with P&PD's vice-president, who was the overall project manager; an engineering superintendent; a technical services officer; and a draftsperson) and partly from the plant site (with a coordinator, two senior and two junior engineers, a civil works inspector, and warehouse staff). They worked with SERETE personnel that handled the construction management and with the project constructor from EEI.

On matters of problems in chemical processes and piping designs, P&PD had the final word. Likewise P&PD reviewed all recommendations of SERETE. However, when problems arose from detailed engineering designs, they were brought to TECHSERVE as one of the conditions of the service contract. SERETE's role was in the construction management of the NaOH–VCM plants. It supervised and inspected the work of EEI for conformity with detailed engineering specifications and budgeted costs. It submitted feedback sheets to P&PD for appropriate action on construction problems, revisions in detailed engineering designs, and other relevant matters. To ensure that installations were properly made, SERETE conducted water tests to determine piping connections and flow.

SERETE's project organization was composed of four French expatriates and about 10 Filipino technical and clerical staff members. SERETE originally planned for an all-French staff; however, MVC pointed out that local expertise in both clerical and technical fields was available right in MVC's own organization. MVC granted leaves of absence to employees who were assigned to SERETE and requested SERETE to maintain the salary scale so that the overall MVC salary structure would not be disrupted. Aside from the savings in project costs, this move provided MVC staff with exposure that enhanced in-house technical capabilities. SERETE commented on the quality of the detailed engineering prepared by TECHSERVE, stating that some aspects of the designs and specifications were inadequate, such as provisions for supports of certain pipes or instruments and others. EEI noted the same weaknesses. TECHSERVE agreed but maintained — and was backed by MVC — that these were extremely minor in nature and could easily be revised.

EEI was responsible for civil construction and equipment installation. There was a 3-month delay in relation to the schedule, which was basically due to a delay in importing construction materials and the fact that there were contracts for each phase instead of one general contract for all phases, which limited EEI's flexibility in allocating construction materials and assigning people to certain work areas in the construction of the plant.

MVC's engineers were sent overseas to be trained by equipment suppliers on operations and maintenance. Furthermore, vendors' representatives were assigned to the project site to assist in the proper installation of the equipment. Three line supervisors (one chemical and two mechanical engineers) from MVC's other plants were assigned to the project, to assist and observe the installation and construction of the plant. These engineers would eventually assume positions in the actual line operations of the NaOH–VCM plant.

COMMISSIONING

The plans were that representatives of equipment vendors and suppliers would commission the respective plant for proper turnover to MVC. This was to be done with representatives of MVC and the Development Bank of the Philippines present during the commissioning stage, following a policy of the Bank.[31] The project was expected to be operational by early 1979.

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[31] The purpose of the policy is to ensure that quality and other specifications of equipment output/product are being met according to agreements. It was adopted because of past experience; in some earlier DBP-funded projects, the desired quality, volume, and other specifications were not attained after the commissioning stage. Furthermore, DBP would not release final payments unless all contract conditions had been fulfilled.

The Local CEDO: TECHSERVE

Technical Services Philippines was organized in November 1970 as a partnership between Juanito M. Andres, a chemical engineer, and Francisco Jimenez, a mechanical engineer, after about 16 years of technical work in Caltex and Union Carbide respectively. These two highly experienced technical engineers had retired, but both felt they still had many more productive years ahead of them and could increase their income with their wide engineering experience by catering to the engineering and technical requirements of the Bataan Oil Refinery Plant of Caltex (Philippines), particularly for its various plant expansion and modernization projects. This was considered feasible because Caltex had found it more manageable and economic to subcontract technical work than to maintain an expanded engineering staff or commission foreign consultants. No feasibility studies or long-term plans were prepared by the partners at the formation stage of the partnership because both viewed the venture as a short-term project-to-project existence with Caltex.

TECHSERVE started with a team of six engineers, including the two founding partners. The team was organized in December 1970, when the first project was contracted with Caltex (the engineering design and project management of a cooling tower with a capacity of 25 MM BTU/h). The staff numbers grew as more projects with Caltex were contracted. In 1973 there were 30 engineers, and at present there are 25 permanent staff members and six consultants.

In its first year of operation, TECHSERVE's gross revenue was ₱250 000. By 1977 it had doubled. Most came from Caltex contracts. The expected revenue for 1978 was about ₱750 000.

Organization

TECHSERVE is headed by a managing partner who handles all the administrative requirements of the organization, such as signing of contracts, personnel recruitment, collections, and specialized technical and engineering work. The other partner functions as the operations manager, responsible mainly for implementing and coordinating the projects being undertaken. The rest of the staff is composed of senior engineers, junior engineers, and draftspersons. The engineers cover fields such as mechanical/piping/equipment, chemical/process engineering, electrical/instrumentation, civil/structural, and materials, with the majority of the staff working in the first three fields. To augment its capability, TECHSERVE has a group of on-call consultants in specialized fields.

Technical Services

TECHSERVE basically provides engineering design services ranging from chemical process flow design to detailed engineering work. The services encompass process design and cost estimation; detailed process flow charts with material and energy balances; plant layout; piping isometrics and orthographics; and civil, mechanical, and electrical engineering detailed design. The group also offers management services, such as preparations of bid specifications and invitations, bid evaluations, contract awards, materials procurement, technical training, cost control, design interpretations or revisions of project constructions and installation, start-up assistance, and other phases of project management.

The firm has so far completed about 30 major projects. These range from utility surveys to operator training programs to design/engineering/ project management of a terminal grease plant (project cost: U.S. $1 million) to detailed engineering of an integrated vinyl chloride/caustic soda plant with a capacity of 30 000 t/year.

TECHSERVE's major services line is in tail engineering work, which is detailed engineering and project management. The vital skill required for detailed engineering lies in the application of established standards and computation formulas. TECHSERVE has not been heavily involved in front engineering work (basic process design); the basic chemical processes are either highly standardized or proprietary information.

SKILL FORMATION

TECHSERVE's technical capabilities are founded basically on the know-how and experience acquired by the founders in research, development, design, and engineering work in Caltex and Union Carbide, both petrochemical industries. To ensure adequate technical staff support, the two partners hired fresh college graduates and provided them with on-the-job training and guidance for an average 3–4 years. However, the turnover rate among these staff members has been rather high, primarily due to TECHSERVE's uncompetitive compensation and distant work location.

To augment its technical capability, the firm has on call a pool of consultants, each specializing in a technical field, to assist in design work and in checking the work of the staff engineers. Most of the consultants are former or retired employees of Caltex. Currently there are six consultants who have been contracted full-time for various projects. In addition to the limited market, a major growth constraint for TECHSERVE has been the lack of qualified senior technical staff to undertake design and engineering work. This problem is aggravated by the fast turnover of its trained staff engineers.

MARKETS AND CLIENTS

TECHSERVE's primary market is Caltex Philippines; in fact, its working office is based in Caltex's Batangas Refinery. Caltex's confidence in the quality and dependability of work done is not based on TECHSERVE per se as an organization but rather on the two partners — Andres and Jimenez — and their technical capabilities.

Through the years, TECHSERVE has been involved in projects with other companies more as a result of coincidence than of any marketing strategy or effort. These projects were collaboration with a local equipment manufacturer, HONIRON Philippines, in the flow process design of a sugar milling plant, and in the design of certain equipment to be locally fabricated — an assignment secured because one of the key executives of HONIRON was formerly a Caltex employee and had learned of TECHSERVE and the type of services it offered; and preparation of most of the detailed engineering of the integrated VCM–soda plant of MVC — again, because of the personal acquaintance between one partner and MVC's management staff.

The oil crisis in 1974 dealt TECHSERVE a nearly fatal blow, as a consequence of its dependence on Caltex as its only client. At that time

Caltex froze all its contracts because of the uncertainty of the oil industry. The option considered then by TECHSERVE was to advertise and look for project engagements elsewhere. Coincidentally, at about the end of 1974, Mabuhay Vinyl Corporation contracted TECHSERVE to do the detailed engineering for its VCM project. This provided work for TECHSERVE up to 1976, when Caltex again started to undertake plant expansion and modification projects, and engaged TECHSERVE's services once more.

Another major growth constraint of TECHSERVE, in addition to the lack of technical personnel, has been the limited acceptance of local consulting and engineering design services. This is brought about by two extreme attitudes characteristic of local entrepreneurs:

- Risk aversion: local entrepreneurs (including financial institutions) do not have enough trust or confidence in local CEDO experts because of their limited track record. As a result, foreign CEDOs are preferred although project fees are four to eight times the local ones.
- Risk-taking: local entrepreneurs take CEDO work as an expensive item that can be dispensed with without hampering eventual project operations — this attitude is particularly prevalent among small- and medium-scale industries. As a result, local consultancy/engineering fees are expected to be relatively small.

These attitudes not only hinder the growth of all local CEDOs but also provide sound reasons for TECHSERVE to stick it out with Caltex, a stable client, and not develop marketing plans for seeking other clients.

Role in Technology Commercialization

Upon finalizing the detailed engineering aspects of a project, TECHSERVE prepares a materials list including installation drawings, specifications, quotation requests, and invitations for bidding on technological requirements. It usually plays an important advisory role in the evaluation and selection of particular suppliers and constructors for its major client, Caltex. Often it has been able to identify and make use of qualified local suppliers and constructors, resulting in lower project investment costs. It assists clients in project management by monitoring and controlling all activities and costs during project implementation, thus protecting the client's interests.

During its work with MVC in the detailed engineering of the caustic soda–VCM plant, TECHSERVE imparted supplementary on-the-job training to MVC's engineering staff and provided engineering standards and formulas for their use. This service has increased the technical capability of MVC's staff and enabled them to undertake design revisions and interpretations on their own during the project implementation stage. TECHSERVE is now providing consultancy services to MVC on a monthly retainer basis. A key role of TECHSERVE has been to make use of local technical experts in the various fields of consultancy and engineering work. For instance, the firm recently contracted one project for process operator training, which is being handled on a full-time basis by a consultant associated with TECHSERVE.

Links with Foreign CEDOs

TECHSERVE has no formal ties with any foreign CEDOs and does not compete with foreign CEDOs for local engineering work. The provision of engineering services to Caltex is sufficient to keep TECHSERVE busy and profitable. The firm recognizes that the lack of senior technical staff is an obstacle to undertaking large-scale engineering work, and, moreover, when financing is obtained from foreign sources, the CEDOs engaged tend to be foreign. Yet there was a case of a foreign engineering firm that, by virtue of its track record, secured the refinery's instrumentation modernization project; ironically, six of the well-trained junior staff of TECHSERVE were "pirated" to work with this foreign outfit.

At one time, TECHSERVE was seriously considered as a subcontractor for the engineering and the project management of a nickel refinery plant but did not undertake the work because the partners could not be assigned full-time to the remote project site due to their heavy work load.

PRELIMINARY CASE STUDIES

DCCD ENGINEERING

DCCD, one of the leading CEDOs in the Philippines, was founded in 1957 by a group of professors at the College of Engineering, University of the Philippines. It provides a wide range of integrated professional engineering services for the planning, detailed design, and construction management of civil, electrical, mechanical, sanitary, and structural engineering projects for both the private and the government sectors. It employs more than 400 persons, including some 250 engineers and consultants, of which 25 hold graduate degrees. The firm has been engaged in more than 600 projects throughout the Philippines, as well as in Indonesia, Bangladesh, and Thailand.

The firm has six technical divisions (civil works, construction management, electrical engineering, mechanical engineering, sanitary engineering, and structural engineering), whose work is organized along project lines. Each project is headed by a project manager who deals directly with the client at all stages of planning and execution. The technical decisions and expertise are provided by the chief engineers and consultants of each participating division. Administrative services, namely, accounting, finance, personnel, systems and procedures, computerization, documentation, and the data bank, are handled by its Operations Department.

The firm is employee-owned. Professional services of its consulting engineers and project managers are compensated on a direct profit-sharing basis for each project undertaken. Gross revenues in 1977 amounted to ₱26 million, with a return on equity of 49%. Of the gross revenue, about ₱2 million was subcontract fees paid to surveying and other outside services.

DCCD can take care of all the successive stages of consulting services from project planning to implementation, in electric generation and distribution, water resource development (water supply, reservoirs, irrigation systems), site civil works, roads, bridges, waterworks, sewerage, buildings and industrial plants, air conditioning, and ventilation. More than half of its engineering assignments involve detailed engineering, although a minor, but significant, percentage entail construction supervision jobs; others include design review and evaluation, design studies, and feasibility studies. The increasing emphasis of government on infrastructure development in the 1960s and 1970s has meant large-scale and complex engineering jobs for DCCD.

The firm has recruited its professionals from reputable schools, preferably with graduate degrees, and has provided them with further training on the job. Two problems have been found regarding the junior staff: first, recruits have shown inadequate levels of technical competence, probably because of poor college training, and second, the turnover is high once recruits have been trained. Turnover at the senior staff level is not too much of a problem because staff members are co-owners of the company. But they have sometimes left to set up their own consulting firms — a loss of expertise and even clients for DCCD.

There are no permanent ties with foreign CEDOs, but often DCCD has associated with them for specific projects. In many cases DCCD's role has been that of a subcontractor with minor technical work and little decision power. The main reasons for such a subordinate role are the short track record of DCCD and the requirements of bilateral financing agreements. More recently DCCD has participated in a very large project as a subcontractor but was assigned important technical jobs and acted as cosignatory to any recommendations thus made.

Although contracts with foreign CEDOs do not normally contain explicit provisions for the training of local technical staff, DCCD and the foreign firms implicitly accept that training is part of the working arrangements. DCCD assigns senior and promising staff to work closely with the expatriates. An important area where local staff have been able to learn much from foreign consultants is project management and control. DCCD suffers stiff competition from foreign CEDOs, both in international bidding and in the local market, even though foreign fees are five to seven times more than those charged by DCCD. Foreign CEDOs moreover tend to employ local personnel, aggravating the turnover problem.

In contrast, DCCD has yet to venture strongly into foreign markets because the domestic demand for CEDO services is still relatively high; in addition, only recently has the government provided fiscal and credit incentives to local contractors and indirectly to local CEDOs to undertake technical work abroad. However, the competitiveness of local CEDOs in foreign markets will depend on factors such as track record and degree of trust of developing countries or financing institutions in Filipino technical capability.

In its planning and design work, DCCD has not extensively adapted or modified technologies to local conditions (e.g., labour intensity, local raw materials) primarily because design technologies in civil and structural work are highly standardized. What can be modified to suit local conditions are the construction techniques and materials. Moreover, there have been no specific professional or governmental guidelines to define and enforce the adaptation of technologies to suit local conditions. In the preparation of books of tender and in the bidding for construction works, DCCD has been recommending the use of domestic enterprises whenever possible because the construction business and technical skills in the country are relatively well-developed.

ALKYLBENZENE PROJECT OF LMG CHEMICALS INC.

LMG Chemicals Inc., a subsidiary of Chemical Industries of the Philippines Inc. (CHEMPHIL), a 100% Filipino company, was organized in 1968 to engage in the manufacture and sales of dodecylbenzene, a basic ingredient in the manufacture of synthetic detergents, which up to that time had been imported. Contact and preliminary discussions with potential alkylbenzene customers were not difficult because they were existing customers of CHEMPHIL. Although the market was definite, negotiations were necessary to standardize product specifications for the potential users. Other favourable factors were the existence of fiscal and other incentives provided by the Board of Investments and the long experience of CHEMPHIL in the chemical process industry.

FIL International Management Corporation undertook the project feasibility study. The results were encouraging, and it was decided to proceed with the project. The various sources of technology and equipment were then considered. One source of this information, according to one executive, was the compilation of available processes by the Stanford Research Institute. Information also came from the potential users. The processes considered were the Chevron process and the Universal Oil Products (UOP) process. A decision was easily made in favour of the Chevron process because the foreign suppliers of potential customers were using it and the feedstock could be supplied by Caltex Philippines.

Two foreign engineering companies with licences from Chevron were considered by LMG Chemicals to design and install the plant: Nigata-Chevron from Japan and Prichard Chevron from the U.S. Prices were similar, but the choice went to Prichard Chevron because of a yen revaluation clause of the Nigata-Chevron proposal. The agreement called for Prichard Chevron to supply all the equipment, supervise the installation of the plant to be undertaken by the Atlantic Gulf and Pacific Co. (AG&P) of the Philippines, train key engineers, start up the plant, and extend technical assistance for a number of years. In return for a guarantee of the process and equipment, CHEMPHIL was not permitted to modify either without approval from Prichard Chevron. It was pointed out by the LMG staff that technological adaptation in this particular situation is difficult. At most, it would be limited to minor equipment modification through the application perhaps of value engineering and economic analysis.

Prichard Chevron decided on equipment fabricators and supervised the local engineering contractors. However, the project proponents felt that some engineering design tasks could be undertaken locally, especially the purchase of equipment from other suppliers. In fact, one executive noted that its own staff members who were in the U.S. for training actually did some follow-up on suppliers of Prichard Chevron just to minimize project delays.

Atlantic Gulf and Pacific Co. of the Philippines was contracted to undertake the civil and mechanical work. The project was not fully turnkey because the proponents had made the decision as to the local contractor even before the engineering design and consulting firm was decided upon.

As part of the agreement, Prichard Chevron provided training to eight LMG personnel. These included the general manager, plant manager, and six engineers who were trained in similar plants in California for an average 6 weeks. However, the "training" included the development of operating manuals and follow-up of equipment subcontracts, which LMG felt should have been done by Prichard Chevron.

The installation of the plant took about 3 years, starting in 1973, with the equipment coming in 1974 and finally being installed in 1976. The delay was caused by several factors and aggravated by the oil crisis, which caused an upward adjustment of prices. There was, however, no provision in the contract as to delays; hence no action could be taken by any party. With the termination of the plant guarantee period, LMG is now free to undertake equipment or minor process modifications. Studies are being made to improve operating efficiency and utilization of raw materials.

SUGGESTIONS FOR FURTHER RESEARCH

The case studies carried out have made it possible to identify a number of questions for further research.

CEDO TYPES AND CEDO DEVELOPMENT

Should CEDOs be in-house units in manufacturing organizations, independent business enterprises, or government agencies; and to what extent should these various modes of operation coexist? For instance, the in-house units of manufacturing organizations could concentrate their work on technology acquisition and project management, whereas the independent CEDOs could specialize in design and engineering work.

What type of business organization of CEDOs would enhance their stability and growth? Possible types are single proprietorships, professional partnerships, employee-owned corporate units, corporate subsidiaries, and autonomous government corporations.

How far should CEDOs be awarded fiscal and credit incentives to enhance their development and their links with the science and technology infrastructure? Should the development of CEDOs be considered as a natural by-product of industrial growth, as in the current policy perspective in the Philippines?

TECHNICAL SERVICES AND MARKET COVERAGE

What mechanisms may be used for upgrading C&E capabilities? Skill formation has faced a number of obstacles, such as limited market opportunities, limited acceptance, inadequate training, inadequate links with foreign CEDOs and research institutes, and concentration of local technical expertise in manufacturing industries. Accreditation and professionalization of local CEDOs would be desirable.

Regarding the markets to be covered by local CEDOs, there should be priorities in line with development policy. In what industrial sectors should CEDO development be concentrated? For instance, should it be existing industries based on local resources, like sugar refining and metallurgical mining? What CEDO services may be provided to small and medium industries?

What technical areas should be given priority for upgrading of CEDO capabilities? This question is related to development policy and to existing conditions as well. Should competence be developed initially at the technical level of detailed engineering and project management or in the field of technology negotiation and acquisition?

Selection and Contracting of CEDOs

There is now a dualism in the market structure of C&E services. Large enterprises, with an aversion toward risk and with strict requirements, tend to engage only CEDOs with a proven track record; here market opportunities are limited to foreign CEDOs, and fees are large. Small and medium enterprises consider C&E services as part of a package technology deal or as an expense item of project development that may not necessarily affect efficient project operations. In this case, market acceptance is limited and C&E fees are expected to be low — facts complicating the problem of getting qualified local experts to undertake C&E work.

Financial institutions crucially affect the choice of a CEDO and tend to protect their interests through the selection of CEDOs with a proven track record, as in the case of large enterprises. Local CEDOs are at a disadvantage and cannot increase their own track record because work opportunities are limited. Another common practice of financial institutions is to require that a certain proportion of the loan be spent on services and equipment of a particular country or enterprise.

Working relationships of local and foreign CEDOs should be defined so as to protect the clients' interests and the local CEDOs' professional status and to allow for the upgrading of local CEDO capabilities. Particularly, to what extent should it be required that local CEDOs be the lead consultant? What should be the technical functions and the role in decisions of local CEDOs that have been subcontracted by foreign CEDOs?

Although CEDO services should ideally be contracted apart from other activities required in an investment project (particularly the supply of equipment), frequently this does not happen because of the turnkey nature of projects, the exclusivity of the process know-how and equipment to the extent that the equipment vendor is contracted as the CEDO, or the investor's desire to hasten the project cycle.

Role in the Choice and Absorption of Technology

A key role of CEDOs in technology commercialization is in the choice and adaptation of technologies to suit local conditions such as labour intensity, economies of scale, and local material content. Mechanisms for inducing such a role include formal links with R&D institutes and technodata banks of the country and among cooperating countries, and various government incentives, for instance tax credits for the acquisition of locally fabricated equipment.

Another key role is in the unpackaging and acquisition of technology components in terms that are beneficial to the client and to the country's development as well. This requires CEDOs to intensify their capabilities in identifying core and peripheral technology components that can be supplied by domestic enterprises; engineering and integrating various technology components obtained from different sources; and evaluating and negotiating technology agreements and licences.

The functions of project management and technical assistance of CEDOs should go beyond the mere coordination of plant construction and installation, to include three vital functions: checking that equipment and construction comply with specifications; integrating technology components from various sources; and fine-tuning of the plant and its operations to clear up bottlenecks and increase capacity utilization and production efficiency.

FRAMEWORK FOR FURTHER RESEARCH

An in-depth, action-oriented effort should be made to define the mechanisms for upgrading local CEDO capabilities. This would require:

- Survey of local CEDO capabilities, including in-house units in manufacturing firms; this would provide comprehensive information about the current status of CEDOs and would permit the identification of gaps in CEDO capabilities;
- Review of policy instruments and government programs that directly or indirectly affect research and production and of their effects on CEDO development; this is to ensure that the existing programs and policy instruments shall be synergistically linked to any government measures proposed for CEDO development;
- Comprehensive analysis of CEDO issues; the factors and constraints affecting CEDOs should be widely studied through personal interviews with CEDO management staff, users, government officers, etc., focusing on the cause-to-effect analysis of specific policy issues rather than documenting company cases; and
- Recommendations for upgrading CEDO capabilities, through the formulation of priorities regarding sectors and technical areas where CEDO capabilities should be upgraded and the development of policy measures and mechanisms to carry out such upgrading.

CHAPTER 6

CASE STUDY OF A CONSULTING AND DESIGN ORGANIZATION IN ARGENTINA

LUIS STUHLMAN, WITH COLLABORATION FROM BIBIANA DEL BRUTTO

SUMMARY

ABC is a medium-sized firm engaged in the engineering and construction of civil and industrial projects. It was founded in 1951 and worked on installation and construction activities for several years, after which it gradually created an engineering capacity, which today is relatively substantial. ABC now employs about 600 permanent staff of whom 140 are engineers and other professionals; it also engages a fluctuating labour force engaged in construction and installation activities of some 1500 persons on average.

ABC grew through successive assignments of increasing size and complexity for state and private clients, progressing from a small construction and installation firm to a complex organization, in a not too favourable environment and with no special help from government policy. Four stages can be identified: (1) during the 1950s a succession of small and sometimes medium-sized jobs was done for electrical companies and industry; (2) in the 1960s there were diversification and growth. Projects were larger; clients were in a wider spectrum of branches, notably railways, telephone, gas, and electricity. The technical office, however, was small; the firm's business was not engineering design but project execution and local purchasing services. A deep crisis was weathered in the mid-1960s when public investment decreased substantially; (3) in the early 1970s, the rate of growth increased, and there was more diversification. The firm entered into industrial projects and started to do some process engineering when it won two bids for simple process plants (peripheral to existing plants). (4) In 1975 ABC joined other larger firms in an engineering consortium for a technologically complex sector. It then needed to build up a strong engineering capability, ahead of likely contracts (rather than line up technical help after getting a job, as tended to be the case earlier on). A sizable engineering department was rapidly formed, with 120 staff members (70 engineers) in 1976; the team that had been working on the two projects mentioned above constituted the basis for the new engineering department. At the same time, the management cadre was expanded, several experienced professionals being brought in, and the management style itself underwent a significant change: the shop became a true enterprise. Forward planning was introduced. A decision was made to hire 10 young professionals and train them for several years (although this has had to be postponed for the time being). Numerous proposals were drafted, and the firm entered a number of bids, primarily to gain experience (from its work and from the comparisons with competitors' offers) and also as a means of getting to be widely known.

More recently, the firm experienced severe setbacks when several projects on which it counted, or which had been successfully bid, did not materialize for various reasons. At the same time, public investment has slackened, and the firm

has been facing a deteriorating situation at a moment when it has to support much higher fixed costs on account of the large, expensive engineering department.

A number of interesting points may be mentioned: (1) the struggle to survive and grow may be seen from the variety of fields of the recent projects for which bids were successfully entered, to wit: (a) part of detailed engineering and construction of a large hydroelectric plant; (b) detailed engineering and construction of a petroleum refinery; (c) same for rail electrification; (d) same for telecommunications network; (e) same for copper rolling mill. All of these projects except the first one were to be done in collaboration with a foreign firm; (2) this wide variety — covering a large spectrum of C&E activities, as well as many unrelated branches — probably reflects the facts of life in ABC's environment in Argentina, where the largest client is the public sector, with large fluctuations in its demand; each branch is a relatively small market for C&E and construction services, and there is stiff competition from other CEDOs and contractors; (3) the main technical decisions are normally made by the client, which is usually a large public enterprise with a certain amount of C&E in-house capability. The outside engineering firm does not participate closely in the preinvestment stage but is brought in to engineer and implement the resulting decisions; it complements, but does not take the place of, the client's own C&E capacity. In fact, the client is bound to have a larger and more sophisticated capability than the local CEDO, which is really a constructor for which engineering is somewhat of an excuse to win a bid and obtain a contract. It is in construction that profits are made, not in engineering; and (4) like other engineer–contractors and consulting firms, ABC has almost no connections with the local science and technology system and does not carry out technical development work. Its access to technical information is through the technical literature, frequent trips overseas, participation in technical meetings, temporary association with foreign CEDOs, and very importantly the hiring of experienced professionals including university teachers.

The history of engineering firms in developing countries is shorter than in the industrialized countries, extending for not more than 40–50 years. In Argentina, there were a few sizable engineering firms before the 1950s; these were engaged in public works construction, usually in a subordinate position to foreign firms. During the 1950s several events took place that helped the appearance of local CEDOs:

- The availability of an important number of well-trained engineers;
- The impetus given to infrastructure development plans: water resources development, railway improvement, ports, roads, etc., sometimes with the support of the World Bank; toward the end of the decade there was a large effort in petroleum exploitation, and large direct foreign investments were made in automobiles and other branches;
- The increasing links with the international financial agencies, which led to the setting up of a planning mechanism that channeled outside financial resources; those agencies, at the same time, demanded technoeconomic studies to justify project feasibility — a requirement that boosted C&E services (IBRD 1974); and
- The influence of U.S. consulting and engineering in the postwar years; C&E services were imported from that country, as well as an

organizational pattern for engineering firms (Perichitch 1978). This pattern affected Argentina in three ways: many foreign engineering firms came for an isolated project; a few installed themselves permanently, particularly in the early 1960s, originally bringing foreign personnel, who were gradually replaced by local people (this sometimes happened in response to a continuing demand by the public sector or foreign enterprises, which could be satisfied by cheaper local engineering personnel of good quality); and more importantly, local engineering firms developed, from different origins but tending to adopt the U.S. pattern of an engineering firm, an autonomous entity, separated from production, with differentiated services of the staff type.

During this period, groups of professionals who were not tied to production began to act as advisers in the solution of diverse problems. They used a set of techniques, some of them sophisticated (operational research, CPM, etc.) that could be applied to different fields for the improvement and modification of design. The organizational model — groups of advisers acting autonomously — was transferred to Argentina and its new engineering firms.

Toward the end of the 1950s and the beginning of the 1960s a number of local engineering firms came into being. Civil, electrical, and mechanical engineers were the first to find a place in this type of activity, and these specializations are still more developed today than others. In the 1960s, with the military government's emphasis on planning and on infrastructure, other consulting areas grew, such as those devoted to economics (economic analysis and profitability estimates to evaluate projects and define investment priorities), sociology, and mathematics, with a tendency toward the integration of interdisciplinary groups. Some state organizations, such as those in charge of roads and hydroelectricity (Dirección de Vialidad and Agua y Energía Eléctrica respectively), accelerated the process through their increasing demand for C&E services, as did other state enterprises later when building their plants.

In the 1970s, ups and downs in the country's economic and institutional situation particularly affected engineering firms. One prime reason is the ways these firms came into being, what may be termed their mode of emergence (EM), which strongly influences development of a firm, the characteristics it acquires, and the policies that may promote its development. The common modes of emergence are:

- Branching off — a large foreign firm making its services available to others, similar to the process taking place in multinational enterprises.
- Differentiation and increasing complexity — the most frequent case being engineering firms in civil construction that took up process engineering, perhaps in two or three stages; this is related to another mode of emergence, differentiation and growth;
- Organizational autonomization — engineering departments that become true engineering firms, using fresh opportunities of profiting from their accumulated experience and their infrastructure; sometimes this takes place in harmony with the mother firm, which keeps links with, and gives backing to, the more autonomous engineering department; in other cases some degree of conflict is involved in the process of gaining autonomy;

• Development, through necessity, of complementary services — engineering firms originating from equipment makers, which to increase their output and sales need to give their customers a growing technical support and end up discovering they have a technical structure able to provide engineering services that are profitable per se in addition to increasing sales capability;
• Segmentative — a branching off from process engineering firms taking place after process engineering consultancy has achieved a sufficient degree of institutionalization (i.e., a group branches off from an engineering firm to form a new engineering firm); in Argentina there is only one case of this among the process engineering firms;
• Organizational creation — several engineers deciding to create a process engineering firm; frequently the partners have spent a long time abroad and have acquired the necessary experience, which they then capitalize.

A survey of engineering firms in Argentina (Suárez and Stuhlman 1975), has shown the percentages of firms that have emerged by branching off (11%), differentiation and increasing complexity (22%), differentiation with increasing complexity and growth (22%), organizational autonomization (15%), complementation of services (5%), and organizational creation (25%). The most recent mode of emergence, organizational creation, accounts for one-fourth — a figure showing the increasing process of institutionalization of the type of activity. Although stable branching off represents only 11%, other foreign engineering firms continuously appear in the market to bid for large contracts; though nowadays they must associate with a local firm.

The process engineering firm that is the subject of this study, the ABC Company, may be classified within the mode of emergence "differentiation with increasing complexity and growth," with the virtues as well as the limitations of this style. The firm complies with the criteria set forth in chapter 2: it serves the process industries and has been engaged in a medium-sized investment project. Unfortunately, we were unable to gather sufficient data to provide an analysis of the project.

ABC was founded in 1951 (under a different name) by a group of engineers, as a limited liability company. The CEDO was initially created to take up diesel engine repairs, and later their installation, together with ancillary elements, in electric power plants. There were five partners originally; three of them have remained to this day and are the firm's owners.

One of the original partners had been the president of a large state enterprise. Another, an electrical and mechanical engineer, had studied and worked in European countries and had some experience locally in planning, feasibility studies, and projects in electrical installations. A third partner was a civil and hydraulic engineer with some experience in the public service. A fourth partner had a degree in aeronautical engineering, had worked for the Transport Ministry, gathered experience through a stay in Europe, and had been technical manager of a firm engaged in mechanical work.

Some important points in the firm's evolution were:
• The first assignment was a high-tension transmission line, for which it had to subcontract another engineering firm to complement its capabilities.

- In 1957 the firm split into three, one of which became ABC. At that time there was a strong interest in expanding the field of action and consolidating the experience as contractors to the state.
- In 1961 ABC became a corporation: "at that moment we understood that we also had to become an engineering company. . . . This needed our development in the electromechanical area: project design, procurement, installation, tests, start-up, sometimes even supervision and technical management, [we were] trying if possible to reach the turnkey stage." During this period the firm built a complete power plant, including high-tension lines, fuel deposits, buildings, installation of a 4550 kW group, cooling tower, etc.
- The most important project in the early 1960s was a power plant for a large state enterprise, including the civil and the electromechanical components (two turbogroups of 10 000 kW each).
- In the late 1960s, faced with a decline in public investment, ABC diversified. However, at the end of the decade an important assignment was undertaken for procurement services and installation of a 132 kV line, 138 km long, with transformer substations. Laying this line was a complex task, which needed numerous special solutions that enriched considerably the company's technical knowledge. During this period ABC also started to work on industrial projects.
- An interesting milestone was a high-tension line in 1970. ABC prepared the projects for supply and installation, but because the towers were steel, ABC engineers were placed in the firm that manufactured them, so that this became an instance of local supplier development through the technical support of the engineering firm.
- The first half of the 1970s showed an important quantitative and qualitative growth of the firm (Table 13). In spite of the ups and downs of the economy and the virtual freezing of public works in 1971, the first two large (for ABC) industrial projects took place: an asphalt blowing plant and a paraffin treating unit.
- Another element characterizing ABC's growth and development in this period was its association with the large CEDOs that operated locally, which until then had formed a closed circle of three firms that shared the large projects among themselves. In 1973 ABC joined one of the large CEDOs in a bid for a high-tension line. In the second part of the decade ABC won, in association with one of the large firms, the high-tension line for a large hydroelectric project, and together with the same associate and another of the large firms, it won the bid for an important communications network.
- A more important indicator of development was the inclusion of ABC as an associate in an engineering consortium for the engineering and installation of atomic power plants. This consortium is made up by the five largest construction and engineering firms in the country. ABC participates with 17% of the capital.

When this study was made (late 1978), the CEDO was going through a critical stage of growth and consolidation of its structure. A new organizational structure and a different policy toward human resources would mean large expenses, particularly a very high payroll (U.S. $8 million a year for the engineering departments only), which the firm could not afford.

Table 13. Projects executed by ABC.

Period	Percent of total
1954–58	9.3
1959–63	7.9
1964–68	15.1
1969–73	24.5
1974–78	43.2

Table 14. ABC's role in 139 projects between 1954 and 1978.

Role	% of Projects
Project design	52
Procurement services	52
Installation	100
Supervision	26
Start-up	64
Study	17
Maintenance and repairs	15

The firm's aim is "to be able to carry out all types of industrial projects," in the words of one of its directors. The goal of progressing from engine repair and electrical installation to the design and execution of large industrial projects has been met in part. The achievement is indicated by the projects in hand in late 1978: procurement services, installation, start-up, and commercial exploitation of seven mobile power stations; project design, construction, and commissioning of several high-tension transmission lines; auxiliary systems (lubrication oil, compressed air) for a large hydroelectric plant; signal system for a subway line; procurement services, installation, and start-up of several telecommunications centres; detailed engineering, complement of process engineering, procurement services, construction, installation, and start-up of a waste liquid treatment plant; installation of a pit furnace for the heating of special steel; assembly and installation of belt transport equipment; and electrical and mechanical installation for a foundry.

Even though the CEDO now offers a wide range of services, it started as an installation firm, and its most important activity is still installation, although projects now offered include industrial plants in the petroleum and petrochemical sectors; industrial plants in other sectors; transmission lines, networks, power plants, substations; networks for the distribution of gas and water; railway networks; and civil works. The services supplied by ABC in each case have been engineering (usually detailed); construction and installation; procurement; start-up; prefeasibility; maintenance and repairs.

The firm states it can study, design, plan, supervise, and execute any type of industrial project. Its involvement goes from the project's feasibility study to turnkey delivery, including all the intermediate stages such as project design, procurement, installation and assembly, tests according to national and international standards, and training of specialized personnel.

Role of the Firm

The ABC company carried out 139 projects since its inception. In all of them the firm was in charge of construction and installation (Table 14–17). Most projects (43%) were carried out during 1974–78, ABC gaining prestige in the internal market since 1970.

Table 15. Type of project according to ABC's role.

Type of project	Role of ABC (% control)						
	Project design	Procurement services	Installation	Supervision	Start-up	Study	Maintenance, repairs
High-tension networks	60	65	100	13	–	12	33
Petroleum/ petrochemicals	75	65	100	30	40	25	–
Industrial plants	50	15	100	62	58	27	–
Railway system	50	25	100	50	–	50	–
Civil works	43	14	100	43	–	–	–
Communications	100	33	100	66	–	–	–
Gas networks	–	66	100	6	–	–	–
Other	40	20	100	–	20	20	–

Table 16. Proportions (% of total projects) represented by different types by period.

Period	Electric projects	Petroleum, petrochemicals	Industrial plants	Gas networks	Civil works	Other
1954–58	41	16	–	43	–	–
1959–63	86	14	–	–	–	–
1964–68	66	–	6	–	13	15
1969–73	65	11	14	9	–	1
1974–78	36	10	17	22	12	3

Table 17. Value (% of total value for each type) of project, by period. [a]

Period	Electric projects	Petroleum, petrochemicals	Industrial plants	Gas networks	Civil works	Other
1954–58	1.4	2.3	–	3.2	–	–
1959–63	4.7	3.2	–	–	–	–
1964–68	5.5	–	1.1	–	4.7	15.6
1969–73	28.4	15.5	12.3	7.5	–	5.5
1974–78	60.0	79.0	86.6	89.3	95.3	78.9

[a] Before calculation of percentages, the value of projects was converted to U.S. dollars at the mid-period rate of exchange.

In the first period, 1954–58, the firm supplied procurement services in most projects, but only in half of them did it carry out the engineering project design. In the following stage (1959–63), the firm provided a greater proportion of supervision services. In the last period, there has been an increase in the proportions of project engineering and start-up, both of which are technologically complex; a significant proportion of projects have included preliminary studies (consulting).

Increasingly since 1970, ABC has provided all services for its projects. The principal source of income has been electrical projects, and this focus has been a reflection of market demand, especially by the state. During the last few years ABC has become more involved in industrial projects and less so in petroleum, petrochemical projects and electric and gas networks.

POLICIES OF THE FIRM

HUMAN RESOURCES

A survey of ABC's professional staff showed that in 1975 58% were between 30 and 39 years old (2% under 30, 21% 40–49 years, and 19% over 50); professionals included civil engineers, builders, and architects (37%); electrical and mechanical engineers (electromechanical 16%, electrical 5%, and mechanical 25%); and other engineering specializations (17%). Formal training after graduation was low: 53% had not taken any courses and 41% had taken postgraduate courses. 60% had worked previously in local private firms, 42% in foreign-owned private enterprises, and only 24% in public administration; 48% had worked in engineering firms, 18% in foreign-owned engineering firms; 44% had worked in engineering departments. At the time of the survey, 35% had teaching activities.

Although the human resources were substantial, as ABC continued to grow and have prospects of more complex and larger assignments, it required higher technical and management skills. Thus, in 1977, it drafted an ambitious plan for managing and training its human resources.

Two aspects of this plan are of special interest. First, developing human resources meant modifying the firm's management structure. Thus, in early 1978, the firm recruited a general projects manager and two projects managers (who came from firms operating in the local engineering and installation market), a supplies manager (from another CEDO), an engineering manager (an Argentine previously working as engineering manager of a Brazilian CEDO several times larger than ABC), and six other professionals (previously in responsible positions in Brazil). In this way, ABC obtained a very good management team, through high remunerations and improved its image in the market as a growing and developing company. Second, a large sum was allocated for a special recruitment and development program to search for and train a group of 10 engineers, of high promise. The 5-year program called for training overseas, in CEDOs, industrial enterprises, R&D institutions, etc., and would produce a technological reserve for ABC. Although the program has been delayed on account of the current economic difficulties of the firm, it has not been abandoned, and high hopes are attached to it.

In 1978, the firm's total personnel, including manual workers, numbered in the thousands, 585 being permanent salaried personnel (Table 18).

RELATIONS WITH USERS

Suárez and Stuhlman (1975) commented on process engineering firms and the forms of association among these firms as a basic commercial strategy. They found that firms of similar size and prestige seldom compete with one another to provide services locally, although they may compete for foreign markets. The exceptions are medium-sized firms, which sometimes form associations but frequently maintain competitive relations.

The large firms, which have adequate marketing strategies, share risks. The size of their staffs means high fixed costs, which they balance by sharing the work load among themselves. Hence, in a not too covert manner, they decide which one of them will take up a certain job, basing the decision on available personnel, relative regional advantages, etc. This strategy allows them to control the market of large jobs that demand a good track record and experience that only these firms have. The lack of competition is clearly perceived by small and medium firms, which complain: "This is an unpredictable market for us but not for the large installation firms, which always associate among themselves. There is no legislation protecting us against this."

Medium-sized firms, reflecting a traditional tendency of small and medium enterprises toward isolation, do not generally adopt a strategy of cooperation; they compete for projects that, on account of their volume, are of no interest to the large firms. They have only occasionally entered into association.

The strategies of small firms are more varied. They scarcely compete among themselves, or with others, but the forms of cooperation that they use or propose are diverse. One frequent practice is to carry out specific

Table 18. ABC's permanent salaried staff in 1978.

Office	Engineers	Other professionals	Non-professionals
General manager	1	–	1
Finances	–	2	42
Administration	–	3	29
Human resources	–	1	21
Advisory (legal, audit, taxes, control, costs)	2	3	11
Sales	4	–	5
Commercial	1	–	3
Contracts	2	1	3
Technical	1	–	1
Construction	36	5	91
Industrial works	31	1	80
Procurement	2	2	62
Engineering	36	9	93

chemical engineering tasks for local large and medium firms. In other cases they prefer to associate with other small firms, usually:

- To complement services and help each other in surviving; the modest aim is not to disappear from the market; and
- To associate with foreign firms to learn the trade and increase the possibilities of winning bids; if an association is formed, the firm usually shares its work with other small firms.

ABC has established links with foreign firms for certain jobs — at first, with English, French, and U.S. firms, for electrical and installation works. It has preferred occasional associations because more permanent arrangements, according to an ABC official, are: "not convenient in Argentina, since currently the process is chosen by the client, not the engineering firm." ABC has favoured occasional associations, both with foreign suppliers of equipment and with local engineering and installation firms, to lower risks and even out the work load. For example, in 1971, it joined SULZER (Switzerland) for the engineering, construction, and installation of a compressed air plant for a large state enterprise, SULZER manufacturing the equipment locally; in 1972, it formed ties with a large local firm for a 220-kV line; in 1975, with a large local firm for a 33-kV line and the start-up of imported equipment for the railways; and in 1977, with a French firm that supplied rail equipment.

The preferred commercial strategy is association rather than direct competition, which was possible only when ABC reached a level where it could compete with other large local firms. The firm has its own financial resources, through a financial company it owns; in large jobs it associates with banking groups that organize the financial package, which is then submitted to the client. In most cases, the contract with the user is through bids, as the user is usually in the public sector (Table 19).

Regarding foreign users, ABC has adopted an interesting commercial and technical approach. The fluctuating government policy on nontraditional exports has brought about insecurity and difficulties in the export of engineering services. However, ABC has systematically submitted bids on international projects, even though the chances for winning the contract were slim. This was done for two reasons: to gather experience on adapting to the rhythm, deadlines, and quality of presentation required by international practice; and to be able to examine the proposals presented by foreign firms.

Table 19. Percentage of ABC projects according to user.

Period	State enterprise	Private enterprise	Public administration
1954–58	83.3	–	16.7
1959–63	72.7	9.1	18.2
1964–68	47.6	–	52.4
1969–73	73.5	–	26.5
1974–78	88.2	3.9	7.9

TECHNOLOGICAL POLICY

RELATION WITH TECHNOLOGY

A CEDO, as any other organization, requires technological inputs to transform them into services. Although the technological management of a CEDO appears to be restricted to the least complex aspects of engineering technology, because of the nature of relations proposed by the user, who chooses the technology to be employed, there has been a good deal of technical progress on the part of ABC. Since the early days of electromechanical installations, the firm has evolved considerably. Today it is participating in nuclear power plants, having progressed from a small project office to a Department of Engineering. Though the firm does not have a central technical file, depending rather on personal files, it is studying the convenience (already perceived) of having a central file with up-to-date technical information.

To the extent that a wider role is expected in the future, the firm wishes to develop its links with the technology-producing system, which would allow it to produce basic engineering. This aspect, however, is more declarative than real in Argentina (with perhaps only one exception, TECNOR), because this is not the heart of the business. In any case, ABC has generated one stable link of this type. An agreement has been signed with an Italian firm for projects in petroleum, petrochemicals, cement, and pharmaceuticals; bids would be presented jointly, the foreign firm supplying technology of its own and basic engineering, and ABC supplying detailed engineering, construction, procurement services, installation, and start-up. In this way, a new role has opened up – that of offering turnkey plants, instead of receiving orders somewhat passively.

RELATION WITH THE LOCAL SCIENCE AND TECHNOLOGY SYSTEM

"Engineering firms emerging through branching-off, or by increasing complexity and growth, have no awareness of the local S&T system, and only get to the point of perceiving university centres, which they regard as academic and not too useful," according to Suárez and Stuhlman (1975). The position of ABC should be seen within this frame. Its perception of the local system is as stated by Suárez and Stuhlman (1975): "We have no links because the system is too isolated. It would be interesting to get connected, but truly this would not be too useful for us, save perhaps with the Atomic Energy Commission."

FORMS OF ACCESS TO TECHNICAL INFORMATION

The most usual ways in which engineering firms keep up-to-date technically are reviews, 69%; trips abroad, 46%; head office, 16%; congresses, 16%; courses, 16%; and university teaching, 16% (Suárez and Stuhlman 1975). ABC employs several of these resources. It has subscriptions to about 15 international reviews. Frequently, staff travel to the U.S., Europe, and Japan. Some information comes from meetings of the Argentine Petrochemical Institute (where at the same time commercial contacts are made). But probably the most important method for updating is the recruitment of university teachers (who account for one-third of the professionals) as well as the later identification of new human resources (outstanding students).

Export of Services

ABC has tried to export its services, particularly in high-tension lines and telecommunications systems. The company has entered several bids in recent years, in Bolivia, Paraguay, Uruguay, and Ecuador, but has not won any of them.

Handling of the Context

The state influence on ABC is decisive because it is almost the sole client. The firm tries to influence investment policy, legislation on price adjustment, and other regulatory aspects, so that they become favourable. CEDOs of relatively large size, like ABC, join forces in the Argentine Chamber of Construction, whereas the small CEDOs do so in the Argentine Chamber of Consultants.

An institutional publicity campaign was started in 1976, through a prestigious and sophisticated agency. Advertisements are regularly published showing ABC's achievements. Sponsorship was given to the junior Chamber for its prize to the Ten Outstanding Young Persons in 1977.

Achievements

Organization of Work

The CEDO has a general organization for the enterprise and a different one for its Engineering Department (since 1978). This department has begun to be structured in matrix form, like the large U.S. CEDOs, with task forces whenever necessary (in general, however, task forces are avoided because they are considered to be expensive; they are employed only as a last resource).

The CEDO has had internal problems (not with its users) on account of the quality of its detailed engineering, the persons in charge of construction being forced to solve too many questions on the spot (it must be remembered that ABC started as a construction and not as an engineering firm). The problem (says the firm) is faced by all CEDOs that carry out both construction and engineering. To overcome it, the firm made an interesting innovation. As was explained by one of the Engineering Department managers, "usually the man designing the project does not know whether the man in the building site has trucks or tractors, or how much manpower is available with what skills. You cannot expect the man at the drawing board to have familiarity with construction activity. A solution we have employed is to bring people from the building site to design the projects. But this is no good; they are men with their own tricks, and very empirical. The solution is coparticipation. This is the experience we are getting, with excellent results. Those from the construction side of the firm come and work with us when the project is about 30–40% advanced, and then, when the project is to be built, they know it well. Also, groups of engineers install themselves permanently at the construction site. We have obtained in this way more rapid communication, technological improvements, and a reduction in costs."

Daily work routines are based on the circulation of documents that must be checked and signed by those responsible for the different specializations. The firm has a library in the Engineering Department, and data processing facilities for technical calculations, material specifications, and project planning and control. The programing of tasks is done both by manual PERT and by computer processes.

The normal routine of work, once a contract has been signed, is:

- One person is given global responsibility for the contract;
- Another person is assigned to be responsible for the project, and also a planner, to estimate total engineering hours, according to the number of documents to be prepared;
- Personnel requirements are estimated; a team is outlined; times for the different tasks are estimated; and the first provisional GANTT chart is prepared;
- The task is divided into what will be supplied by the user, the CEDO, and outsiders;
- Each document that is prepared goes to the filing section, which is responsible for its handling;
- At a certain moment the procedure starts to be handled by Supplies, which gives the data from Engineering to the vendor and from the vendor to Engineering;
- The set of documents is sent to the user for approval;
- When the documents are returned, modifications are incorporated or discussed; documents then go to the checkers (specialists in each task) for quality control; and
- Once approved, documents go to the building site.

The Success of ABC

The great success of the CEDO is eminently economic and is shown by the enormous growth of sales in the 25 years since its foundation. This, according to the firm's managers, is due to a very dynamic handling of the enterprise, good commercial contacts, good economic decisions at the right moment, and a continuous improvement in the technical level.

In terms of impact on the context, rather than of enterprise growth, the firm has had some influence on the development of equipment suppliers and has repatriated an important group of Argentine professionals that had emigrated for lack of opportunities. But, at least up to the present, ABC has not had a significant impact on autonomous technological development. This is probably due more to the nature and modalities of the Argentine environment than to the vocation of the CEDO itself. Indeed, in Argentina the large users have their own engineering capability, which is employed as internal consultancy for investment projects, and can then purchase technology and basic engineering abroad, allowing the CEDO only the role of builder and installer.

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CHAPTER 7
REVIEW OF THE NATIONAL CASE STUDIES

ALBERTO ARÁOZ

The four national case studies carried out in Korea, Brazil, the Philippines, and Argentina describe the characteristics and evolution of a CEDO and analyze how it has performed in an investment project. This chapter reviews and compares these national experiences (Table 20) and derives some conclusions from the exercise, pointing to further research activities on the subject.

The characteristics of the four CEDOs differ substantially. Three are nationally owned and in the private sector; the Korean example (K) is a joint venture with a foreign CEDO, in which originally the local partner was the state. Three are medium to large organizations, ranging from 500 to 1200 persons; one, the Philippines CEDO (P), is small (30 persons). The Argentine example (A) is a builder–contractor, only recently counting engineering as an important activity, and the CEDO in Brazil (B) owns and runs a production plant. Perhaps the only mature one is B, which has mastered the technology of some processes and is able to undertake for them the complete range of C&E services, including basic engineering. The other CEDOs offer preinvestment, detailed engineering, and project execution services.

B and P have specialized in one market, whereas A and K serve diverse markets. The state is the most important client for all except P, which practically works for one private client, a petroleum refinery. Only K has a stable relationship with a foreign CEDO, but the others carry out projects in collaboration. B has been able to diminish its use of foreign CEDOs as its own know-how and expertise have increased.

K was explicitly founded by the state, whereas the others were founded by a few professionals. The founding partners of B and P were highly experienced. Three were founded around 1970, and, although A was founded in 1952, it took up engineering as an important activity only in the early 1970s. The original know-how was that of the founding partners in B, P, and A (not too high in this case), whereas in K it was brought in by the foreign associate.

Only B originally set out an explicit strategy for its evolution: to master the technology of the phosphoric-fertilizers complex through the sequence sulfuric acid–phosphate fertilizers–phosphoric acid (the goal now largely accomplished); and to work on petroleum refining (this goal being discontinued when the principal client created its own engineering division). K had a general idea of acquiring experience in a number of fields. P simply wanted to work for its sole client in areas well known to the partners.

Table 20. Comparison

	Korea	Brazil
Present status		
Type of CEDO; size	Private CEDO; staff 500 (1978)	Private CEDO; controls, operates a sulfuric acid plant; C&E staff 1200 (1977)
Ownership	Joint venture with Toyo Eng. Co. (Japan)	Fully national
Range of activities	Preinvestment studies, detailed engineering, project services	Complete range of C&E services, including basic engineering, for sulfuric acid and phosphate fertilizers
Markets	Diverse; civil and industrial projects, for private and state clients; some exports	Sulfuric acid, phosphate fertilizers, phosphoric acid, Cl-Na; state almost only client
Relations with foreign CEDOs	Stable relationship with partner, Toyo Engineering Co.	Diminishing use of foreign CEDOs as own know-how and experience grows
Origins		
How it originated	Founded 1970 as joint venture of Korean government and Lummus Co. (U.S.)	Founded 1967 by a group of professionals from the state petroleum company, PETROBRAS
Original sources of know-how	Principally the know-how and expertise of the foreign partner, first Lummus, then Toyo	Know-how, expertise of partners (considerable); know-how licence for sulfuric acid with a U.S. firm, with full-disclosure clause
Strategy envisaged by founders (fields and activities)	To work as a multipurpose CEDO in various fields	To master technology of phosphate fertilizer complex, through sequence sulfuric acid–phosphate fertilizers–phosphoric acid; to work in petroleum refining (this failed)
Evolution		
Evolution of markets and of services rendered	Served first state, later private sector; diversified its services, became multipurpose; some exports; big role expected now that firm is wholly in private sector	Period 1: rapid growth of market; many small projects, peripheral installations; most important market is detailed engineering for state sulfuric acid plants; period 2 (1972–75): sales multiply by five, larger contracts, start with phosphoric acid; period 3: fewer, larger projects, wider front as phosphate fertilizer and chlorine are started
Acquisition of personnel	Could get few qualified professionals; had to recruit from chemical plants and to hire fresh graduates who had to be trained in design skills	Rapid incorporation of manpower (origin not specified); policy to train well and to retain professionals, leading to heavy investment in human resources

— CEDO case studies.

Philippines	Argentina
Private CEDO; engineering staff 30 (1978)	Private contractor with CEDO capabilities; staff 600 plus about 1500 construction personnel (1978)
Fully national	Fully national
Detailed engineering, project services	Preinvestment studies, detailed engineering, project services, project construction
One main client, Caltex (petroleum refining), and occasionally other clients	Very diverse; civil, infrastructure, industrial projects; state is most important client
Projects usually employ foreign basic engineering; no stable relation with foreign CEDOs	Most recent projects are in collaboration with foreign CEDOs
Founded 1970 by two retired Caltex engineers	Founded 1951 by five partners, three of them with experience in electromechanical installations
Knowledge, expertise of partners considerable	Knowledge, expertise of partners
To work principally for Caltex in areas well-known to the partners	No definite long-run strategy except to make use of opportunities, adapting to a context that changes its nature every few years
Firm has always worked for the same client, Caltex, except on two occasions, and on the same type of project, even to this day	Firm took different jobs in construction, installation, in diverse markets; engineering was a separate activity started much later; many different types of projects were prepared (detailed engineering), wishes to look for opportunities in a not too stable context
Hire young graduates, train them; high turnover; regular use of experienced consultants for certain tasks	On forming engineering dept. in 1975, quickly acquired personnel, apparently from market; hired group of experienced managers; formulated a 2-year training program for young professionals (postponed)

(continued)

(Table 20 concluded)

	Korea	Brazil
Acquisition of knowledge	Apparently much learning on the job from partner, foreign associates; much progress but not able yet to carry out basic engineering stage	Clear long-run strategy: choose areas where technology may be mastered, go from simple to complex; main instruments: full-disclosure clauses, get to be prime contractor, have own dept. for study and research, own sulfuric acid plant, much trained staff; support from clients' confidence; high profits reinvested in learning; reached basic engineering stage
Relations with foreign CEDOs	Close, stable relationship with partner, Toyo Eng. Co. (details not specified)	Look for full disclosure; have aggressive policy to learn as much as possible and to achieve higher responsibility in projects, if possible as prime contractor
Government support on demand side (contracts, responsibility)	Government demand very important, particularly during the first few years	Key role by granting contracts, allocating increasing responsibility, backing negotiations with foreign CEDOs; weak support in early years probably retarded technical progress of firm
Govt. support on supply side (finance,incentives)	Government created the CEDO, enacted legislation in 1968 favouring local C&E	Seems to have been significant in SULFAB investment and apparently also in other cases
Main problems faced in development	Difficulty in hiring trained professionals; hesitation of investors to employ local CEDO	Risk aversion by state clients at early stage
Some positive characteristics shown	Good success in work; one of the few Korean CEDOs able to provide "authentic engineering services"	Good management; good market strategy; good strategies, procedures for learning

EVOLUTION

A and K became multipurpose CEDOs, working in a variety of markets and in the case of K exporting services. The variety is particularly striking in the case of A, showing the wish to profit from opportunities. Excepting P, which has shown almost no significant changes, the firms have progressed in the range of services rendered, and the projects undertaken have become larger and more complex. B has moved cautiously, mastering the technology and the whole project cycle in one area before moving on to another; it has been helped in this by the relatively large, fast-growing

Philippines	Argentina
No explicit policy beyond using know-how of partners and consultants; learning on the job	In contracting stage, on-the-job learning; later, technology acquired through hiring experienced professionals and through the preparation of a number of proposals (in cooperation with foreign CEDOs in many cases) and also on the job; learning not concentrated in one or two major fields; still far from reaching basic engineering stage
No links with foreign CEDOs	On projects employing foreign know-how (little information on this)
Government plays no role: not a client	Firm prospers when government demand increases; strong fluctuations, no policies to even them out
No role is played by the government	Not indicated
Expansion is difficult because of risk aversion, lack of senior professionals, difficulty in recruiting and retaining human resources	Fluctuations in government work; no explicit promotion policy for CEDOs on the part of government
Careful to do high-quality work	Good eye for opportunities; firm now interested in progressing technologically, in diversifying, and in linking up with foreign CEDOs to supply turnkey plants

Brazilian economy, which has assured a sufficient volume of work in new plant C&E.

All firms heavily recruited young graduates and found it necessary to put much effort into training them, particularly in engineering design skills. A prepared a 2-year training program for young professionals, which has been postponed until business again picks up. K has hired professionals from industry, and A has recruited several experienced managers for its expansion into engineering activities. P regularly uses experienced consultants (usually retired people) for certain tasks; it is not clear whether the other firms, which are larger, find it necessary to do likewise.

B is notable for its clear long-term objectives and for the strategies it adopted. It chose areas where technology mastery could be achieved; it went from the simple to the more complex; it obtained full-disclosure clauses in contracts with foreign CEDOs; it got to be the prime contractor; it devoted abundant resources to the training of personnel; it created its own Department of Industrial Processes, for study and research; and it became the controlling shareholder in a sulfuric-acid plant, which it now operates, using the plant not only for production but for experimental and demonstration purposes and retaining part of the profits for research and experimental work. It was strongly supported by the confidence placed in it by its clients and financial institutions and by substantial profits in its operations, which it has largely reinvested in training, research, and learning. As a consequence, it has reached the stage of basic engineering in sulfuric acid and in phosphate fertilizers. New goals are now to reach this stage in phosphoric acid and in the chlorine–soda complex, the latter as a prelude to going into pulp.

A acquired its engineering skills by recruiting experienced professionals and managers, and much of the expertise was acquired on the job. P has drawn on expertise of partners and consultants but has not devoted special efforts to technology acquisition. K has apparently learned from its foreign associate, as well as from its own experience.

Whereas K has a stable relationship with its foreign associate, and P seems to have no links with foreign CEDOs, A and B associate with foreign CEDOs through project work. B carries out an aggressive policy to learn as much as possible from the foreign CEDOs with which it works. It looks for full disclosure and aims at sharing the major decisions and in fact at having full responsibility by becoming the prime contractor.

With the exception of P, demand from public-sector investments has been crucial. A has prospered when this has been high; but there have been strong fluctuations, and no countercyclical government policy has existed for its benefit or that of other CEDOs. For K, government demand has become less important in recent years as private demand has increased.

In B, public-sector investors have played a key role by granting contracts, allocating increasing responsibilities, and backing up the firm's negotiations with foreign CEDOs. Such support was not fully given at first, and this hesitation somewhat retarded the firm's technological development. Confidence placed in B seems to have played a crucial role in enabling it to participate as an investor in the SULFAB project and to take up the turnkey operation. Such confidence has been important in the rest of its assignments in recent years. How to create credibility and confidence in prospective clients remains a most important question.

No indication of government support on the supply side has been given in A. In K, this support has been very important, first through the act of creating the firm by decision of the government and with its financial participation, and second through the 1968 legislation favouring local C&E. In P, the government seems to have played no role at all. In B, assistance of government financial agencies has been sizable, particularly in relation to the SULFAB project.

The following would appear to be the most important problems faced by the firms during development:

- Risk aversion of clients, which limits the market and limits the scope of responsibilities assigned to the CEDO (mentioned by B, P, and K);
- Fluctuations in government investments and hence in demand for C&E services (A);
- No explicit government policy that in practice favours local C&E;
- Difficulty in recruiting and training capable professionals (P, K); and
- Lack of senior professionals (P).

The CEDOs studied have all been successful and have shown good management characteristics, although the management style has varied according to the circumstances: A needed adaptability and a good eye for opportunities, whereas P with its sole client could principally concentrate on doing a good technical job. B is notable for its well-thought-out strategies regarding markets and technological learning.

Performance in Investment Projects

An important question is how far the CEDOs have improved the way investment projects have been carried out, by increasing their social efficiency. There are indications that each one has improved social efficiency to a certain extent, although it is difficult to appraise the results from a mere reading of the studies.

B carried out the SULFAB project totally by itself, as a turnkey job, including the basic engineering. The technical performance was good; the work was finished on time and practically within the budget (other investments at that time in Brazil's petrochemical sector had large cost overruns), and the plant has performed well in operation. Purchases from local industry were not higher than in other cases — about 27% — so there does not seem to have been an extra impact here. However, one may point to other benefits such as the impact on the firm's technical progress during the investment work itself and during the operational phase afterward.

Two investment projects in which K participated were studied. In the first one, a styrene monomer plant, preinvestment work was done by the client; a foreign CEDO (in fact, K's associate) had responsibility for the basic engineering for some ancillary facilities. The government, which was the majority owner of the project, pressed for local purchasing, and, thanks to this effort, the share of local supplies was increased notably; K surveyed and recommended local suppliers whom it helped to comply with the requirements. These activities undoubtedly had a favourable impact on social efficiency. However, finance was a problem; financing and loans took priority over technical matters, and alternative technological choices had to be made according to the financial possibilities. K's technical performance was considered satisfactory. The second investment project was an ABS resin plant, and K was in charge of most stages of the project except basic engineering. Great efforts were made to increase the local component, and there were no obstacles on the financial side because the project was being self-financed by the client. Once again, technical performance was good. For comparison purposes, a turnkey project with a foreign CEDO was briefly analyzed. It was a large fertilizer plant, and the engineering fee was also very large; some of it went to local CEDOs that were subcontractors. The local supply of components was considered to be lower than if local CEDOs had had a more important participation.

The case study from the Philippines is no doubt the most carefully documented as regards the analysis of an investment project. The preinvestment work was done by the local project owner with his own staff. The technology chosen was a process that was more adapted to local conditions and had a higher employment potential than more modern processes would have had. It was decided to undertake the project's engineering and execution principally with in-house capacity. This meant later that a possibility of financing by IFC had to be foregone. The owner's Planning and Projects Department prepared the basic engineering project and took up project management responsibilities. Detailed engineering was subcontracted to a local CEDO — the one studied — and the supervision of construction was given to a French firm by request of a financial source from that country (learning opportunities here were used well). Local procurement was maximized. There were problems with government programing that required changes in the project, but apparently this project has been successfully carried out.

CONCLUSIONS

The CEDOs under study show quite different characteristics (Table 20), which to a certain extent reflect the diversity of national situations. Although their development has been highly idiosyncratic, it is clear that they share certain problems and face them in not too dissimilar ways. Such behaviour is roughly in line with what is expected on the basis of empirical and conceptual analysis, as reviewed in chapter 1 and would tend to show that regularities exist, so that comparative research on these topics may be significant and useful. Even though these CEDOs are all independent organizations, a study of their experience may shed some light on captive CEDOs, particularly regarding the acquisition of human resources and technology.

The four CEDOs have been successful (one of them very much so) as judged by their growth and by the results of their project work; thus, one cannot learn much from them about unsuccessful CEDOs. What can be gleaned, however, from some of the national situations is that very few CEDOs are able to prosper and mature from a much larger field of candidates: markets for C&E services in developing countries — at least, markets for domestically produced services — are not large. This means that diversification may be needed if a high and stable income is to be achieved. This we find in three of the four CEDOs reviewed.

An interesting feature comes out clearly. Large public and private enterprises frequently use their own in-house C&E capabilities to carry out a substantial part of the preinvestment work for their investment projects, down to the choice and negotiation of technology and the purchase of basic engineering. Outside C&E services are contracted to provide some inputs for those tasks and later on to carry out detailed engineering and other project services. One or more CEDOs may be involved, including foreign CEDOs. To understand the present role and future prospects of local C&E capabilities, one would have to learn about the usual practices of the major investors regarding the contracting of C&E services. This may need (as suggested by the Korean team) a longitudinal study in production branches.

The case studies have also supplied evidence of the positive role of domestic CEDOs when they are given the opportunity to disaggregate investment projects and engage local inputs. The tendency to do so seems to be present in all of the CEDOs reviewed, but it needs an enlightened project owner and the backing of authorities and local financial institutions if it is to be brought to fruition.

The important role of the state regarding CEDO development and performance, both as a client and as a direct supporter of CEDOs, is abundantly confirmed by the case studies. When state support has not been forthcoming, the result has been a long struggle in which the CEDO is forced to engage in whatever endeavour it can; like the luckless Spaniard in Manrique's famous poem, "Coplas," "con oficios non debidos se mantiene" (with unwonted trades surviving).

Finally, the case studies have largely fulfilled their primary purpose of helping to produce an understanding of the problems in developing and using C&E capabilities in developing countries, to indicate the researchability of the subject, and in general to contribute to a better formulation of an international collaborative project. The researchers who undertook the case studies were unanimous in their appreciation of the importance of the subject and, through their largely successful efforts, showed that it is possible to get access to the sort of information needed for a fruitful analysis of the subject. They identified important issues, recommended methods and approaches, and made concrete suggestions for further research, which they felt should be of an action-oriented nature. These contributions and those of the participants in the St. Jovite seminar are taken up in the next chapter, which deals with future research on CEDOs.

CHAPTER 8

FURTHER RESEARCH ON CONSULTING AND ENGINEERING

ALBERTO ARÁOZ

The case studies and other documents were examined at a review meeting that took place in St. Jovite, Quebec, Canada, in October 1979, with the participation of a group of professionals with great experience on the subject. In the very rich and imaginative debate that took place, the participants raised a number of interesting points that complement those included in the papers reviewed at the meeting. It seems valuable to review them, briefly.

THE ROLE AND ACTIVITIES OF A CEDO

Consulting and engineering design have recently become a separate economic activity that is concerned with the management and utilization of certain kinds of information. More needs to be learned about the economic role of this activity, on account of its importance for development and the achievement of technological self-reliance.[32]

One important aspect of this role is what may be called disaggregation of the package of risk. A large project, when taken as a whole, may appear to be too risky for local handling, but a local CEDO may disaggregate it into smaller parts, many of which can be handled locally without undue risk (like structure, electricity, steam, and other peripheral processes), leaving the core aspects to be managed by a foreign CEDO or supplier.

Regarding the role of a CEDO in linking productive units with the S&T system, participants remarked that a CEDO normally works with state-of-the-art technology; if a locally developed technology is to be introduced in an investment project, the risks must be assumed to a large extent by the project owner.

The success of a CEDO from a social point of view may be expressed by quantitative indicators such as:

- Technological self-reliance ratio (TSR) = Total cost of local inputs in a project/Total cost of the project;

[32] Alternative definitions were offered for this concept: capability to select technology appropriate to the country; capability to select and perform basic engineering and to develop basic know-how within the country where projects are based; capability to design and engineer projects that utilize locally available resources of personnel, finance, and equipment and that promote their development when not there; capability to increase proportion of local-to-foreign inputs in the implementation of investment projects.

- Coefficient of use of local services and equipment (C_E) = (Cost of locally provided C&E + surveys + equipment)/Total cost of the project;
- Coefficient of use of local technology (C_{RD}) = Cost of projects based on local technology/Total cost of all projects; and
- Coefficient of use of local basic engineering (C_{BE}) = Cost of basic engineering performed by local CEDOs/Total cost of basic engineering in the project.

These indicators may be expected to increase with successful expansion and use of local C&E capabilities.

CEDO Development

It was suggested that political stability is a necessary condition for the development of C&E capabilities to a mature stage. In the development of a CEDO, the efforts of the owners and staff combined with favourable market conditions and some general support by the state may allow the CEDO to reach a certain point. To go beyond this point, i.e., to acquire sufficient size and maturity expressed in capabilities for basic engineering and turnkey projects, extraordinary support measures are needed, including profitable large contracts, strong support vis-à-vis foreign technology owners, risk-taking on the part of clients, ample credit, and other facilities. This hypothesis, which seems to be borne out by the findings in the Brazilian case study, has significant policy implications. It would be important to identify the moment when a promising CEDO has reached the "inflexion point" in which a package of measures may speed up and consolidate its development; and it would be useful to develop guidelines for the design of those measures.

The Organization of a National C&E Capability

The development of C&E capabilities implies the development of CEDOs and that of design capabilities in project owners, productive units, construction firms, and capital goods manufacturers. It is very important to develop in-house capabilities related to the "factory floor," and it was mentioned that of some 100 cases of exports of turnkey plants from Argentina none had been done by an independent CEDO.

The problems in building up a national C&E capability are bound to be very different in countries of different size and production structures (for instance, Peru and India), so that policy suggestions cannot easily be transferred from one to the other. Different sectors show different types of CEDOs, which may require different promotion policies.

Type of Knowledge According to Sector

From (1) to (5) in the following typology, there is an increase in (a) the intensity of links in the industrial system that are produced by CEDO activities and (b) the volume of consulting and engineering design services as a proportion of the total cost of investment projects: (1) civil works, infrastructure, building: knowledge — embodied in civil engineering construction; CEDO — civil engineering design firm; (2) textile, plastics, mechanical, and similar manufacturing industry: knowledge — embodied in layout, organization of production, and internal transport; CEDO —

engineering design firm oriented to the industrial buildings, equipment installation, the supply of utilities, a general engineering design firm; (3) steel, cement, paper: knowledge — embodied in equipment; CEDO — engineering design firm specializing in the erection of heavy equipment; (4) automated installations (telecommunications, automatic transportation of products, automatic production plants): knowledge — embodied in the software; CEDO — automatic systems engineering design firm; and (5) chemicals, petrochemicals: knowledge — embodied in the process; CEDO — process engineering design firm (J. Perrin, contribution at the St. Jovite meeting).

FURTHER RESEARCH

Finally, the participants discussed the question of further research on consulting and engineering design. There was general agreement about the major role of C&E capabilities in development and the need for explicit government intervention to build those capabilities to the level of basic engineering. Further studies were felt to be necessary on the subject, and it was agreed, on the basis of the results shown by the case studies, that significant policy issues could be identified and subjected to research through the use of appropriate social science research methods.

The participants agreed that this research is not easy. How developing countries may acquire and utilize C&E capabilities is a complex question, on which there is much scattered knowledge but also much ignorance. Empiric research tends to come up with many anecdotal views, which have to be pieced together. Mention was made of the iterative approach taken in the past 10 years by researchers at Grenoble University: hypotheses were made about the role of CEDOs and C&E services in economic development, and case studies were conducted in different locations, leading to a new round of reflection and theorizing, more case studies, etc.

Although the formulation and the testing of hypotheses in this field were recognized as difficult tasks, some major lines of inquiry were suggested that could lead to testable hypotheses:

- The CEDO as a link between different activities related to industrial development (production, construction, capital goods, R&D, training, and finance) and between the services required to formulate and implement an investment project (feasibility studies, basic engineering, detailed engineering, procurement, construction, commissioning, etc.);
- The factors affecting the development, functioning, and utilization of CEDOs: explicit and implicit policies, characteristics of the national context, characteristics of the international context; and
- Alternative strategies for the development of CEDOs and the measures required by each.

It was agreed that research should be action-oriented, looking for results that are directly useful to policymakers and promoting the participation of the latter and other important participants in the research process itself and in the discussion of results.

The participants felt that a concerted effort to carry out studies on C&E in a number of developing countries would enhance the value of research, through discussion and comparison of results; this would naturally call for a common method and instruments of research as uniform as possible.[33]

The Shape of Further Research

What shape is further research to have? What topics should it deal with, and how? Partial replies to these questions came up in some of the case studies presented in this volume and in the conclusions of the St. Jovite meeting.

Conceptual, Policy, and Practical Research

Research may touch on a large number of topics; in some cases it may have as its principal objective an increase in knowledge about a specific aspect of C&E and of its impact on development. This conceptual research, leaning toward theory, is needed both to increase the basic understanding and to help prepare the ground for research programs of a more applied nature.

Policy research, i.e., research aimed at identifying policy options and evaluating policy instruments and concrete measures, would probably be a more important endeavour in developing countries, because of its direct relevance to policymaking and policy implementation, particulary when conducted in an action-oriented fashion.

Empiric research may also be carried out on very practical questions, such as the development of useful procedures, guidelines, and methods of immediate application to the management of CEDOs and of investment projects. On this there is already a certain amount of experience in some developing countries, which it may be worthwhile to examine, codify, and make available to other such countries. A promising way to accomplish this task is through a cooperation network of mature CEDOs in several countries.

Main Areas and Issues for Research

Research on the development and utilization of C&E capabilities in developing countries may be carried out at three levels: that of the organization producing C&E services, the focus being on its evolution, maturing, and functioning; that of the project, the focus on performance of local CEDOs and the value of the services they produce; and finally, at a general, macro level, an examination being undertaken of the supply of C&E capabilities, nationally and by sector, and their utilization by public and private units.

Some of the principal aspects that merit research are:

- The mature CEDO and its functioning: (a) role of a CEDO as a link, or an intermediary, between technology-generating activities and productive activities, and between the capital goods sector and the productive activities, with experimental evidence of this role; (b) rationalities of

[33] An international collaborative research project on Consulting and Engineering Design Capabilities in Developing Countries was drafted by the participants in St. Jovite as a basis for a proposal to be submitted to the International Development Research Centre.

different types of CEDOs — the captive CEDO, the state CEDO, the private CEDO (is the profit motive detracting from the potential social role; when can private CEDOs function as pure CEDOs, and when do they need to be a part of a larger organization with other activities such as construction or production?); (c) efficiency of a CEDO and of the services it produces; here one may use the approach suggested in the Korean report; dependent variables would be the productive efficiency of the engineering services (achievement of cost and duration targets, production of quality services) and the productive efficiency of the CEDO; factors affecting them are environmental (noncontrollable), policy level (semicontrollable), and project level (controllable); a model would have to be developed about the interrelations among the variables, from which hypotheses may be derived for a systematic analysis; and (d) models of CEDOs in the mature state; differences with CEDOs of developed countries.

- Development of a CEDO: (a) influence of CEDO origin on later development; (b) acquisition of human resources; problems and solutions; training; (c) acquisition of technology; paths of technological learning; regularities; the main problem here is how to acquire basic engineering capabilities, and ultimately the capability to innovate on basic technology (can an independent CEDO do it in a developing country, or is a captive CEDO the solution to achieving the mastery of technology in the dynamic branches? See the enumeration of factors affecting the achievement of technology mastery in project engineering in the Brazilian case study); (d) relations with foreign CEDOs (are there typical patterns; what are the problems in participating in the crucial project decisions so that one may achieve full transfer of technology?); (e) government policies and their effects on demand, particularly purchasing practices; types of contracts; pricing policies (what can the state do to minimize fluctuations in demand, and what can the CEDO do to cope with them?); (f) effect of government policies on supply.
- The investment project: (a) the advantages of local C&E services over foreign ones; here a large number of questions dealing with the private and the social efficiency of C&E may be posed, having to do with the impacts on the various participants and the country at large, the costs, the self-reliance aspects, etc.; (b) the provision of local C&E services; the complementarity of in-house capacity and outside CEDO capacity in different types of investment projects; terms of reference and types of contracts; etc.; (c) the associations between local and foreign services; responsibilities given to local C&E capacity; demands made to the foreign CEDO, ensuring technology transfer, full disclosure, training of C&E personnel, etc.; (d) the source of funding as a barrier to the use of local C&E capabilities, technological inputs, equipment, etc.; what evidence may be gathered regarding different sources; what may be done (for instance, a persuasion campaign in regard to local development banks, or a joint international effort vis-à-vis international and regional banks); and (e) the effects of certain attitudes toward risk on the part of state and private project owners as a barrier to enlightened project formulation and implementation and what can be done about them.
- Building up and utilizing the national C&E capacity: (a) organization of the national C&E capacity; the C&E capacity needed for the major sectors in the economy; criteria for appraising requirements and for planning the

development of capacity; the advantages and drawbacks of different types of CEDOs, in the context of a certain sectoral/national situation: large or small; in-house or independent; public or privately owned; specialized or multipurpose; pure or attached to another type of activity (construction, equipment-making, production); and the problems of small- and medium-scale industry (what type of C&E capability may be set up for them?); (b) government policies in favour of demand for C&E services locally produced, such as legislation favouring the use of local C&E; protection measures for the C&E infant sector; and selection procedures that will not discriminate against local C&E; requirements for well-prepared investment projects for presentation to state banks and to the departments in charge of administering investment incentives; modification of unfavourable attitudes and behaviours of public-sector investors; regulation of the demand for C&E services by the public sector so that fluctuations are minimal, creation of a fund to finance certain studies not urgently needed that CEDOs can carry out when demand slackens; criteria the government can use in bargaining with foreign financial sources to ensure a higher local C&E participation; (c) government policies in favour of the supply of local C&E services, such as credit lines for working capital and preparation of proposals; incentives of various kinds for supplying the local market and for exporting C&E services; regulation of the participation of foreign capital in local CEDOs — for instance, rules of the game to prevent undesired takeovers of successful national CEDOs; and (d) policies in favour of cooperation with other developing countries regarding C&E; creation of larger markets in one or more sectors at a subregional or higher level; guidelines for export of C&E services from one country to another so that the latter receives full benefits.

It is clear that research efforts at the three levels of CEDO, project, and country should not proceed independently but should be integrated. The same issue will come up in two or more levels, and findings in one level will frequently feed another level. In the case of an international comparative research effort, frequent comparisons of the results achieved by different national teams would be useful feedback for the quality of the work.

Research at the level of the CEDO should concentrate on:

- CEDOs serving modern infrastructure or industrial sectors that carry out large investment projects, where the main agents are public enterprises and agencies; such CEDOs may be captive or independent, public or private; they are crucial if a country is to achieve self-reliant development; they serve sectors such as infrastructure (buildings and civil works, roads, ports, airports, water and sewage systems, transport systems, communications systems), energy (oil and gas extraction, generation of thermal, hydro, and nuclear energy, electricity transmission lines), mining (coal, iron, copper, tin, etc.), basic metallurgy (iron and steel, aluminum and copper smelting and refining, etc.), and process industries (chemicals, petrochemicals, pulp and paper, etc.).
- CEDOs that provide a wide range of C&E services to small and medium industry; they may be a part of an institution like a technology institute, information centre, productivity organization; some countries have developed special consultancy institutions for the small-scale sector. These CEDOs are mostly in the public sector, have a very large variety of customers, and may charge only nominal fees for their services. Once

again, they share many similar problems that are worth studying. In particular, the case of technology institutions may constitute a worthwhile focus for research efforts; and

- CEDOs that principally carry out preinvestment work; these include government groups in ministries, development banks, or special agencies that are devoted to the preparation of investment projects; more or less stable in-house groups of productive units; and small private firms that may also offer a narrow range of engineering services as subcontractors to large CEDOs.

At the project level, one may follow the suggestion contained in the Korean case study and carry out a combined cross-sectional and longitudinal analysis. The first step would be to examine a number of similar projects, and the second would be to analyze investment projects carried out during the last 10–15 years in a branch or branches and to outline their evolution in terms of the way they have been carried out. The focus of such research should initially be on the CEDOs reviewed in this publication, as a natural extension of the information gathered thus far.

Finally, at the country level, a survey should be made of the evolution of C&E activities, relating it to the characteristics of industrial and technological development in the past. This information would serve as a framework for studies at the CEDO and project levels and would shed light on the factors that have influenced the past development and utilization of C&E capability. Another general aspect to be examined is the national environment within which CEDOs operate at present — policies, legislation, contextual factors. Such an examination would permit a more adequate discussion of possible actions in the policy areas under study. Here, as suggested in the Philippines case study, it would be desirable to focus research on cause–effect analysis of specific questions, rather than to make case studies. The methods can be designed on the basis of some of the categories and approaches developed in the STPI project.

PROBLEMS

Research on C&E presents certain difficulties, springing from the relative novelty of the field, the complexity of the subject, and the problems in gaining access to data.

The relative novelty of this field as a focus for research means that basic concepts have not yet crystalized sufficiently and that there is a need to structure properly this field of work.[34] Thus, further exploratory work is needed before efforts on theory, formulation of detailed hypotheses, and the application of the hypothetical–deductive methods of social science research will be meaningful. The comparison between national and sectoral experiences may show those aspects that are specific to certain sectors and countries and those that are more universal.

The complexity of the subject is reflected in the fact that there are many different participants and a large number of variables (related to the environment, the policies of government, and the characteristics of CEDOs, clients, and projects). This complexity makes it difficult to

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[34] The novelty came out clearly at the St. Jovite meeting, where new concepts and new situations were being introduced into the discussion almost up to the last moment.

formulate testable hypotheses, and the testing is often difficult because not enough cases may be found for statistical validation in developing countries — few CEDOs worthy of study, few investment projects with significant local CEDO participation in which data may be collected, etc. Also, CEDOs, taken as units of analysis, are sometimes difficult to define (when does a technical group in a firm become an in-house CEDO; what part of an industrial research institute may be considered as a CEDO?) and show widely varying characteristics, with strong idiosyncratic overtones in their structure, behaviour, history, relations to other participants, etc. Thus, a search for regularities and general conclusions is difficult.[35]

The study of the process of development of C&E capabilities faces the problem that whatever factors have been important influences in the past may no longer be significant and, therefore, their study would be of little use as a basis for predictions or as a guide to action at present. A successful strategy used by a CEDO in the past may not be successful today for a similar CEDO.

In addition, there may be problems in gaining access to information about CEDOs and investment projects. Even with a great deal of openness and goodwill on the part of the CEDO, it may be difficult to carry out the necessary series of interviews with key personnel, who are busy and always on the run or to obtain information from documents and files, which may be in disarray, if they exist at all. In the case of projects it may not be easy to get in touch with all the principal participants, particularly if the task has been carried out long ago. However, the successful experience of the case studies included in this volume has shown that the necessary information can be collected if the research team makes sufficient efforts and makes a correct approach to the different participants possessing the information.

METHODS

At this relatively early stage of knowledge about the subject, research has to rely mainly on inductive methods, which gather a large amount of information and extract tentative conclusions on a weight-of-evidence approach; statistical testing of hypotheses is feasible only in a few well-defined situations.

Case studies, cross-sectional analyses, longitudinal or time-series analyses, historical analyses of the development of an industrial sector and the role played by the C&E design capability, and prescriptive analyses of policy issues are potential first steps. Various research instruments should be developed, among them: measurement scales for a number of parameters (such as those mentioned earlier in this chapter); interview guidelines and questionnaires for users, project owners, CEDO managers, and policymakers; guidelines for prescriptive analysis, etc. The collection

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[35] An example is the study of technology acquisition by a CEDO in a certain branch. It is likely that very few CEDOs will be found in one branch and country for which it makes sense to study this characteristic; hence the universe is small. Each CEDO in a certain way is unique; technology acquisition seems to be a highly idiosyncratic process where personal and chance factors play an important role. Perhaps anthropologic approaches would be better, because they would retain the richness and diversity of the process under study.

of data would take place mainly through the analysis and summary of existing literature, surveys of quantitative information, questionnaire surveys, and interviews.

Case studies, in particular, are useful ways of starting research in complex situations where many variables and decision centres are present, as in many aspects of C&E development and utilization. Case studies incorporate this complexity in the detailed descriptions of individual situations. Because they require the use of an inductive methodological approach and do not imply the collection of data for testing conjectures and hypotheses, they cannot give conclusions of a general validity. But the analysis of all the elements of a situation and their interrelations permits the identification of aspects that otherwise would not be clearly perceived. Case studies performed in different sectors and countries on the same situation and issue (for instance, training of C&E personnel through association with a foreign CEDO in an investment project), if done with a similar design as regards the main questions asked and the type of information collected and examined, may allow a certain degree of comparison of results and make it possible to formulate conceptual interpretations and hypotheses that may later be submitted to further corroboration, perhaps through statistical evidence.

As has already been said, research should be action-oriented, aiming at producing not only intellectual results but also a number of practical results, principally a change of attitudes, a learning process in those participating in the work or being in close touch with it, and the collection and analysis of much useful information through the study and comparison of experiences, the discussion of results, and the gathering of data in general.

As indicated by Sagasti in *Science and technology for development: main comparative report of the STPI project* (1978, Ottawa, Canada, IDRC, IDRC-109e), in action-oriented research the objective should be to generate useful knowledge for policymaking, decision-making, and planning. This goal calls for an attitude different from that in academic social science research.

Action-oriented researchers should avoid simplifying a problem too much but rather look at it in all its complexity. The temptation should be resisted to fragment a problem too much and to introduce simplifying assumptions that would allow the use of more conventional research approaches. There should be an effort to understand the nature of conflicts, the value premises, and the attitudes of different participants. The collaboration of researchers from different disciplinary backgrounds would seem to be important so that issues may be considered from different viewpoints.

The involvement of policymakers and participants is essential in action-oriented research. This close interaction may bring about important practical results, as a consequence of the collective learning exercise.

Prospects

Although the subject of consulting and engineering design is still to be thoroughly examined and requires further exploratory work, a number of important problem areas and issues can be identified and may be explored principally through inductive approaches that need the gathering of ample evidence. In a novel and complex field of research such as this, there are limits to the possibilities of experimental verification and to attempts at explaining clearly causal relations between policy measures and effects. In the face of such limitations one may not be able to give a definitive reply to questions, but it may be possible to develop explanatory hypotheses, which, when confirmed to a certain degree, may be able to reduce the uncertainty borne of ignorance and help in connecting knowledge with action. Successive approximations may enable one to produce a significant answer to a clearly formulated question, on the basis of three, four, or five cases from which certain patterns emerge, allowing one to formulate tentative generalizations to be checked at a further stage. Furthermore, there are certain issues where the deductive approach may be employed at this stage.

In this incremental way, results may be achieved that will undoubtedly lower the coefficient of ignorance of policymakers and participants, particularly if comparisons can be made from the experiences analyzed in different countries, so that better measures may be envisaged to develop domestic C&E capabilities and apply them efficiently in a given developing country.

APPENDIX

PRESIDENTIAL INSTRUCTION ON THE CREATION OF ENGINEERING SERVICE COMPANIES IN KOREA, 15 MAY 1969

The majority of major industrial plants, into which a vast amount of foreign and domestic capital investments has been channeled, have been built with foreign capital, foreign technology, and foreign services in all phases of their construction: from basic design to test operation. Therefore, the participation of the Korean engineers in, and the use of domestically available materials for, the construction of these plants has been impossible, while the lack of our technical know-how and the shortage of adequately trained Korean engineers have made it difficult for us to ask foreign countries for our greater participation in these projects. As a result, the drain on our foreign exchange reserves has been considerable. Should this situation be allowed to continue, the loss of foreign exchange will certainly increase as the amount of investments goes up.

To deal with the situation, the government will henceforth do away with the turnkey job principle to make newly emerging Korean engineering service companies and homemade products take a greater share in these projects. For this purpose, the establishment of joint-venture service companies will be encouraged between foreign engineering service firms of high standing and able engineers at home who have been pooled by industries, and thus to form a combination of foreign capital and domestic skills.

By so doing, the government encourages the use of homemade equipment and materials fully in the construction of plants and promotes a learning process through the participation of local engineers in all phases of plant construction, from basic design to final operation.

At the present stage, the most important problem is how to increase the degree of participation of Korean engineers in, and the quantity of homemade materials to be used for, such plant construction. In particular, the government is striving for the construction of petrochemical plants, for which an investment of about $200 million will be required. In the implementation of these projects, conventional methods will be boldly discarded in favour of the utilization of the aforementioned joint-venture engineering service companies so that any further drain on the country's foreign exchange may be curbed. In addition, the government will encourage the integration of Korean manufacturing industries with an eye to raising the standards of domestic products, and all efforts will be made to search for able brains and excellent engineers hitherto untapped.

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