Technology, Finance, and Development

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An Analysis of the World Bank as a Technological Institution

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1 Introduction: The World Bank as a Technological Institution

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This book is about the union of money and technology. Its central message is that one of the world's leading financial institutions—the International Bank for Reconstruction and Development (IBRD), more generally known as the World Bank—has had a substantial impact on the development and diffusion of technology in the Third World. In fact, the World Bank has become one of the main technological institutions catering to the needs of the developing world, although it did not plan to assume such a role. This status may come as a surprise to those who view it exclusively as a financing institution, as well as to those for whom technological activities are associated essentially with industrial corporations, research institutions, or government ministries for science and technology.

The central mission of the World Bank, as well as its raison d'être in the international system, is to act as a development agency. But in fulfilling this mission, the Bank has also become a technological institution. This book examines the many facets of this function. By *technological institution*, we mean an organization that, directly or indirectly, finances or carries out research, transfers technology, promotes better choices and uses of technology, encourages innovation, and contributes to the building up of technological capabilities.

The process whereby the Bank has become such an institution is fairly simple. All of the projects the Bank finances involve technology in some way or another; machinery, for instance, has to be purchased from industrial suppliers, people have to be trained in new skills to operate productive units efficiently, and new crops and new ways of operating have to be diffused to farmers. Some of the technologies necessary to the success of a project must be transferred from abroad, while others can be found locally, and the execution of the project generally contributes to the building up of a local technological capability in the country concerned. The range of technologies thus transferred or developed is extremely wide; it includes both hardware—machinery, equipment, tools—and software, or organizational tools, managerial methods, training programs, and institutional schemes.

What has contributed perhaps most directly to making the World Bank a technological institution is not only this essential linkage between technology and projects; after all, hundreds of other large banks throughout the world finance projects without playing a significant technological role. Their primary concern, however, is to provide money for investment purposes, and not to determine whether the technology chosen for the investment makes the most efficient use of resources, whether local people have been trained to master the technology, or whether there has been a thorough assessment of the impact of the project on the environment or on the society. What makes the Bank a technological institution is its active role in the choice of technologies appropriate to each particular situation and in the mobilization of local technological capacity for the accomplishment of socioeconomic objectives and human development.

When the World Bank helps one of its member countries to plan the development of national power supplies or the modernization of the agricultural sector, it not only sets the stage for specific projects but helps the country to examine the various ways in which the development objectives for that sector can be achieved. This sector work brings into play a wide range of factors, which include finance, economics, sociology, politics, institution building, and technology taken in the broadest sense.

The Bank's advice carries weight not only because it is linked with large sums of money but also because of the Bank's experience as a development agency. Ultimately, however, it is the government that selects a particular project from its portfolio for Bank assistance, and it is the government that organizes and manages the design and implementation of the project. Hence the successes and failures of the projects that the Bank finances are shared with the governments to which it lends. The Bank is one of the few sources of disinterested advice on development policies and projects. Furthermore, because of the Bank's worldwide experience and the fact that its staff is drawn from all over the world, the formal and informal advice of the Bank is a means of sharing the experience of developing and developed countries. The Bank's staff no doubt may be biased by their training and experience, but they are held to strict neutrality with regard to sources of equipment and technology. Some government officials often welcome a close involvement of the Bank in the management of a project in order to protect themselves against political and other pressures that could endanger the success of the project.

The Bank's attitudes toward the choice of technology, the development and diffusion of technological innovation, and the building of technological capacity in developing countries have evolved in a pragmatic and unplanned way. One of the strengths and originalities of the Bank's technological activities is that they are intimately linked with, and indeed an integral part of, the development projects financed by the Bank. Another is the Bank's

access to the economic and financial decision makers in each country. These two factors, combined with the Bank's long and diverse experience as a development agency, can ensure a better fit between technological planning and development priorities and help to overcome one of the major problems facing the developing countries in their attempts to mobilize technology for development: the poor linkage between indigenous research activities on the one hand and the whole gamut of activities aimed at promoting economic and social development on the other. For this reason alone, the Bank's experience as a technological institution deserves to be closely studied by the development community and by experts in science and technology. Indeed, we may well be witnessing the beginnings of a new type of technology policy based on financial institutions, unlike our current technology policies, which are based for the most part on research institutions.

The analysis presented in the chapters that follow of the World Bank's technological activities appears particularly timely at a time when technology policy matters. once confined to the field of academic research and internal politics, have reached the public domain and become a central concern to diplomats and policymakers and a major subject of negotiation between industrialized and developing countries.

Themes and Outline of the Book

The chapters in this book illustrate the ways in which the World Bank has come to play the part of a technological institution. They do not cover all of the Bank's activities but only those—and they are numerous—where this technological role is most conspicuous. The book suggests a number of relevant conclusions for policymakers and for all others interested in the role of financial institutions in the process of technological development. Most of the chapters have been written by World Bank staff members and consultants who were directly involved in the conception and execution of the development projects presented here. They do not present an official view of the World Bank, and the authors bear full responsibility for their facts, interpretations, and conclusions.

This book is divided into four parts, each illustrating a general theme or central aspect of the World Bank's activities as a technological institution. Part I examines the ways in which technology is mobilized at the sector level and shows how in this process the Bank has come to develop a vast store of knowledge and experience, as well as a set of coherent sectoral technology policies, which may be considered an important innovation in their own right. This is perhaps most conspicuous in the case of agriculture and rural development but is also evident in the promotion of industrial innovation,

civil works construction, urban traffic management, and the uses of satellite remote sensing.

The four chapters in part II extend this sectoral approach and focus on the applications of appropriate technology to meet the basic needs of the poor. The sectors examined are water supply and waste disposal, sanitation, urban development, and education. These chapters show, among other things, that the World Bank has become one of the leading innovators in the field of appropriate technology for the poor.

The authors of part III focus on the problems of technology transfer in sectors where the Bank traditionally has been heavily involved—the development of water resources, power generation and distribution, fertilizer production, and investments in private industrial corporations—as well as in a newer but nevertheless rather similar sector, the engineering industries. These five chapters show the ways in which modern technology is transferred in the course of projects and how such transfers contribute to the building up of local technological capabilities in the borrowing countries.

The authors show that complex operating technologies can be successfully transferred to developing nations, even though the process may not always be easy, no doubt a reassuring conclusion for those who question the ability of the international technological system to contribute to the development of the world's poorer nations. One of the most significant conclusions emerging from this presentation is that, contrary to what often happens in the private sector, restrictions on the use of imported technology are generally unimportant, the costs of imported technology appear to be reasonable, and multinational corporations tend to play a subordinate rather than dominant role.

The last part of the book focuses on efforts to develop global international research networks. The World Bank has been involved in three such networks described here: the Consultative Group on International Agricultural Research (CGIAR), the Tropical Diseases Research Program (TDR), and the proposed (and now defunct) Cotton Development International (CDI). In these chapters, the authors describe the ways in which the Bank has contributed, financially and organizationally, to the building up of these networks and also look into the complex issues of institutional entrepreneurship, research priorities and opportunities, political support, and social relevance. Their presentations amount to a state-of-the-art method for managing international research networks.

The concluding chapter attempts to draw all the threads together and to present a general reflection on the role of the Bank as a technological institution and on the emergence of financial institutions as major actors in the mobilization of science and technology for development. The central conclusion is that financial institutions such as the World Bank have become important partners in the technological system and that this role probably

could be made yet more effective if it were more generally acknowledged and used by all those who have a stake in the economic and social development of the world's poorest countries.

The Missing Elements

Any book, particularly a collective work such as this one, gives rise to a number of questions as to what it does not contain. The omissions in this book are of three distinct types: omissions due to errors of the editors or to the unavailability of prospective authors, omissions due to the fact that a particular subject was too new to warrant a full chapter or detailed presentation, and omissions due to the fact that certain issues, however important in general, do not greatly affect the work of the Bank.

Among the last type of omissions, the most important lies in an area of central concern to policymakers involved in international negotiations about technology: the role played by multinational corporations in the process of technology transfer. But in the day-to-day operations of an international development agency such as the World Bank, as well as in the formulation of its long term development strategies, this issue is largely peripheral. The chapters of this book show, convincingly we believe, that when the borrowing government has a firm political commitment to build local technological capacity and to meet the needs of its population, development projects financed by the Bank do not in general raise any major difficulties as to the cost or availability of technology; multinational corporations, when they do intervene, generally play a rather minor part and are usually pitted against one another in the process of competitive bidding for the supply of equipment. Perhaps codes of conduct may be useful, but even in the absence of such a code, substantial amounts of technology are transferred effectively from industrialized to developing countries.

In general, technological problems in the sectors in which the Bank lends tend to result from inappropriate choices (which in turn often stem from inappropriate policies) and from inadequate local capacity to import and absorb technology rather than from external obstacles to the transfer of the required knowledge. Water development projects, slum upgrading programs, or rural development schemes financed by the Bank, for instance, do not involve proprietary technology, and what technology is needed is generally well known to all of the specialists involved. As for projects that do fall within the purview of multinational firms or need proprietary technology—as in the case of fertilizer plants or steel mills—the way in which they are prepared and the role of the Bank as a disinterested technical adviser

can be used by the member countries to reduce the difficulties that often occur in bilateral relations between unequal partners.

This book does not explicitly discuss the concepts of technological self-reliance and technological dependence—not because we believe them to be irrelevant or unimportant but because they have come to acquire political and rhetorical overtones and would therefore call for long qualifications and complex definitions. Nevertheless, much of the material presented in this book describes efforts aimed precisely at solving the problems of central concern to writers on technological dependence and proponents of greater technological self-reliance on the part of the developing nations: the development of a capacity to choose, adapt, and create technology suited to local needs and conditions.

Another concept that does not appear explicitly within this book is that of technological cooperation between developing countries (TCDC). Technological cooperation is indeed taking place among developing nations through the World Bank's developmental activities and notably its projects, although in a somewhat different way than the term generally suggests. The main agents of transfer, or technical cooperation, are the Bank staff members (many of whom are nationals of developing countries and some of whom eventually return home to assume important responsibilities) who have participated in the preparation of projects. In the same way, the Bank finances (and sometimes directly assigns) experts and consulting firms from developing countries to work in other developing countries on specific projects, and this is also an important channel of technology transfer between such countries. Cooperation does indeed take place, but it is primarily a side effect of projects and development strategies rather than a goal in its own right.

The second group of omissions from this book relates to issues and sectors that were too new to the Bank at the time this book was conceived to warrant a full chapter. The most obvious of these is that of energy, today certainly one of the world's most pressing problems. Although the Bank traditionally has been heavily involved in the financing of power generation and distribution projects, only in 1978 did it begin to support the development of petroleum resources in non-oil-producing developing countries. The Bank now devotes some 20 to 25 percent of its lending to energy projects.

The role of women in technology and development is another deliberate omission. Here again the reason is the relative novelty of this concern to the Bank, or for that matter to the development community as a whole. Most of the Bank's current projects attempt to evaluate their likely impact on the social position of women, on their earnings, on their role as producers, and on their function as innovators. They also look at women's contribution to the attainment of their objectives. This is most evident in the case of projects dealing with rural development, education, nutrition, and population.

The World Bank as a Financing Institution and Development Agency

The main business of the World Bank, which was established in 1945 as part of the United Nations system, is to provide loans for development projects. The sums involved are considerable; in fiscal year 1983 (the year ending June 30, 1983), for instance, lending commitments reached $14.6 billion, of which $11.3 billion were committed by the World Bank itself, $3.3 billion by the International Development Association (IDA), its affiliate specializing in concessional loans to the poorest of the developing countries, and $845 million by the International Finance Corporation (IFC), its affiliate devoted to investment in the private sector. (Equity investments by the Corporation amounted to $55.3 million.)

A commitment is an engagement to lend a specified sum of money for a specific project, but the disbursement of the sums thus promised generally extends over many years as the project progresses. Since the Bank's operations have expanded rapidly in the last decade and since the Bank generally reimburses its borrowers for sums of money actually spent, its disbursements in a year on past loan commitments are lower than its commitments during the year; in fiscal 1983, they were $6.8 billion for the Bank and $2.6 billion for IDA. These disbursement figures will increase in the coming years as borrowers spend the money committed in recent loans.

The World Bank is by far the largest of the international development banks. In 1982, loans approved by the European Investment Bank, for instance, amounted to some $4.1 billion, and those of the Inter-American Development Bank and the Asian Development Bank totaled $2.7 billion and $1.7 billion, respectively. The commitments of the African Development Bank, the newest of the big international regional development banks, amounted to $766 million.

The World Bank lends at somewhat below commercial rates. During fiscal year 1983, its variable lending rate ranged from 11.43 percent (beginning of the fiscal year) to 10.97 percent (end of the year). The terms of Bank lending are more favorable than those typically available from sources of commercial credit. The grace and maturity periods of World Bank loans depend on the financial needs of the borrower and on the construction and payback periods of the project. They are typically on the order of three to five years and fifteen to twenty years, respectively.

The average size of the 143 loans made by the World Bank proper in fiscal year 1983 was just below $79 million; that of the 120 IDA credits was just under $28 million. The average investment of the IFC during that same year was $14.6 million.

The overall size of projects is considerably larger than these figures suggest because the Bank rarely finances the full cost of a project. The govern-

ment of the country in which the project is carried out shares in the financing, and both the Bank and the government are frequently joined by bilateral agencies, commercial banks, or other independent funds. The Bank's contribution to a project varies considerably from project to project and from country to country (it tends to be higher in the poorest of the developing countries) but on average amounts to around 35 percent of the project's costs.

The World Bank generates the major portion of its gross revenues from interest on loans and by investing its liquid assets. Outstanding loans totaled $34 billion at the end of fiscal 1983. The average interest rate on outstanding loans during the year was 7.9 percent, producing income of $2.5 billion. In addition, commitment charges on undisbursed loan balances produced $213 million, and front-end fees earned on new loans, $97 million. Altogether the income on loans was $2.8 billion. Liquid assets aggregated $13 billion, net of commitments for settlements and cash collateral received on loaned securities. The Bank invests its liquid assets throughout the year. These investments yielded an average realized rate of return of 12.15 percent and generated $1.4 billion of investment income. An additional $18 million of revenue was derived from other income.

Expenditures of the World Bank, which include administrative expenses, interest, contributions to special programs, and issuance costs on borrowings, totaled $3.5 billion. Administrative costs were $322 million, after deducting $214 million for the management fee charged to the IDA and $4 million for the service-and-support fee charged to the IFC.

The Bank's net income ranged from $183 million to $275 million, with an average of $217 million, between 1970 and 1978. It rose sharply to $407 million in 1979, ranged between $585 million and $610 million between 1980 and 1982, and reached $752 million, the highest figure to date, in 1983.

The major source of funds of the IDA, the Bank's soft-loan affiliate, is the contributions from the Bank's wealthier member countries. In addition, each year the Bank has transferred some of its net income to IDA; in fiscal year (FY) 1983 the amount was $125 million. IDA funds are lent on concessional terms to the Bank's developing member countries with a per capita income below $795 (1980 dollars). These credits carry a ten-year grace period and are repaid over a period of forty additional years. There is no interest and only a 3/4 percent service charge.

Traditionally the World Bank has financed capital infrastructure, notably roads, railways, ports, power generation facilities, and basic industries. In recent years, its development strategy has placed much greater emphasis on projects aimed at increasing the well-being of the masses of poor people in the developing countries by making them more productive and by integrating them as active partners in the development process. Lending in tra-

ditional types of projects has continued and expanded, but a more systematic effort is being made to make these projects more responsive to the needs of the poorest segments of the population.

A senior Bank official has characterized the difference between a typical loan of the 1950s and one of the 1970s as follows:

> The 1950 loan would be for power generation in a middle-income developing country. In a sense it would be an "enclave" project, designed and supervised by foreign consultants, executed by foreign contractors and supplied and managed with the help of expatriates. The technical and financial viability of the project would be analyzed, as would be its organization and management, but little attention would be paid to its setting within the energy sector, to how the electricity would be distributed, and to the impact of the level and structure of tariffs on power consumption.
>
> The loan of the 1970s would be for rural development in a low-income developing country. It would provide an integrated package of goods and services (extension, credit, marketing, storage, infrastructure, research) to raise the productivity and living standards of the farmers. Existing local institutions would be strengthened or new ones established; local staff would be used as much as possible, with the help of extensive training programs; low-cost design and appropriate technology would be emphasized, giving greater opportunities for local contractors and sources of supply; a built-in system of monitoring and evaluation would help to adjust the project as it went forward and to draw lessons for future projects; and attention would be paid to cost recovery from the beneficiaries so that the project would be replicable.[1]

Both in its traditional projects and in its new-style projects, the Bank has deliberately sought to act as a development agency and not just as a financial institution; the purpose of a project is to promote broader development objectives, not merely to finance an investment opportunity. In order to understand the relationship between projects and development strategies, it is useful to take a closer look at how projects are identified, selected, prepared, appraised, and carried out and at the relationship between projects and development strategies.

Project Cycle

The project cycle, which can be defined as the set of procedures whereby projects are conceived, planned, appraised, approved, implemented, and evaluated, generally begins in informal discussions between government officials and Bank staff members that lead to an agreement that Bank financing is needed for a particular development project. There are many opportunities for such discussions. Bank missions consisting of staff members and consultants visit each member country at regular intervals, and govern-

ment officials are frequent visitors to Washington, where the Bank's headquarters and 90 percent of its permanent staff are located. (At present there are permanent local offices of the Bank in thirty-two developing countries.) These Bank missions to member countries range from short visits by one or two experts to update economic data, to four- to six-week missions of teams of eight to ten staff and consultants whose role might be to make an overall economic survey of the country or appraise a complex large-scale project. Occasionally Bank staff members are seconded or posted overseas for months, and even years, to deal with particularly difficult operational problems.

Bank economic missions review the overall economic situation of a country (annually in the case of major borrowers), discuss development priorities, and assess its need for foreign credit as well as its ability to absorb it, and later to repay it. In addition to their work on the general state of the economy and its financial stability, these missions also analyze the major sectors of the economy—agriculture, industry, and energy, to take but a few examples. These missions are complemented at various times by sector missions whose role is to analyze in greater depth a specific area of the economy—perhaps transportation, the promotion of small industries, forestry, or dry-land agriculture—in which Bank lending is likely to focus in the future. One of the main functions of such missions is to provide a general background on the sector, identify its major problems, and outline possible strategies for its long-term development as a framework for lending operations. This is one of the stages in which broad technological choices and priorities are identified and analyzed. These sector missions are generally undertaken by staff members and outside consultants, but in certain areas they are frequently joined by experts from other UN agencies.

When the country and the Bank have agreed that financing is likely to be needed in a particular area, a project identification mission of Bank staff and consultants visits the country to confer with government officials and other people knowledgeable about the problems at hand. The main object of such missions is to achieve a general agreement as to the size and scope of the project to be financed. It then becomes the responsibility of the country to prepare the project—that is, describe it in sufficient detail so that it can be appraised by the Bank and a recommendation made to the Bank's management and the executive directors representing the member countries that it be financed. In certain sectors, such as agriculture, education, water supply, and industry, this task may be undertaken by staff of a UN specialized agency, with which the Bank maintains a cooperative agreement. These are the Food and Agricultural Organization (FAO), the UN Educational Scientific and Cultural Organization (UNESCO), the World Health Organization (WHO), and the UN Industrial Development Organization (UNIDO), respectively.

The appraisal procedure is the most important phase in the project as far as the Bank is concerned. Its purpose is to provide a careful and considered

judgment of the overall soundness of the project and not merely to evaluate its financial viability or the likelihood that its revenues will be sufficient to repay the investment. Appraisal procedures focus on six aspects of the project. Its technical dimension is evaluated to ensure that alternatives have been adequately considered and that the solution finally retained is the optimum from the point of view of technical soundness, efficiency in the allocation of resources, and efficiency in the operation of the undertaking. In the economic part of the appraisal, an effort is made to estimate the true value of the project's inputs and outputs to the nation's economy. This is done with all the tools of modern economics, and the conclusion of this work is summarized as an economic rate of return. Shadow pricing techniques are used to eliminate the distortions caused by unrealistic exchange rates, tariffs, regulated prices, and other such factors and to eliminate biases with relation to the cost of using labor and capital. The financial part of the appraisal focuses on cash-flow analysis to estimate profitability and is particularly important in the case of projects dealing with revenue-earning enterprises. This financial analysis is complemented by commercial analysis of the market demand for the products or services to be produced by the project. The appraisal also checks that adequate managerial talent and operational skills are available, or will be developed, to run the project and that its organizational aspects have been taken into consideration.

In addition to these six elements, the appraisal procedure takes into account a number of nonquantifiable and more qualitative elements, such as the project's likely environmental and social impact and its effects on the role and status of women. The Bank's standards of project appraisal are probably as rigorous as those of any other project lending institution in the world, and its attention to socioeconomic, technical, and environmental issues certainly far exceeds that of a typical commercial bank.

A Bank-financed project is ultimately embodied in a legal document known as a loan agreement, which commits the Bank and the borrower to a specific set of actions. This loan agreement normally incorporates a description of the physical works and equipment to be financed by the Bank and also specifies the policy changes agreed on by the borrowing government and recognized as necessary to the success of the project.

Once a project has been appraised by the Bank staff and approved by the board of executive directors, it is the responsibility of the borrowing country to implement it. The Bank's role, however, does not end here; staff members monitor the project at regular intervals and provide technical support if and when difficulties arise. In the course of this monitoring work, discussions with government officials and the experience gained in the field lead to the formulation of general ideas for other projects and for new issues to be addressed in future economic missions or sector missions.

In practice, the design and implementation of a project do not proceed step by step down a clear, smooth, straightforward path. There are numerous overlappings and interactions between the different stages. For each specific

project, there is also a terminal point as far as direct Bank involvement is concerned. Once a project is completed—and this may be ten or more years after a first identification mission took place—it is subject to an independent audit whose purpose is to measure its overall results, including its economic and financial return, as compared to the projections made in the appraisal. The last annual review of these evaluations, which covered projects evaluated in fiscal 1982, reported that only 8 percent of the total investments evaluated had yielded results that appeared uncertain or unsatisfactory at the time of the audit. In addition to this post-audit, one fifth of the projects financed by the World Bank are subject to a so-called second look five years after their completion; the purpose of this examination—carried out by social scientists, economists, and other specialists—is to make a careful assessment of the projects' actual economic and social impact.

The Role of Technology in World Bank Operations

In the course of its activities as a financing institution and development agency and largely as a result of the ways in which projects are prepared, appraised, and carried out, the Bank has come to acquire a large amount of technical expertise, both in very specific areas (rural development or power generation, to cite but two examples) and in the more general field of mobilizing technology for the purposes of development. This expertise is embodied at the individual level in the people who help countries to prepare projects and design development strategies and at the collective level in the Bank's institutional memory, its networks of consultants and experts, and its relationships with decision makers in both industrialized and developing countries. The Bank differs from most other development assistance agencies in the importance of the role played by its technical staff. Of 3,100 professionals, 600 are experienced technical specialists, such as engineers, agronomists and educators. While it is impossible to measure the importance of this expertise in quantitative terms, it is central to the Bank's operations and constitutes one of its major assets.

Perhaps the main difference between the Bank and the more traditional types of technological institutions, such as government agencies for science and technology, research organizations, or technological institutes, is that technology is essentially a tool among many others rather than the central concern. Technology transfer, the promotion of innovation, and the diffusion of technology are not goals in themselves but simply some of the instruments, along with many others, that contribute to the success of a project and thereby to the economic and social development of the borrowing country. This project orientation forces the Bank's staff to focus clearly on the

ultimate value of a technology in solving a practical problem, even when that technology is in a relatively early stage of development.

The chapters in this book show how technology comes into play in the design of projects and the formulation of development strategies. We hope they lead to a better understanding of the ways in which the Bank operates as a technological institution. The lessons of this analysis suggest that other development-oriented financial institutions may also be playing a similar role and that banks are becoming or could become more active partners in the process of technological development. This may be particularly important at a time when the developing world is desperately looking for more effective ways of mobilizing technology for development.

Note

1. Warren C. Baum, "The Project Cycle," *Finance and Development* (December 1978).

Part I
The Sectoral Approach

The five chapters in this part explore some of the ways in which technology is used as one of the instruments of development strategies in specific sectors. Two general themes underlie the analysis. The first is that in the sectoral development strategies put into effect by the World Bank and its partners in the borrowing countries, we are beginning to see the first signs of what might be called sectoral technology policies; these are in many respects rather different from the conventional types of national technology policies. The second theme is that, unlike national technology policies, which are defined and implemented by national governments, these sectoral technology policies are being developed by an international agency, the World Bank, in cooperation with a number of local partners, which are generally not involved in a direct way in the formulation of a national technology policy.

Sectors, in World Bank terminology, are not quite the same as the sectors defined by economists or by national accounts statistics. They are either broad fields of activity, such as agriculture and rural development, more narrowly defined problems areas such as population, or issues that do not fall into conventional economic categories but nevertheless have many elements in common, such as urban traffic. This definition of what constitutes a sector may not be entirely satisfactory from a conceptual point of view but is useful for delineating administrative responsibilities in a development agency such as the World Bank and as a unifying theme for projects in related problem areas.

Conventional technology policies carried out by national governments have tended to focus on the supply of technology through such means as the building up of basic infrastructures (such as research laboratories and technological institutes), the support of technological research activities in industrial firms, and controls on the import of foreign technology. The assumption was that if the supply of technology could be increased, the resulting innovations would gradually feed into the productive system and thereby contribute to economic growth and social development. The experiences of the last twenty years in both industrialized and developing countries have shown that this approach alone was not always very effective. In fact, it is becoming increasingly obvious that although the supply of technology, and of the people to develop and use it, is very important and will continue to remain a major focus of national technology policies, the more critical element is the demand for technology. Sector strategies play a key role in promoting this demand.

It is only in a large, industrialized country that does not have a clearly defined national technology policy, the United States, that government intervention in the technological system has tended most clearly to focus on manipulating and creating a demand for new technologies. This has been done through a wide variety of means, ranging from the somewhat artificial creation of new markets (often in the military field) for high-technology products such as computers and microelectronic devices, to regulatory measures such as new emission controls and fuel efficiency standards imposed on the automobile industry. This wide range of measures enacted by the U.S. government was not intended to promote technological innovation, but this, in effect, is what often happened as a result.

The five chapters in this part address, explicitly or implicitly, the issue of whether it might be possible to promote technological innovation, and hence development, in specific sectors by acting not so much on the supply of technology as on the demand for technology. The authors suggest that several of the major elements for sectoral technology policies are already in place and that policies of this type can be a major instrument of development.

This is perhaps more conspicuous in the case of agriculture and rural development, discussed in chapter 2 by G. Donaldson. The author suggests that one of the central functions of an agricultural project is to serve as a vehicle for technological change. He recognizes three main variables in a technology development strategy for agriculture. The first is the technology package of on-farm inputs (machinery, improved seeds, fertilizers, irrigation equipment); the second is the physical infrastructure (roads, dams, irrigation systems, storage facilities); and the third is the institutional infrastructure (credit institutions, extension services, distribution services) and the overall policy measures taken by the government to promote agricultural development. He shows how the Bank's technology strategy in this sector has evolved over the years and examines its role as a direct sponsor of particular kinds of technology, as the indirect instigator of further investment in new technology, and, more recently, as the direct originator of new technology.

In chapter 3, K.N. Rao and C. Weiss describe the World Bank's efforts to develop a set of approaches, consistent with its lending practices and its financial objectives, to encourage innovation at the industrial enterprise level. On the basis of case studies of technologically innovative industrial projects supported by the Bank in Spain, Israel, and Korea, the authors suggest that some of the most effective means of fostering development and change are generalized financial incentives for technological improvements, active government intervention to catalyze innovations across a broad front, and programs to develop new technology and to strengthen local technological capabilities in specific areas through the concerted action of government research centers, financial institutions, and private industrial firms.

In chapter 4, B. Coukis and N. Jéquier examine the research sponsored by the World Bank and other organizations on the applications of labor-intensive technologies for road construction, as well as specific projects in which such technologies have been used. This research shows clearly that labor-intensive methods can be economically efficient but that considerable attention has to be given to the supervision of the labor force, the design of better hand tools and animal-drawn equipment, and the timing of the works in relation to agricultural priorities if such projects are to be viable. What emerges from this chapter is the need for a well-defined sectoral technology policy that helps to build rural roads efficiently and to meet broad social objectives in the field of income and employment.

Chapter 5 by H. Werlin describes a variety of innovative solutions to the problems of urban traffic management. All of these solutions involve a blend of hardware and software, but in most cases the most important element by far is the software. Werlin shows that in major urban areas, seemingly intractable traffic problems, with all their ensuing drawbacks for the community, can be solved or dramatically alleviated at reasonable cost. His demonstration is also particularly instructive because it shows that, in this sector at least, the developing nations have something to teach the industrialized countries, rather than the other way around.

In chapter 6, W. Drewes and A. Sirkin examine the impact of a revolutionary new technology—remote sensing from outer space—on agriculture, water management, and the development of natural resources. This highly sophisticated technology is opening up new possibilities for developing nations that lack personnel trained in resource evaluation and have inadequate mapping capabilities. Effective application of such new techniques requires a minimum of reorganization of existing resource-oriented agencies such as geological surveys, forest services, and water planning authorities, yet offers much new information useful to resource planners and decision makers involved in development activities.

Technology in Agricultural Development

Graham Donaldson

Food production is the first systematic activity undertaken by any society, and all countries, regardless of their level of economic development, have an established agricultural sector. In developing countries, farming traditionally provides the main source of employment, and the rural areas generally contain the majority of the population. All models of economic development attribute a particular role to agriculture in the development process. As agriculture increases both its aggregate output and the productivity of its prime resources (particularly land and labor), it diversifies its range of products for domestic consumption and export and generates a surplus for further investment, growth, and development. In the face of high population growth and renewed concerns about the long-run availability of food supplies, the importance of agriculture has received further emphasis.

The World Bank has been responsive to these concerns and increasingly has directed its attention to the agricultural sector of developing countries. Its lending program provides substantial support for innovations designed to improve established farming technology and raise the productive capacity of agriculture. In many instances, a World Bank–financed project may be the only means by which a small farmer can gain access to new methods and resources. The technical package is recognized as the kernel of every project. However, initiating acceptable technological change in agriculture is a complex process, which requires far more than just efficient production methods. Although the provision of capital remains a key component, the Bank approach to agricultural development has changed markedly over the years in line with the emerging awareness of rural problems and the changing needs of developing societies. The approach has been broadened to include support for forestry and fisheries and deepened to provide many of the concomitants of farm production.

The Special Characteristics of the Agricultural Sector

Even within a particular country or region, agriculture is generally very diverse, and this diversity is magnified by differences in climate and geog-

This chapter draws extensively from John P. McInerney, *The Technology of Rural Development,* Staff Working Paper 295 (Washington, D.C.: World Bank, 1978).

raphy. Therefore care must be exercised not to refer to the agricultural sector as though it were a uniform entity. The location-specific characteristics of farm production are such that one cannot usefully refer to change in agricultural technology with the same generality as one might refer to changes in the technology of steel production or transportation, for instance. Agriculture around the world is practiced under a whole set of technologies. Attempts to change this set, whether initiated by a national government or an individual farmer, must choose among individual components or a subset of components that are to be a focus for change. The problems of inducing and supporting the adoption of new technology in agriculture are consequently diffuse, determined as they are by an array of different technical, organizational, and socioeconomic features.

From a technical standpoint, plant and animal production are essentially natural biological processes upon which humans have progressively imprinted their influence. Humans first injected their own labor to control and direct the biological growth sequences and subsequently added an increasing array of man-made and artificially applied inputs. As a result, change in farm technology can be brought about in a number of ways: through altering the basic biological processes (for example, through the use of improved seed varieties and livestock breeds); by new or modified labor operations (for example, weeding, pruning, or row planting); by the application of novel chemical inputs to the production process, most notably fertilizers, disease and pest-control chemicals, and veterinary products; and through the use of tools and mechanical aids supplying either additional power (cultivators, pumps) or the facility to carry out particular operations (moldboard plows, threshers). Despite these expanding possibilities for bringing the biological processes of food production more directly under control, there still remains an inescapable natural pace and sequence of events in farming that govern the production possibilities. Variations in climatic conditions and other uncontrollable biological phenomena leave food output and quality ultimately unpredictable, even under the most advanced production technology.

The organizational structure of activity is more diverse than in other sectors. New production technology may need to be directed toward nomadic pastoralists or to producers with highly intensive cattle feed lots; new methods may be required either for plantation production or for tiny village plots; innovation may be in the hands of highly commercialized, market-oriented farmers or self-sufficient subsistence family units; production may be oriented toward world export markets or to local domestic consumption; farmers may be secure owner-occupiers or insecure share-tenants effectively ruled by a landlord; decision making and its attendant success or failure may rest with staunchly independent farm operators or may be governed by a tradition of shared responsibility within the community; farm-

ing may be a full-time and exclusive commitment or a part-time source of accessory income. Compared with many other industries, a typical production situation cannot be defined, especially in developing countries, and any single agricultural commodity may be produced under an immense variety of social and organizational systems. This characteristic in itself weakens the meaning of general statements about changes in farm technology and requires a particular understanding of specific local conditions.

Agricultural production has strong links with the sociocultural pattern of life in rural areas. There are numerous interrelations between farming activity and the life-style of the people. This arises partly from the historical place of agriculture as one of the earliest human activities, so that many customs, traditions, and living patterns stem from agricultural practices and the cycle of the farming year. In addition, the countryside is at the same time the place of work and the place of living for rural people, and both farming fortunes and general welfare are entwined. Changes in agricultural technology, which inevitably modify the characteristics and modes of farming activity, therefore also cause changes in life-styles and impinge far more on the overall fabric of society than do innovations in sectors where work and home, employment and leisure, are separate. As a consequence, successful agricultural innovation is influenced and constrained by much more than the technical and economic characteristics of the productive environment. Its effects go beyond the quantitative impact on food output and embrace a host of qualitative adjustments in the patterns of rural life, as reflected in the structure of institutions, dependencies, values, and expectations within society.

Together these distinctive features of the rural scene exert a major influence on the nature and process of technological change in agriculture and created special conditions for the design and implementation of projects aimed at improving farm technology.

The Agricultural Project as a Vehicle for Technological Change

Development is characterized by a cumulative series of changes in the technology employed by society. Projects have been referred to as the cutting edge of development because they serve as a key instrument for introducing and delivering new elements into the established pattern of activity. In countries where agriculture is characterized by low productivity and the predominance of small-scale, subsistence systems that have evolved over a long period, there usually is little experience of internally generated innovation, and change is unlikely to occur unless it is deliberately introduced from outside. Since an agricultural project is essentially "an investment

activity where we expend capital resources to create a producing asset from which we can expect to realize benefits over an extended period of time," it is in the physical components (the hardware) financed by the project that new technology is usually to be found.[1] Farm technology also has a so-called software aspect that embraces the supporting systems, institutions, and organizational structures associated with agricultural production. These, too, are provided in development projects and have received an increasing emphasis in World Bank financing for agriculture.

If one conceives the general structure of agricultural production to be one in which numerous individual farmers make resource-use decisions within a framework of shared physical and institutional facilities (the infrastructure), it becomes possible to identify the major points in this structure where development projects might exert their impact. It is thus useful to distinguish three broad classes of projects according to the type of technology they make available to the agricultural sector. (Any particular project may, of course, contain elements of all three types.) Each has its own particular characteristics and practical problems, and each has an identifiable place in World Bank lending for agriculture.

On-Farm Inputs

These projects provide technology in the form of totally new, locally novel or improved traditional inputs and processes, as directly selected and employed by the individual farmer. Typical examples include seeds, fertilizers, tractors, machinery, tubewells, and livestock. The actual mechanism of the project may be to provide credit facilities to enable farmers to finance their own purchases or investment decisions, but the focus of the project can nonetheless be identified as specified hardware components. Special considerations in such projects include the need to identify the particular group of farmers (in terms of size, type, location, and so on) to whom the new technology is to be directed; ensuring that the inputs and processes are appropriate to their situation; making available a suitably complete package of project elements for successful implementation by the farmer; providing the required information, guidance, and support to overcome the barriers created by unfamiliarity; and achieving adequate reliability and predictability in use so that the new technology is both acceptable to farmers and successfully applied. This type of project is appropriate where the micro-objectives for technological change, outputs, and resource use have been clearly identified.

Physical Infrastructure

One of the constraints facing the developing countries is that their basic rural infrastructure is insufficient to allow the successful absorption and exploitation of new technology by individual farmers. The prime role of project lending in such a case is to provide for investment in such facilities as dams and irrigation canals, roads, electricity networks, and product storage and processing facilities. The provision of such facilities is dependent on public investment rather than individual farmer decisions, and in many instances rural infrastructure has the classic characteristics of a public good. The technology embodied in such investments is supportive rather than directly productive, and its value depends on the extent of changes in on-farm activities that it permits or induces. Because it is part of the general fabric of farming, it is often not possible to tailor its availability or direct its benefits to a particular group in the rural population, such as small farmers, landless laborers, or maize producers. Indeed, by the very nature of the infrastructure, the exclusion of certain interest groups may be unavoidable. Furthermore, in many cases, the success of the project in changing the technology of farming depends as much on the particular arrangements made for the use of the facility as on the inherent technical quality or efficiency of its physical structures.

Institutional Infrastructure

Recognition of farm technology as an interconnected system of resources, activities, facilities, and processes highlights the importance of the software elements that must be included in agricultural projects if they are to be fully effective in sponsoring technological change. In many instances, this implies the establishment of particular institutional structures necessary to support the newly adopted physical farm inputs and interfarm infrastructure. These might include farmer cooperatives to supply inputs and handle output; product collection, grading, and distribution agencies; credit institutions to serve the specific needs of innovating farmers; and farm advisory and veterinary services. All of these project components require the use of scarce and perhaps novel resources, though their totality is not just the physical capital structures that are erected. Furthermore, they are just as much an integral part of the production technology as are the hardware items, which would not be viable or self-sustaining without the support of these institutional arrangements.

One crucial type of institutional infrastructure that is gaining increasing emphasis in the World Bank's agricultural projects is the establishment of local research and extension agencies. These seek to sustain a continuing

momentum of technology development, adaptation, adoption, and diffusion. The technology of institution building—the establishment of appropriate and effective institutional arrangements, responsive to the needs of target groups, suited to the conditions surrounding the use of new technological hardware, and adaptable in the face of changing circumstances—is one of the most difficult and least charted aspects of contemporary agricultural project work, yet is is crucial for successful development through technological change.

One particular feature of an agricultural project (as compared with many large-scale industrial projects for example) is that its implementation rests in the hands of many individuals; no single entrepreneur, commercial concern, or elite cadre of businessmen makes the decisions about investment and exploitation. Rather, the project's success is the result of the collective action (or inaction) of countless individual farmers, many of whom often have little experience with innovation or with commercial production. In these circumstances, changing established farming practice requires more than the provision of new facilities. Whether it is making fertilizers available for sale or placing irrigation canals in situ, the innovation has to be accepted, taken up, and used by the target farmers. In addition, the new technology can often be applied in a number of different ways. Mechanization, for instance, can be used to increase the intensity of land use, to expand the area farmed, or just to replace labor. There is often a need to reconcile the needs and motivations of the individual with sectoral objectives and the wider social good. To achieve this, the agricultural project must be carefully prepared and must fit into the context of a balanced policy toward agriculture and a structured program of change. Without such an approach, the project might otherwise serve merely as a temporary, and perhaps largely unbeneficial, disturbance to the system.

Agricultural Lending in World Bank Projects

In the thirty-six years since it funded its first agricultural project—a $2.5 million loan to Chile in 1948 for the purchase of agricultural machinery for land clearance—the World Bank has made available almost $30.2 billion in loans for agriculture. The Bank on average provides about 39 percent of the total funds for the agricultural projects it supports, so that Bank-financed projects have in total directly initiated perhaps $77 billion worth of agricultural investment. Since this sum constitutes more than 20 percent of net public investment in developing-country agriculture over the period, it represents a substantial amount of technological change initiated from one institutional source. The importance of agriculture in the Bank's activities is indicated by the fact that a quarter of its total lending to date has been directed to this one sector. During much of the 1970s, the proportion of

agricultural lending reached 30 percent. This emphasis has leveled off in recent years, and today about one-quarter of the Bank's project funds are still directed to agriculture and rural development.

The World Bank performs three main roles in relation to technological change in agriculture. It serves, first, as a direct sponsor of particular types of technology through the various project components (on-farm inputs, physical infrastructure, institutional infrastructure), and the specific mix of elements within these categories that it finances. Second, it serves as an indirect instigator of further investment in new technology—most obviously because traditionally it has not financed total project costs but only foreign exchange costs and approved local costs, thereby drawing in domestic funds to support the project. In addition, because technological change is not a discrete event but a continuing process, a diverse array of associated secondary adjustments, investments, and expenditures by farmers are inevitably induced as they respond to the new production possibilities made available by the project. Third, the Bank serves as an originator of new technology. This has been a relatively recent but growing facet of the Bank's influence through its funding of international and national agricultural research systems that are expanding, developing, and adapting existing knowledge and practices for different situations around the world.

The Bank has made important policy changes in its agricultural lending programs in developing countries since the early 1970s. These recognize three important steps in achieving the policy goals implied by the "Nairobi Address": allocating a larger proportion of its lending to agriculture, increasing the share of lending to the poorest countries, and introducing projects to benefit larger numbers of people in the poorest countries.[2]

The growing involvement of the World Bank in developing-country agriculture is reflected in table 2–1. During the first twenty years or so of its operations, the ruling philosophy of economic development emphasized the importance of industrialization in leading the growth of aggregate gross national product (GNP) and modernizing the economy, loosely taken as synonymous with development. In consequence, agricultural projects formed a relatively small proportion of Bank lending, accounting for roughly 10 percent of the total lending over the entire period. Since then, the emphasis on agriculture has increased dramatically, rising to 20 percent and then to 30 percent of total lending in successive five-year periods, although it has recently declined as a proportion to 25 percent due to the expansion of energy projects and structural adjustment lending. During this time, the Bank's scale of operations in all sectors has increased fivefold, so that in absolute terms, its involvement in new agricultural technology projects has become significant. Some indication of this recent growth is given by the fact that of the total amount of capital made available to agriculture since 1948, almost three-quarters was lent in the last seven years.

Table 2-1
World Bank Lending in Agriculture, 1948-1983

	Number of Projects	*Total Cost of Projects ($ million)*	*Amount Lent by Bank ($ million)*	*Proportion of Cost Funded by Bank (%)*	*Total Bank Lending to All Sectors ($ million)*	*Agricultural Lending as Proportion of Total (%)*
1948-1963	55	1,736.6	468.1	27.0	7,208.6	6.5
1964-1968	45	1,277.8	620.8	48.6	5,632.8	11.0
1969-1973	178	6,436.4	2,586.3	40.1	12,849.4	20.1
1974-1978	358	23,855.9	10,018.7	42.0	32,556.3	30.8
1979-1983	386	43,629.5	16,519.9	37.9	61,276.0	27.0
Total	1,022	76,936.2	30,213.8	39.3	119,523.1	25.3

Source: World Bank, *Annual Reports.*

Among the regions of the world, Asia receives the largest share of the projects; the other regions of the world take an equal share among themselves. This pattern is consistent with the distribution of rural populations in the world and also in agreement with the primary objective of the Bank—removing rural poverty. Table 2-2 gives the distribution of rural poverty and the allocation of Bank funds in different geographical regions. Over 85 percent of the rural poor are living in the countries of Asia and Africa, and they receive close to 60 percent of the Bank funds allocated for agriculture.

Starting from the mid-1970s, special projects were prepared to benefit small farmers (defined here as those with landholdings under 5 hectares) and landless laborers in the poorest countries. During 1978 alone, these projects were aimed at nearly 21 million families (direct and indirect beneficiaries) or 105 million people in the rural areas. About 90 percent of these beneficiaries are located in the countries of Asia and Africa. In Asia the major share of these benefits goes to the world's poorest population situated in India, Pakistan, and Bangladesh.

The path of agricultural lending over time, and particularly this recent phenomenal expansion in project activity, is explained partly by the overall growth of the World Bank as an international development agency during the development decade of the 1960s and the worldwide attention to the plight of the poor countries. It can also be viewed from the standpoint of particular developments in agricultural technology. In the 1950s and early 1960s, the identified needs of developing-country agriculture, as well as the dominant transferable technology, were seen as rural infrastructure facilities. Lending in this period therefore focused on dams, irrigation canals, and product processing facilities. During the 1960s, there was a

Table 2-2
World Bank Lending in Agriculture by Region, and Distribution of Rural Population in Poverty

	Percentage of Agricultural Lending (1974–1978)	*Percentage of Population in Rural Poverty (1974)*
Africa	15.9	18.9
Asia	44.1	66.4
Europe, Middle East and North Africa	18.7	6.0
Latin America	20.3	8.7
Total value of World Bank lending to agriculture	$10,018.7 million	
Total number of people with income below $50		580 million

Source: World Bank, 1980.

gradual recognition of the possibilities of applying modern types of farm inputs developed in the framework of Western science-based agriculture to the problems of agricultural development and food output expansion in developing countries. The emergence of the green revolution gave added impetus to this change, which provided many more opportunities for injecting new technology into agriculture by the typical lending project. Consequently the character as well as the extent of the World Bank's lending gradually shifted, with an increasing number of projects to finance new seed varieties, fertilizers and chemicals, mechanization, livestock development, and other direct on-farm resource-use activities.

Some idea of these changes emerges from table 2-3, which shows the breakdown of agricultural lending by conventionally defined subsectors. This classification of subsectors were done for administrative convenience; thus the content of the subsector is only an approximation implied by the name. As time passes and the scope and size of projects change the original classification may have little relevance. For example, irrigation projects of the 1950s differ considerably from irrigation projects of the 1970s. Before the early 1960s, such projects concentrated on the construction of dams and canals with a power plant; an example is the Indus Basin in Pakistan in 1961. But now the irrigation project is a complete system that emphasizes water management and includes both on-farm facilities for using water and supporting facilities to make available such inputs as seeds, fertilizers, and extension services, as in the case of the 1970 Kadana irrigation project in India.

Even with this limitation, the tables indicate the changes that have taken place over time in the allocation of Bank funds for agriculture. Between 1948 and 1963, nearly 87 percent of rural lending was for irrigation (77 percent) and general agriculture (10 percent), but in the 1979–1983 period, only 34 percent was allocated to these subsectors. By contrast, agricultural credit, agroindustries, fisheries, livestock, agricultural research and extension, and area development were given more importance in the later time periods. The best way to show the changes that have taken place in the Bank lending program is to analyze it project by project in different time periods since classifying any project in a single category is difficult. A typical agricultural credit project, for instance, will provide funds to buy seeds, fertilizers, pumps, tractors, power tillers, threshers, bullocks, and dairy animals or will help the farmer to construct wells and drainage canals and provide training in improved agricultural practices. This project can, in fact, be classified under any or all of the subsectors listed in table 2-3. A case-by-case analysis of the 954 agricultural projects financed by the Bank would bring stronger evidence to the main hypothesis of this book—that the World Bank is a technological institution and is performing as an agent of transfer for new agricultural technologies from the North to the South countries through its support of technologically innovative projects.

Table 2–3
World Bank Lending to Agriculture, by Subsector, 1948–1983

	Total Rural Lending ($ Million)	*Percentage of Rural Lending Allocated to:*										
		General Agriculture	*Agricultural Credit*	*Area Development*	*Fisheries*	*Irrigation*	*Livestock*	*Agro-industries*	*Perennial Crops*	*Forestry*	*Research and Extension*	*Other*
1948–1963	468.1	10.3	4.3	5.4		76.4	1.5	1.0		1.1		
1963–1968	620.8		13.6	10.4	3.6	44.5	23.5	3.1	1.3			
1969–1973	2,586.3	1.0	19.1	6.0	1.2	31.0	20.5	8.1	11.2	0.5	1.4	
1974–1978	10,018.7	0.6	15.2	23.7	1.0	31.6	8.6	5.8	7.0	4.7	1.8	
1979–1983	16,519.9	1.2	14.7	23.7	0.9	32.9	1.6	9.5	6.8	3.4	4.3	.9
Total	30,213.8	1.1	15.0	21.6	1.0	33.2	6.0	7.9	7.1	2.6	4.0	.5

Source: World Bank, 1984.

Technological Changes Induced by Bank-Financed Projects

One of the important innovations in irrigation technology in the 1960s was the widespread diffusion of the tubewell. The tubewell is basically a pump mounted on a pipe that is sunk from 50 to 300 feet into the groundwater-bearing layers. Potentially, tubewells can be constructed small enough to meet the requirements of farm holdings of the order of 2 to 5 hectares. Irrigation can thus be made more directly available to the individual farmer since it is embodied in on-farm inputs rather than in physical infrastructures. Two irrigation projects using this technology were set up in Morocco during 1976 and 1977; they are supported with Bank loans totaling $71 million and will ultimately benefit 7,000 families working on 30,000 hectares of rain-fed land.

As an indirect instigator of further investment in technology, the Bank has encouraged the use of underground plastic drainage tiles to rectify salinity in Egypt and Pakistan and the use of glass-reinforced plastic and timber flumes for tertiary canals in Malaysia. As an originator of new technology, it has funded the experimental development of solar pumps for irrigation in India.

Another developing strand in World Bank lending is the emergence of projects that include a greater recognition of the essential software elements of agricultural technology, particularly in the form of institutions and organizational arrangements that cater to the farmer's needs for inputs and to the problem of marketing his products. Institution building is not easily identifiable as a capital project that can be directly funded by the Bank, but it inevitably receives attention as a component of carefully prepared agricultural projects because it is often an essential determinant of their success. In some cases, new institutional arrangements emerge as a by-product of investment in physical infrastructures, as water management schemes often do in canal irrigation projects. In other cases, they are central to the project and its implementation. Thus, for instance, the funds made available to the farmer for the purchase of machinery will be disbursed as a credit project operated by rural financial institutions in the country. In such cases, the capability of these institutions to serve the expanding needs of farmers is expected to be increased through their association with the project.

Typical projects that emphasize the software elements of agricultural technology include the Lilongwe Land Development Program in Malawi, the Pider Project in Mexico, and the Agricultural Refinance and Development Corporation (ARDC) Credit Projects and Drought Prone Areas Program (DPAP) in India. The ARDC projects have supported the training of large numbers of participating State Land Development Bank staff and increased the involvement of commercial banks in agricultural lending. The

DPAP provides for strengthening the central government agencies in charge of this program unit, creating an interdepartmental coordinating committee at the state level, and establishing district-level development authorities to coordinate and supervise the development of minor irrigation and watershed management, the adoption of dry farming technology, and the improvement of sheep and wool production.

Livestock projects in recent periods have focused increasingly on the livestock needs of small farmers, and particularly on dairying. A series of projects in Turkey have sought to reach small dairy farmers and promoted village livestock development on a group basis. Projects in Honduras and Panama have supported the development of dual-purpose dairy-beef production on farms. In India, the National Dairy Project as well as dairy development projects in the states of Karnataka, Madhya Pradesh, and Rajasthan are supporting the widespread adoption of an Indian model of cooperative dairy production and marketing that involves dairy cooperatives, unions of village cooperatives, and federations of milk unions. The technology package includes the upgrading of native cows through cross-breeding with high-producing exotic breeds, the development of milk transport systems, and the establishment of large, sophisticated milk-processing plants. Farmers are using their income from the sale of milk to purchase more fertilizers and better seeds, as well as irrigation water for their crops.

Before 1971 the Bank initiated six fishery projects that provided mainly for the purchase of commercial fishing vessels and the improvement of port facilities. After 1971, twelve projects were specifically implemented to benefit small fishermen. The Bank has provided improved equipment such as fiberglass canoes, synthetic nets, and outboard motors and has developed a technical package for aquaculture that includes the fertilization of selected ponds, the introduction of new species of fish (notably the *tilapia*), and supplemental feeding with bran.

Bank-financed projects in forestry have shifted away from industrial forestry—generally large-scale plantations supplying logs and pulpwood for the domestic market—to rural forestry.[3] The latter includes attempts to deal with the environmental consequences of deforestation (as may occur in agricultural settlement projects) and to provide the rural poor with adequate supplies of wood for heating, cooking, and shelter through such means as village woodlots.

Projects on agricultural crops, which tended to focus on export crops like rubber, oil palm, cocoa, coffee, and tea, now emphasize fruit trees such as mangos, avocados, and apples, and there has been a similar shift away from perennial crops to annual crops. These changes have benefited small holders rather than private and government-owned estates. Technological innovations introduced as a result of Bank-financed projects include dwarf varieties of coconut trees, a low-volume herbicide sprayer, and puncture tools for the easy tapping of rubber trees.

The Bank's involvement in physical infrastructure frequently consists of advising on post-harvest treatment, crop storage, and the marketing of farm products. Grain storage, which forms a growing part of such loans, used to be done mainly in large steel or cement silos located in urban areas; several new projects in rural areas now concentrate on small steel storage bins located on the farm or, alternatively, on plastered rattan containers and on controlled open storage. Such projects encompass far more than the mere creation of physical structures; they touch on the building of rural institutions. The Indonesian Nutrition Development Project, for example, is supporting the establishment of a Food Technology Development Center, which is assessing traditional processing and storage technology, erecting prototype storage units varying in size from 1 to 10 tons that are managed by the local village cooperative, and monitoring and evaluating their use as a basis for developing a national storage program. This project includes training extension workers, producing storage units, and developing a storage credit system. A project in the state of Himachal Pradesh in India that centers on the apple processing and marketing industry is introducing technological innovations in the processing, packing, and grading of fruit; it has also established a commercially oriented marketing organization and made further infrastructural improvements to handle 25 percent of the region's output.

The Role of Research

If an agricultural project is a vehicle for technological change, research is the fuel for project innovation. The Bank has recognized the importance of research, and a majority of projects include a research component when feasible. Over half of the Bank-financed agricultural projects now have agricultural research components, which amount to over 5 percent of total lending in the sector. Important research components in recent projects include adaptability trials, fertilizer trials, variety trials, the testing of alternative crops, quality improvement, the improvement of local research capabilities through technical assistance, and the development of new knowledge and techniques in specific areas. The fourth Philippines Agricultural Credit Project, for instance, includes provisions for research on appropriate farm mechanization technology for different agroclimatic and socioeconomic conditions. The results of this study will benefit farmers, policymakers, rural banks, and equipment dealers in the Philippines and may be applicable to other countries in Southeast Asia.

Along with this support of research as a component of agricultural projects, the Bank also directly funds agricultural research and extension projects.[4] This is the case, for instance, in Spain, Indonesia, Malaysia, Brazil,

and India. Four such projects in India (West Bengal, Madhya Pradesh, Rajasthan, and Bihar) are aimed specifically at strengthening agricultural research and extension services for the benefit of millions of farm families.

Some projects in the field of education also contain an agricultural research component. The first large-scale education loan was provided to help construct and equip buildings at the College of Agriculture of the University of Philippines and was part of a comprehensive program to increase agricultural production. Through 1983, 105 of the Bank's 264 education projects have had an agricultural research component aimed at providing training in agricultural techniques to rural populations.

The Bank is also a major sponsor of international research in agriculture through its participation in the Consultative Group on International Agricultural Research (CGIAR) which supports major research institutions in twelve countries working on the major food crops and ecological zones of the developing world.

Agricultural Components in Other Bank-Financed Projects

Technological change can be characterized by the wider use of such modern inputs as fertilizers, pesticides, tractors, pumps, threshers, harvest combines, high-yielding varieties of seeds, and improved agricultural practices.[5] One necessary condition for the full realization of the fruits of modern technology is an uninterrupted supply of supporting inputs. In developed countries, industrialization acted as a complement to technological changes in agriculture by supplying such factors as fertilizers, pesticides, tractors, pumps, threshers, harvest combines, and other industrial products. The industrialized nations have a great ability to deal with disequilibria[6] and have achieved a balanced growth in both agriculture and industry.[7] In the traditional societies of developing nations, where this ability to deal with disequilibria is much weaker, the software component of a new technology is critically important to the successful adoption of innovation—hence the importance of infrastructural facilities and the need to remove the constraints to the adoption process. Through its lending programs in developing countries, the World Bank has played a significant role in inducing technological changes in all sectors of the economy.

Bank projects in the industrial sector often contain an agricultural component in the same way that projects in the agricultural sector often contain industrial components (for example, food processing or sawmilling). The size of the agricultural component may vary from nearly 100 percent in the case of a fertilizer plant to a negligible share, as in a project to finance a steel industry. Power projects financed with Bank funds have been critically

important in providing the energy to power the pumpsets for irrigation. Projects in health, population, nutrition, and transportation also often have agricultural components, and as a technological institution the Bank has organized projects in such a way that technological changes in different sectors are complementary to each other.

From this short account, it is evident that the agricultural projects supported by the World Bank in the last 35 years have evolved through all the types of technology identified previously: on-farm inputs, physical infrastructure, and institutional infrastructure. The Bank's original emphasis on technology embodied in physical infrastructure became progressively more balanced through its support to the science-based technology embodied in new inputs for direct purchase and use by farmers. More recently, this emphasis has been overlaid by the emergence of institutional infrastructure as a frequent and important component of agricultural projects. Among other things, this is a reflection of current concerns about the needs of the masses of rural people in poor countries and about the appropriateness of the technological innovations that can be made available to them through agricultural projects.

Notes

1. J. Price Gittinger, *Economic Analysis of Agricultural Projects* (Baltimore: Johns Hopkins University Press, 1972), pp. 1–2. Investment is often interpreted to include items of production expense as well.

2. Robert S. McNamara, address to the Board of Governors of the World Bank, Nairobi, September 24, 1973.

3. See *Forestry—Sector Policy Paper* (Washington, D.C.: World Bank, 1978).

4. See *Agricultural Research—Sector Policy Paper* (Washington, D.C.: World Bank, 1980).

5. T.W. Schultz is in favor of defining technological change as identifiable new factors of production accounting for an increase in output. See his *Transformation of Traditional Agriculture* (New Haven: Yale University Press, 1964).

6. Exogenous technological changes are shocks to the equilibrium producing dynamic endogenous changes to move toward a new equilibrium.

7. Agricultural modernization displaced labor in the rural areas, but industrialization was able to absorb the migrated labor.

Government Promotion of Industrial Innovation

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The art and science of industrial innovation, a process by which technical ideas are implemented and new products and processes are successfully introduced into the market, is attracting much attention in both developed and developing countries. The developing countries, whose industrial development is based primarily on imported technology, are showing a heightened interest in how their own technological development strategies could be redirected to stimulate the innovative activities of their public and private enterprises. This chapter describes the World Bank's efforts in assisting several developing countries in promoting both technological innovation in domestic industry and concomitant changes in public policies and institutions.

The Bank's approach to industrial innovation in the developing countries is in essence an experimental attempt to apply what has been learned over the past decade about the processes of technological development and innovation in developed and developing countries. It recognizes the variety of capabilities and experiences of the different developing countries. In some countries, technological development is well advanced. In others, even the basic industrial and technological infrastructure has yet to be laid.

The Bank's Approach to Industrial Innovation

Industrial innovation does not occur in a vacuum. It feeds on, and contributes to, an existing base of industries and a supportive infrastructure of institutions. It cannot flourish where such a base does not exist. Present understanding of the innovation process has led to the recognition that several elements must be available at the right time in the right proportions: a potential demand (that is, a market or social need), a base of scientific and technical knowledge, a source of creative effort, an attractive investment

The ideas developed in this chapter are derived from many sources. The general country descriptions were drawn from World Bank reports. Descriptions of individual projects are drawn from World Bank reports and from materials by George Wayne (Israel), Magdi Iskander (Korea) and Wolfgang Wipplinger (Spain). We also acknowledge the contributions of Yitzhak Yaakov, Jose Maria Castañe, J. Herbert Hollomon, Jack Baranson, Enrique Bia, Jose Veiga Simão, Mario Kamenetzky, Augustin Que, K. Challa, Larry Westphal, and Frederick Moore.

opportunity, the ability to assemble capital and the resources necessary for development, and, above all, the availability of entrepreneurial and professional personnel who are able to mobilize the resources to satisfy these needs.

Research and development may be necessary, but they are not a sufficient condition for innovation. Frequently an advanced engineering capability may be all that is required to bring technical ideas to the marketplace. There are many situations, however, in which hardware developments focused purely on technology—indigenous or foreign, new, adapted, or transferred—are unlikely to succeed if they are not accompanied by, and integrated with, a package of policy and institutional changes on the part of government and a concern on the part of the innovating enterprise for the whole sequence of idea generation, its technical implementation, and marketing of the resulting product or process.

In general, technology policymakers in developing countries have sought to increase both the supply and demand for technology—the former through government assistance to research and development and, to a lesser extent, to engineering, and the latter through innovative activities in public or private enterprises. Until now, however, the supply side of technology has received much greater attention and resources than the demand side. Demand for technology may be stimulated by a willingness to allocate public resources to local enterprises for improving product design to meet market needs, for carrying out preinvestment studies for shopping, selecting, and negotiating for technology, for quality control and cost-cutting innovations in processes, and for launching original products based on local research and development.

The paucity of entrepreneurs and managers who combine skills in engineering, production, and marketing and the lack of start-up and venture capital to underwrite risky ventures of indigenous firms are, however, a serious impediment to innovation in the developing countries.

The technical capacity of a nation—its ability to use and master technology—is an elusive concept. It includes the analytical capability of government decision makers, the technical capabilities of research scientists, engineers, managers, technicians, skilled workers, shop floor innovators, and consultants, and the all-around capability of the entrepreneur to make technical choices and implement them. It also includes the capability to deal with agents of technology transfer—chiefly the salesmen of equipment and technical services and the licensors of technology and know-how. It means the mastery of technology to the point of being able to design the next installation locally, to act as one's own prime contractor and to carry out adaptations, and eventually to develop new products and processes based on original research and development.[1]

Many developing-country governments, acting on the assumption that such capacity is best developed through institutions, have established national science and technology councils for publicly supported multidisciplinary institutes of industrial technology patterned on those of advanced industrial countries. Unfortunately, publicly supported technological institutions tend to achieve only very weak collaborative links with their clients in the productive sector.

The revitalization of existing institutions by removing the bureaucratic constraints under which they operate, or the creation of new ones with vital connections to the sector to be served and more direct participation by representatives from industry, is a question of renewed concern to developing-country policymakers and international development agencies. Still, it is the quality and capacity of the technical manpower available in the countries concerned, not the variety of institutions that house them, that is critical to an indigenous capacity for innovation.

World Bank Lending for Industry

In order to provide a background for the World Bank's current interest in industrial innovation in the developing countries, it is useful to sketch the role that the Bank and its affiliates have played in the industrialization of the developing countries for more than two decades. The Bank directly finances large industrial projects in member countries through loans and credits guaranteed by the government of the country in which the project is located. Such assistance to developing countries totaled $6.7 billion for the 1970–1982 period and financed 130 projects in 46 member countries. Between 1957 and 1982, the Bank's affiliate, the IFC, has made a cumulative investment of $4.8 billion in 653 projects with a total cost of $21.5 billion. In fiscal year 1982, IFC investments totaled $612 million and expanded greatly to $845 million in fiscal year 1983. Unlike the Bank, the IFC operates without a government guarantee of repayment. In addition to investing its own funds, it serves as a catalyst to mobilize domestic and foreign private capital, management, and technology to expand existing enterprises and to promote the formation of new ones.

Indirect assistance to medium-sized and some relatively large enterprises is provided by the Bank and the IFC through lines of credit extended to public and private development finance companies (DFCs) in the developing countries. Through fiscal year 1982, the Bank Group (the IBRD, IDA and IFC) has lent more than $7.9 billion to over one hundred DFCs. In fiscal year 1982, the Bank lent $1.3 billion through DFCs. In addition, financial assistance to small industrial enterprises in member countries is provided through DFCs or other financial intermediaries such as commercial

banks. Frequently small enterprises are also assisted through loan components built into urban and rural development projects. The concern with the subsequent phase, in which a developing country's institutions could themselves move into the practice of industrial innovation, is recent. Since 1974, the Bank has made investments in ten countries aimed directly at technological improvement and the stimulation of innovation by domestic enterprises. Assessment of their effectiveness must await the time when the products and processes developed by the assisted enterprises achieve technical and commercial viability. The countries themselves do not form a homogeneous sample and vary greatly in their scientific and technological capabilities.

The Spanish Experience

Farsighted economic liberalization and growth-oriented policies implemented in the early 1960s have propelled Spain into the league of industrialized countries in the short span of some fifteen years. Its per capita GNP of some $2,700 in 1975 entitled it to be classified in the lower stratum of the high-income countries. Between 1961 and 1973, GNP expanded in real terms by an average of 7.5 percent per year, and industry, the leading sector, grew at an annual rate of 9.6 percent. These rates are among the highest achieved by developing and industrialized countries.

With import substitution gradually losing its stimulating power, industrial growth was sustained by exports of manufactures, which in 1970 surpassed Spain's traditional exports of agricultural and mining products. In 1974, industry accounted for about 42 percent of Spain's GNP, while agriculture's share dropped to 10 percent, a ratio characteristic of many developed countries. Growing external demand for industrial goods and Spain's comparative advantage in lower labor costs and supply flexibility contributed to this impressive record. The preferential Trade Agreement concluded in 1970 with the European Economic Community (EEC) opened up a market of vast proportions in the EEC countries for Spain's increasingly sophisticated industrial goods.

Although, in common with many other countries at similar stages of development, worldwide recession and high energy costs have caused a downturn in the exuberant growth of the 1960s and early 1970s, Spain now has a sufficiently large and diversified industrial structure on which to base further development. This structure, consisting of capital-intensive enterprises in the basic metals industry, in transportation equipment, chemicals, and the metal-forming and engineering goods sectors, has been laid, for the most part, with large infusions of foreign capital, technology, and know-how but with all the constraints such a process implies.

The process of industrialization, which has significantly raised the standards of living for Spain's rapidly urbanizing population, has brought several problems in its wake. Labor costs have increased substantially in recent years and have seriously eroded the competitiveness of Spanish industry's products and processes in foreign markets. The flexibility of small-scale firms, which have traditionally produced small orders with varying specifications, is seriously compromised, the investment climate for the start-up of new technology-based firms is less favorable, and it has become clear that Spanish industry must seek new directions to remain competitive.

As an outgrowth of discussion with the Spanish government dating back to 1972, the Bank entered in 1975 into negotiations on a five-year $18 million loan for the support of research, development, and engineering in industry. It was a path-breaking loan, the first Bank project intended to assist the improvement of industrial technology through indigenous efforts in product and process development. It was viewed as a demonstration of new approaches to the technological improvement of Spanish industry.

The economic rationale for the project loan was clear; unless domestic capabilities in industrial innovation were substantially improved, industrial growth fueled until now by large importations of foreign capital, technology, and expert assistance would falter and seriously impair Spain's ability to compete in world markets.[2]

Redressing current deficiencies in domestic technological capabilities is a large and complex task. Dependence over extended periods on foreign technology, lack of tax incentives and other inducements to promote industrial research, low rates of national investment in research, development, and engineering spread over too many institutions and programs, lack of venture capital firms, and the conservatism of the banking system were (and to a large extent still are) characteristic of the Spanish industrial scene as it entered world markets in technology-intensive goods. In 1974, Spain invested only 0.3 percent of its GNP (or $280 million) on R&D compared to between 0.9 and 2.3 percent in the EEC countries and 2.6 percent in the United States. Its deficit in technological balance of payments ($280 million) was the highest among Western industrialized countries.

Qualitatively, Spain's investment in research and development has been traditionally concentrated at the basic research end of the innovation spectrum. Rough estimates of the R&D gap and judgments on the absorptive capacity of industry were used to determine the size of the initial total investment by the Bank and the government required to develop a program of support to industrial R&D.

It quickly became clear that for the program to achieve its intended impact on Spanish industry, new organizational devices with sufficient freedom of action had to be created. A Center for the Development of Industrial Technology (CDTI) within the Ministry of Industry and Energy was estab-

lished to receive and administer the Bank's loan and government grants, a total of $40 million that constitutes the five-year budget of the program. CDTI is more insulated from bureaucratic pressures and constraints than are other parts of the Spanish government, but its management could not pay salaries to its personnel beyond those accepted for government agencies nor freely dispose of the income CDTI receives for services it provides. Steps were taken in December 1983 by the Spanish government to change CDTI's status to that of a public law entity and thus to provide CDTI's management the full autonomy of a corporate body.

In January, 1983, CDTI had a total staff of thirty-seven persons, of which twenty were professionals. The evaluation of research projects presented by industrialists and inventors and the follow-up of the approved projects were proceeding at an increased pace. From its beginning up to 1983, 211 projects have been presented to CDTI, of which 123 have been approved and 33 are already marketing the products resulting from the development work supported by CDTI.

Contrary to the image of government organizations as passive responders to proposals from researchers and enterprises, CDTI actively seeks out opportunities to encourage the development of indigenous technology to meet local needs. For example, CDTI found that Spanish tile manufacturers were dependent on foreign suppliers of kilns. The kilns available to them were a generation or two behind those available to tile manufacturers in the supplying country, which in many cases were linked to the kiln manufacturers. CDTI promoted the formation of a consortium of Spanish tile manufacturers to develop a kiln with up-to-date technology suited to Spanish conditions.

In another case, CDTI organized a consortium of Spanish suppliers to design and produce a prototype locomotive to specifications set by the Spanish railways, which will use the prototype as the basis for future tenders. The participants hope that an exportable locomotive of Spanish design and manufacture will result. CDTI is systematically reviewing goods procurement by the Spanish government in order to uncover more opportunities for this kind of entrepreneurial intervention.

CDTI's loans to enterprises for research and development work are forgiven if the work is not successful. If the work does lead to marketing of a new product or service, the principal is repaid at the rate of 5 percent of net sales. The profits to CDTI come from a charge of 2.5 percent of net sales for a period equal to the time elapsed from the closing of the project to the end of the repayment of the principal. The closing of the project is taken as the date on which the enterprise has successfully tested a product model and is ready to enter full-scale production and marketing. Any delay in marketing the product is in this way penalized, since it increases the time

during which CDTI receives profits. In other words, the enterprise reduces its investment in the research if it achieves early commercialization of the developed product.

In a new promotion program begun in 1981 for the small entrepreneur, CDTI helps support "regional technological advisors," local professionals (mainly engineers) working under contract with local chambers of commerce, who visit local industries trying to develop new projects that could be supported by CDTI. Twenty-nine such regional advisors are now in place, and a strengthening of the program is planned. CDTI also organizes workshops for entrepreneurs and seminars for graduate students in Spanish universities, on the financing of research, invention and innovation, and the organization of new enterprises.

In 1982, CDTI added three new programs: the promotion of better industrial design, the promotion of companies for technological innovation, and the provision of services and facilities for inventors. The companies for technological innovation are cooperative efforts among small enterprises, which set up a special enterprise to develop and market a new idea with the technical assistance of CDTI. The capital is financed one-third each by the enterprises, the Institute for the Small and Medium Industries, and financial institutions mobilized by CDTI.

"Arpegio," the service provided to individual inventors in order to help them to develop an idea, provides facilities and common services that can be used by potential inventors under conditions previously agreed with CDTI. Facilities in the Arpegio building are modular and can easily be rearranged to suit individual requirements.

An interesting new development in the financial scene in Spain is the emergence of SEFINNOVA (Sociedad Española de Financiacion de la Innovacion), a new privately owned venture capital company, one of only two in the country. This company assists smaller enterprises in pursuing growth opportunities, either in existing lines of business or through new product and process development. This assistance takes the form of equity or convertible debentures, with investment timed to coincide with the commercial launching of a new product, process, or service.

The IFC, the World Bank's affiliate, has subscribed to equity shares amounting to approximately $0.9 million, representing some 20 percent of the paid-in capital of SEFINNOVA. This was the first investment by the IFC in a technologically oriented venture capital company. (A similar investment has since been made in Singapore.)

To complement the work of SEFINNOVA, the government has organized within the National Institute of Industries, the holding company of Spanish public enterprises, a public venture capital company called National Enterprise for Innovation (ENISA) with an initial capital of 1 billion

pesetas (or 10 million dollars). CDTI works closely with both SEFINNOVA and ENISA to support the commercialization of new ideas, by helping to organize the new enterprise or the new activities within an old enterprise and by helping to launch the product or service into the market. Two members of CDTI's staff are on the Board of ENISA and the president of SEFINNOVA is on the Board of CDTI.

The Israeli Experience

Industrial research and development have been key elements in Israel's strategy for the development of research-intensive industries and the promotion of exports of technology-intensive products and processes. For a small country of 3.6 million people, located far from the markets of industrial countries and poor in natural resources, Israel has demonstrated unusual vigor in promoting exports of high-technology products. Israel's major asset and its comparative advantage is its large pool of highly trained scientists and engineers. Its ratio of 275 scientists and engineers per 10,000 population is one of the highest in the world, and its universities and research institutions have achieved world renown in many areas of science and technology.

With much of its research effort traditionally concentrated in universities and research laboratories, Israel launched a major effort in 1966 to reorient research toward commercial application. The function of promoting research in private industry was entrusted to the Office of the Chief Scientist (OCS) of the Ministry of Industry, Commerce and Tourism, and a well-conceived program of matching grants to private industry, differentiated according to the level of risk and the expected returns of the supported projects, now operates in Israel. The most widely used fifty-fifty matching grants are made from the Research Fund for projects proposed by industry and evaluated by the technical committees of the OCS for their technical and market feasibility. National Projects, funded more generously at 80 percent of their costs, are those with higher risk and long-term payoff; they are beyond the ability of firms to finance on their own, especially when private risk capital is in very short supply.

Less frequently, the OCS also provides 100 percent financing to the so-called infrastructure projects for the exploitation of natural resources, or to nurseries of technologies for future entry into advanced technology fields, or to provide technical support services to industry. In this class of projects, joint industry-university research teams are encouraged to work together on problems common to an industrial sector as a whole. Cooperation of Israeli firms with foreign enterprises and investors is encouraged through the OCS program. More recently, another window for financial assistance to enable

U.S. and Israeli firms to collaborate in the development of export products has been opened by the U.S.-Israel Binational Research and Development Foundation (BIRDF), to which the governments of Israel and the United States have each contributed $30 million.

The Israeli scheme for the promotion of industrial innovation has other interesting features. A program of the OCS that reimbursed firms up to 80 percent of the costs of subcontracts with universities was recently followed by grants to universities to commercialize technologies developed by them through local firms. These mechanisms have encouraged many universities to undertake industrially oriented research and development projects. Plant modernization and expansion are facilitated by a variety of other grants and loans at concessional rates provided by the ministry and by commercial banks. The OCS is also considering the initiation of loans to assist firms in carrying forward their innovative activities beyond formal research and development to pilot plant, prototype construction, and product testing and marketing in order to hasten the introduction of new products into the marketplace.

The competence of the members of the Israeli academic and industrial communities and the existence of an organization with a history of administration of grants for R&D augured well for the World Bank to consider a loan of $5.0 million for industrial R&D, a component of an industrial development project that included a fourth loan of $25 million to the Industrial Development Bank of Israel and a vocational-technical training component of another $5.0 million. A principal goal of the loan was to improve the recipient organization's institutional capacity in project evaluation and selection and in subsequent monitoring. The choice of the project, jointly made by the Bank and the OCS, emphasized the technologies that might be useful to other developing countries. The latter criterion of selection among subprojects was used in addition to other criteria, such as benefits to the Israeli economy, nondefense orientation, and possibilities of technical and commercial success.

Initially six subprojects were selected for Bank support. All were designated by the OCS as projects of national importance and given grants covering 80 percent of costs. Of these, three were classified as commercial subprojects aimed at the development of preproduction prototypes; two were classified as precommercial subprojects because they were in a much earlier stage of development; and one was classified as an infrastructure subproject with the purpose of providing R&D and testing services for industry.

The R&D component of the Bank loan has financed the foreign exchange components of three subprojects aimed at developing commercial prototypes: a computerized axial tomograph (CAT) scanner (an X-ray device that can scan the whole body rapidly with low exposure and is particularly useful in locating tumors); a Rankine cycle turbine, for electric power

generation from a variety of energy sources, including fossil, solar, wood, waste products, and geothermal, for application primarily to rural areas with limited accessibility; and a rural telephone system to serve small communities of 100 to 400 subscribers through a telephone exchange with radio links to a parent exchange, designed and packaged to minimize the need for skilled maintenance personnel. The first two of these projects have resulted in marketable products, which are being sold internationally. The tomograph manufacturer is the second largest producer in a very competitive and sophisticated world market; the rural telephone will reach the commercial stage soon, and a very large market is projected.

Two other projects supported by the Bank have a longer time horizon because of their unusual character and the need for further applied research and evaluation. One of these, the solar ponds project, is based on solar energy research in which Israel is a world leader. This subproject is aimed at developing commercial prototypes of a nonconvecting solar pond collector, an innovative approach to the problem of collecting and storing solar energy. A layered, shallow, black-bottomed pool of saltwater is set up so that the salt solution remains denser at the bottom than at the top. The absence of convection allows solar heat, absorbed by the more concentrated solution at the bottom, to be trapped there. The heat can be extracted by heat exchangers for direct use or for conversion to electricity.

The second project with a long time horizon is aimed at the commercial cultivation and industrial exploration of the jojoba, a wild desert plant native to the Southwest of the United States and Mexico. Its beans contain a thermally stable, odorless, and colorless oil, resembling that from sperm whales, which has potential applications in high-temperature lubricants, cutting oils, cosmetics, and medicinals. The adaptation and cultivation of a plant species in different soil and climatic conditions is a long and expensive process. The Research and Development Authority of the Ben-Gurion University of the Negev has already conducted extensive field tests of jojoba and laboratory analyses of the oil and the wax resulting from hydrogenation of the crude jojoba oil. Optimism concerning the commercial viability of jojoba products is sufficiently high to encourage project leaders to form a company to complete development and to market the products, especially for cosmetics and medicinals. As a byproduct of this project, plant propagation techniques were developed which may be applicable to other plant varieties.

The Bank loan also supports three infrastructure subprojects, two of which were added after the beginning of the program. The original subproject was a multipurpose common services facility in the Negev desert for the provision of material testing and pilot plant facilities to support local industry and to attract new industry to the area. The second subproject is a

Standards Institute to provide industry with information concerning non-tariff requirements of other countries and to provide design, measurement, and test facilities to aid manufacturers in meeting such requirements. The third subproject is the provision of equipment to facilitate the consolidation of several independent laboratories operated by the Ministry of Industry into a single industrial development institute.

The Bank's loan has also provided funds for an analytical study of industrial innovation in Israel, including the impact of existing incentives on exports, the availability of start-up and risk capital, and the formation of new technology-based firms in Israel. The result of this study should be useful to Israel policymakers and instructive to the Bank for investments in similar projects elsewhere. Indeed, to learn such lessons was a major purpose of the Bank in financing this project.

The Korean Experience

The remarkable economic performance of Korea since the early 1960s, sustained principally by the expansion of manufacturing activity and manufactured exports, is widely known and admired. The growth of aggregate GNP at an average annual rate of 10 percent between the early 1960s and the late 1970s and projected growth rates of exports of 6 percent or more through the mid-1980s, despite slow growth in the rest of the world, are indexes of development that have sparked the interest of many in the dynamics of the Korean model of export-led industrial development.

Within the manufacturing sector, the Korean electronics industry has been the leading workhorse, contributing some 11 percent to the country's merchandise exports between 1970 and 1978. Production and exports of electronics goods have risen at a staggering average annual rate of 50 percent from the low base of a decade ago.

The Bank's support of a comprehensive project proposed by Korea to advance its electronics industry to state-of-the-art levels by the mid-1980s was dictated by two important considerations: the rapid erosion of Korea's comparative advantage of low labor costs and the far-reaching technological changes taking place in the electronics industry worldwide.

Although the description of Korea's outstanding industrial performance as one based on the export of labor-intensive, low-cost, technologically mature products is historically and technically correct, it does little justice to the critical role played by the government's imaginative use of economic policies to initiate and sustain a fairly efficient and equitable process of industrialization. By careful management of the exchange rate close to the free trade level, by providing exporters with easy access to imported inputs, and by protecting industrial sectors with unusual opportunities for

import substitution, the government built an industrial production capability to serve domestic markets but strongly biased toward exports. Close consultation between industry and government in the establishment of indicative export targets discriminated by product, market, and exporting enterprises has helped to focus export efforts of Korean enterprises to a remarkable degree. It has also helped them take advantage of government-supported export promotion activities and, especially, of market research.

The export-targeting system is refined to a point that the government can act promptly and flexibly in changing the structure of incentives, and entrepreneurs can alter their investment strategies and production processes. The Ministry of Science and Technology and the infrastructure of planning and information agencies play a critical supportive role in the dynamic interaction between the government and the entrepreneurial community.

An export strategy based until now on labor-intensive manufactures has yielded important social dividends. The economy has performed well in generating employment and distributing income equitably. Employment is estimated to have increased at a rate of 3.7 percent per annum between 1965 and 1975, and 2 percent per annum between 1975 and 1983. Real wages in manufacturing grew at an average rate of 9 percent between 1965 and 1983. Korea's population of 40 million had a per capita income of $1,800 in 1983.

Because of the high value Koreans place on education and the willingness of parents to spend their own funds for the education of their children, a significant private educational sector has developed. Korea's literacy rate is among the highest in the world, and its universities have produced well-qualified scientists and engineers. Stability and buoyant industrial development have encouraged Korean scientists and engineers abroad to return home in large numbers. Government incentives have contributed to the enlargement of the high-level manpower pool available for development. Contrary to the experience of many other countries, public scientific and technological institutions such as the Korean Institute of Science and Technology (KIST) have been unusually effective in contributing to industrial development.

Korea has also made important strides in building up a technological base to support the reorientation of its industry towards skill- and technology-intensive industries. As a percent of GNP, total spending for research and development doubled in the last decade, from 0.3 percent in 1970 to 0.6 percent in 1979—among the highest rate in developing countries. During the same period, industrial spending for research and development increased rapidly, at an annual rate of over 20 percent per year.

Despite this impressive growth, the research and development sector in Korea still faces important weaknesses. First, research and development

spending by industry accounted for 34 percent of the country's total in 1979—a very creditable figure for a newly industrialized country but still short of the 40–70 percent typical of highly industrialized countries. Second, although some fifteen public research institutes have been established with a view to meeting industry's growing technological needs, their links with industry need improvement and their manpower resources for research and development remain inadequate and dispersed over too many institutes. Third, industry's efforts to innovate are still considerably underfinanced, particularly at the development and engineering phases, because of the lack of suitable financing instruments in the capital market for such risky ventures.

The World Bank's support of the development of the Korean electronics industry demonstrates that when a country has carefully specified its objectives and policies in a particular industrial sector and has developed an institutional capability for analysis and implementation, external resources can be directed to specific activities and projects. These initial conditions existed when the Bank started negotiations on the Electronics Technology Project in Korea, to which it has now provided $29 million in foreign exchange toward the total project cost of $63 million.

The technological opportunity addressed by this project arises from the dramatic changes that have taken place in the field of electronics in the last decade. The driving force behind these changes has been the development of integrated circuits, which combine thousands of individual components in one small chip, and has led to the development of the microprocessor computer on a chip. The phenomenal increases in the capabilities of integrated circuits and their remarkable cost reduction—on the order of 15 percent per year—are creating an important industry that is having a profound impact on factories, offices, homes, cars, telecommunications, and virtually all other facets of human life. The industrialized world is now entering the age of electronics. Indeed, the world electronics industry should surpass the steel industry in size in the late 1980s.

Increasingly governments in industrialized countries have recognized the importance of this industry and have extended to it considerable financial support. Korea is well placed to benefit from opportunities emerging in this field because rapid technological change is prompting companies in advanced countries to concentrate their scarce manpower and resources on the latest technologies and products with the largest potential for profit and growth (such as computers and telecommunications equipment). This trend is creating opportunities in the intermediate technology areas, such as consumer electronics and microprocessor applications, where the advanced countries have already progressed down the learning curve, and further cost reductions are possible only by transferring operations to countries like

Korea, where wages for skilled labor and engineers are relatively low. It is on this niche, between labor-intensive assembly operations on one hand and the advanced technology products on the other, that Korea plans to focus in order to sustain the impressive growth of its electronics industry.

To succeed in this field, Korea will have to concentrate initially on a few technologies, which will allow it to upgrade the design and reliability of its products and simultaneously provide the core around which to build technological capabilities for the future. This effort will require substantial design and manufacturing know-how, as well as expensive technological infrastructure, which is beyond the individual capabilities and resources of Korean or joint-venture firms. As has been the case in industrialized countries, the government plans to stimulate, support, and complement industry efforts.

The centerpiece of this project is the recently founded Korea Institute of Electronics Technology (KIET), which has developed strong connections to the industry it is expected to serve. It is designed as a service, research, development, and engineering organization with strong industry and government representation on its board of directors and a president with wide experience in research and development administration.

The structure of KIET reflects an engineering service rather than a research orientation, and it is organized along three major functional lines: semiconductor design, semiconductor processes, and systems. The three divisions are headed by persons with significant industrial experience and knowledge of technological developments abroad, a background especially important in the fast-changing field of electronics technology. A U.S. Liaison Office has been set up in the San Francisco Bay area, in the so-called Silicon Valley, whose Korean counterpart, the Gumi Industrial Estate, is planned to be the center of the Korean semiconductor and electronic systems develpment. The U.S. Liaison Office is intended to provide a window on U.S. technology and a point of contact with U.S. corporations interested in transferring mature semiconductor product and process technologies to overseas locations and in offering training to Korean engineers and technicians in their application.

The role KIET is intended to play in advancing electronics technology in Korea is a major departure from activities of similar government laboratories elsewhere. First, KIET will provide production services through its specialized, relatively capital-intensive equipment and service divisions that cannot be acquired economically by each individual firm but are essential for the industry's development. Second, through the Research, Development, and Engineering Program, a number of selected subprojects in semiconductors and digital systems technologies and product groups will be undertaken. Costs, and therefore risks and benefits of research, development, and engineering, will be shared with industry for these projects where

Korea can take advantage of its low-cost engineering and skilled labor resources to compete effectively in the world market. The goal is to transfer research results and to assist industry beyond the initial stages of design and development through production and commercialization. The structure of prices KIET charges for its services and products has been established in such a way as to enable KIET to become financially self-sustained in about four years.

In addition to its involvement in the development of Korea's electronics industry, the World Bank made a $50 million loan in 1982 to support the Korean Technology Development Corporation (KTDC), a financial institution that combines the patterns of action of Spain's CDTI with some of the attributes of a venture capital company. KTDC finances research, development, and engineering in private industry through loans, which are made without collateral and which are partly forgiven if the project fails. KTDC also provides equity funds to companies set up to exploit new research and development results.

Support of Industrial Innovation in Other Developing Countries

Capsule descriptions of a few other World Bank projects in support of industrial innovation illustrate the Bank's rapidly developing interest in this subject. They also exemplify the use of local development finance corporations and other types of financial intermediaries in the disbursement of project funds and their value in developing a capacity to appraise research, development, and engineering projects. In some of these projects, World Bank funds are clearly identified with the strengthening of local research and development organizations and their ability to interact effectively with small- and medium-sized firms. In such cases, institutional development continues to remain a major thrust of the Bank's assistance program.

The Training, Technical Assistance and Technology Fund (TTTF) of $3.3 million and a local training and consulting component of $1.2 million are part of a project loan totaling $80 million to finance the modernization and export capability of the Turkish textile industry. This loan is patterned after a similar $5 million Industrial Technology Loan Fund to Colombia. These funds are intended for textile firms for use in production improvement, pollution control, export market analysis, and foreign training and upgrading of R&D-oriented activities. Review procedures are kept simple in order to encourage small- and medium-sized firms to obtain needed technical services expeditiously. One of the two private development finance corporations that serve as intermediaries for on-lending the proceeds of this project loan will administer the TTTF as well as the funds for local training and consultancy extension services.

A $2.5 million component of a $45 million loan to Portugal provides a package of technological support and assistance activities designed to help small- and medium-scale firms develop new products and improve the quality of their export products. These activities will be undertaken by a group of research and development institutions in the food, industrial physics, and energy sectors operating under the National Laboratory of Engineering and Industrial Technology (LNETI). The overall objective of the project is to bring new small- and medium-scale industries to the less developed regions of the interior, provide employment opportunities for displaced persons from former colonies, and tap new sources of entrepreneurship by providing assistance to firms located in industrial estates.

In Uruguay, a World Bank loan of $9.7 million is financing a multidisciplinary industrial technology and research institute, vocational training, and technical assistance for studies of the technological aspects of Uruguayan industrialization plans and for the achievement of increased preinvestment analysis capability. The loan responds to the need for the revitalization of an inefficient, protected industrial sector in a small country, where traditionally import substitution was extended even to activities where foreign exchange savings were negligible. The Technological Laboratory of Uruguay, whose modernization would be financed in part by the loan, is expected to develop its capabilities in industrial research, training, dissemination of information, and technical assistance to entrepreneurs.

In Mexico, where industry has reached a relatively high degree of sophistication and is supported by a substantial pool of scientific, engineering, and technical skills, the World Bank's projects have proceeded along several interesting lines. Mexico has introduced in recent years various policies and has developed institutions with explicit concern for technological development. The National Council of Science and Technology (CONACYT) and its affiliate, the Technology Information Service (INFOTEC), the Mexican Institute for Technological Research (IMIT), and the National Registry for the Transfer of Technology (RNTT) represent a constellation of institutions addressing issues of national technology policy, information, industrial research and project appraisal, and review and control of foreign licensing of industrial technology.

Among the financial institutions providing loans for medium- and larger-sized companies, the Fondo Equipamiento Industrial (FONEI), a trust fund of the Bank of Mexico, has been in the forefront. Smaller enterprises are supported through trust funds administered by the National Financiera, a large government-owned development bank. The World Bank has been working with these financial entities since the early 1970s. A technology improvement component of a World Bank loan is being used by FONEI for subloans, at interest rates below the required lending rates, to

such activities of firms as research, development, and engineering design of new or improved products or production processes, technical information searches, and overseas training and service of technical experts related to new products and processes. Unlike other countries reviewed in this chapter, Mexico does not currently have substantial government-operated incentive schemes to promote research, development, and engineering in industry, and the loan component for technology improvement would enable FONEI to promote such activities in industry and to gain experience in their appraisal and supervision. FONEI would also make a special effort to seek out projects in enterprises located outside the principal metropolitan centers. The proposed loan would attempt to address the vexing problem of industrial pollution in Mexican cities by financing not only the purchase of equipment required by law in Mexico but also the technical services for the design and selection of such equipment. A financial incentive in the form of a reduced interest rate several points below FONEI's standard lending rate would be provided to encourage firms to use this component of the World Bank's loan. The Bank's loan also provides funds for FONEI to organize training courses for its own staff to undertake project appraisals and to assess the recommendations of external project evaluation organizations that are contracted for such services.

Some Lessons from the Bank's Involvement in Industrial Innovation

Innovation is a process of creating change—in policies, in institutions, and in people. In industry, the central agent of change is the entrepreneur. Ultimately entrepreneurs take the risks and enjoy the benefits. They are aided by a supporting cast of research, development, and engineering personnel, administrators, managers and marketing specialists who identify opportunities, and sales representatives who maintain contact with customers or users. If the description of how the World Bank has supported industrial innovation has emphasized the role of institutions, it is not that the role of the entrepreneur is not considered critical. On the contrary, the Bank sees its role as catalyzing the activities of local institutions in such a way that they stimulate innovation in local firms.

In spite of several studies of this problem in the developing countries, the identification of entrepreneurs and methods for stimulating their creative endeavors remains elusive. While the model of the large corporation has been transplanted to several developing countries and is thriving in some, there is a great shortage of entrepreneurs for small technology-based firms. While government agencies administering incentives and development banks that provide capital are able to deal with the larger established

enterprises, their capacity to identify and support riskier ideas of new entrepreneurs and smaller firms has yet to be developed. Experience suggests the need for new types of organizations that provide a package of services to small- and medium-sized firms, including start-up capital, assistance with technology and product development, and, especially, with assistance in marketing, both at home and abroad.

A frequent handicap of developing-country industries is their lack of design and engineering capability, whose development has been thwarted by reliance on imported technologies. The current interest of several developing countries in "unpackaging" imported technologies would also hinge on the availability of local engineering capabilities. This has implications for engineering education in the developing countries.

While the projects financed by the World Bank provide for local procurement of preinvestment and engineering services, the small number of engineering consulting companies and their limited capabilities frequently force reliance on external sources of such expertise. Projects supported by the Bank encourage the use of local consultants and consulting companies whenever available. But new approaches to encourage private engineering and consulting companies in the developing countries are needed, for unlike enterprises that possess physical assets against which loans could be made, they deal in the intangible assets of knowledge and information. Perhaps even more than research and development, what is urgently required is the strengthening of the engineering function within domestic enterprises. Such internal capability is not only important in itself; it is essential if the firm is to be able to interact with outside engineering and consulting companies.

The quality and availability of technical and market information to local firms is an intractable issue. Even if technical information is locally available, information about local markets and especially about export markets is usually in short supply. National documentation and information centers frequently cater to the scientific research community and occasionally to the needs of larger enterprises, but small and medium enterprises frequently are unable to obtain technical information in a useful form. Productivity centers and industrial research organizations on occasion provide such assistance, but the need for very specific information on product or process development has not been met.

In some of the projects financed by the World Bank, such as in Mexico, provisions are made to enable firms to purchase the information they need, but it remains to be seen how the facility is used. Clearly much of the information is embodied in people, and the continual updating of their knowledge and skills, as well as the creation of conditions favorable to their mobility, are extremely important. While Bank-financed projects make provisions for project-related training, the concern for qualitative improvement of profes-

sional and technical manpower is clearly a subject of importance to governments and to local firms.

The case of Israel presents an imaginative approach to the institutionalization of research and development in industry. Israel has been successful in encouraging firms to make increasing investments in research and development, leading to exports of technology-intensive products. The experience of Brazil also indicates that somewhat similar approaches may be effective in other countries.

It is natural for research within industry in the developing countries to take an evolutionary path, with the development of capabilities in testing and engineering first. The rapidity with which firms might undertake research and development activities frequently will depend on stimulative government policies and even more on the recognition by the entrepreneur of the risks and benefits of such activities.

In other countries, the almost complete absence of industrial research at the enterprise level may force a government wishing to encourage innovation to do so through government-supported research institutions. In such countries, a problem frequently encountered is to find ways to organize and reorient the activities of such institutions to respond to the needs of industry. The Uruguay project is a case in point. There, the close contact between laboratory and industry makes the project institution a good bet even in the absence of experience with research management. KIET of Korea may represent a more far-reaching approach to institutional orientation. Here, government, industry, banks, and KIET cooperate in an ambitious, integrated, sectoral development plan.

Several countries, such as Brazil and Korea, have taken steps to convert existing government research laboratories to autonomous corporations, to be supported in the future through contracts with private industry. Such restructuring and reorientation of research institutes is a long and difficult process, and the Bank's approaches to such institutional development, in which it continues to be involved in several countries, can be described at best as a learning experience for itself and its member nations.

In the triad of industry, government, and financial institutions necessary to promote innovation, the Bank has naturally been drawn to the vehicle provided by development finance corporations. While external assistance may be initially helpful in directing their effort at technological improvement in domestic enterprises, there is no substitute for a strong cadre of local specialists in government agencies and development banks who are capable of undertaking sector studies, identifying firms and entrepreneurs who can develop products and processes of commercial importance, and devising incentive loan and grant schemes to encourage their interest in innovation.

New technologies remain on the shelf if their entry into the marketplace is not facilitated by a timely release of money at the appropriate stages of the innovation process. The Spanish project seems to demonstrate that a well-staffed semiautonomous institution may play a valuable entrepreneurial role in promoting innovation at the firm level, with minimal involvement of government-supported research institutions. In many other developing countries, however, entrepreneurs need to be educated in the process of applying for government or bank assistance that would help them traverse the learning curve of innovation. They might not even know that government incentives are available and on what terms and conditions.

This chapter has provided a sketch of significant experiments on the part of the bank and its members with alternative approaches to stimulating innovation in the industrial environment of the less developed countries. While a few guidelines for successful promotion of innovation in relatively advanced developing countries have emerged, the strategies that need to be followed in the less industrialized countries are far from clear. The adaptation of the experience gained thus far to conditions in these countries is the next critical task.

Notes

1. See C. Weiss, M. Kamenetzky, and J. Ramesh: "Technological Capacity as an Element of Development Strategy," *Interciencia* 5, no. 2 (March 1980).

2. Information drawn from Bank appraisal reports.

Civil Works Construction

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Basic infrastructure works such as roads, irrigation canals, flood control systems, and crop storage facilities are important elements for economic development and the improvement of living conditions in rural areas. Most countries are aware of this importance and devote a large share of their annual public investment to civil works. Aid agencies, both bilateral and multilateral, devote substantial assistance to such projects. In the case of the World Bank, over 40 percent of its annual lending goes to civil works. In low-income, labor-abundant countries, civil works are also a source of employment and often are used to provide jobs for the poor.

Although labor-intensive construction methods are still widely used in many developing countries—notably in Bangladesh, China, India, Indonesia, and Pakistan—for building rural roads, digging irrigation canals, or erecting earth-filled dams, the trend during the last thirty years has been toward equipment-intensive methods of construction. The use of thousands of unskilled laborers instead of sophisticated machines came to be seen as a relic of the past or a bowing to social necessity rather than as a viable technological alternative. This view is not totally unjustified; large-scale labor-intensive civil works aimed primarily at providing employment usually register low productivity of labor and a high total cost of the end product.

The preference for equipment-intensive methods is reinforced by a number of social, cultural, and political factors. Developing-country engineers and planners trained in the universities of the industrialized world are much more familiar with, and attuned to, modern technologies than to the traditional ways of doing things at home. Engineering and consulting firms working on civil works projects tend to promote sophisticated technologies. When foreign aid is involved, procurement practices and financial conditions generally favor the use of imported machinery.

In 1971, the World Bank, in cooperation with several bilateral aid agencies, initiated a major study to investigate the prospects for labor-intensive technologies in civil works construction, specifically rural roads and irrigation works. The research was motivated by a number of factors. First was the growing realization that rural civil works could be more beneficial to the local populations if, in addition to their end product (a rural road, an earth-filled dam, or an irrigation system), they were also to

provide employment opportunities during construction and for maintenance. Second was the Bank's strategy aimed at meeting the basic needs of the poorest segments of the population in the developing countries, particularly in rural areas. Third was the fact that although labor-intensive construction methods in civil works were known to be technically feasible, little empirical evidence was available about their costs, their organizational problems, their prospects for improvement, and their competitiveness relative to equipment-intensive methods.

Technological and Economic Feasibility of Labor-Intensive Construction Methods

Early phases of the World Bank study investigated the technical and economic feasibility of using labor-intensive construction methods in civil works.[1] This research, which started with a comprehensive literature survey and then went on to field observation of some thirty road, irrigation, and dam construction sites in India and Indonesia, confirmed the technical feasibility of substituting labor for equipment in a wide range of activities. It also showed that most construction activities can be carried out with methods ranging from the most labor intensive to the most equipment intensive, and that apart from a few very specific tasks (such as the laying of high-quality pavement), the quality standards of labor-intensive methods can be as high as those achieved with equipment-intensive methods.

These conclusions may seem obvious today, when the promotion of employment through the choice of more appropriate technologies is recognized as a major objective by international development agencies and most national governments. When the World Bank study started in 1971, however, the use of labor rather than sophisticated machinery in civil works projects was largely viewed as rather impractical, if not totally counterproductive. It also ran counter to the prevailing belief that the only possible path of technological evolution was toward a greater use of better and more expensive machinery.

The substitution of labor for equipment is but a reflection of the civil works construction process. For example, for many road works, the work consists basically of a small number of repetitive and fairly simple operations such as the excavation of earth and other materials, its loading and transportation over fairly short distances, and finally its unloading and spreading in the appropriate place. Earthworks may represent the most important task in the civil road construction and typically account for up to half of the construction cost of a project. Other important activities include the production of aggregates (crushed stones, for example) and the laying of pavements.

Although the study confirmed that each of these tasks could be carried out in a variety of ways (haulage, for instance, can be done with headbaskets, wheelbarrows, oxcarts, tractor-trailer combinations, flatbed trucks, or large bulldozers) and that it was theoretically possible to combine these tasks in a great number of different configurations, it also showed that, in practice, the choice of a particular technology for a specific task (such as large-scale excavators for digging a canal) dictated the use of a similar type of technology for most of the other tasks in the project. In other words, it is difficult to combine equipment-intensive methods in one part of the project with labor-intensive methods in another part. The main reason is the very different rate of output of humans and machines, as well as the basic differences in the organization of the work for each type of technology.

What is technically feasible is not necessarily economically justifiable. One important conclusion emerging from the World Bank study was that most traditional labor-intensive projects showed very low productivity rates. Consequently, they were not economically competitive with equipment-intensive methods, even when the prevailing wage rates were very low. The study did suggest, however, that significant scope exists for improving the efficiency of traditional labor-intensive operations. With better planning, good supervision, improved tools, incentive payment systems, a proper organization of work, and interventions to upgrade the health and nutrition of the laborers, productivity can be increased several-fold. The research showed that productivity improvements could be achieved without significant increases in physical investment and that labor-intensive methods could become much more competitive relative to equipment-intensive methods for civil projects carried out in low-income countries.

Managerial and Organizational Factors

Showing the technical feasibility of labor-intensive projects and demonstrating their potential economic efficiency is one thing. Designing viable projects that employ thousands of workers and supervising such a complex operation is quite another. A substantial part of the research carried out by the World Bank was devoted to investigations of the organizational and managerial factors that account for most of the differences between efficient and inefficient labor-intensive projects.

Although each labor-intensive project is unique, even similar types of projects carried out within the same country, the research revealed a number of general principles about the organization and management of such projects, and in the second half of the 1970s, a number of civil works projects financed by the World Bank attempted to implement some of these findings.

The first requirement for a labor-intensive civil works project is that there be an adequate supply of labor on the project site or close to it. Even in countries with a large labor force and a high rate of unemployment, the labor supply at specific sites may be inadequate, a situation that can cause delays in the project work. One of the most frequent reasons for this apparently paradoxical situation is that although there may be an annual surplus of workers in the rural areas, the demand for labor in agriculture increases very sharply at certain times of the year, notably during sowing and harvesting. Workers can be diverted from peak-season agricultural work by higher wages, but this solution may result in a noticeable decline in agricultural output—a drawback that must be balanced with the economic benefits of the project—and it can raise the overall cost of the project to unacceptably high levels. What is more, workers who have been enticed away by comparatively high wages from their seasonal agricultural job may not be willing to accept lower wages for the same civil works job during the slack season.

Furthermore, the availability of surplus labor at certain times of the year does not necessarily mean that this labor will be available to work on a civil construction project. The willingness to work on such projects depends not only on the level of wages but on the worker's perception of long-term and short-term earning differentials relative to other types of employment, on his wealth (that is, the size of landholdings), on the disutility of work in terms of forgone leisure, and on his perception of the additional costs, such as transport, food, and lodging, of working on the project.

The research showed that one of the critical managerial tasks is scheduling the civil works tasks in accordance with local agricultural practices, which may differ from one region to another. It also showed that large projects are more difficult to organize than smaller projects. If thousands of workers have to be assembled, transportation costs rise, and it becomes necessary to spend large amounts of money on housing, food, and social services. With smaller projects using workers from nearby villages or farms, the overhead costs are much lower, and once the project is completed, some of the same workers may be employed to perform regular maintenance.

A second major problem regarding management is the organization of the work force. In traditional labor-intensive projects, the most usual form of organization is force account, laborers employed more or less permanently by a public authority. This form has a number of advantages, the main ones being the availability of workers throughout the year and the flexibility to shift them from one site to the next. There are, however, many drawbacks—low productivity, poor motivation, high overhead costs—that make this form of organization much less efficient than the subcontracting of various parts of the work to local entrepreneurs. But force account organization may be the only feasible solution in countries where the con-

struction industry is in the early stages of development and where technical and managerial skills are scarce, and it has played an important part in training personnel and in establishing standards of design and construction.

In countries that already have a developed construction industry and a certain amount of experience with labor-intensive civil works projects, however, research has shown that the contracting system is significantly more efficient than the force account system. The work must be organized in such a way that local contractors—most of them very small with limited financial and organizational resources and therefore limited ability to carry out a big project—are in a position to carry it out. A large project, for example, must be divided into clearly identifiable small components that do not exceed the technical and organizational capabilities of the likely contractors.[2] This principle, referred to as slice and package, has now been accepted as a means of fostering the participation of small local contractors in civil works projects.

By their nature, labor-intensive construction projects require much greater supervision than equipment-intensive projects. While a bulldozer manned by one or two skilled workers can move up to 1,000 cubic meters of earth per day, 200 to 300 unskilled laborers might be needed to do the same amount of work. With labor gangs of 20 to 30 people, often dispersed over a fairly wide area, a dozen or more competent supervisors capable of motivating the labor force and controlling both the quality and organization of its work are required. In many countries, the availability of a sufficient number of skilled supervisors is a critical constraint on the feasibility of labor-intensive projects. It is possible to train fairly large numbers of people to assume such supervisory tasks, but this can add significantly to the cost of the project and to the time needed for its execution. And training, however well done, is not a perfect substitute for the years of experience accumulated by seasoned supervisors.

If the availability of supervisory skills is one of the big bottlenecks in the wider use of labor-intensive methods in civil works construction, another is the availability of engineers and other high-level technical personnel with the ability and inclination to organize and supervise projects of this type. Traditional engineering schools familiarize students with modern equipment-intensive methods but not with the less glamorous, but in many ways equally complex, labor-intensive methods. Furthermore, labor-intensive projects, which are often used primarily as a means of creating employment opportunities, tend for this reason to have a rather unfavorable image in the engineering community and are therefore unlikely to attract the best technical people. This problem is not specific to labor-intensive civil works projects alone. Until fairly recently, most attempts to promote appropriate technologies (many of which are of the labor-intensive type) were viewed with derision by policymakers and engineers and seemed

unworthy of attention except by a small number of marginal groups with relatively little engineering experience and almost no familiarity with the management of large-scale projects. In recent years, things have changed. The concept of appropriate technology has entered the mainstream of development thinking and is being promoted by many development agencies. The political and cultural legitimacy attached to appropriate technology has encouraged the search for innovative labor-intensive technologies and is gradually helping to bring some of the better engineers and managers into the field. In this perspective, one may surmise that one of the most important indirect benefits of the World Bank's study on labor-intensive construction methods is to give these technologies respectability. This indirect benefit is probably as important as the basic technical and organizational aspects developed in the course of this action-oriented research.

The research carried out by the World Bank suggests that from an organizational and managerial standpoint, labor-intensive civil works projects are rather complex, even if the basic technologies used are fairly simple. In fact, the managerial and organizational elements are critical to the success of a project, and one of the basic aims of the research was to develop the know-how to make such projects economically efficient. As experience was to show, some of the organizational means required to meet this criterion of efficiency are fairly straightforward. This is the case, for instance, with the whole program of wage structures and incentives. The research showed that with adequate wage incentives, the productivity of labor could be increased significantly. While this conclusion may seem logical and obvious, the research did highlight two important points. The first is that the productivity increases that can be fostered by an effective system of wage incentives (piece-rate systems instead of daily wages) are exceptionally high. In the case of earthworks, for instance, it was observed that the output per worker could be increased by a factor of two or even three.[3] The second is that the development and administration of an effective incentive system is a rather difficult and complex task. Detailed job analyses have to be carried out, and a schedule of productivity norms must be established. Furthermore, the payment basis must be fully understood by the labor force, and it must be perceived as fair by the workers. It is also important that wages be paid regularly and promptly.

Wages and incentives are but a part of the much greater problem of financing. The research showed that many such projects sponsored by public authorities suffered from irregular supplies of funds to pay workers and contractors and that this had a very negative effect on worker morale and on productivity. The problem is particularly acute when the work is carried out by small contractors who do not usually have the financial strength to overcome the difficulties caused by delays in payments or have the resources to make the initial investments for mobilizing the manpower

needed in the project (advances to prospective workers, transportation costs, and so on).

Technical Factors

The World Bank study pointed to the paramount importance of managerial and organizational factors in the planning and implementation of labor-intensive civil works projects, but it would be a mistake to belittle the role of technical factors. In fact, a significant part of the research was devoted to detailed investigations of the wide range of technologies used in civil works construction and to painstaking comparisons among alternative ways of performing the same task. This research, summarized in a large number of technical memoranda, represents one of the most comprehensive bodies of knowledge and experience about labor-intensive construction methods and amounts in effect to the current state of the art in this field.

Wheelbarrows are one of the many factors studied. This is a well-known technology that at first sight would appear particularly appropriate in labor-intensive construction projects.[4] In many countries, however, the wheelbarrow is a totally unknown tool; workers are not familiar with it, and no local manufacturers make them. The research carried out in India and Indonesia showed that the traditional wheelbarrow with plain bearings has little advantage for short haul distances over the seemingly inefficient head-basket. The only competitive alternative is the more costly scooter wheelbarrow, which has a pneumatic tire wheel mounted on ball bearings. Haulage of earth with wheelbarrows of this type is economically and ergonomically efficient but only within rather specific limits. If earth has to be moved short distances, purely manual methods are preferable, and if the haulage distance exceeds 100 meters, the modern wheelbarrow is no longer the most efficient tool. Furthermore, much depends on the nature of the terrain. With level ground, the wheelbarrow is easy to operate, but as soon as the slope exceeds a certain gradient, it is more cumbersome than helpful. Investigations were also carried out on other types of wheelbarrows, notably the two-wheel Chinese type, which has the advantage that a larger proportion of the load rests on the wheels but which is rather unstable, and difficult to maneuver over rough ground.

Research was also carried out on the use of draught animals. It showed that for short hauls with a large rise, as in the final portion of a high embankment, panniers are a rather effective technology. With medium-length haulage distances (between approximately 100 and 1,000 meters), the traditional animal-drawn cart is economically and technically efficient provided the terrain is fairly flat. Using large numbers of draught animals in civil works projects is far from simple, however. Provisions must be made for

feeding the animals, keeping them in good health, and organizing the sequence of their work in such a way that idle time is not excessive.

Another area to which substantial research was devoted was that of hand tools.[5] In many developing countries, the only hand tools used in civil works projects are either traditional agricultural implements or inferior copies of Western-style tools. In most projects, the cost of hand tools accounts for a very small proportion of total project costs. An ordinary shovel may be worth four or five days of a laborer's wages, and total cost of all the hand tools used in a project may not be more than 3 or 4 percent of the total wage bill, even when one assumes that the hand tools' useful working life does not exceed six months. Because tools are relatively inexpensive, their importance tends to be overlooked. But the productivity of labor can be markedly reduced if inadequate tools are used. Inferior tools are a bad investment because of their poorer productivity and because of the need for much more frequent replacements, which rapidly offsets their lower purchase price. The World Bank study showed that this tendency to overlook the importance of providing the right tools for the right job was one of the most common problems in traditional labor-intensive civil works projects.

The productivity of workers is influenced not only by the quality and efficiency of their tools, by wage incentives, and by the level of organization and supervision of the project but also by health and nutrition standards. Many workers engaged in civil construction projects are undernourished and in poor health, and one of the most productive investments is to provide workers with an adequate diet and good health supervision. Studies on the relationship between nutrition and worker productivity are complex and painstaking, and their results are not always very conclusive, but in some cases, a direct linkage can be established between a specific nutrition deficiency and worker productivity.[6] It was observed in Indonesia, for instance, that a simple iron supplementation program costing half a dollar per worker resulted in productivity increases of up to 25 percent. A similar study carried out in India indicated a close correlation between output and body weight, which indirectly confirms that food supplementation programs aimed at increasing caloric intake can be highly beneficial.[7] Perhaps even more important than specific nutritional programs is the provision of clean drinking water and sanitary waste disposal facilities on the work sites and within the camps where the laborers are housed.

This rather brief review of some of the technical findings of the World Bank's research on labor-intensive civil works construction would not be complete without some reference to the possibilities of using intermediate technologies in such projects. The term *intermediate technology* is generally understood to refer to technologies that in terms of complexity and cost lie somewhere between the simple labor-intensive technologies, which are still widely used in the rural areas of developing nations, and the complex

equipment-based technologies of the modern sector. In this sense, a small tractor with a trailer represents an intermediate technology, halfway between the traditional headbasket on the one hand and the bulldozer or the motorized scraper on the other. In the civil works field, the term tends to be used somewhat differently. By *intermediate technology*, one generally means not a specific technology or piece of equipment but rather a combination of labor-intensive and capital-intensive technologies. In other words, *intermediateness* refers to the whole complex of technologies used in a project rather than to specific pieces of hardware.

Experience seems to suggest that the possibilities of combining labor-intensive technologies with equipment-intensive technologies are very limited. Operationally it is feasible to bring a few sophisticated machines (a bulldozer or an excavator, for instance) into an otherwise fully labor-intensive civil works project. In practice, however, such combinations are not appropriate. Part of the reason is the additional complexity this combination introduces into the organization of work and the difficulty of coordinating the fast pace of the machine with the much slower pace of the laborers. In addition, the use of sophisticated machinery requires a fairly complex support service (fuel supplies, spare parts stocks, maintenance facilities) whose buildup is justifiable only if the number of machines is sufficient. With only a few machines on site, setting up such support services is not economical. Furthermore, when only a few machines are used, they tend to lie idle for long periods of time since their rate of output is so much faster than that of the laborers. As a result, the cost of using them tends to become prohibitively high.[8]

One of the most significant lessons of this research from a technical point of view is the need to maintain a certain degree of technological integrity in the whole project. If the project is to be labor intensive, it must be consistently so; if it is to be based on equipment-intensive methods, then there is but limited scope for introducing labor-intensive components. Experience also shows that this need for technological integrity also applies to the maintenance work. If a road has been built with labor-intensive methods, then the maintenance work is best carried out with the same methods.

Another important lesson of the World Bank's study concerns the size of labor-intensive civil works projects. Although in principle it is possible to carry out very large projects using such methods—as indicated by the experiences of countries such as China or India—the evidence suggests that smaller projects involving a few hundreds of workers are easier to design and manage and fit much better into the local environment. The optimum size depends on the nature of the task and local traditions. In countries such as India, for instance, there is a long-standing tradition of labor-intensive projects, and large gangs of workers can be assembled from hundreds of

miles around. But in many other countries, very large projects raise major social and organizational problems, and this makes them rather risky propositions.

Design and Implementation of Labor-Intensive Projects

The World Bank study was also designed to provide a workable methodology for preparing and implementing well-defined and economically viable infrastructural projects. Although in its early stages, the study focused primarily on existing projects carried out by local agencies, it soon shifted to experimentation and analysis of new projects, many financed in part by the Bank. One of the most important outcomes of the study was the preparation of a very detailed guide that outlines the technical and organizational problems of labor-intensive civil works projects and summarizes the basic know-how in this area.[9]

This guide, which marks the culmination of ten years of research, provides planners, administrators, and engineers involved in the design, execution, and supervision of labor-based construction projects with practical help on all of the important aspects of such projects—from the initial design and preparation phase to full-scale implementation. Its purpose is not to make a case for labor-intensive projects but to show how best they can be executed in practice. For this reason, it does not address such issues as the evaluation of projects from the viewpoint of the national economy or the determination of the economic value of a labor-intensive project versus competing demands for investment funds by other types of projects. It takes for granted that a project has been found to be valuable for the economy and seeks to provide planners and managers with the necessary information to make it successful.

The guide presents the basic steps in initiating and planning labor-intensive civil works projects and examines such issues as the technical and economic feasibility of labor-based technologies, the choice of technology, the nature of the physical works, the need for institution-building and support activities, and the ways of ensuring support from the authority that is to finance the project. It examines the critically important role of pilot projects and the transition from the pilot project to a full-scale program. Special chapters focus on the detailed planning, management, and organization of a full-scale project. Others examine the problems of site planning and logistics. What construction resources are available? How should labor camps be laid out? How can on-site transport best be organized? What is the cost of bringing in labor from far away? One chapter examines the problem of site engineering. How should roads and irrigation works be designed? What is the most appropriate way for conducting topographical surveys and

soil surveys? How should the site be cleared in preparation for the construction work? What is the most efficient way for moving the earth? What types of pavements and linings should be chosen? How should quantities be measured? How is subsequent maintenance work to be organized? The final chapter is devoted to site administration and management and focuses on such issues as the recruitment of labor, the design of a wage system, the training of workers and supervisory staff, the measurement of productivity, production planning and control, and the evaluation of productivity data.

Each chapter contains an annotated bibliography, and the guide includes a number of technical appendixes dealing with such subjects as the design of hand tools and light equipment, different methods for cost calculations, and the implementation of a monitoring and reporting system.

This guide is important for a number of reasons. By bringing together all of the research carried out by the World Bank on labor-intensive construction methods as well as its practical experience in the design and execution of both pilot projects and full-scale projects, the book summarizes the basic technical and organizational know-how for designing and implementing projects of this type. It also epitomizes one of the major ways in which the Bank operates as a technological institution: what has been developed is not primarily new technology in the hardware sense of the word but a large body of organizational and managerial knowledge based on economics, management science, engineering, and technology, in an attempt to synthesize theory with practice and research with current operations.

Another important aspect of this research on labor-intensive construction methods is its cooperative nature. It was prepared not only by World Bank staff members but by independent consulting firms, public authorities in developing countries, and individual researchers from a large number of countries, and the project itself was financed from a wide variety of sources, both national and international. Clearly the research allowed for an active and vitally important contribution on the part of the developing countries themselves in the process of research and experimentation, and this may well point to the new forms of action-oriented research, which will increasingly be needed in the years to come.

Policy Issues

Labor-intensive civil works projects are technically feasible, and the study sponsored by the World Bank clearly demonstrated that they can also be economically competitive, provided they are well designed and adequately supervised. They can be of interest only to countries with a rather low level of income and a relatively abundant supply of labor. What is technically and economically feasible, however, is not necessarily politically and culturally

acceptable. Furthermore, even when such basic conditions as low wage levels, an abundant supply of labor, and the political willingness to experiment with such methods are met, there are still a number of problems to overcome.

One of these is the way in which projects are designed and prepared. The study sought to investigate the feasibility of using labor-intensive methods in civil works projects and was aimed at developing the necessary know-how for designing and carrying out such projects. Comparatively less attention was devoted to the influence of project identification on the choice between labor-intensive and equipment-intensive technologies. What generally happens is that this preliminary phase in which a potential project is identified and its broad characteristics are determined, exerts a major, if largely unrecognized, influence on the types of technology selected for carrying out the project. A typical illustration of this is the overall scale of the project. If a project is identified at the outset as a rather large undertaking, it almost inevitably follows that equipment-intensive technologies will emerge as the choice for works execution. If the basic design parameters are set according to high technical standards, it becomes difficult to choose labor-intensive methods for carrying out the construction work.

Techniques that will help overcome the inherent biases of current project identification and preparation procedures against labor-intensive technologies can be extremely helpful. In this connection, reference must be made here to a major conceptual innovation developed by the World Bank, that of neutralization.[10] This is a set of techniques in procurement procedures that are aimed at identifying and removing the biases in favor of equipment-intensive technologies so as to allow the contractor a freer choice in the selection of technologies that may be used for carrying out parts of the project. The purpose is not to discriminate against equipment-intensive technologies or to give particular preferences to labor-intensive technologies but simply to ensure that the different technologies are put on the same footing. This can be done through a wide variety of means, ranging from technical specifications to the definition of the size of the tasks to be carried out, and from bid evaluation rules to the choice of financing schedules.

This concept of neutralization, developed within the framework of a guide to competitive bidding, is of much wider relevance than to the field of procurement alone and is in fact applicable to all of the early phases of a project as well as to the design of sectoral development policies. Its importance is twofold: as an instrument for reducing the inherent biases against the use of labor-intensive or appropriate technologies and as a tool for widening the range of technology choice and suggesting alternative options that would not normally be taken into account. In a sense, it represents a major effort for bringing the problem of technology choice into the policy-making process.

In the same way, this research of the World Bank on labor-intensive civil works construction might be viewed not only as an important contribution to the organizational and managerial state of the art but also as a major attempt to explore alternative development strategies and to present policymakers with a number of options more appropriate to local conditions.

Notes

1. This section draws heavily on *The Study of Labor and Capital Substitution in Civil Engineering Construction: Report on the Bank-sponsored Seminars in Washington, Cologne, Copenhagen, London and Tokyo* (Washington, D.C.: World Bank, 1978).

2. See *Guide to Competitive Bidding on Construction Projects in Labor-Abundant Economies* (Washington, D.C.: World Bank, 1978).

3. On this point, see *Technical Memorandum No. 12, Haulage by Headbaskets, Shoulder Yokes and Other Manual Load-Carrying Methods* (Washington, D.C.: World Bank, October 1975) and *Technical Memorandum No. 19, Excavation* (Washington, D.C.: World Bank, February 1976).

4. See *Technical Memorandum No. 1, Comparison of Alternative Design Wheelbarrows for Haulage in Civil Construction Tasks* (Washington, D.C.: World Bank, January 1975), and *Technical Memorandum No. 13, The Use of Wheelbarrows in Civil Construction* (Washington, D.C.: World Bank, October 1975).

5. See *Labor-Based Construction Programs—A Practical Guide for Planning and Management* (Oxford: Oxford University Press, 1984), Appendix C.

6. See *Technical Memorandum No. 4, Effect of Health and Nutrition Status of Road Construction Workers in Northern India on Productivity* (Washington, D.C.: World Bank, January 1975).

7. See "Iron Deficiency Anaemia and the Productivity of Adult Male Workers in Indonesia," World Bank Staff Working Paper No. 175 (Washington, D.C.: World Bank, April 1974).

8. On the scope for using intermediate technologies, see, for instance, I.K. Sud, C.G. Harral, and B.P. Coukis, "Scope for the Substitution of Labor and Equipment in Civil Construction—A Progress Report," a paper presented at Indian Roads Congress, Thirty-Seventh Annual Session, Bhopal, December 1976 (New Delhi, 1978).

9. *Labor-Based Construction Programs—A Practical Guide for Planning and Management,* op. cit.

10. See *Guide to Competitive Bidding on Construction Projects in Labor-Abundant Economies* (Washington, D.C.: World Bank, 1978).

Urban Traffic Management

Herbert H. Werlin

Inadequate transport undermines the capacity of cities to fulfill their functions, and it negates the advantages that densely populated areas enjoy by virtue of their concentration of skills and purchasing power. Poor transport and poverty are interrelated. In many countries, roads often are badly located, poorly built, and badly maintained. So dusty are they in some of the *pueblos jovenes* (new settlements) in Peru that road traffic is considered responsible for the high incidence of respiratory disease. In Recife, Brazil, some urban arteries cannot be used at all by public transport for as long as two months during the rainy season.

Poor roads, combined with poorly maintained vehicles and inadequate traffic control, are also responsible for the high fatality rates from accidents in many developing countries. A recent study of some of the cities of these countries found these rates to be eight times greater than in Great Britain and up to thirty times greater than in the United States. The highest figure was in Bombay, with 53 fatalities per 10,000 vehicles. This compared with 4.2 fatalities per 10,000 vehicles in Great Britain and 1.6 in the United States.

Most urban poor are dependent on their own feet to get where they have to go. In many cities, half of all work trips are made on foot, often for long distances. For poor people, the cost of motorized transport can be a severe impediment to finding employment. Of those able to afford motorized transport, between two-thirds and three-quarters use the bus, but services tend to be unreliable and inadequate.

What can be done to improve urban transport in the developing world? Traditional transport planning methods, with their emphasis on deciding when and where to build the next road, do not provide the answer. Even in developed countries, the costs of urban road construction are becoming unacceptable, not only in monetary terms but also in terms of social disruption and environmental destruction. Traditional approaches have also encouraged private automobiles, leading to intense congestion of urban streets, air and noise pollution, and the allocation of scarce foreign exchange on fuel, gasoline stations, and repair facilities. In terms of costs per passenger mile, buses are clearly much more economical than automobiles. A bus costing $40,000 in 1975, or thirteen times more than a typical automobile, may average forty times the automobile's annual passenger mileage.

Much of material included in this chapter was originally prepared for and presented in the *Urban Edge*, a World Bank-sponsored newsletter published by the Council for International Urban Liaison.

Because of their concern to make maximum use of limited resources and to avoid past mistakes of North America, where resources went to improving facilities for private transport at the expense of those needing public transportation, leaders in developing countries are looking to innovative solutions. These include such approaches as greater priority to projects aimed at improving public transportation, the orientation of public transport to the needs of residents in low-income areas, the development of traffic engineering and management measures that make better use of the existing street system, the application of new organizational and financial techniques to improve the efficiency of bus fleet operations, the encouragement of low-cost fuel-saving transportation systems, and the change in such social habits as working hours. These approaches, used singly or in combination, will be illustrated in this chapter with the help of a number of examples taken from large cities of the developing countries in which the World Bank has been involved. They will show that a balanced approach to urban transportation can help to reduce travel time, bring jobs closer to home, and allow the poorest people access to transport, a vital necessity in their search for jobs.

Making Better Use of Existing Roads

Making better use of existing roads and streets is one of the first and most obvious approaches to improving urban transportation. The problem is more one of traffic management than of physical improvement or enlargement. The building of new roads makes sense only if they are properly integrated with existing roads. One illustration of this approach is provided by the city of Calcutta, which is attempting to reduce traffic tie-ups by restricting certain streets to pedestrian use, improving traffic islands in the center of wide roads (particularly at junctures), introducing new or improved road markings and signals, enforcing more effective parking controls, and creating exclusive bus lanes with indented bus stops and other protective measures to facilitate passenger pickup.

Such an approach is being increasingly used in a number of other cities. San José, the capital of Costa Rica, is avoiding an expensive road construction program. Only one section of a new road will be built to link up with a new intercity highway. In four corridors, the streets will be widened, where possible, within existing rights-of-way, to allow the introduction of exclusive bus lanes during peak hours. A number of Brazilian cities are paying particular attention to the development of bus lanes. In Recife, about 40 kilometers of exclusive rights-of-way for buses are being constructed in four radial corridors leading into the central area. The work includes repaving or constructing new sidewalks, curbs, bus stops, and shelters and signals.

In addition to over 20 kilometers of exclusive and priority lanes for buses and taxis, Manila is planning to provide or improve over 20 kilometers of footways, together with 200 crosswalks in mid-block positions. Madras is another city that recognizes the importance of both foot and cycle paths. Its project calls for the improvement of about 200 kilometers of footpaths and about 50 kilometers of cycle tracks, together with the construction of nine pedestrian underpasses and the lighting of twenty-four dangerous intersections.

The effect of unpaved roads on public transportation is long remembered by passengers required to use such vehicles during a rainy season. But a road-paving program need not be expensive. Where soil conditions are reasonably stable, the paving can take the form of a simple macadam surface dressing, which can cost as little as 20 percent of the cost of traditional road construction.

In San Salvador, a new two-lane road is being planned to allow bus services to penetrate for the first time into the heart of one of the poorest neighborhoods with about 60,000 inhabitants. The project also includes about 5 kilometers of two-lane access roads with very simple design standards for service vehicles, such as garbage and utility trucks. To improve access from houses to the bus lines, about 18 kilometers of current tracks will be paved on a width of 3 meters as pedestrian footpaths. Finally, a series of concrete stairs will be provided to eliminate the need for bus passengers and other pedestrians to scramble up and down muddy hillsides.

In Madras in 1976, it was estimated that 40 percent of all daily passenger trips were made between 8 A.M. and 10 A.M. and between 4 P.M. and 6 P.M. This concentration resulted in severe congestion during these hours and the overloading of buses by as much as 100 percent. To alleviate this situation, the state government in August of that year implemented a system of staggered work hours for government offices, private business, factories, and schools. The impact of this change is currently being evaluated. A similar experiment is being carried out in Bombay by the state government of Maharashtra.

In mid-1975, Singapore became the first country in the world to curtail systematically the use of private automobiles in congested areas. The need was clear; within a radius of 8 kilometers, over 1.5 million people were using over 250,000 registered motor vehicles, of which 150,000 were private cars. A number of alternatives were considered, among them import duties, gasoline taxes, city street tolls, and higher parking fees. The solution eventually adopted—area licensing—has proved more effective than any of these alternatives could possibly have been, though it required significant political courage and planning. Area licensing in Singapore initially comprised five steps: the designation of a restricted area, the requirement of a dated windshield sticker for passengers to enter the restricted area between

7:30 A.M. and 10:15 A.M., the opening of 10,000 spaces in car parks around the periphery of the restricted zone, the operation of shuttle buses from the fringe car parks to the central areas, and the doubling of parking charges at public car parks within the restricted area, making them especially high for all-day parking. Based on experience, minor modifications have been made, including better bus services, restrictions on taxis, and upgrading of roads. The following description provides some insight into the mechanisms of Singapore's experiment:

> The restricted zone covers the previously most congested part of the central business district (CBD) about 500 ha, leaving diversion routes for motorists who do not have destinations within the zone. During the time the system is in operation (7:30–10:15 A.M. weekdays) the red overhead lights at 27 gantries spanning all approach roads to the CBD are lit and roadside checkpoints at the gantries are staffed by polite uniformed women, 55 in all, who check as the traffic slows without stopping whether the prominent daily or monthly sticker is displayed on the windshield. Booths that sell the stickers operate daily at the approaches to the gantry points and monthly stickers are also on sale at banks and post offices.
>
> On the rare occasions that a stickerless windshield or invalid coupon passes by the argus eyes of the gantry women, the culprit can look forward to a summons and S$50 [1 U.S.$ = approximately S$2] fine in the next day's mail—violations average about 70 a month out of more than 11,000 properly documented trips into the central area. There is a S$2,000 fine and a jail sentence for forgeries or illegal tampering with the sticker, but no instances of this kind have been reported to date. The system operates without fear or favor and it certainly encourages car pooling as the gantry attendant checks either for four heads or for the sticker on the windshield. Promptly at 10:15 A.M. the "In Operation Restricted Zone" red neon sign atop the gantry is turned off, the women go off duty, and normal traffic resumes. Amazingly simple and inexpensive to operate, besides producing revenues, area licensing has proved effective in reducing the use of private cars, with resultant savings of imported fuel. The ridership and cost-effectiveness of public transport in the inner city has been increased. Besides, pollution levels have dropped significantly, as determined by the regular monitoring of air quality carried out at selected stations in the CBD.[1]

The success of the Singapore experiment soon became apparent. Since its introduction, speed within the restricted zone during the restricted hours has improved within two years by an estimated 22 percent and on inbound radials by 10 percent. The number of cars entering this zone during the restricted time dropped by 73 percent. Approximately 18 percent of the vehicle owners chose new options. Of these, about equal numbers changed to the bus, joined car pools, or made the trip at different times. The total capital costs have already been recovered almost entirely from the sale of stickers costing U.S.$26 a month or $3 a day. Above all, the public has been pleased with the experiment. According to public opinion surveys, Singa-

poreans note less congestion, safer streets, and reduced pollution in the central area. Even business leaders agree that the scheme has not had the adverse impact on sales that was initially feared.

The success of an area license scheme depends on a number of factors: competent management, comprehensive policymaking and planning, attention to administrative details, preparation of the public, and flexibility. While Singapore has a number of advantages in this regard, other cities could, with suitable modifications, follow this example. What is essential is the conviction that such a scheme would be worthwhile and the political will to carry it through.

Paratransit Alternatives

Paratransit refers to a range of vehicles—from minibuses to carts, powered by motors, animals, or humans. Paratransit services are privately owned. Beyond that, generalizations are difficult. Often these vehicles have no fixed hours of operations or destination, and their drivers charge whatever can be negotiated or demanded. Their flexibility, accessibility, and relative cheapness make them highly competitive. Because of their importance, a number of countries are trying to regulate the various forms of paratransit without discouraging them and to enhance their positive features while controlling some of their less desirable characteristics.

In many countries, bus companies are in financial difficulties. Costs of fuel, vehicles, spare parts, and labor have risen more rapidly than fares, which need to be kept low for political reasons. There is also the requirement to operate buses at times or on routes where there are few passengers. An alternate form of service is the minibus, often nothing more than a pickup truck fitted with benches for ten to fourteen passengers and a rack on the roof for goods. In case of rain, roll-down plastic sheets may be provided for protection. Minibuses can operate efficiently with fewer passengers and typically need only 25 percent of the fuel required by a sixty-passenger bus. They also make better use of road space in congested areas. Because minibuses are generally privately owned, they are not a drain on local government resources, as are the public bus companies plagued by costly overheads.

The efficiency of minibuses makes them an attractive business proposition in many developing countries. The rate of return on such vehicles suggests that they can be financed at commercial rates of interest of about 18 percent per annum. Such a loan can be amortized without too much difficulty, even when gasoline prices are high and occupation rates only 60 percent; this still leaves enough for insurance and allows for a take-home income equivalent to $1,200 per year. In addition to creating employment

and income for owners and operators, minibuses stimulate the development of small engine and repair shops and other businesses in poverty areas. Other positive side effects include the spread of mechanical skills and vocational-technical education.

The usefulness of minibuses often makes official opposition to them counterproductive as well as futile. In Hong Kong, for example, during the early 1960s over 2,000 illegal minibuses were estimated to carry 17 percent of all bus passengers.[2] During the political disturbances of 1967, these minibuses were legalized. By 1976, the number of "public light buses" had reached 4,350 and carried an estimated one-third of public transport passengers. So profitable were these public light buses by 1980 that their owners could recover two-thirds of a vehicle's purchase price in a single year.

Kuala Lumpur, Malaysia, is another major city that recently has encouraged minibuses, licensing 400 of them between 1975 and 1977. Direct observation, inquiries among residents, and published accounts indicate that the minibuses are providing a valued service, particularly in reducing congestion in central Kuala Lumpur. It is estimated that in 1980 they handled about 8 percent of peak hour trips and 6 percent of all trips, with average trip time reduced to about thirty-five minutes.

Contributing to the success of the Kuala Lumpur licensing project has been the effectiveness of certain regulations such as the requirement of a standard color for the minibuses, the display of route numbers recognizable from a distance of 50 yards, the designation of twenty-eight routes averaging 12.4 miles, each passing through the central area, the fixing of a maximum fare, double that of buses for a comparable distance, and the prohibition of standing passengers. Fourteen terminals have been set up at which passengers have a choice between at least two different routes through the central area. Passengers also can hail a minibus anywhere along the route as well.

The jitney, jeepney, or shared taxi did not originate in the developing world. *Jitney* was early slang for a nickel said originally to have come from the French *jeton* (token). Jitneys seem to have originated in San Francisco, picking up passengers for a nickel along a more or less fixed route before World War I, before becoming the victims of mass transit opposition. Shared taxis are now starting to come back in a few U.S. cities.

The distinction between jitneys and minibuses is not always easy to make because the larger jitneys carry as many passengers as the smaller minibuses; however, they are usually passenger-carrying automobiles rather than converted trucks or vans. They differ from conventional taxis by operating on fixed routes, stopping to pick up and discharge passengers along the way. Like minibuses, they are hailed from the street. In many developing countries, jitneys are an effective response to the inadequacies of

public transit. Indeed, they may be the only practical alternative for the majority, who cannot afford private cars. In Lagos, which suffers from serious transportation inadequacies, the *kia-kia* service is crucial to the operations of the city although frowned on by officials because of its freewheeling nature.

In Tehran, some 2,000 jitney-taxis running on fixed routes carry about 100 million passengers a year, compared with 700 million carried by buses. In Manila, an estimated 18,000 jeepneys carry as many passengers as do buses. Here buses and jeepneys charge the same fare and operate along the same routes. The major distinction is that buses are perceived to be more comfortable for longer journeys, while the jeepneys are faster.[3]

For countries anxious to discourage private automobiles, jitneys can prove quite useful. In Mexico City, they carry more passengers than private automobiles, though they are much fewer in numbers than private autos. The popularity of jitneys seems to be extending to industrialized countries. In Osaka, Japan, a taxicab company that started out with twelve jumbo cars at the end of 1976 now has nearly three hundred in operation, using a computer-assisted dispatching service. The nine-passenger cabs pick up and discharge passengers along their route, charging each new user the equivalent of $1.25 for the first kilometer and 25 cents for each additional third of a kilometer. The cabs may also be hired by the hour for about $10, and they are being used increasingly by companies to pick up employees and for company outings.

Many countries have had a problem regulating jitneys. In Manila, public agencies, while controlling the entry of new operators, have been relatively unsuccessful in introducing service criteria and follow-up enforcement. As a result, the police department estimates that three-quarters of local accidents are caused by poorly maintained and badly driven jeepneys. In Caracas, on the other hand, where jitneys serve about a half-million people daily, effective controls are maintained on the number of vehicles allowed on the streets and on the rates charged. Owners are required to obtain permits and licenses from a ministry, must be approved by a city department, and have to be accepted by an association (a form of transport union). Specific routes are determined by the more than fifty existing associations, each with 150 to 300 jitney owners.

Pedicabs, three-wheeled muscle-powered vehicles, have been going strong since invented in 1847 by a U.S. Baptist missionary concerned with public transportation difficulties in Japan. They now go under many different names: *trishaw* in Hong Kong and Malaysia, *samlor* in Thailand, and *becak* or *betjak* in Indonesia. Until recently, pedicabs were very common in most Indonesian cities; there were an estimated 300,000 in Jakarta alone. Gradually, however, governments have discouraged them because they are blamed for accidents and traffic congestion. Moreover, leaders such as the late Ayub Khan of Pakistan viewed them as undignified and degrading, and

he therefore banned them in his country in 1961. The Bangkok government prohibited them from operating within the metropolitan area in 1961, and in central Jakarta, they were banned in 1972.

The outlawed pedicabs increasingly have been replaced by motorized rickshaws (three-wheeled motor taxis). Like pedicabs, the superstructures are produced in local workshops, often with elaborate canopies, including silver, gold, and mirrored surfaces. In Karachi, the auto rickshaws operate in the taxi mode but are much less expensive. At the same time, they can go much faster than buses. Their maneuverability allows them to penetrate even the narrow back alleys of residential districts. Thus, short or long hauls throughout the metropolitan area can be undertaken on demand.

Motorized rickshaws, however, create noise and air pollution, particularly when they are not properly fueled and maintained. Drivers tend to be reckless and unconcerned with traffic regulations and speed limits. The instability and fragility of the vehicles causes accidents. There are also complaints about rigged meters and refusals to make short trips. Nevertheless, motorized rickshaws could become increasingly important in many places.

Proposals for Nairobi's Transportation System

Like so many other cities in developing countries, Nairobi's roads can no longer provide easy access for its rapidly growing population, which has doubled in the last twenty years to almost 900,000.[4] Existing problems include the heavy financial burden of importing fuel, high accident rates, lack of adequate pedestrian facilities, inadequate public transport, and congestion at access points to the central business district and the industrial area. To deal with these problems, various strategies are currently being analyzed by representatives of government ministries, the municipality, the police, and other interested parties, working within a Transport Advisory Group. A number of measures are being considered for implementation with World Bank assistance.

A bus and minibus priority route system. The central part of Nairobi would be linked to low- and middle-class residential areas by a network of bypass roads, crossing the city center from east to west and north to south, thereby dividing the city center into four traffic cells. A fifth cell, to the north of the main center, will be created by a proposed northern bypass. Buses and minibuses would have exclusive rights-of-way on these roads. Automobiles would be restrained within the cell boundaries formed by these busways by using physical barriers or other traffic management measures.

Area traffic control (ATC). Vehicular flows would be more efficiently regulated through a new ATC system comprising approximately sixty sets of signals within the city center, the industrial area, and the immediate ap-

proaches. The proposed system would be capable of expansion up to ninety-six signals, including pedestrian phases and special phasing for public transport and emergency vehicles.

Pedestrian facilities. Some 90 kilometers of footpaths and walkways are to be introduced or improved throughout the city serving low-income families. When necessary, footbridges or signalized crossing places are to be provided. Where pedestrian malls seem appropriate, motor vehicles would be excluded.

Parking restrictions. Parking meters are to be installed throughout the central area, with a progressive increase in fees and penalties to discourage long-term use. A parking tax on all privately controlled parking spaces is proposed, and the number of parking spaces available for private nonresidential use will be limited. Off-street car parks maintained by the city council are to be operated more effectively. Vehicles entering them during the morning peak hours may be subject to parking surcharges.

Decongestion measures. One-way street systems and junction improvements are being planned. Another strategy is to stagger working hours in the central and industrial areas. Shopkeepers would be encouraged to open later and close later. A timing differential between school and work starting times would be attempted, which would have the added advantage of making regular buses available for school use.

Safety improvements. Driving tests are to be made more rigorous, and vehicles will be periodically inspected. Traffic violations are to be enforced more vigorously, with the police better trained for this purpose. A special unit within the police department will be established to investigate accidents and to devise improved accident prevention measures. This unit will also be responsible for developing public education programs emphasizing lawful and safe driving.

More and better matatus. The Nairobi form of paratransit (*matatus*) consists largely of pickup trucks fitted with benches for twelve to eighteen passengers and with a rack on the roof for goods. Their seats or benches are sometimes folded away to allow more goods to be carried. According to a 1979 survey, there were about 3,600 urban and intercity *matatus* operating in Nairobi carrying over 66,500 passengers daily. Despite their usefulness, *matatus* have a bad reputation. They are often overloaded, which makes them dangerous as well as uncomfortable. Only a minority are covered by insurance, and those who have it are seldom properly insured. Hired drivers, in contrast to vehicle owners, tend to be especially irresponsible, ignoring traffic regulations and safety requirements. In addition, *matatus* frequently obstruct traffic, illegally parking to pick up and discharge passengers.

Can *matatus* be regulated without being discouraged? This is the question currently being considered by Kenyan officials with World Bank assistance. What has been proposed is an assistance program, making low-cost

repair facilities, insurance, and credit available to small-scale *matatus* driver-owners with the stipulation that the driver take courses in lawful and safe driving, as well as in vehicle servicing, and pass a competence test in these fields and that the vehicle be maintained in good condition and inspected annually, be adequately insured, provide adequate safety and comfort for the passengers and not be loaded beyond its specified capacity, and be fuel efficient and, preferably, diesel engined.

Better Public Transit for Tunis

In 1972, 75 percent of all passenger trips in greater Tunis were made by public bus or train and only 15 percent by private car. However, because of the inability of the Société Nationale des Transports (SNT) to maintain its bus system and railway line (the TGM line), general public dissatisfaction was high. In 1972, the SNT fleet comprised 355 buses. Almost one-third were over twelve years old, and about 10 percent could no longer be used. On an average weekday, only 58 percent of the fleet was available for service. Forty percent of the buses departing from the depot were experiencing breakdowns, half of which required towing back to the depot. Because of this depot's inadequate space and facilities, it was difficult for proper repairs and preventive maintenance to be carried out. SNT experienced similar problems with its railway line. So old was its equipment, according to officials, that operation could not be kept up for more than another five or six years without a major modernization program; however, lack of funds precluded such a program.[5]

In 1973, with World Bank assistance, the Greater Tunis District government undertook a comprehensive approach to its transport problems, which included the purchase of 210 new buses, the construction of a new bus maintenance depot, the purchase of 13 new railroad cars and modernization of the TGM track and signalization equipment; the raising of fares and improvement of collection procedures; and the upgrading of all agencies responsible for project implementation. Traffic management was also improved with the upgrading of street intersections, the establishment of new traffic regulations, the introduction of parking bans, the opening of restricted bus lanes, and the closing of certain streets to traffic.

By 1977, many of the project's components were benefiting the public; 85 percent of the SNT bus fleet was in daily operation, and frequency of breakdowns had declined to 20 percent of the previous figure. Bus ridership was estimated to be about 15 percent higher than it would have been without the project. Ridership on the TGM rail line was significantly higher than it would have been without modernization.

Since 1980, there has been a marked improvement in bus services. With the purchase of 600 new buses, the fleet size has been increased by 69 per-

cent relative to 1973. As the average age of the fleet has been reduced to under five years, breakdowns have been reduced by one-third, enabling buses to complete 85 percent of scheduled trips. This improved service has generated a 77 percent increase in passengers over the past eight years, compared to a predicted increase of only 44 percent.

Tunis' suburban light rail system has been completely reconstructed, including tracks, signals, substations, and depot. With the introduction of thirty-six cars, the new service is reliable and fast (about forty km/hr. travel speed). The ride is comfortable, and vehicles and stations are well maintained. Tunis is also redeveloping its streetcar system, which ceased operation in 1960. It is purchasing seventy-eight vehicles from Germany, each with a capacity of about 300 passengers, at a total cost of $168 million.

Improving Road Use in Brazilian Cities

In Brazil's large cities, competition for the limited road space has intensified in recent years. The increased number of cars, buses, trucks, and pedestrians has resulted in greater delays, accidents, and pollution. The most serious situation is in the residential areas where the poor live; there, most roads are unpaved, making traffic movement almost impossible during periods of heavy rain. Frequently after a period of rain, bus services to these areas are suspended, causing residents to miss work or to lose job opportunities.[6]

To deal with these problems, the Brazilian government, with World Bank assistance, is proposing to undertake projects in five of its metropolitan regions, with populations ranging from 1.2 million to 3 million. The components include road upgrading and widening, exclusive bus lanes, improved traffic signal systems, and redesign of intersections. An important element is the paving of bus routes to poor residential areas. Where possible, a simple macadam surface dressing costing as little as 20 percent of traditional road surfaces will be used.

In addition to these general features, each of the cities concerned has been implementing specific measures appropriate to local conditions. Since 1976, the city of Salvador has opened three fringe car parks with 2,500 spaces that are linked with the central area by air-conditioned minibuses. As a result of a low park-and-ride fee and an intensive publicity campaign, the service is popular with motorists. To reduce traffic congestion further, authorities are attempting to improve roads and bus terminals and increase the efficiency of the existing bus fleet. The measures proposed include bus lanes, reorganizing terminals to reduce the number of buses circulating at less than full capacity, and linking the terminals by a new circular bus service. A special transfer system would enable bus passengers to go long distances at little cost. In low-income areas, there are to be sheltered waiting terminals.

Since 1974, the city of Curitiba, Brazil, has introduced the concept of structural axes, each of which contains three parallel roads one to five blocks apart. The central roadway consists of an exclusive busway and adjacent service roads for local traffic and parking. The two outer roads are one way in each direction and provide for through traffic and access to commercial developments. In the future, the busway could possibly be converted for use by trams or light rail. The land fronting the central road is zoned for high-density commercial and residential development. The development of a mass transport system on the central road is expected to facilitate this commercial and residential concentration along these axes. So far, the system has worked as planned. Whereas the population from 1970 to 1974 increased by 22 percent, the population along the structural axes grew by 67 percent. Traffic congestion has been substantially reduced in the central area and virtually eliminated elsewhere. Most helpful has been the public transportation developments. Currently two distinct bus systems exist. Within the exclusive busways built into the structural axes, express buses operate to and from the city center. The second system, using local bus routes, connects the express bus system with adjacent residential areas.

Although this bus system has been rapidly expanding the number of passengers served, help has been requested from the World Bank to extend the road system and to expand services on existing roads. Also traffic management schemes in the city center are being developed, including the coordination of 200 traffic signals, the implementation of a central area parking policy, and the introduction of an extensive system of pedestrian streets. About 30 percent of the streets in the central business areas are already devoted to exclusive pedestrian use. In the other streets, parking is either prohibited or severely restricted.

In the city of Recife, traffic is burdened by inadequate bridges, an antiquated system of traffic lights, and narrow streets within the congested central core. To relieve these problems, the municipality has initiated a series of measures and is planning others. Existing roads are being upgraded to provide an inner cross-town route, the first perimetral, that avoids the city center. This is to be followed by a second perimetral, diverting traffic from the center and, with it, significant commercial and service activities. Roads linking poor residential areas to these perimetrals will be improved. The perimetrals are to be linked by certain streets on the periphery of the central nucleus so as to form a city-center ring route. Other measures are also being used to encourage private motorists to use other forms of transportation. Parking charges increase with the number of hours parked, and cars will be excluded from a number of streets. At the same time, bus operations are to be improved. By coping with the existing situation in these ways, officials hope that future traffic problems will become manageable.

Bangkok Traffic Project

Like so many other cities in developing countries, Bangkok, with a population of 4.8 million, suffers from too much traffic on too little road space. Only about 10 percent of the city's inner core is devoted to roadways, and they consist of a discontinuous jumble of narrow, winding streets. Yet the number of motor vehicles in the city continues to expand at an annual rate of over 8 percent. Consequently travel costs have become so high as to threaten the city's economic development. To improve this situation, the Thai government's Office of the Committee for Management of Road Traffic (OCMRT) undertook a $34 million project in 1979 with World Bank assistance. The objective is to make Bangkok's existing transportation more efficient with minimum additional investments.

A first element in this program is to increase road capacity. Road flyovers are to be introduced at critical intersections. Certain roads are to be widened, junctions will be improved, and missing road links, generally less than half a kilometer in length, are to be provided. Sidewalks are to be included or widened in certain places.

Another element is to set up bus lanes along roads with the highest volumes of bus passengers. Some of these will contain physical barriers preventing their use by automobiles. Bus bays are to be extended, allowing dispersal of stops so that buses with different destinations will have separate stops. This will avoid the current delays in bays now often used by over 100 buses per hour. Bus shelters will be provided at these bays and other heavily used locations. In addition, regulations restricting minibuses are being relaxed.

In addition to giving priority to buses, OCMRT has suggested a number of parking policies designed to discourage long-term commuter parking, increase parking spaces for short-term parking, and expand the traffic capacity of arterial streets. On-street parking will not be allowed wherever it appears to reduce traffic capacity seriously. Parking regulations will be strictly enforced by hiring an additional 1,000 parking attendants, providing stiff penalties for violations, and by a graduated increase in fines.

While these measures are expected to be useful, the government has also studied the possibility of an area pricing scheme to discourage the use of centrally located roads by cars during the working day. The project includes measures to increase the government's capacity to improve traffic planning, operations, public relations, and enforcement. Air and noise pollution as well as traffic volume are to be carefully monitored so that abatement measures can be successfully carried out. The Bangkok Mass Transit Authority is also to be assisted with such operations as rationalization of routes and schedules, finance and accounting, management of materials and equipment, and vehicle maintenance.

Low Cost Parking Controls Bring Tel Aviv Revenue

An ingeniously simple parking coupon system used in Tel Aviv for the past six years has eliminated parking meters and their associated costs while raising money for the city. Anyone desiring a parking license for use in the inner city may purchase a booklet containing ten detachable tabs. On finding a vacant space, the driver parks, detaches a coupon, tears off a tab indicating his arrival time, punches out the perforated date, and displays the card against the inside panel of his side window by rolling up the window against the folded upper edge. Each card can be used only once, being invalidated by the perforations. Some drivers keep them to document parking expenses.

After several years of operations the Tel Aviv system takes in more than $80,000 annually, as against parking meter revenues of less than a quarter of this total, at the time when the new system began operating in October, 1971. The expenses of purchasing, maintaining and collecting coins from the meters, which exceeded the revenues collected, was completely eliminated.

Tel Aviv Deputy Mayor Ramot told the city council after the system had been in operation a few years "we got rid and relieved of the complaints against broken meters, their bothersome supervision, criticism of inspectors, vandalism and burglary. We introduced the parking card patiently . . . and we are now completely relieved of the drivers' arguments."[7]

The system uses inexpensive cardboard and requires no special instrument to mark the card; it eliminates the cost of parking meter purchase, installation, and maintenance and allows for parking fee increases without meter changes; it saves the costs of parking restriction signs along streets as entire sections of town may be designated as short-term zones. It also allows for overnight parking according to local regulations (as cards may be preprinted to give free time from any late afternoon to the following morning) and earns the local jurisdiction advance fees from the coupon distributors who handle the business as concessionaires.

Art of Traffic Management

It may be appropriate to include the following section of a report prepared for the Fourth African Highway Conference (Nairobi, Kenya, January 20–25, 1980) by Peter Midgley, a member of the World Bank's Urban Projects Department, which summarizes some of the ways in which the World Bank can contribute to the exchange of knowledge and experience in an economically important sector.

Traffic management is scorned in some circles as being a palliative inappropriate for "our problems." Why is this so? In most cases because traffic management techniques are developed *in situ* in response to a problem in a specific city, region, country or continent. They are hence regarded as being non-transferable. How many times have I heard the phrase "OK, that may work in country X because they are disciplined but you know in our city drivers would never respect the signs." In fact, as experience has shown, traffic management concepts and techniques are often not directly transferable.

They are adaptable. Often the adaptation of a concept developed in one city will lead to the development of a totally new concept in another city. Unfortunately, no international mechanisms exist for the transfer of information regarding traffic management in a systematic way. Organizations such as the OECD, the Department of Transportation in the US and the Transport and Road Research Laboratory in the United Kingdom have documented and compiled information on certain categories of traffic mangement techniques in Europe and North America. In the Urban Projects Department of the World Bank we have started to compile information on traffic management experiences worldwide derived in part from European and North American sources and from urban transport projects financed by the Bank in Africa, Latin America and Asia. Many traffic management measures are not documented even by the city using them. This is often due to the municipal staff being unaware of the need to report what appears to be an obvious or common sense technique. I would like to give two examples of this. They illustrate the notions of simplicity, practicality and adaptability I have described as well as revealing the problem of documentation.

Before joining the Bank, I was working in France on research into busway systems. A colleague mentioned to me that when visiting friends in the city of Liège in Belgium he had noted a busway was operating in the main shopping street of the city. I had reviewed *all* available literature on busways and Liège was never mentioned. I visited the city and to my astonishment found not only a busway but a complete network which had been operating for some five years! The city engineer had thought it would be a good idea to use the right of way of a tram system which had been removed years before to run buses on in order to avoid congestion in the city center. It worked, and so the system was extended to other routes in the city. In Paris we had been experimenting with different carriageway widths to try to determine an optimum width for bus operation. Our experiments had determined 6.5 meters to be the optimum for two way bus flow at speeds of 50–60 km/hour. The Liège system had carriageway width of 6.5 meters and buses were running at 50–60 km/hour!

The second example concerns the city of Grenoble in France. I had visited Grenoble several times in connection with a tram feasibility study. On one of these visits I decided to take a look at the new town being built on the outskirts of the city. As I walked through one of the residential communities I came upon a section of road with what at first appeared to be a scaled down version of a tank-trap. As I was examining this rather peculiar structure a bus appeared, approached the "trap" cautiously, passed over it without any problem, and went on its way. I was mystified. On speaking

with some residents I discovered that the trap was designed to stop cars from using what was a bus-only route. The trap was designed to accept the axle width of a bus and had iron posts set to a height to allow a bus body to pass. If a car attempted this it either smashed its axles or broke its bodywork. Apparently, when the road was opened for buses three cars attempted to use it. No one ever tried again! I never discovered who had thought up this ingenious, albeit radical, method of bus priority enforcement, but it revealed a great sense of practicality and simplicity which worked most efficiently. Needless to say, I have never seen this technique documented. The "inventor" probably thought it was so obvious that to write it up was unnecessary! But this illustrates what traffic management is all about: the art of making better use of existing facilities based on the science of monitoring the use of such facilities.

Notes

1. George Wynne, *Urban Transit Abroad* 2, no. 2 (Fall 1979).

2. See Gabriel Roth and George Wynne, *Free Enterprise Urban Transportation,* 1982, available for $4.95 from Council for International Urban Liaison, 818 18th St., N.W., #840, Washington, D.C. 20006.

3. See Sigurol Grava, "The Jeepneys of Manila," *Traffic Quarterly* (October 1972).

4. This section draws heavily on a paper by Paul Mbau, Nairobi's city engineer, prepared for the 1980 Fourth African Highway Conference.

5. This section is based on an article prepared for *The Urban Edge* by Noel Carrere of the World Bank's Urban Projects Department.

6. This section is based on an article prepared for *Metropolis* by Peter Watson of the World Bank.

7. See George Wynne, *Urban Transit Abroad,* op. cit., p. 6.

The Uses of Satellite Remote Sensing

Wolfram U. Drewes and
Abraham M. Sirkin

The connection between the high technology of the space sciences and the problems of economic development may not be readily apparent. One link is the urgent need of developing countries for accurate, up-to-date resource information. Space technology is helping to fill this need. For all countries, the need to acquire, analyze, and use valid information about the nature, location, and state of their physical resources increases significantly as economic development proceeds.

The obvious development projects—cultivation of arable land, cutting of natural forests, grazing on lush grasslands, exploitation of surface or near-surface mineral deposits—were recognized and carried out for generations with little recourse to formal surveys. Even the extension of arable lands by irrigation facilities and the production of hydroelectric power in obvious sites such as river gorges required little advanced scientific investigation. Further development, however, generally depends on less apparent and less accessible resources. If development programs are to be effective and prudent and if they are not to squander a nation's limited resources, they must be projected on a detailed and accurate information base, and the pertinent information must be made readily retrievable.

The development gap between the industrialized and developing countries is accompanied by a resource information gap. Industrialized countries are generally well mapped and continue to gather, analyze, store, and use a wealth of resource information, but developing countries generally are inadequately mapped and at earlier stages of resource data accumulation. The paucity of resource information is both a symptom and a contributing cause of underdevelopment.

Developing countries need an information base about both their nonrenewable and renewable resources. They must know where nonrenewable resources—fossil fuels and minerals—may be found within their borders, and they must know the location, extent, and current condition of their renewable resources—vegetation, soils, forest, and water. In order to identify, prepare, monitor, and evaluate specific dvelopment projects, planners and resource managers need detailed information to determine the suitability of the project site, to calculate its chances for success, and to estimate its probable impact on the surrounding areas.

Developing countries currently face the interrelated problems of the time needed to acquire and analyze resource data, the open-ended costs of data acquisition and processing, and the choices that have to be made among the various options for study.

The numerous technological means of data acquisition, processing, and storage that have become available in recent decades have both facilitated and complicated the task of gathering and using resource information. Helicopters, airplanes, and satellites serve as the instrument platforms; many camera and multispectral sensor systems, as well as highly specialized instruments such as magnetometers and laser measuring devices, obtain data to display on screens, to be stored in memory banks, or to be converted to film or map form on automated cartographic tables.

The World Bank is continually assessing and using the latest techniques to obtain the information needed to support its own operations. At the same time, it has sought to strengthen the capabilities of developing countries themselves to acquire and use resource information. To this end, it has financed a number of projects designed to enable developing countries to take advantage of the new technologies and thereby speed up their access to, and effective use of, information about their own resources.

New Technologies

Until the advent of the photographic camera and the airplane, resource information could be acquired only by direct observation on the ground. For the past half-century, however, the primary means of gathering geographic and resource information have been medium- and low-altitude aircraft, various types of cameras and film, and numerous technical devices to facilitate aerial photo interpretation and map production. All countries of the world have been covered, some lightly and some intensively, by aerial surveys, mainly by conventional black-and-white film, generally accompanied by the necessary ground observations and geodetic controls to validate the accuracy of the photo interpretation. After World War II, remote sensing from aircraft became the standard mode for acquiring resource data, and many developing countries have commissioned aerial surveys to generate a national data base for some resources or to establish a factual foundation for a particular development project.

In its own operations, the World Bank has incorporated aerial surveys as integral elements of many of its development projects. Aerial photography has been used to define drainage basins and determine watershed characteristics relevant to irrigation proposals, to identify alternative transportation corridors, and to ascertain the needs and opportunities for reforestation, rangeland improvement, and population resettlement.

In the 1970s, two technological revolutions strongly affected the remote sensing field. One was the launching of the Landsat series of earth-observing spacecraft by the U.S. National Aeronautics and Space Administration (NASA). The other was the refinement of computer technology to permit measurement of homogeneous areas noted on the digital tapes carrying satellite data and to store physical and other relevant factors in automated geo-based data formats.

The multispectral scanner (MSS) aboard the Landsats senses and records the reflectance of energy radiated from earth features in four different wavelengths of the electromagnetic spectrum. Two of the wavelength bands are in the visual region, and two are in the near infrared region. Since the different objects or phenomena on the earth's surface reflect different intensities of energy in each wavelength, each surface feature has its own spectral signature and thus may be distinguished on tape and films. Three Landsat spacecraft, launched by the United States in the 1970s and no longer operational, carried multispectral scanners that provided resource data for virtually all areas of the world. Landsat 4, launched in 1982, and Landsat 5, launched in 1984 at an altitude of 705 kilometers, carry advanced sensors called thematic mappers, as well as multispectral sensors to provide continuity of data compatible with the data from the earlier Landsats.

Each Landsat satellite circles the earth on a near-polar orbit fourteen times in every twenty-four hour period. Its sensor system records data of a swath of earth 185 kilometers wide as it passes overhead. The orbit is timed to cover each area at approximately 9:45 A.M. local time so that the shadows are the same from day to day and the usual midday cloud build-up is avoided. On the next day, the swaths covered are immediately adjacent to, and west of, the swaths covered on the previous twenty-four hours. The radiation intensities sensed and registered by the sensors are transmitted in digital form to ground receiving stations. In 1984 three such stations were operating in the United States, two in Canada, and one each in Argentina, Australia, Brazil, India, Italy, South Africa, Sweden, Thailand and Japan. Additional stations were under construction or planned in other countries in Asia, Africa, and Latin America.

For processing and filing purposes, the strips of data are divided into segments or scenes, each also covering a lineal distance of approximately 185 kilometers, and the required corrections and annotations are made by computers. The data products emerge in two modes: computer-compatible tapes and reconstituted black-and-white imagery, in film or print form. The tapes contain a record of the energy intensities radiated by each 60 × 80 meter portion of the earth's surface on a scale of 0 to 64 intensities. On the black-and-white print and film formats, this range of intensities, in any one of the four spectral bands, is compressed to 16. Color composites of three bands are also produced by passing light of different intensities through color filters to facilitate identification of surface features.

The Landsat data products cannot match aerial photographs in showing, and generally permitting identification of, fairly small objects or phenomena. But they have numerous advantages over aerial photography, advantages of particular value to developing countries. They offer a synoptic view of a large area in one scene from the same angle of flight and from the same sun angle, differing in this respect from the many aerial photographs needed to cover the same area. Entire regions and countries can be viewed and mapped on a uniform basis by assembling mosaics of Landsat scenes taken at the same altitude, flight angle, and sun angle. Coverage of the same area at different times and seasons can be provided by later flights of the satellite, a capability useful for monitoring changes in vegetation, water, or land use patterns. Acquisition of the data in the original digital format permits rapid processing of large amounts of raw data and production of usable information in a short time. Under current financing arrangements, the use of Landsat data costs less than conventional surveys. This is likely to be the case as long as governments capable of operating equipment in space, such as the United States, continue to underwrite the larger share of the capital and operating costs of satellite sensing.

After the launching of Landsat 1 in 1972, scientific investigations carried out in different countries showed the capabilities and limitations of satellite remote sensing, as well as its value as an analytical tool for resource managers and planners. These early experiences of both investigators and users showed that certain significant features or phenomena, such as sizable water bodies or areas of clear cutting of forests, could be identified even in the simplest Landsat data products—the black-and-white imagery. They also demonstrated that it was possible to satisfy many other information needs of resource managers, such as the identification of major land use associations, the evaluation of crop conditions, the demarcation of recently flooded areas, and to some extent the definition of saline soil areas. Satellite data were shown to save time and money by eliminating areas not worth further examination and by identifying areas that deserved closer study by means of aircraft or direct ground observation. This is particularly important for the exploration of fossil fuels, minerals, and groundwater resources. The synoptic character of Landsat images furthermore offered an integrated view of a nation's resource conservation problems, its development potential or limitations, and the interrelationships among various physical phenomena affecting development.

Other new technologies include platforms and sensors that provide additional choices and advantages for special remote sensing tasks. High-altitude aircraft (some flying twice as high as normal commercial aircraft) carry high-resolution or multispectral sensors, which are used for broad-area mapping or for highly specialized sensing chores such as damage assessment following floods and earthquakes or demarcating crop diseases invisible on normal films.

Microwave sensors on aircraft are able to penetrate cloud cover or can operate at night. Thermal infrared devices, which can detect radiation differences on the earth's surface to a fraction of a degree, are useful in pollution control and hydrologic investigations. Airborne magnetometers, which indicate changes in the earth's magnetic field, direct the attention of geologists to areas deserving more detailed study in the search for minerals and fossil fuels.

These developments in platforms and sensors have been accompanied by a revolution in the processing and storage of remote sensing data. Numerous sophisticated techniques are now applied to the data on Landsat digital tapes to elicit from them much more resource information than can be gleaned from the basic film imagery. When the digital material is reconstituted into imagery, arbitrary false colors can be assigned to the different radiation intensities throughout an image. If sufficient ground truth is available to confirm the identification of the resource elements represented by the various intensities in the Landsat scene, the image can be categorized and can offer much valuable information to resource managers. (See figure 6–2.) Different types of forests, cultivated land, or other types of ground cover are clearly distinguishable in such imagery. The cost for sophisticated "edge enhancement" or categorization of a single Landsat scene, covering about 34,000 square kilometers (13,000 square miles), ranged from $900 to $3,000 in 1984, depending on the type of processing desired.

Even more information may be obtained by emphasizing or "stretching" the digital data about a scene or part of a scene in one band of the electromagnetic spectrum in relation to the data from the other bands in the same composite image of the scene. Merging data from two or more different data acquisition systems can also yield additional information. For instance, the comparison of Landsat and meteorological data has proved in worldwide tests to be successful for large area crop prediction.[1] Landsat data have been combined with aerial side-looking radar data to emphasize relief, and space imagery has been combined with aerial radar profiling or with known spot elevations in experiments to obtain more useful imagery. "Stereo combinations" of Landsat and aeromagnetic data have also been produced by Australian and U.S. scientists to facilitate interpretation of aeromagnetic surveys by exploration geologists. Digital data storage analysis and display systems now can put together relevant social, economic, and administrative facts with physical data from Landsat and other sources to offer a comprehensive "geo-based" data service to resource managers and development planners.

Despite their high-technology character, these space and digital systems are highly appropriate to developing countries because they provide the information needed for sound economic development and also because they do so at a substantial saving of time and in a manner that promotes an inte-

grated approach to resource planning. Moreover, the transfer of the most useful elements of these new technologies to developing countries can be accomplished with relative ease. Nations do not have to own reception stations or elaborate computer systems to acquire and analyze satellite data. In early 1984, Landsat scenes could be bought in the United States for $20 to $60 in standard image form. Tapes could be purchased for $400 to $650 and be processed for $1100.[2] Sophisticated processing and analytical services are available from contractors in several countries. It takes only limited periods of training for a small number of specialists to enable a country to use the new data products effectively.

The World Bank's Use of Remote Sensing in Agricultural Projects

Shortly after the launching of Landsat 1, the World Bank began to test and use satellite data for project planning. Its use of such data has increased steadily since, mainly in the identification and preparation phases of projects. By 1984, the Bank had obtained and used Landsat data in connection with forty-one project loans in thirty-one countries.

Landsat data can be of value for agriculture in two distinct ways. One is helping to make earlier and more accurate crop predictions, a capability that is being tested on a global scale by the U.S. government. The other is by contributing to the execution of soil surveys and land use studies for the siting or expansion of agricultural development projects. Thus far, the Bank's use of satellite imagery has been concentrated on the latter and can be illustrated by two cases, one concerned with project identification and preparation and the other with a comparative study of seasonal cropping patterns.

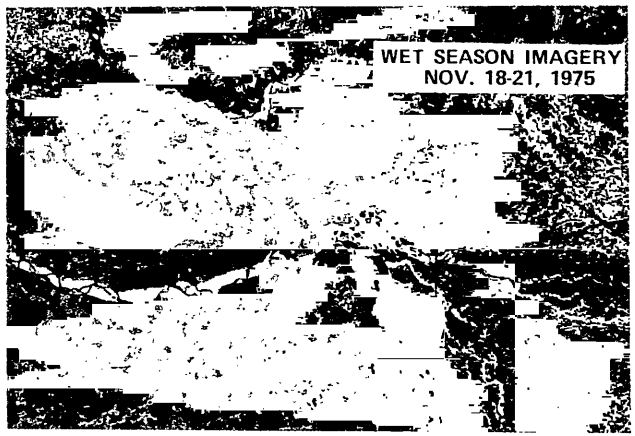
In 1976, the government of Upper Volta requested the urgent help of the IDA of the World Bank to identify areas in which to settle thousands of nomadic families forced out of drought-stricken regions of the northern part of the country. The sites selected needed to have good soil, adequate rainfall, and a sparse population ethnically compatible with, and receptive to, the incoming migrants. The general area selected was the southwestern part of the country, which receives more rainfall than the northern regions bordering the Sahel. Because of the severity of drought conditions in the north, the government wanted potential resettlement areas designated within six months. To meet the deadline, it was necessary to use existing sources of information.

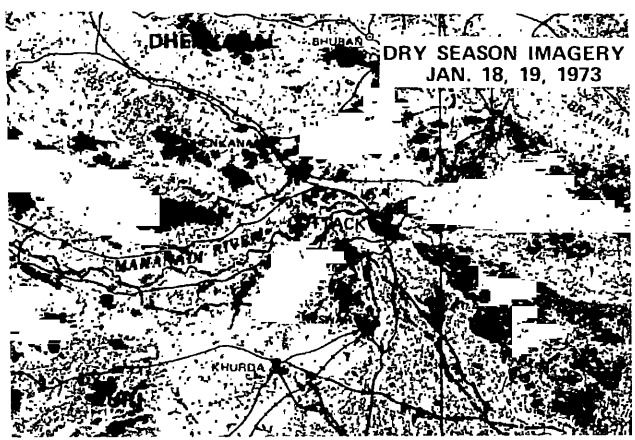
The French government's Office for Overseas Scientific and Technical Research (ORSTOM) had produced a soils reconnaissance series of maps in 1969 and a potential land use map in 1976. The other main source of exist-

Figure 6.2
Orissa, India: Land Cover–Land Use Association

The upper picture is a portion of the Orissa Land Cover Land-Use Association Map, based on the categorization of Landsat imagery taken during the wet season in 1975. In the color-coding of the 23 categories of land cover elicited from the Landsat data by computer processing, red represents forests, the light beige areas are barren or fallow fields, the light green indicates some vegetation cover and the dark green signifies vigorous plant growth, predominately rice.

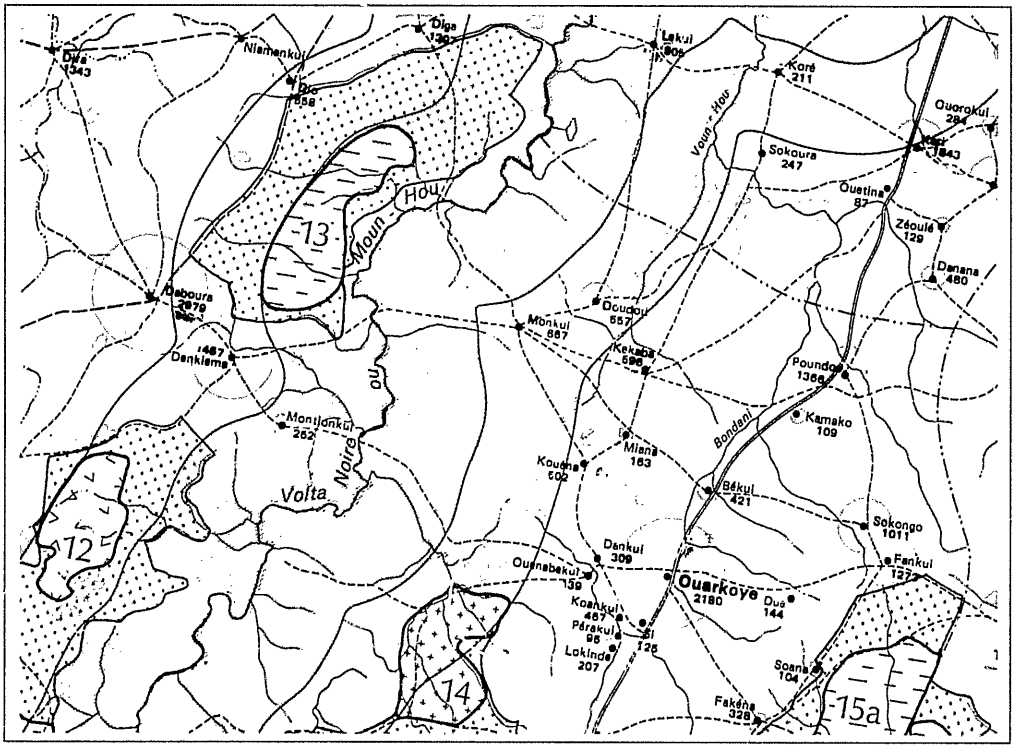
The lower picture of the same area is based on categorization of 1973 dry-season imagery. The dark green shows rice and other crops covering most of the non-forested areas. The obvious differences shown between the dry-season and wet-season plantings focuses the attention of agricultural planners on the lands that could produce a second crop if provided with irrigation. The pie-shaped wedge between the dark green areas of the lower river's distributory system should have particular developmental potential since soils of most of the delta are similar.





COLOR	COVER TYPE
	Unclassified/Cloud Shadow
	Ocean, Deep Lakes/Coastal Currents
	Rivers/Lakes
	Shallow/Turbid Water
	Swamps/Marshland
	Wetlands/Flooded Fields
	Pulses/Upland Rice/Dry Farming
	Single Crop Rice
	Double Crop Rice/Other Crops
	Double Crop Rice
	Barren Land/Scrub Vegetation
	Fallow Land/Unknown Vegetation
	Grassland
	Riverine Shrubs/Reeds/Sugarcane
	Palms/Horticulture/Mixed Farming
	Highland Mixed Forest/Dipterocarps
	Lowland Mixed Forest/Mangrove
	Hill and Ridge Shadows
	Conifer-Casurina Pine/Bushland
	Forest Anomaly/Rubber, Teak, etc.
	Sand/Saltflats
	Mudflats/Silt Deposits
	Urban/Industrial

Figure 6.1
Upper Volta: Selection of Land for Settlement

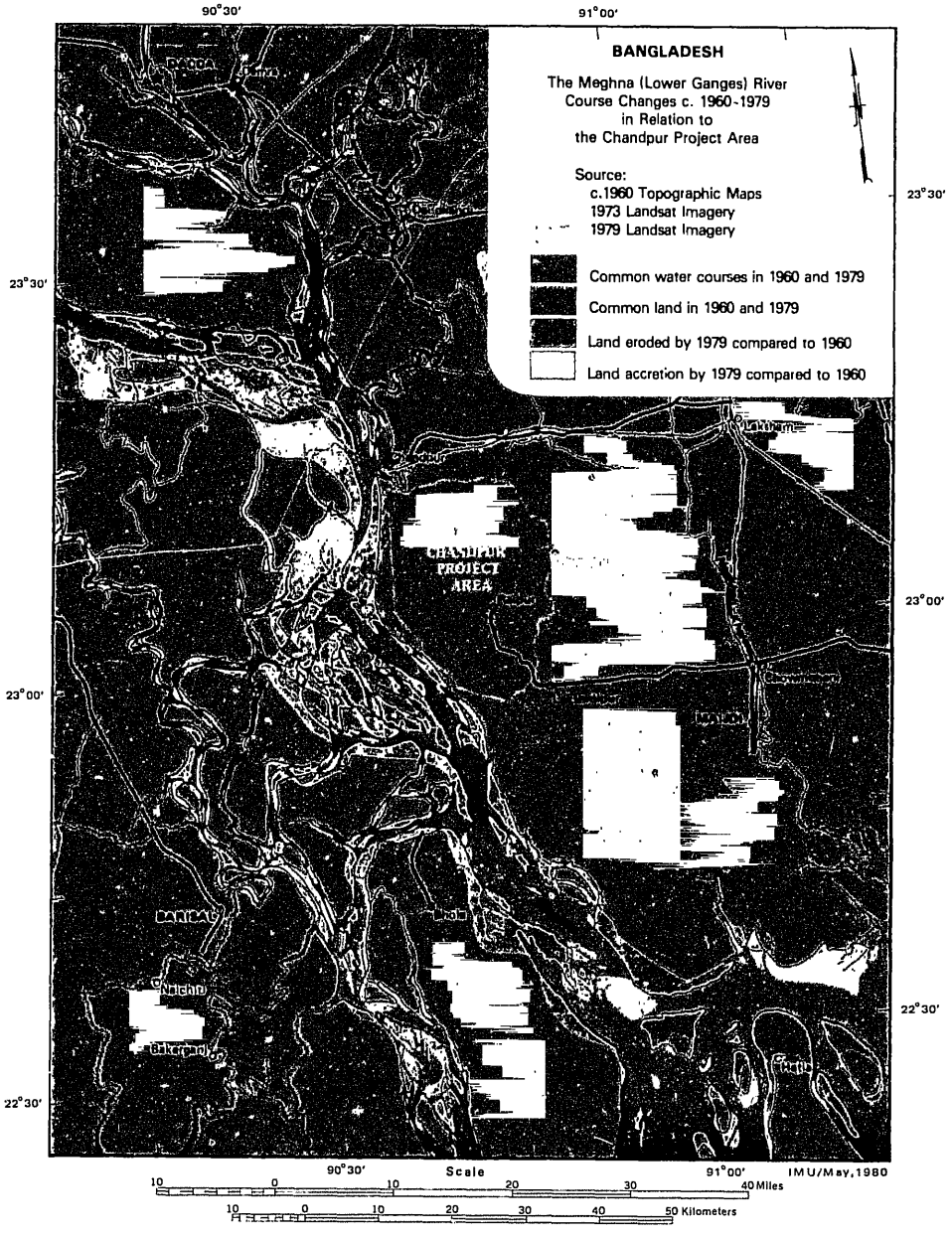


This portion of a map of southwestern Upper Volta, prepared by World Bank resource planning specialists, shows four of the 19 potential areas of settlement selected as a result of a study of Landsat imagery and various physical, demographic and socioeconomic factors. The red circles indicate villages, with the diameter size of each related to the number of inhabitants. The brown and yellow patches cover areas recognized in Landsat imagery as rocky outcrops and shallow oxide soils, respectively. Both offer severe physical limits to cultivation. The blue areas have been delineated as zones subject to river blindness and cannot be used for settlement. The polygons marked 12, 13, 14, and 15a are areas of good soils. These are surrounded by or adjacent to, dotted patterns (of lesser quality soils) that are bounded by actual physical features such as trails or streams. Villages for the new settlers would be more suitably located in the dotted areas rather than on the better soils suited for cultivation, as indicated by the markings within them, area 14 is rated "high", area 12 "medium" and areas 13 and 15a "low", but all are adequate for developing agriculture.

Figure 6.3
Example of the Detail That Can Be Obtained from Landsat Imagery

This edge-enhanced false color image of a portion of a March 1979 Landsat scene illustrates the detail that is obtainable by intensive computer processing. In this picture of the Meghna River (lower Ganges) in Bangladesh, forests and crops appear in various shades of red, clear water is colored dark blue, and various degrees of sedimentation toward the mouth of the river show up as various shades of lighter blue. This 1979 image, by comparison with Landsat imagery taken in 1973 and topographic maps published in 1960, indicates numerous areas where erosion of one side of the river and land accretion on the other side have occurred. The extent of such changes is noted in the map shown as Figure 6.4.

Figure 6.4


90°30'
91°00'
23°30'
23°00'
22°30'
BANGLADESH
The Meghna (Lower Ganges) River
Course Changes c. 1960-1979
in Relation to
the Chandpur Project Area
Source:
c.1960 Topographic Maps
1973 Landsat Imagery
1979 Landsat Imagery
Common water courses in 1960 and 1979
Common land in 1960 and 1979
Land eroded by 1979 compared to 1960
Land accretion by 1979 compared to 1960
CHANDPUR
PROJECT
AREA
Scale
10 0 10 20 30 40 Miles
10 0 10 20 30 40 50 Kilometers
IMU/May,1980

ing information was Landsat imagery, on which areas with serious physical limitations for agriculture were readily identifiable. Shallow soil hardpan, rock outcrops, and swampy areas were clearly distinguished.

Of four Landsat scenes of the western third of the country taken in November 1976, one full scene and a third of another, both in the extreme southwest portion, seemed to offer the most promising physical terrain. Digital processing of these scenes produced fifteen separate reflectance categories. A different color was assigned to each reflectance category on a reconstituted color print. In January 1977, a Bank field mission, including specialists in soils science and remote sensing and accompanied by a botanist-ecologist in Upper Volta, visited the region to gather the essential ground truth in a limited number of sample areas. With the aid of helicopters, they sought to match specific colors on the Landsat print with the actual land cover in the sample area. They found that three distinct reflectance signatures corresponded with areas unsuited to agriculture. These were areas of sandstone and granite rock outcrops or shallow soil areas containing a high percentage of iron oxides. These areas were then plotted on base maps prepared from a U.S. government map series at a scale of 1:250,000. The unsuitable areas detected by the Landsat sensors included numerous sections of rock out-crops and poor soil that were too small to be noted on the ORSTOM soils map.

As a result of this elimination process, areas of low population density that had a presumed potential for cultivation were visited and field checked on the ground, primarily to review the soils quality. Soil samples of each area were analyzed in the laboratory, after which nineteen sites were selected for potential settlement. Each area was rated high, medium, or low for agricultural potential, based on soils quality rainfall and accessibility. A map of the whole region was then produced by the Bank, with the nineteen areas, totaling 58,000 hectares, clearly located and rated (see figure 6-1). Seven areas were rated high, six medium, and six low. The Landsat data made a significant contribution to the process of elimination and thus to the preparation phase of the resettlement project, which was jointly financed by the Bank and the government of Upper Volta. The use of Landsat data resulted in major savings of time and money for the project. An aerial photographic survey of the same area would have taken about two years to complete.

The Landsat component of the project, including the printing of a potential settlement area map at a scale of 1:250,000, cost $31,700, of which $12,000 was paid for computer tape analysis and $10,100 was attributed to fees for remote sensing and soil consultants. Cost estimates from a commercial firm for an aerial photographic survey to accomplish the same objective were $340,900, eleven times the cost of using satellite data.

The second example of the Bank's use of remote sensing in agriculture is drawn from India. In 1975, the Bank responded to a request from that

country's government, on behalf of the state of Orissa, for assistance in obtaining resource information needed by state planning authorities. The state government wanted to test the ability of Landsat to identify various land use categories and to quantify the acreage devoted to single-crop rice production and to double-crop production. The information was needed for a regional food grain production review and for agricultural planners who wanted to move from single cropping to doublecropping. To provide the required answers, Landsat imagery for two different seasons was needed, one set before the primary rice crop was harvested and another set showing a maturing secondary crop. Accordingly eleven Landsat scenes for most of Orissa, taken in the dry season of January to March 1973, were obtained to disclose the secondary paddy crop.

A team of Indian scientists from the National Remote Sensing Agency of India (NRSA) and the Orissa state government, including soil technicians and foresters, was trained by a World Bank group to make the ground observations needed to identify and confirm the categories of land cover visible on the satellite imagery. In November, 1975, right after the monsoon season and before the primary crop was harvested, the ground truth team initiated field operations in the area with the aid of a small plane, a helicopter, and four-wheel drive vehicles. The team covered the area to provide ground truth for new wet season Landsat imagery on the exact days that the satellite, activated by NASA, was passing overhead during four consecutive orbits.

Processing of the cloud-free Landsat scenes of Orissa was performed by staff members of the Bank and NRSA using a commercial firm's interactive computer system. On the basis of this digital and the matching ground truth data, twenty-three different categories of land cover, including ten relating to agriculture and five to forest types, could be distinguished and their areas quantified. Comparisons of the land use on these scenes with those of the dry season permitted ready identification of single- and double-cropping areas and indicated clearly where a second crop of rice could be produced if the needed irrigation and drainage canals were built (figure 6–2).

Multiple copies of the printed Orissa Land-Cover/Land-Use Association Map, based on a mosaic of the categorized Landsat scenes, were produced by the Bank and widely distributed to state and central government resource managers and planners. The map proved to be of value to scientists beyond the agricultural sector. It showed foresters how much more wooded land had been cleared than was previously realized, it drew attention of hydrologists to areas suitable for dams and barrages, helped cartographers correct their maps of a river that had changed course, and directed geologists to areas of interest for mineral investigations. The Orissa map thus exemplified the comprehensive approach made possible by the synoptic view of resources offered by satellite sensing and illustrated also the value of doing comparisons of multiseason imagery.

Most of these results could have been achieved by aerial photography, but the work would have taken longer and cost substantially more. The Landsat survey of Orissa took nine months from the initial purchase of Landsat imagery to the publication of the land use map. Mounting an aerial photographic project with dual season coverage, completing the photo interpretation, and producing a mosaic of the hundreds of photographs would have cost at least $500,000. The total cost of the Landsat survey to the bank and the government of India, which shared the financing, was $68,000, of which $31,800 was for computer processing of the Landsat tapes and $24,300 for remote sensing consultants engaged in ground truth field surveys and cartographic activities.

Remote Sensing in Forestry and Range Management

Many developing countries have difficulty keeping track of the rate at which their forests are being depleted. One problem is that in most countries information on timber holdings is in the hands of private concessionaires who do not share it with the government. Another is the cost of monitoring large tracts of land either by road or from the air.

Since the development of aerial photography, remote sensing has been the standard means of conducting forestry surveys in virtually all countries. Aerial surveys are used not only to define areas of standing trees but also for such purposes as assessing fire damage, demarcating areas affected by insects or other diseases, and identifying tree types and crown sizes in order to estimate timber volume.

Digital tapes of Landsat scenes that are intensively processed can provide most of the data essential for sound forest management. Even in its simplest black-and-white film form, Landsat imagery has demonstrated its unique capability to disclose the changes that have taken place in forest cover in recent years, and it does so more cheaply and quickly than can aircraft imagery. In several developing countries, including Brazil, Indonesia, and Thailand, the governments are using Landsat imagery to determine whether national regulations on forest cutting are being enforced. In several instances, new logging roads in forested tracts could be identified since their reflectance is in high contrast to the surrounding forest cover.

The World Bank has incorporated remote sensing elements in a number of its forestry or forest-based settlement projects. In 1972, for instance, the government of Nepal asked the UN Food and Agriculture Organization (FAO) and the World Bank for assistance in establishing a settlement of landless farm workers in the forests of the Terai plain. The forests were being rapidly depleted as new settlers were moving in and clearing woods on their own. For the Bank's appraisal of the settlement project, six Landsat

scenes, taken in 1972, covering the Terai and nearby regions, were processed in color composite form and enlarged to a scale of 1:25,000. The scenes showed that forests covered only 27.4 percent of the Terai in 1972 as compared to 52.6 percent indicated in aerial photos taken six years earlier. Of special relevance to the project was the fact that one of the areas proposed for settlement showed substantial cutting. When further investigation confirmed that 40 percent of the proposed site was already occupied by illegal squatters, the settlement project was modified into a forest conservation project.

As part of a forest plantation project in Kenya, the Bank approved a land use study of forest and water catchment areas. The purpose of the study was to provide a basis for decision making on the future of the nation's forests, vast tracts of which had been cleared of timber to make way for agriculture. The budget for the project included $300,000 for the acquisition and processing of Landsat tapes to cover the entire country. Initial work was done by the Kenya Rangeland Ecological Monitoring Unit (KREMU), financed originally by the Canadian government's aid program and after 1982 by the World Bank. A small-scale (1:1,000,000) forestry map for all of Kenya, based on the black-and-white film copies of thirty-three scenes involved, was produced using existing and new aerial photography for checking specific areas of deforestation. An inventory of forested areas for Kenya was prepared for the Ministry of Environment and Natural Resources and showed a serious reduction in forest lands from the areas previously registered. In 1984 KREMU was continuing its work of processing the satellite tapes and was producing large-scale edge-enhanced images and maps of forest and rangeland areas to serve more specific forest management and agricultural needs, as well as to identify rangelands and areas subjected to overgrazing. The Ministry of Energy is also using the imagery in its search for minerals. In 1984, KREMU asked the Bank's help in producing a new series of maps of Kenya.

Landsat imagery, if well processed, has proved capable of identifying several forage types by measurement of the biomass. Evidence of plant vigor in grazing lands is essential in any rangeland inventory or rangeland improvement program. The Bank has used Landsat data in projects designed to promote rangeland and livestock development.

In Somalia, for example, where two-thirds of the population are pastoralists, a World Bank identification mission in 1976 proposed a rangeland development project for the central region of the country. Its resource information elements included a resource inventory and a range ground survey. To provide a foundation for the ground survey, tapes of seventeen Landsat scenes were acquired, processed, and analyzed. When the first five scenes were processed and reconstituted into visual imagery, they provided the field team working on the rangeland study more information on the vegeta-

tion and soil moisture content of the area than had been available from maps or other sources. Preliminary ground truth for the Landsat data was obtained by field inspection from low-flying aircraft. An estimated count of herds was also obtained by direct observation from the flights and from enlargements of 35mm photographs. The Landsat portion of the inventory was budgeted at $16,000, and the rest of the inventory, including the aerial phase, was to cost about $200,000. The ground survey, designed to validate the Landsat and aerial data, was being carried out by a joint team of Somalian and foreign professionals.

Hydrology and Geology

Remote sensing from both planes and satellites is playing an increasingly important role in the search for and development of water resources. Aircraft have been used for decades to measure surface water bodies, monitor snow melt, help site dams, spot seepages in irrigation systems, and measure sedimentation in reservoirs for river courses. All of these tasks relating to surface water can now be accomplished, to some extent, by satellite sensing. From Landsat data, it is also possible to note geological and vegetational evidence pointing to the potential locations of groundwater. But it is in connection with surface water data that Landsat has shown unique capabilities. Even in the simplest black-and-white Landsat film, surface water is easily recognized. Other hydrological factors are also observable, including the outlines of drainage basins, extent of snow, various watershed characteristics, broad irrigation channels, levels of water in reservoirs, and changing course of meandering rivers.

The World Bank has used Landsat imagery to obtain information for some of these purposes in connection with its projects. In some cases, satellite sensing proved helpful in the monitoring of projects. In Thailand, for instance, Landsat film of the area covered by the Northeast Thailand Irrigation Improvement Project was obtained in 1974. Visible in the black-and-white film was unexpectedly heavy sediment in one tributary from a recently filled dam. This information led to the discovery that numerous farmers, displaced from the flooded areas, had resettled in rich bottom lands along the tributaries leading into the reservoir rather than in the less fertile upland areas that had been assigned to them. Their tilling of land in the riparian watershed area of the reservoir led to accelerated erosion and a shortening of the expected life effectiveness of the reservoir, indicating the need for closely integrating resettlement policies with infrastructure development. The potential value of Landsat data for supervision of water projects was further demonstrated when a holdup in construction was identified on the Landsat scene by a gap that then still existed between the northern and southern portions of the primary canal networks.

Timely satellite imagery can show the extent of flood coverage. The Bank successfully tested the value of Landsat data in two flood situations—in Pakistan in 1973 and in the Sudan in 1978. The sensitivity of the Landsat MSS to clear and turbid water was proved useful to the Bank in connection with two coastal tourism projects. In Gambia in 1975, black-and-white Landsat films showed a littoral ocean current passing an area near the capital city, Banjul, where a hotel beach complex was to be built with the help of a Bank loan. Investigation confirmed the existence of a current carrying effluents from the city. An alternate site was then chosen for the hotel project. In Turkey in 1976, Landsat imagery showed distinct discoloration in offshore currents passing the area of a proposed tourism complex on the Mediterranean coast. In this case, further checks found that the discoloration was caused by chemicals from an urban complex that was going to be displaced by the tourism project. In both cases, the costs of the Landsat imagery and analysis were nominal.

Mineral Resources

Aerial photography has provided the primary data base for geologic mapping and for mineral and petroleum exploration for the past half-century. Satellite sensing is now used to complement the aerial surveys. Large geologic features, such as major lineaments, can be recognized more easily in the synoptic view of large areas available from satellite-imagery than in mosaics put together from many aerial photos. The broad Landsat view also provides an excellent framework on which to present geologic data and can direct the attention of exploration geologists to areas deserving closer study by aerial photography, ground observations, and test drilling. Aerial surveys, however, are still essential for doing detailed studies and to carry specialized sensing equipment such as magnetometers, thermal infrared sensors, and high resolution multispectral scanners.

In response to requests from the UN and other international bodies, the World Bank in 1979 announced its Program to Accelerate Petroleum Production in Developing Countries, including support for geological surveys. Bank staff are helping countries to keep abreast of the latest technological developments and to determine the most efficient and economical means of evaluating their fossil fuel and mineral resource potential.

In 1979 the Bank responded to a request from the government of Nepal for help in determining whether any reserves of petroleum or natural gas could be located in the country. The request was prompted not only by Nepal's urgent need to reduce the financial drain caused by petroleum imports but also by encouraging indications of gas seepages reported in various parts of the country. A loan was approved for an aeromagnetic

survey to be carried out in the most likely area, the Terai foothills of the Himalayas bordering the Gangetic plains of India. The survey was completed in 1980. Since 1980, Bank geologists have continued to examine Landsat imagery in many countries as a first step in their fossil fuel resource surveys.

Technology Transfer

In its use of remote sensing data for identifying, preparing, and monitoring the development projects it supports, the World Bank has sought, whenever possible, to secure the participation of professional and technical personnel in the country concerned. The purpose is not only to obtain knowledgeable assistance for particular studies but to familiarize local resource specialists and survey technicians with new data-gathering and analytical systems. In some instances, resource professionals or remote sensing specialists have been brought to U.S. laboratories to work on the processing and categorization of Landsat imagery. In addition, the Bank has given direct support to projects aimed at transferring the newer resource information technologies to developing nations.

In 1971, for example, the Bank produced six maps at a scale of 1:500,000 covering administrative subdivisions, population, transportation, hydrology, land use, and land capability to assist in the analysis of feasibility studies in Bangladesh. The maps were based on the best data available at the time; however, after the first Landsat imagery of Bangladesh became available, it was evident that the maps, based on old topographical sheets, were out of date. When the Bangladesh government asked in 1973 that the earlier map series be republished, the value of using Landsat to update the maps was recognized. An inexpensive color-composite mosaic of the whole country processed by the "dye transfer" method was produced by the Bank. This mosaic was the first Landsat color image of a complete country ever processed. It could readily be evaluated for cartographic fidelity and it reconfirmed the extensive changes, sometimes up to 10 to 12 kilometers, of river courses in the lower Ganges-Brahmaputra basin. Imagery taken in later years and intensively processed by edge-enhancement or categorization methods showed further changes. (See figures 6–3 and 6–4.)

A mapping program was worked out between the Bank and the Bangladesh government operating through its Space Research and Remote Sensing Organization (SPARRSO). The first phase of the mapping effort was completed in 1980 with the production of a new mosaic based on edge-enhanced images and on categorized Landsat imagery taken in 1976–1977 and incorporating land use information from the 1971 land use map. Staff members of the Bank and SPARRSO worked together in the computer tape process-

ing of the imagery. The cost of the new map, produced in 2,000 copies, was $68,500. The updated map can now serve as a base for updating the other thematic maps needed for development planning in various resource sectors.

A second example is taken from Indonesia. In 1974, the government, aware that the country lacked an adequate resource information base, asked the World Bank for assistance in developing a comprehensive mapping and survey program as a foundation for national and regional planning. Information was needed to assess deforestation, erosion, and other ecological deterioration on the main, overcrowded islands of Java, Madura and Bali. Especially wanted were resource surveys of the poorly mapped outer islands, where resources remain largely untapped and where the government has been trying, on a massive scale, to resettle families from the more densely populated areas. The Bank approved a two-part National Resource Survey and Mapping Project, estimated to cost $48 million. Part I, financed by the Bank, was to cost $26 million, and part II, to be supported by the Canadian International Development Agency, was estimated to cost $22 million. Both parts of the project were designed to strengthen Indonesia's own capability to gather, update, store, and use the resource information it needs for its development.

By the time Bank financing ended in December 1983, two elements of part I had already been completed: the construction of new, enlarged quarters for BAKOSURTANAL, the National Coordinating Agency for Surveys and Mapping, and the procurement of modern equipment needed for expanded map production and for resource evaluation of a volume and quality to match Indonesia's planning requirements. Still in progress were the coverage of aerial photography, at 1:50,000 scale and larger, of about 300,000 square kilometers to support current development projects funded by the Bank; analysis of remote sensing imagery including Landsat scenes; technical services of survey firms and consultants to provide assistance to geodetic control, cartography, map printing, and resource analysis; and training of BAKOSURTANAL professional staff and technicians both in Indonesia and abroad. By mid-1983, more than seventy-five Indonesian staff members of BAKOSURTANAL had already completed such training programs.

Much of the project emphasis is on the resource data needed to find suitable sites for resettlement on the outlying islands. The Landsat imagery and the small-scale photography provide reconnaissance-level data to locate broad areas for potential development. These in turn lay the groundwork for regional surveys directed by the respective ministries. Surveys are carried out by teams from various government departments and the universities or by local and outside consultants. The work of the regional survey teams is supported by the large-scale photography and intensively processed Landsat data.

To facilitate efficient retrieval, management, and use of the information gathered on Indonesia's 3,000 islands, a highly responsive geo-based computer

data system with an automated mapping component was installed as part of the project, along with a satellite image processing system. These computerized systems are able to analyze and integrate physical, socioeconomic, and administrative data in digital form. By means of visual displays, quantitative tables, and map overlays, the system can respond quickly to questions from planners and resource managers about the physiographic, socioeconomic, and administrative factors relevant to any particular spot within the archipelago, provided the proper basic data is available and has been digitized.

Several countries besides Indonesia have asked Bank assistance in acquiring and introducing efficient systems to integrate resource data already available and to incorporate data to be obtained by remote sensing. Among countries requesting such help are some that have been meagerly studied in the past but are now undergoing a multiplicity of resource surveys and others that have a substantial volume of resource information already accumulated. Nepal is an example of the former and Malaysia of the latter.

Multilateral and bilateral aid organizations are administering development projects separately in different regions of Nepal and have had to gather original data on which to base project planning. West German teams are gathering data in major drainage basins for hydrological projects in eastern Nepal. The Canadian International Development Agency has been collecting data on land use and soils in the whole of Nepal. Three multinational agencies—the Asian Development Bank, the World Bank, and the International Fund for Agricultural Development (IFAD), financed by Arab nations—are supporting various development projects and associated studies in central Nepal. Superimposed on these regional undertakings are sectoral studies such as the World Bank's aeromagnetometer survey for petroleum and gas exploration and two surveys financed by the U.S. Agency for International Development. One of these is a survey of roads, trails, and bridges in connection with transportation projects. The other focuses on areas subject to erosion and landslides.

To integrate the data from these disparate studies, the World Bank is working with Nepalese government agencies to establish the foundation for a geo-based information system. With the assistance of the German Development Agency, Landsat imagery of the whole of Nepal was computer processed in 1979. Based on this imagery, a new map of Nepal was produced on a Universal Transverse Mercator grid. This and new maps at the 1:250,000 scale, scheduled for publication in 1984, will facilitate computer analysis of the voluminous resource data now being collected in the field by various national and international development agencies.

In the case of Malaysia, the government has conducted extensive surveys of soils, land use, water, and forests in the past two decades and has produced highly detailed maps of the country's resource base. The Bank was

asked to assist in modernizing the country's regional planning and information system by helping to evaluate equipment and software for data analysis and automated mapping. The Bank provided such assistance in connection with a state and rural development project supported by the UN Development Programme (UNDP).

For some time the Ministry of Agriculture has been doing automated mapping in its flat-bed plotter for land tax purposes. The government's interest in automated analysis and mapping, however, extended to the broader land management field. Malaysia required a more efficient way to organize the regional resource information that had been accumulated and to make it readily accessible to regional planners. The Bank examined a number of sophisticated geo-based data systems to help the Malaysian authorities decide which would meet the government's needs.

In a test of such a system by Bank staff, facts from the detailed 1976 map of one Malaysian state were programmed into the computer, and a series of questions were asked. Was rubber being grown on lands of 8 percent or steeper slopes, or was it occupying flat lands highly suitable for agriculture? Was rubber growing on heavily acid soils or also on good-quality soils optimal for other cultivations? How seriously do open pit mining areas impinge on good agricultural soil? In each case, the geo-based digital system responded, within fifteen to twenty-five minutes, with displayed maps of the areas and tables of acreages printed alongside. The test demonstrated the capability of such systems to extract quickly the type of resource information that planners, resource managers, and economists need for identification and preparation of development or conservation projects.

In numerous other cases, Bank staff members have evaluated data acquisition proposals, equipment, contracting firms, and software systems to assist developing countries in deciding on the options most suitable to, and cost-effective for, their resource information needs. The Bank's objective has been to promote high standards of accuracy, efficiency, and appropriateness in evaluations of the new technologies and data products. Experience with new devices and systems in one developing country is made known to other countries facing similar resource information problems.

In addition to these examples of technology transfer to specific countries, the World Bank has facilitated the independent utilization of the new techniques and data products by developing countries. In 1976 the Bank published *Landsat Index Atlas of the Developing Countries of the World* to help users in those countries locate usable Landsat imagery for areas of interest. The atlas notes the Landsat scenes that were taken from 1972 to May 1975 and identifies each scene by its numbered north-south orbital path and its number or row in each orbit. In addition, each area is keyed to tell whether the scenes taken on particular dates have 0 to 10, 20 to 30, or 40 to

50 percent cloud cover. Scenes of more than 50 percent cloud cover are not included. This atlas has complemented other resources indexes and has made it easier to locate source materials and imagery needed to carry out resource evaluation for the justification of development projects of the Bank.

Future Prospects

As technology advances and innovations multiply in the various phases of resource data acquisition and analysis, the World Bank continues to monitor those improvements that can bring immediate benefits to developing countries. The European Space Agency, France, India, Japan, and the United States have already announced plans to launch remote sensing satellites. These proposals, which are in different stages of planning or development, variously involve higher spatial resolution, multiplatform stereo capability, improved radar imagery to pierce cloud cover, and thermal sensing that would provide more information on soil and water resources. Additional reception stations will be available in the 1980s to receive data directly from satellites for the part of the earth's surface not previously served by direct reception. This should speed up the delivery of the data and eliminate delays that thus far have hindered the use of Landsat imagery for efficient monitoring of environmental change.

The higher spatial resolution expected from the next generation of satellite sensors in the mid-1980s should provide more detail of the type previously available only from aircraft: more precise crop prediction, recognition of smaller geologic features and water bodies and identification of more types of trees, soils, and vegetation. Greater [illegible] of combinations of satellites and aerial data can be expected, as can further refinements in the services performed by the integrated geo-based information systems.

The Bank is watching these innovations and improvements in order to take advantage of the opportunities they may offer to save time and money. The Bank is also keeping in touch with the discussions at the UN and in national legislative bodies regarding the institutional, political, and financial future of the remote sensing enterprise.

The attractiveness of satellite sensing to developing countries has been increased by two factors that may be affected by institutional changes. One is the current policy of open distribution of Landsat data products to all who wish to purchase them. Any restrictions placed on such distribution for political or economic reasons would lessen the value of the technology for developing nations. The new data acquired about the resources from outer space should not be considered the exclusive property of any single satellite-owning government or its private entrepreneurs but rather are for the use and benefit of all the countries of the world.

The other factor is the relative inexpensiveness of Landsat data for all users, including developing countries. The reason for this low cost is that the heavy investment in the spacecraft and sensing packages aboard them has been borne by the U.S. government. Satellite operating costs have also been paid by the United States. If users of satellite data products had to pay their full economic price, to cover capital and operating costs, the price would be prohibitive for most developing countries.

The industrialized nations—the United States, Canada, the Soviet Union, Japan, and the member countries of the European Space Agency—are planning expanded satellite sensing programs with at least two objectives in view: they want better and more detailed information about their own resources, and they also want a stronger grasp of both the renewable and nonrenewable resources that may be available to them from elsewhere on the planet. Satellite sensing represents an advanced technology that is benign in its impact on developing countries and is highly appropriate for meeting developmental requirements. Current knowledge of the state of the world's resources—whether it be the health of crops or the availability of fuel—is becoming increasingly important. The developed nations should be able to offer the by-products of their own remote sensing programs to the rest of the world, as they do with satellite meteorological and navigational services, without seeking a full financial return on their investment.

From the point of view of the developing countries whose interests the Bank seeks to serve, remote sensing of earth resources from space should be viewed as a global service, similar to the World Weather Watch. It should be made available to all at nominal cost by the nations that can afford it, in their own interests and in the interest of the international community.

Notes

1. Executive Summary, Large Area Crop Inventory Survey (LACIE), Houston, National Aeronautics and Space Administration, Lyndon B. Johnson Space Center (August 1978).

2. The prices differ for standard Landsat data products from reception stations outside of the United States. In Italy, for example, standard images could be purchased in 1984 for $50 (black and white) to about $200 (color composite) and $450 for a computer-compatible tape.

Part II
Appropriate Technology and Basic Needs

There are few issues in the debate about the role of technology in the development process that raise as much enthusiasm on the part of its proponents and as much derision on the part of its critics as the concept of appropriate technology. The debate is not simply semantic or ideological; it touches on one of the most fundamental problems in national development strategies: how best to meet the basic needs of the poorest people for food, health, shelter, and work.

The four chapters in this part describe the ways in which the World Bank is attempting to mobilize and use technology (taken here in the sense of both hardware, or equipment, and software, or organizational tools) to meet some of these basic needs of those who by and large have been left out of the development process of the last thirty years.

In chapter 7, Julian Bharier examines the problem of supplying safe and clean water. The magnitude of the issue can be gauged from the well-known, yet often forgotten, fact that there are today in the developing world over 2 billion people who have no access to safe drinking water. Most of the technologies needed to provide them with this basic amenity are well known, but as Bharier clearly shows, the central issue facing policymakers and development agencies such as the World Bank is to ensure the widespread dissemination and diffusion of these technologies. This is done essentially through projects, and the author touches here on the central issue of replicating successful projects so as to reach the widest possible number of beneficiaries. He also shows that the key element in successful replication is organizational ability rather than technology in the hardware sense of the word.

In chapter 8, Charles G. Gunnerson examines some of the main low-cost technological options in sanitation and waste disposal and shows how the Bank's socioeconomic and technological research in this field is beginning to feed into the design of new projects in this sector. Perhaps the most important lesson to be drawn from this action-oriented research work is that low-cost sanitation technologies are not only a viable alternative to capital-intensive water-borne sewerage systems developed in the industrialized countries but are also the only feasible alternative if poor countries are to meet the needs of hundreds of millions of people for safe, yet inexpensive, waste disposal.

In chapter 9, Herbert Werlin presents case studies of the World Bank's experience in meeting the needs of the poor in urban areas for low-cost shelter. The concept of sites and services, pioneered by the Bank along with

a number of other organizations, represents a major social innovation in its own right and appears to be a potentially extremely successful contribution to the seemingly insoluble problem of urban housing in developing countries. The experiences Werlin describes show that the critical determinants in the innovation process are organizational tools, such as land tenure systems, pricing mechanisms, and the provision of inexpensive credit—not new types of hardware. Werlin also suggests that the problems of innovation and improvement in urban areas are not only technical (in the organizational sense) but also, and very largely, political and social, and he shows the important role of action-oriented research in the design and implementation of urban projects. This chapter points to another major emerging innovation: the concept of integrated urban development, similar in many ways to the idea of integrated rural development.

The last chapter in this part deals with basic education. Based in large part on the innovative experiences of a few African countries, this chapter by Francis J. Lethem shows not only that there are low-cost technologies in the field of education but that these technologies can be extremely successful in providing basic education to those who have been left out of the traditional educational system. The innovations described in this chapter—from Mali's functional literacy program to Upper Volta's rural education centers—suggest that many developing countries, often in conjunction with World Bank educational projects, have developed or are in the process of developing what amounts to a truly appropriate educational technology.

The four chapters in this part do not cover all of the basic human needs. Health, for instance, has been left out, not because the subject is unimportant—quite the contrary—but because this is an area traditionally covered by other agencies (the World Health Organization and the UN International Children's Fund in particular) and because the World Bank has only recently begun to move in this field.

The four experiences or cases presented here suggest a number of important conclusions for policymakers and others interested in the role of technology in the development process. The first of these lessons is that largely as a result of its new policies focusing on meeting the needs of the poorest people, the World Bank has become one of the world's major proponents of, and innovators in, appropriate technology, a term that here includes all types of low-cost technologies aimed at meeting the basic needs of the poorest and most underprivileged. This view of the World Bank as a major force in the field of appropriate technology may come as a surprise to those who still view this conceptual innovation as the preserve of a few marginal groups at the fringe of the industrialized societies or as a counterculture in the elite of the developing nations. These experiences of the Bank show very clearly that low-cost technology, even if it is not called specifically by the name *appropriate*, has become an integral part of mainstream development thinking.

A second lesson that stands out from these experiences is that in a number of areas—water supply, sanitation, housing, and education—there are many viable alternatives to the traditional capital-intensive technologies developed in the industrialized countries. These alternative technologies may somtimes be rather experimental, and the social technology for ensuring their widespread diffusion may not yet be fully mastered, but they do work. What is more, many of these technologies are already well known and, although much research is required to understand how best they can be diffused to those who need them, are adequate from a purely technical point of view. This indirectly suggests that one of the strategic issues in the field of appropriate technology today is not that of doing more research on hardware, as most appropriate-technology proponents seem to believe, but rather that of understanding the social processes of innovation and integrating more appropriate types of technology in the design of development projects.

A third lesson is that appropriate technology, contrary to what some of its critics tend to argue, is neither an obstacle to development nor the manifestation of a plot by well-meaning intellectuals against accelerated industrialization in the developing countries but rather one essential tool in a well-balanced development effort. Appropriate or low-cost technology is certainly not a panacea, but in a number of sectors it is the least expensive and possibly the most effective means of meeting the basic needs of the most underprivileged.

Water Supply and Waste Disposal

Julian Bharier

There is very little of the theory or technology of water supply and waste disposal that has not been known for a long time. Over 2,000 years ago, Romans drew their water from the Tiber or from wells and springs. Yet the city grew so rapidly that these sources soon proved inadequate. Aqueducts had to be built to bring water from outside the seven hills, and sewers were built to dispose of the wastewater.

As far back as the first century A.D., Frontinus, the water commissioner of Rome, realized that even this supply was becoming insufficient, and he began to ration water among users by various metering devices. The Romans were neither the first nor the last to be concerned with municipal water supply and waste disposal practice, for the same reasons that we are today: to protect human health and provide a safe and aesthetically pleasing environment for living.

Disinfection of polluted water also had been practiced for many centuries; boiling and filtering water to remove impurities had been recommended by the Greeks at least as early as 500 B.C. From the middle of the nineteenth century, when sanitary conditions in England became intolerable because of the concentration of people in urban areas in the wake of the industrial revolution, efforts to purify water by consumers intensified. The correlation between increased purification of water and a decline in the incidence of water-borne diseases did not pass unnoticed. Epoch-making discoveries in bacteriology from around 1880 onward showed that cholera and typhoid, as well as many other serious diseases, could be water carried and that many intestinal diseases were caused by drinking water polluted with human waste. Hence, many of the more advanced countries constructed central treatment facilities.

In most advanced industrial nations, the water supply systems, particularly in towns and cities, are very similar, as are the waste disposal facilities. In many developing countries, it is now realized that there are distinct advantages in the construction and operation throughout every urban community of a water supply system along the lines of those now found in the towns and cities of the advanced countries. Such a system incorporates a centrally controlled and treated source of water, wide-ranging transmission lines, and metered, multiple-tap connections in every house or apartment. Such a system, properly managed, can provide large social and economic benefits. The systems are convenient for consumers, reduce users'

costs of storage and purification, and, through their universality of use, can limit the possibilities for infection. Meters can be used to levy a range of tariffs, which in turn can be used to produce a financially viable public undertaking, to discourage waste, to assist investment decisions, and, possibly, to contribute to income redistribution.

Experience in both rich and poor countries shows that cheaper distributional technologies, such as public standposts, have drawbacks. Standposts are subject to vandalism, and vandalism can bring about wastage. Health hazards can result if adequate drainage is not provided around them, and it is usually difficult to collect revenue from them. Patio or yard connections (outside connections serving a single residential building), though they are usually more convenient and though revenues are more easily collected, also have drawbacks (wastewater disposal, for instance, starts to become a problem). Much study is still required before the optimum design of a distribution system, which evolves through the various stages of standposts, patio connections, and modern multiple-tap connections in houses, can be determined.

Nevertheless, it is now quite clear that if all of the 2 billion people in the developing world who do not have access to safe water and sanitary waste disposal are to be provided with this access by any reasonable future date, say, the end of this century, cheaper service standards must be considered. These are generally well known and have been used at some stage in the now-rich countries, abandoned only when service was upgraded.

Because these are old rather than new technologies and are low level rather than high level, even if they employ modern materials such as plastics, there is often opposition to their use by governments in the developing countries. This opposition is based less on rational economic and social reasons than on the fact that there is little external or internal political mileage to be gained from them. Externally, the appropriate, intermediate, or low-level technology generally has a much lower import component. This may assist the balance of trade but will not be appreciated by foreign suppliers of the advanced equipment or by foreign visitors to the country. Internally, popular reaction tends to depend first on the existing distribution of technology within the country (a country that has advanced technology in its larger cities may find it difficult to get the smaller cities to accept a lower-level technology); second, it depends on whether people percieve the benefits of low-technology water supply and waste disposal in relation to their existing facilities. There are some countries where the shock of a cholera epidemic has changed people's perception of the health benefits to be achieved, but generally most people count benefits in terms of their own convenience rather than their improved health.

The type of technology appropriate for any given water supply system depends on health and sanitary factors, functional factors, and environmental

factors. The techniques used must be suitable in relation to the health improvements expected from them; they must be suitable from the point of view of design and performance; and they must operate without adverse side effects on the physical and social environment of the area concerned.

For most small communities, ranging in size from individual households to, say, 1,000 people, it is usually economic to employ low-level technology to obtain a safe water supply. The technology may take the form of a properly protected rainwater collection system or groundwater spring, a simple gravity feed system from a surface source, or, at a somewhat higher level of technology, a hand-dug or bored well. The well should be protected against pollution from contaminated surface water or groundwater and from external contaminants, such as dirty buckets used for drawing the water. In most cases, this implies a sensible location of the well, a good lining, a well head consisting of a headwall and drainage apron, and, best of all, a covered top with a fitted pump. The per capita investment costs of any of these systems will be one-fifth to one-tenth that of a full-fledged treated water supply system in an urban area, but experience shows that it is difficult to ensure that proper maintenance is carried out.

For waste disposal, there are many technological alternatives between the pit latrine and the complete (water-borne) sewerage system. Indeed environmental sanitation can be improved significantly by the installation and proper maintenance of systems with costs per household one-third to one-tenth those of conventional sewerage, providing certain conditions are met.

Many different techniques can be used at different stages in a waste collection and disposal system, and one important point to note is that to a large extent social customs determine the range of feasible lower-level technologies. In some countries, the reuse of human waste on the soil goes against local customs; in others, communal facilities are frowned on, or deposition is always into running or stagnant water. In contrast, there appear to be no social constraints in any country on water-borne sewerage, possibly because the system (except for deposition facilities) remains unseen. When the costs of alternative systems are being considered, these customs must clearly be taken into account.

Since the end product of a safe water supply and waste disposal facilities is health, the quality of service levels is as important as the levels themselves. A poorly maintained or badly operated water supply system may produce an unsafe supply, irrespective of how many people have access to this supply. In some cases, where the growth of population causes overuse of the system and leads to intermittent supplies, the whole system may be rendered unsafe because of the intrusion of contaminated water from outside the system. Thus, further investment in a city's water supply may be justified even where a high proportion of the population has house connections and their present water supply is safe if, in the absence of any

action, future growth of the city is likely to lead to a breakdown of this service. In other cases, the beneficial effects of a safe water supply may be reduced by poor sanitation practices, or conversely, sensible sanitary precautions by consumers may make a technically unsafe supply of water safe for all practical purposes. These factors generally cannot be put into quantitative terms. As a result, it is often very hard to assess whether, for example, people in a particular community are actually better off now than they were twenty years ago in terms of water supply. The same is true for waste disposal. For example, there are many cities with water-borne sewerage facilities working near full capacity that, when flooded during the monsoon, become almost as much of a health hazard as if no facilities existed at all. Safe facilities for ten months of the year are not safe facilities.

Changing Emphasis in the Bank's Lending Policy

Before 1971, the major emphasis in the World Bank's lending for water supply and waste disposal projects focused on the development of urban facilities. The idea was that service for towns and cities should take priority over rural service because the demands placed on traditional urban systems by rising population densities and the concurrent public health problems are much greater, concentrating any given amount of investment in towns and cities would benefit a larger number of people, and the planning of major urban water supply and sewerage projects could have an impact on the broader problems of urban planning. It was also felt that water-borne sewerage was the only satisfactory method of removing human waste in urban areas.

These arguments emanated largely from the Bank's experience in lending for water supply and sewerage, which had started only in 1961 and had expanded relatively slowly through the decade. Before 1971, Bank lending in the sector had been almost exclusively for country capitals or very large cities and was generally regarded simply as a contribution to economic infrastructure in the same way as investment in any other public utility such as power or telecommunications. This was in keeping with the Bank's underlying philosophy in the 1960s that national income growth, stemming from increases in productive investment based on suitable economic infrastructures, would trickle down to all social groups in the economy.

During the 1970s, the Bank's perception of the process of economic development changed. It was realized that the process of growth differed dramatically in countries at different stages of growth; that concentration on development efforts in the urban areas often worsened conditions in the towns because it led to massive immigration from the rural areas; that attempts to replicate the economic structure of rich industrialized countries

could be successful only under special circumstances; and that whatever the development process in a particular country, some of the population was likely to lack the means to obtain even the bare necessities with which to achieve the potential for a productive existence.[1]

In line with this change in perception came a reevaluation of the Bank's role in water supply and waste disposal. As a result, the Bank now regards adequate water supply and waste disposal facilities not only as contributions to infrastructure but also as social services with a major impact on the quality of life. It is now accepted that without adequate and convenient supplies of safe water for drinking and washing and without adequate waste disposal facilities, people cannot attain a reasonable minimum standard of living. Water that is unsafe for human consumption carries and spreads disease; water that is inconveniently situated leads to considerable loss of productive time for those who have to fetch it; inadequate supplies of water can frustrate attempted improvements in many aspects of social welfare; and inadequate waste disposal leads to the spread of a wide range of parasitic and other debilitating diseases. There is also increasing recognition that all aspects of sanitation, defined broadly as all actions or processes that promote hygiene and prevent disease by establishing and maintaining sanitary conditions, must be considered. This includes the educational process by which people are made aware of the causes of disease and of the preventive measures made possible through the use of safe water, proper disposal, and general cleanliness. Consequently, since the early 1970s, a growing proportion of loans in the Bank's expanding lending program in water supply and waste disposal has been directed toward smaller towns and villages, and greater emphasis has been placed on the development of waste disposal so that the full health benefits of safe water supply can be realized.

The use of low-cost techniques designed to improve the access of the poor to such services has become an integral part of the Bank Group's lending in many parts of the world. Since 1978, for example, over half of the water supply loans have included financing for low-cost methods of providing service to the urban poor. Because of the present backlog of people without access to adequate supplies of safe water and sanitary waste disposal, particularly in the rural and urban fringe areas, as well as the expected growth of population, there is tremendous scope for expansion of this type of lending.

Research on Low-Cost Technologies

As a basis for this expansion, the World Bank has carried out and commissioned a number of operationally oriented research projects. One of the first major research projects in this field was a study on village water supply

in 1972. Because the technical issues were fairly straightforward and well understood, this study emphasized the economic, social, financial, and administrative issues characteristic of village water supply and sanitation programs and outlined some general principles. These were subjected to empirical testing in a follow-up research project on rural water supply in 1978, which, on the basis of village studies, attempted to determine factors common to the success or failure of water supply programs. This research highlighted the problem of quantifying the benefits of investments in the sector, even though it has clearly been established that water can be a vector of disease and that the provision of a safe and adequate supply is essential for the protection of public health.

To address this issue, the Bank commissioned a background paper on the measurement of health benefits of investments in water supply to identify the interrelationships among the numerous factors that impede the accurate forecasting of the health impact of changes in water supply.[2] An adequate quantity and quality of water must be considered together with other factors such as social, political, economic, environmental, and educational variables, which have a significant impact on the health of a population.

The proposed impact study methodology combines standardized methods of measuring relevant variables with simplified methods of data collection while maintaining as high a degree of reliability as possible. Three variables are of particular relevance:

1. The water-use variables, representing the quantity and quality (in terms of fecal pollution) of water supply.
2. The health variables, representing the large group of relatively universal water-related diseases, symptoms, and conditions. The one to fourteen age group, considered to be most sensitive to waterborne and water-related diseases, should form the basis for the examination and collection of information.
3. The health-related variables, including the extent of health and general education, sanitation- and health-related facilities, dietary differences, and economic, social, and cultural differences.

The use of questionnaires and surveys, fecal inspection, and clinical examination of skin, as well as the status of physical development and personal hygiene, were among a large number of alternative information sources examined by the panel. For practical field applications, however, the panel recommended the use of selected health state indexes that could be of significant value. Alternative forms of health impact studies, including retrospective studies and longitudinal studies of total health impact, were also discussed. The panel concluded that the benefits could not be fully quantified given the present state of knowledge and that studies to establish

a rigorous relationship between water supply and health would not only be extremely expensive but would also lead to conclusions with doubtful applications elsewhere. Another important finding of the early research was that in order to bring about a rapid improvement in the access of low-income groups to adequate water supply and sanitation facilities, it was necessary to ensure that service standards were not unduly high and that appropriate technologies would be employed. Research in the field of water supply and waste disposal has been dominated by these criteria.

A study on the design of low-cost water distribution systems attempts to provide designers with simplified analytical tools to improve the design of secondary distribution systems to serve slum, squatter, and urban fringe areas.[3] Such areas, including some larger rural communities, require a basic needs supply network that does not overtax scarce financial resources. Therefore it is essential to eliminate overdesign and hence to minimize costs.

Relatively simple mathematical models are used that take into account specified input data relating to the population to be served, the rate at which that population is increasing, and the area occupied by the population. The decision variables include the accessibility of water to consumers (for example, the spacing of standpipes), per capita consumption levels, minimum allowable pressures in the network, and the measures to be taken to improve system reliability (such as extent of looping or number of valves).

The models have proved useful in extensive fieldwork and analysis of supply networks in two cities, one in the Middle East and the other in West Africa. The methodology has enabled quick analysis of the effect of several design options and assumptions on system costs.

Research and development cost computed has been completed for water supply hardware in rural areas. The Bank sector policy paper on village water supply recommended the use of hand pumps and shallow wells to augment the supply of safe water in groundwater reservoirs. The major problem was that available hand pumps, which have been designed for light use in temperate climates, were unsuited to the conditions and use patterns in rural areas. Research was commissioned on a hand pump for rural areas of developing countries to define conditions of service in the rural milieu and to initiate developmental work on a rugged hand pump.[4] The design was to make greater use of locally available materials and be mechanically simple enough to allow for trouble-free maintenance. Principle features of the hand pump include the following:

1. A polyvinyl chloride (PVC) replacement for the steel used for the well casing. PVC is extruded in many developing countries and has an added advantage of being inert. Furthermore, PVC casing is not affected by corrosive groundwater conditions.

2. The piston and check valve were made of interchangeable components to reduce complexity. Suction losses are avoided (thus increasing efficiency) by keeping the valve and piston submerged.
3. Locally available buoyant materials (such as bamboo, wood, and galvanized steel tubing with sealed cavities) are used to construct the pump rod, which connects the lever (handle) and piston. This helps reduce the amount of energy expended in lifting.
4. The design included allowances for minor structural modifications, such as change in color size and lever arrangement. Also, the use of leather cup seals to minimize wear on cylinder walls and of metal-wood interfaces for pivot points are recommended.

An effective but low-cost well screen was needed to control the migration of soil particles carried by the water from alluvial aquifers through the various well and pump components. Commercial screens, manufactured from plastic or metal, had some drawbacks, which had to be overcome. Metal screens, although more effective than plastic types because they were rugged and had a larger open area (20 to 35 percent), were expensive. The plastic screens had a smaller open area (1 to 10 percent). A study was therefore commissioned on the development of PVC well screens for local fabrication to tackle the problem.[5] A less expensive PVC screen of medium strength and adequate open area was needed. A sufficiently reliable fabrication technique was also important to allow for manufacture in developing countries. Developmental work resulted in an inexpensive but rugged plastic screen with an open area of 20 to 25 percent. The fabrication technique employs a circular saw to make a continuous helical cut in a standard pipe. Stiffeners are used to strengthen the pipe. The final design, called the Roboscreen, will require further developmental work to improve the fabrication technique and will have to be tested under field conditions.

A program of testing of wood bearings for hand pumps formed part of the developmental work on the use of metal-wood interfaces to reduce wear on pump parts.[6] The hand assembly, in particular the pivot points, is subjected to heavy loads during pumping. Under such heavy use (typically eight to twelve hours per day in many villages), the metal-metal interfaces wear out quickly. Initial tests on metal-wood interfaces produced less wear. Oil-impregnated wood bearings coupled with steel pipe shafts were found to show little wear. The investigation was expanded, from early work involving bubinga (*Guibourti* spp.) wood, to wear tests on eight samples of bubinga and common pine bearings. The eight samples, four of each type of wood, were tested simultaneously on 1/4-inch (inside diameter) galvanized steel pipe rig. The results indicated that wood handles work well on simple pivots and that oil-impregnated wooden handles are more durable than dry ones.

The greater share of the World Bank's investments in this sector between 1962 and 1983 was for water supply. The problem of waste of water was a recurrent one, and losses of water at public standpipes and unaccounted-for water were a major source of concern. A number of research projects have addressed this issue of wastage. In most projects, the level of unaccounted-for water was found to be very high, and measures to reduce such losses are under study. This research project will eventually produce a *Manual on Control of Unaccounted-for Water,* which will help identify the extent and causes of unaccounted-for water and define the levels of unavoidable losses in relation to norms of good performance.

A related study on the costs and benefits of water metering has applied the theoretical economic framework underlying the decision process on whether to meter household water supplies to examples drawn from several Asian cities. The study attempts to clarify some critical points in this area. All of these studies, including another one on the state of the art in wastewater (agricultural and industrial) reuse, are proceeding in parallel.

The Bank has recently completed a two-year research project to study appropriate technology for water supply and waste disposal. The long-range objective of this research was to help the Bank direct the benefits of its water and sanitation loans to the urban and rural poor. The immediate objectives were to determine the technical and economic feasibility of various options available for water supply and waste disposal in developing countries; the economic, environmental, and sociological effects of the technologies that provide for conservation of water and reclamation of wastes; and the scope for designing technical improvements of existing intermediate technologies to improve their efficiency or increase their transferability and acceptance.

Data were collected on existing sanitation technologies in over fourteen countries, which encompassed a variety of stages of development, cultural and institutional forms, and environmental conditions. Field consultants were chosen from developing countries to the extent possible, and detailed studies of two to four communities in each country were made. For each technology studied at the community level, a technical evaluation was carried out of the system's construction and operation. Using standard cost-benefit techniques (including economic conversion factors where appropriate), each technology's economic feasibility was analyzed, and average household costs were computed. Special emphasis was given to the ability and willingness of consumers to pay for the system, their real or perceived improvement in health and living conditions, and any obstacles to adaptation of the technology for other communities.

As a complement to the field studies, a detailed bibliographic search for literature relevant to low-cost waste disposal was carried out by the International Development Research Center (IDRC). Over 18,000 potentially

relevant publications selected by key word indexing were reviewed. Less than 2 percent were of practical value for developing-country application, however, and 25 percent of those relevant were unpublished documents obtained from private libraries. Thus the publication of this abstracted bibliography was a significant contribution for disseminating information on appropriate sanitation technologies for developing countries.

A second complementary input to the field studies was the work of the Ross Institute of Tropical Hygiene in London, England. Researchers there undertook an evaluation of the relationship of different technologies for waste disposal to specific categories of water- and waste-related diseases. Their analyses suggested that no simple ranking of waste disposal technologies according to their effects on community health is possible. While good sanitation is certainly an important factor in promoting good hygiene, a sophisticated and expensive sewerage system is neither a necessary nor a sufficient condition for high levels of general health.

Reports from the field studies and other inputs indicate that there are many technological alternatives between the pit privy and the complete sewerage system. Environmental sanitation can be significantly improved by the installation and proper maintenance of systems costing one-tenth to one-third as much per household than conventional sewerage. When combined with water supply systems by standpipe service, the transmission process of most water-related disease can be broken at significant savings.

The Dissemination of Research Results

The findings of the World Bank's research projects in water supply and waste disposal are disseminated in various ways to officials of member governments, professionals involved in the technical or financial aspects of investment and/or aid in the sector, and the Bank's operational staff.

A major concern is to establish the commitment of the governments of developing countries to the principle of providing safe water and adequate waste disposal facilities to all people in their countries, not just to the richer people in larger towns. This, in turn, often requires a decision to reorient investment and institutional planning, as well as to accept the need for low-cost technologies. In this respect, the Bank has made important contributions to international conferences, in particular to the UN World Water Conference held in Argentina in May 1977. At this conference, a resolution was passed that the 1980s would be known as the International Drinking Water and Sanitation Decade, and targets for access to service were set for 1990. Although the likely impact of such resolutions and targets should be assessed with caution, World Bank staff have already found increasing interest in the move toward 100 percent coverage for water supply and waste disposal in a number of member countries.

The World Bank has also taken steps to provide middle-level managers and engineers from the developing countries with the results of continuing research. Lectures and seminars have been (and are being) given by Bank staff to participants at the practical courses of the Economic Development Institute and the International Institute for Hydraulic and Environmental Engineering in Holland, as well as at OXFAM conferences and at the Ross Institute. The Bank has also financed workshops in Ghana organized by the International Reference Center and in francophone Africa by the World Bank/World Health Organization Cooperative Program Staff, and efforts are being made by seminars and other means to ensure that consultant firms working in the developing countries are kept up to date on World Bank work. Because of the importance of these techniques in disseminating research findings as widely as possible, World Bank staff are increasing their emphasis on presenting lectures and participating in workshops organized by professional groups.

The most important element in the dissemination process is the inclusion of pilot or demonstration schemes in World Bank projects. A major example of this is the loan for provincial regions of the Philippines (FY 1977), which included $200,000 for training local staff for operations in the rural areas. The Bank has arranged that a former staff member, an expert in water supply and public health and a well-known proponent of low-cost technology, will carry out this program. Under the Bank's loan to Nicaragua (FY 1978) for rural water supply and sanitation, the hand pumps and well screens developed under Bank research projects, as well as the wooden bearings for pumps, are being tested. The U.S. Agency for International Development (USAID) and the UN International Children's Fund (UNICEF) are also proposing the trial installation of the PVC screens in wells in several countries.

An integral part of the Bank's preparation for future loans in the sector is an appraisal of how research results can be translated into practice. To this end, the Bank has joined forces with the UNDP to implement a global project, costing about $750,000, designed to demonstrate the feasibility of low-cost water and sanitation techniques in rural and urban fringe areas. This will be achieved through the development of prototype systems in consultation with local communities and using local consultants. The methods identified consist of technologies that will reduce the costs of providing water supply and sanitation services, simplify operation and maintenance, and be socially acceptable to the intended beneficiaries. The project emphasizes the training of local consultants and community workers in low-cost water and sanitation technologies and will concentrate on projects that can be duplicated elsewhere.

The effect of the Bank's dissemination of research findings on low-cost technology for water supply and waste disposal will be seen in its sectoral

lending program during the coming years. How quickly this happens will depend on the Bank's ability to encourage greater government commitment to providing services for the poor, on the degree of community participation in construction and maintenance programs, and on the absorptive capacity of backup organizations. Results so far indicate that the elapsed time between obtaining research findings and their practical implementation is relatively short; thus there should be a substantial increase in projects incorporating these new technologies during the coming years.

Sector Strategy and Finance

Any strategy for the development of the water supply and waste disposal sector must dovetail with the government's strategy for the economy as a whole. At the least, it should imply a recognition by the government of the roles played by this sector and a commitment to establish or strengthen sector institutions, allocate appropriate investment funds for the sector, and ensure adequate funding for operation and maintenance; otherwise the quantity and quality of water supply and waste disposal facilities will become an ever-larger constraint on social and economic development. Although every country has many priorities besides water supply and waste disposal, methods must be found to ensure that investments in this sector can compete for funds against other investment priorities.

In this respect, mention should be made of four rules, which appear to apply generally in the sector. First is that the systematic development of source works, together with construction of transmission and distribution networks, has to occur before the final consumer can be provided with service. Second, domestic consumption of water is usually a small part of total consumption. Third, there is a ratchet effect in levels of service such that, once house connections for water supply are available to consumers, it is usually politically impossible to downgrade their supply to, say, communal standposts (or to reallocate shortages) and may well be technically impossible if the water supply is associated with sewerage connections since the sewers will not work without adequate water supply. Equally, it is inequitable to refuse house connections to new applicants who can afford to pay the costs (in practice, such people will usually find a way to obtain an illegal connection if a legal one is denied to them). Fourth, it is usually politically and economically impossible (or self-defeating) to attempt to provide levels of service for the poor that are better than those for the not-so-poor.

With these rules in mind, the first step in developing a sector strategy is to recognize that for most water supply and waste disposal undertakings, there is a long lead time—seven to eight years from identification of a project

to full implementation. The five-year time horizon of most development plans is not sufficient for the sector and should be extended to about fifteen years. Second, it is essential to produce a systematic framework for sector development, starting from the water sources to be used, through the mains transmission networks, to the final elements of the distribution networks, with an analysis of the implications for waste disposal at all stages.

Third, a decision should be taken, in view of other developments in the country, on the types of service to be provided at different stages in the investment program and the ways these will be upgraded over time. This is to ensure that source and transmission mains investments for one type of service will be suitable and economic for an upgraded type of service. For example, for a city with 20 percent of the population having access to house connections, 20 percent to patio connections, and 60 percent to standposts, a certain size of source and transmission mains may be appropriate. If, however, it is intended to upgrade this service to, say, 60 percent house connections, 30 percent patio connections, and 10 percent standposts, this may, because of the higher levels of essential water now required, make this same investment in source and transmission mains inadequate.

Fourth, it is necessary to determine the extent and coverage of investment within the distribution networks. Some water supply and waste disposal undertakings provide only the transmission mains, leaving the costs of investment in small distribution networks, including house connections and/or meters, to the final consumer; for others, investment includes all items in the distribution network up to and including the meters in patio or house connections. In the former case, it is clearly necessary to assess the ability of households to provide their share of the investment; if such investment is not affordable by all, it may well be that unexpected surplus capacity will exist in the water supply system.

Use of different types of technology and service standards for water supply and waste disposal often implies different types of institutional arrangements. For example, maintenance of a small rural water supply scheme may be best organized through an informal arrangement in the villages concerned; waterborne sewerage, however, must usually be organized by a government or semigovernment institution; simple well protection or cartage of human waste may be carried out by extension agents of the government or by the private sector. The range of organizational structures is wide, although, as the Bank puts greater emphasis on new-style projects in the water supply and waste disposal sector, it is likely that existing organizations in developing countries will be asked to make loans to less formal organizations. Already, Bank loans are being channelled to individuals for house connections and to village committees for small rural projects, and this process will gain momentum.

An important element in the development strategy of the water supply and waste disposal sector is the scope for cost recovery through tariffs and other charges. With respect to tariffs, there are two major factors. First, the revenue base of the entities providing the service is usually fairly limited (in other words, there are large numbers of potential consumers with relatively low incomes, and therefore the amount they can afford to spend on these services is limited). Second, demand for these services is increasing rapidly, not only because of rapid population growth and the effect of rising levels of income but because the increasing density of population in communities is threatening the adequacy of existing services.

Since it is difficult to measure the benefits of water supply and waste disposal, and these difficulties are compounded when comparisons are attempted between the benefits accruing to consumers as a result of different types of technologies (for example, between waterborne sewerage and on-site disposal of human waste), standard cost-benefit approaches cannot normally be used. Consequently, greater emphasis is placed on pricing policies that, on average, relate tariffs to the long-run incremental cost of supplying the service. Such a policy provides a means of signaling the justification for an expansion of service, as well as establishing a benchmark by which other social or economic objectives may be evaluated.

There are also operational problems in using the concept of marginal cost. One problem is how to deal with the costs of large increases in the source, transmission, and distribution capacity of a particular system. There is no fully satisfactory answer to this problem, and, as a compromise, the operational definition normally comes down to an estimate of incremental operating and capacity costs averaged over time.

A second problem is that marginal cost pricing may not produce adequate financial results since it ignores sunk costs and so may lead to operating deficits. As a practical matter, it is usually essential to ensure that the entity is financially viable and financially independent. This means that it should earn a positive return on its assets (preferably one that equals or exceeds the opportunity cost of capital) and should be able to finance all (or a significant part of) future investment. Linking marginal cost pricing and financial viability often can be achieved through designing a tariff structure that takes into account what various groups of consumers can afford while aiming at an overall (weighted) average tariff level consistent with the two objectives. Such a structure normally consists of increasing block tariffs, with the richest consumers subsidizing the poorest or, at least, with the tariff for a basic minimum level of consumption for all being subsidized by higher charges for consumption in excess of this minimum amount. The extent of cross-subsidy within the tariff structure will depend on the amounts demanded by different types of consumers, if, as is often the case, over 80 percent of consumers account for less than 20 percent of consumption. The

other 20 percent may not have to be charged much in excess of marginal cost. An important point to note in this respect is that for efficient pricing and financial viability, a service must serve the rich as well as the poor.

The type of cross-subsidy used is linked to technology since the type of service determines the potential for obtaining revenue for that service. A metered house connection allows many options for charging consumers, ranging from a flat rate to variable charges for different quantities consumed. A nonmetered house connection or a patio connection generally must rely on a regularly collected fixed charge system, sometimes linked to the size of the property, the size of pipe, the number of fittings, or the estimated number of users. Charges for standposts can be levied according to the volume consumed (if there is an attendant) or per household in the area served. In many cases, however, the consumers pay no charges at all; all standpost consumption is subsidized by other users or paid for by the municipality or local government on a fixed-charge basis.

It is sometimes argued that economically efficient pricing in the water and wastes sector is a contribution to the overall economic efficiency of the country; however, this depends on a number of factors. First is the situation in other sectors; if these do not apply the same economic pricing principles, then there is no guarantee that an efficient tariff structure for water and wastes will increase national welfare. Second is the technical efficiency of the sector; if, as is often the case, a large part (20 to 50 percent) of the water produced is not paid for—because of leakages in the supply network, deliberate evasion of payment, or poor revenue collection procedures—then the subsidization of this amount by those who pay may actually reduce national welfare. Third, specific climatic, geographic, or temporal conditions may require special pricing arrangements if national needs are to be met efficiently. And fourth, a lack of sufficient general information among consumers about the personal and social benefits of proper water supply and waste disposal will affect their decision as to the willingness to pay for service and will thus affect the rationale behind marginal cost pricing.

There are difficulties in developing a suitable tariff structure for urban water supply; these are even greater for rural water supply and all types of waste disposal facilities. For many small rural water supply and on-site waste disposal schemes, which generally have a very high labor component, payment is most easily arranged through free labor provided by the consumer and, possibly, through a nominal (subsidized) charge for the materials required; in addition, the consumer may also be responsible for maintenance. For waterborne sewerage, it is usually easiest to put a surcharge on the water tariff to reflect the incremental cost of providing sewerage, even though this will still not justify the type of sewerage selected, nor, in many cases, will it give consumers a real opportunity to show willingness to pay.

The costs of water supply and waste disposal to consumers who have house connections are not always those of the tariffs alone. There is often a connection charge, which can range from a nominal amount to one that is so large that it effectively prevents some connections from being made. Thus a major issue, particularly in many urban areas, is who pays for the connection. There are two aspects to this question, depending on whether the charge is simply a reflection of actual costs of the connection or whether it represents a clearing price for queues of customers who can afford the connection. In the first instance, potential consumers may have to pay for parts of the system on the basis of accident or location (for example, the farther away a house is from the mains or the materials depot, the higher the cost) and the economies of scale (such as the savings on a once-for-all connection of all houses in a particular neighborhood) may be gained neither by the individuals nor society as a whole. If the government accepts the basic needs approach in water supply and assesses all benefits, properly weighted, relating to health, capacity usage, and so on, it will usually be found that if the water supply project is justifiable, then so is the financing by the water supply entity of house connections or at least of enabling house owners to obtain loans to finance the connections themselves. In the second instance, the queuing for the connection, and the apparent ability and willingness of consumers to pay for this connection, is a clear indication (in the same way as the ability and willingness to pay a higher tariff) of the need for an expansion of the supply system. Indeed, while the connection charge may assist financially the entity in the early stages, in the longer run it would be preferable to include all costs of expanding the system (including financing of the house connection) in the tariff.

In addition to house connections as part of the investment costs of any project, some provision should also be made (either through the establishment of specific funds or other means) for providing financial assistance for future house connections, as well as for minimal in-house installations. This is particularly important in low-income areas and is already standard practice in some development institutions, such as the Inter-American Development Bank.

Where service levels lower than house connections are considered, the main criteria in determining the type of service are the number of people to be served and the amounts they can afford to pay for service. Where even a basic minimum level of service cannot be paid by the consumer, the second criterion must be expanded to incorporate the potential for internal cross-subsidies.

The actual tariffs and charges set will depend on the financial goals of the entity, the social goals of the government, the economic analysis of the investment planners, the political viability of tariff changes, and the affordability of the tariffs by consumers. Consequently both the average level of

tariffs and their structure will be very much a matter of compromise among these various aims. Moreover, none of these various aims will be achieved unless revenues are actually collected for water consumed.

Conclusions

The Bank's lending program for water supply and waste disposal will expand rapidly during the next ten to fifteen years. Moreover, the structure of Bank lending in the sector will also change, with greater concentration, where feasible, on new-style projects aimed at providing affordable access to service for the poor in both rural and urban fringe areas. Obtaining the full health benefits of this investment will require an efficient, workable balance between the sectoral approach, through the handling of source development, transmission, and distribution of services in a vertically integrated manner, and the package approach, through the horizontal integration of water supply and waste disposal with health, education (including health education), shelter, nutrition, and environmental aspects. There are no simple rules of thumb that can be followed about the weight given to each approach in any given country; however, speed of action is essential when dealing with people who suffer from absolute poverty and are deprived of a basic minimum of services.

There are many advantages in a package approach, but access to service of any one element of the package must not be delayed while other elements are prepared unless it can clearly be shown that such a delay would be cost-effective. The water supply and waste disposal sector is clearly able to prepare, appraise, and supervise projects at a relatively low cost in terms of staff time, and it can deliver, on time, the necessary service to the target groups. With known and proved technology, there is an excellent chance that the objective of providing safe water supply and sanitary waste disposal facilities in the foreseeable future can be achieved.

Notes

1. See Robert S. McNamara's annual addresses before the board of governors of the World Bank since 1972.

2. *Measurement of the Health Benefits of Investments in Water Supply*, Public Utilities Report No. PUN 20 (Washington, D.C.: Energy, Water and Telecommunications Department, World Bank, 1976).

3. *Design of Low-Cost Water Distribution Systems,* Public Utilities Report No. RES 11, (Washington, D.C.: Energy, Water and Telecommunications Department, World Bank, 1977).

4. *A Hand-Pump for Rural Areas of Developing Countries,* Public Utilities Report No. RES 9(a) (Washington, D.C.: Energy, Water and Telecommunications Department, World Bank, 1978).

5. *Development of PVC Well Screens for Local Fabrication,* Public Utilities Report No. RES 14 (Washington, D.C.: Energy, Water and Telecommunications Department, World Bank, 1978).

6. *Testing of Wood Bearings for Hand Pumps,* Public Utilities Report No. RES 13 (Washington, D.C.: Energy, Water and Telecommunications Department, World Bank, 1978).

Sanitation Systems for Developing Countries

Charles G. Gunnerson

Between 1976 and 1978, the World Bank undertook a research project on appropriate technology for water supply and waste disposal. The need for the research and its implementation lies in the $60 billion estimated cost of providing safe water to those in developing countries who do not now have it and the additional $300 billion to $400 billion to dispose of this water if conventional practices are followed. Initial implementation of research findings is underway in cooperative World Bank–UNDP demonstration projects and in Bank-supported sector projects.

The long-range objectives of the research project were to improve the efficiency of the Bank's lending operations and to improve its ability to direct the benefits of its loans to the urban and rural poor. The immediate objectives were to determine the technical and economic feasibility of available options for water supply and waste disposal in developing countries, the economic and environmental systems effects of technologies that provide for conservation and recycling of water and other resources, and the scope for designing technical improvements of alternative technologies to improve their efficiencies or add to their transferability and acceptance. Emphasis was on sanitation, a necessary but insufficient requisite of good health, and its interrelationships with water supply and resource recovery.

The research methodology drew together local consultants and participants from fourteen countries at various stages of economic development and technological transition. Appropriate technology, according to the operational definition adopted in the project, is a replicable process or technique that provides a socially and environmentally acceptable and a technically upgradable level of service or product at the least social cost.[1] Lack of quantifiable health and other benefit information reinforces the need for careful and complete cost calculations that consider incremental costs to the economy rather than simply those to the ministry or utility. For this, shadow pricing of foreign exchange, unskilled labor, power, and other inputs is necessary. In addition, all costs to the householder, such as indoor plumbing and labor contributed for latrine construction, must be taken into account; for example, the economic cost of flushing water raises total sewage systems cost by 20 to 30 percent. Finally, adjustments must be made for unused capacity (which produces no benefits) during the early years of a large water or sewerage project when its costs are compared with those of small decentralized alternatives. The traditional methods of costing

used by engineers often ignore these factors and thus bias the choice of technology toward large capital- and import-intensive designs. The research results presented here will be most successfully applied when system stability is considered.[2] Environmental and technological descriptors of stable systems include small-scale, diffuse, diverging, redundant, separated from geophysical hazards (such as floodplains), recycling of materials (easy with carbohydrates, difficult with chlorinated hydrocarbons), conservation of energy, and matching of capacity to demand (where emphasis is on end use rather than supply). Socioeconomic descriptors include sustainability, emphasis on marginal rather than sunk costs, replicability, individual dignity (uniqueness, color), user access and participation in planning and implementation, indigenous innovation, high employment, entrepreneurship (as opposed to vertically integrated monopolies), good community health, low costs, and minimum service levels matched to basic needs.[3]

Service Levels

Water supply service levels establish sanitation service requirements. A safe, adequate water supply is also something people are willing to pay for.[4] It has not always been this way. In the first official British document to deal with sanitation for the working classes, Edwin Chadwick urged the installation of water systems under pressure not so much to provide a safe supply but to flush away the wastes.[5] This says that waste disposal, which on the average is invariably more costly than water supply, should be paid for proportionately by the user. But the user perceived a need for water only, not for its disposal. These perceptions became conventional wisdom when John Snow's classic work, written in 1854, showed the cause-and-effect relationship between a single polluted well and local incidence of cholera.[6] Costs of sewerage systems have accordingly been borne by the community through cross-sectoral transfers of funds. Because it is cheaper to treat water supplies than to treat wastes, investments in waste treatment are deferred, and streams and lakes that supply the water become polluted.

Water Supply Service Levels

In rural areas, domestic water may be carried as much as 5 kilometers. Distance affects the amount of time spent carrying water, but it has little effect on the amount of water used.[7] Although water use may be as little as 2 liters per capita per day (lcd), most people using water carried by householders or vendors from springs, wells, standpipes, or kiosks consume 20 to 25 lcd. The value of gathering at the village well has been overrated, at least in Central America where quarreling may dominate socializing.[8]

In fourteen cities of 150,000 to 12 million people where there are World Bank water supply projects, average use is 33 lcd from neighborhood standpipes and 120 lcd from yard or house connections. Corresponding ranges were 5 to 71 and 63 to 194 lcd, respectively. There are local areas where low or intermittent system pressures provide much less water. In areas with rainfall greater than 80 centimeters per year, there is no correlation between average water use and precipitation. Luxury consumption of water greater than 100 lcd is based on availability and convenience of house connections.

Household storage capacity for hand-carried or vendor-delivered water may be a limiting factor. Storage systems include pottery jars where water is cooled, rainwater catchments, and 55 gallon drums sometimes filled by hose from a nearby standpipe.[9] Available data on operations of water supply systems indicate that all essential public health benefits of a safe water supply are provided by water service levels of 20 to 50 lcd for drinking, cooking, utensil washing, bathing, and pour-flush toilets.[10] The amount used for bathing depends on the climate. In Moslem countries, estimated water use for ablutions and anal cleansing is 0 to 2.5 lcd, depending on availability. Water for laundry, garden and stock watering, and occasional stock washing (as in Egypt) often requires higher service levels or alternative sources of supply.

Sanitation Service Levels

In the twenty-five communities, no consistent relationship was found between areal use and sanitation systems except for three similar Southeast Asian communities with 160, 180, and 207 lcd, and on-site systems for 90, 66, and 47 percent of the populations, respectively. As water service levels exceed 50 to 100 lcd, off-site disposal of sullage (grey water), often combined with sewage, becomes necessary.

Health Aspects of Service Levels

Improved community health is generally considered the major benefit of improved sanitation; however, repeated attempts have failed to establish quantitative relationships between these benefits and sanitation costs. Fortunately, achieving rather than merely measuring benefits is the primary objective of improved sanitation.[11]

The risks of infection from human feces are well known. Urine is ordinarily sterile, the only exception being in areas where urinary schistosomiasis is prevalent. Feachem and his colleagues have summarized current knowledge of excreta-related diseases, their environmental charac-

teristics, and the effectiveness of alternative sanitation systems in preventing them.[12] All of these diseases can be controlled by the physical separation of feces and people. This means that with proper operation and maintenance of toilets and surrounding areas, all types of sanitation can provide the same health benefit to the user. In practice, because of aesthetic, cultural, and operating requirements, household systems in which odors are vented outside of the latrine and from which insects are excluded tend to be better maintained.

The fecal hazard of sullage has yet to be demonstrated. Crude estimates assuming a high value of 150 lcd of sullage and based on U.S. data indicate that per capita discharges of the bacterial pollution indicators, fecal coli and fecal streptococci in sullage, are 10^6 and 10^5 bacteria per day, respectively.[13] If these indicative values are generally representative of pathogenic bacteria concentrations, they would constitute approximately one median infective dose per capita contribution of sullage. Corresponding per capita discharges in feces are approximately 5×10^{10} and 10^9, respectively—some four or five orders of magnitude greater than those for sullage. This means that even though ratios of pathogens to indicators may be higher for sick people than for healthy ones, relative risks of infection from nightsoil or sewage are four or five orders of magnitude greater. This is consistent with case study results about possible differences in health profiles between people living in sewered areas and in adjacent areas with nightsoil collection and sullage discharge to surface drains.

Some concern has been expressed over a possible contribution by sullage to increased populations of the mosquito, *Culex pipiens,* which breeds in polluted water and is a vector of filariasis.[14] A good theoretical case can be made for this concern, although no field evidence to support it has been accumulted to date even though sullage and sewage treatment plant effluent are being used for garden watering and green-belt irrigation in North Africa and elsewhere. The potential importance of sullage to mosquito breeding is determined by environmental factors such as low aridity and local soil permeability, which allow the water to remain on the surface long enough to permit mosquito breeding. Where there are extended periods of relative drought, persistent surface impoundments of sullage could contribute to extending periods during which mosquitoes normally breed. In sum, while disposal of large amounts of sullage resulting from high water service levels may require sewerage in densely populated areas, in areas of lower water consumption and/or lower population density, the problem of sullage is a low-priority one.

Community Access and Participation

Community access and participation in selection of service levels, implementation, and capital recovery elements of sanitation programs are es-

sential. Specific objectives of community participation are the selection of technologies that are acceptable to the community and offer the benefits they consider important at a cost they can afford, can be operated and maintained by the local community with minimum input from outside agencies, and use the most effective materials and methods of construction.

Work toward achieving these objectives begins in early planning and feasibility study phases and includes identification of formal or informal community leadership and communication channels; determination of existing practices in water use and excreta disposal and the community's attitudes toward them; determination of the community's willingness to pay for desired improvements through cash contributions, labor, or materials; organization and execution of any agreed self-help construction input; and operation and maintenance of communal facilities, assistance to users in maintaining individual facilities, and collection of funds.[15]

Six tasks have been identified as the minimum for a community participation program that leads to a successful project:

1. Unstructured interviews with community leaders and a limited number of users to identify user attitudes and preferences.
2. Design and testing of a questionnaire for structured interviews.
3. Structured interviews with a representative sample of households.
4. Presentation of feasible technologies with their costs to the community or its leaders to determine willingness to pay.
5. Organization of construction and execution of the work.
6. Continued operating, maintenance, and monitoring activities, including the assessment and collection of fees.

The first three tasks should be undertaken at the beginning of project development, the fourth toward the end of the selection phase, and the final two scheduled to meet technical requirements and community work patterns.

In sum, community participation and assessment of the willingness to pay for improved service levels depend on both household income levels and perceived needs. The assessment is affected by the accuracy, completeness, and timeliness of information exchanged between the residents and those who are conducting the feasibility study. Analysis of social factors and conduct of interviews should be the responsibility of people accepted by the community or by members of the community; they are too important to be entrusted to strangers.

Institutional Factors

The constraints imposed by limited management and technological skills are well known. It is occasionally assumed that sewers require management

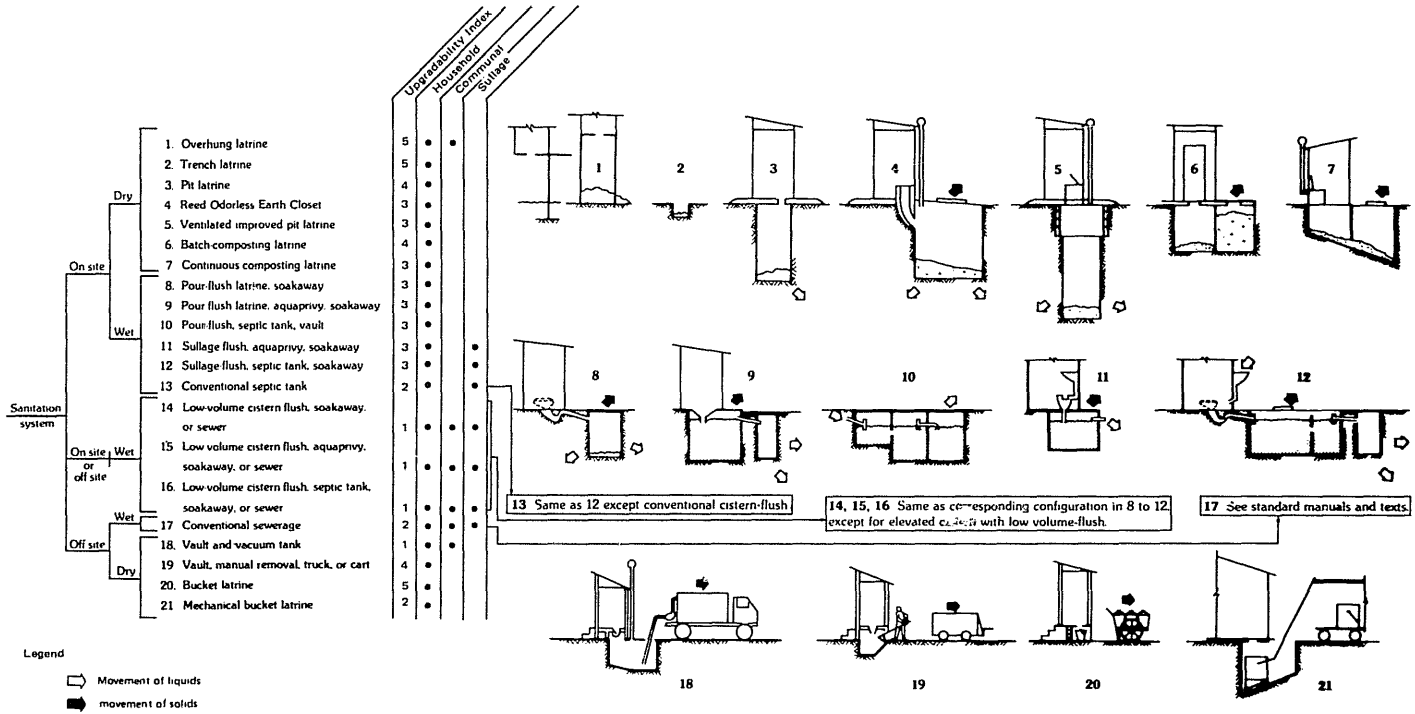
skills only during their construction period and that thereafter they work by gravity. Only rarely is this so; more commonly, they become clogged by excess solids or too little water, their surfaces or joints may corrode and fail so that groundwater infiltrates and sewage exfiltrates, or else the street surfaces above them collapse because of inadequate inspection and maintenance. In contrast, adequate institutions can make the simplest and least costly systems work.

Other institutional matters include cost recovery (and water conservation) by means of increasing block tariffs for water and assurance of land tenure before evaluating willingness to pay. Terms of reference for engineering feasibility studies or design services can be expected to include the following: fees based on time and materials rather than on a percentage of construction costs; additional funds and time for an effective counterpart training component, which is part of a much broader continuing national training program; an increase in fees (but no increase in time) for interdisciplinary development of community willingness to pay; and the requirement for financial and economic comparisons of alternative technologies and potential upgrading sequences and schedules.

Alternative Sanitation Technologies

Basic design factors for sanitation systems include 0.8 to 1.2 lcd of excreta, with as much as 1.8 lcd in areas with vegetarian diets. Traditional and potential anal cleansing materials must be considered. Water-seal toilets ordinarily will not accept rocks, mudballs, maize cobs, large leaves, or similar materials; the only exception is the aquaprivy. Water use for anal cleansing varies from 2 to 5 lcd where water is carried to 30 or more liters per latrine per hour with continuous-flow piped systems. Pour-flush toilets requires 3 to 6 lcd. Excreta from dry systems can be readily composted with minimum amounts of dry cellulosic material such as straw, ricehulls, and wood chips, for bulking. Anaerobic composting (generally greater than 20 percent solids) or digestion (generally less than 10 percent solids) is feasible with low water use. High water use requires treatment (for example, by oxidation ponds), pretreatment, and ocean discharge, or some combination of treatment and disposal systems.

The generic classification system shown in figure 8–1 includes only systems that are in use and systems with minor modifications to those in use. It does not include exotic household schemes such as incinerating or recirculating toilets, which are too expensive and too energy intensive, or systems for adding proprietary microbial cultures or enzymes. System suitability for household or community excreta disposal and for sullage (grey water) disposal is indicated. Change from a communal to a household system ordinarily will be preferred by the user because of the additional privacy it affords. Other examples of sanitation-upgrading sequences are



Adapted from: World Bank, Water Supply and Waste Disposal. Poverty and Basic Needs Series (Washington, D.C., September 1980).

Figure 8-1. Generic Classification of Sanitation Systems

presented in the concluding section of this chapter. Meanwhile, some generalizations about major classifications can be made:

On-site systems are appropriate where water use is low or where sullage is disposed of separately.

On-site systems, because they are dispersed, have less environmental impact than off-site systems.

On-site systems are generally preferable where population densities are low.

Costs of off-site systems are generally higher than for on-site.

Institutional and management strengths are more important for off-site systems.

Dry systems offer the same health benefits and are ordinarily less costly but require the same user care and efforts as wet systems.

Off-site systems generate more employment.

Actual costs are country specific, so a particular technology may fall into either the low- or medium-cost category. Table 8–1 summarizes the costs of technologies studied in detail by the Bank's research project. For low-income households, low-cost sanitation systems ranged from 2 to 6 percent of average household income. Corresponding costs for high-cost systems were 9 percent for a communal toilet and 10 percent for a household composting toilet.

Case study data from Kyoto, Japan, are revealing. This historic city has a modern, well-operated water supply and sanitation system. Of a population of 1.5 million, 41 percent are served by sewers, 41 percent by vaults and vacuum trucks, 15 percent by septic tanks, and 3 percent by other means. Sewage and diluted nightsoil are treated by conventional activated sludge with sludge incineration. Total 1978 annual costs per household were $641 for sewerage, of which $79 was for flushing water, $172 for vaults and cartage, and $390 for septic tanks. Health and environmental benefits were the same for all systems. No differences in health profiles were found among residents in areas served by sewers or by vaults and cartage. Although sullage from the latter areas necessarily discharges to surface drains and streams, no differences in stream water quality were found, except for the point-source effect of the sewage treatment plant discharge. Stated reasons for changing from nightsoil collection systems were the same in Kyoto as in other Asian cities: difficulties in obtaining nightsoil collectors, the unwillingness of farmers to use nightsoil, and the desire for modern convenience. Staffing may be more of a long-range planning problem than a current

Table 8–1
Financial Requirements for Investment and Recurrent Cost per Household
(1978 dollars)

	Total Investment Cost	*Monthly Recurrent Cost*	*Monthly Water Cost*	*Hypothetical Total Monthly Cost*[a]	*Percentage of Income of Average Low-Income Household*[b]
Low cost					
Pour flush toilet	70.7	0.2	0.3	2.0	2
Pit latrine	123.0			2.6	3
Communal toilet[c]	355.2	0.3	0.6	8.3	9
Vacuum truck cartgage	107.3	1.6		3.8	4
Low-cost septic tanks	204.5	0.4	0.5	5.2	6
Composting toilet	397.7	0.4		8.7	10
Bucket cartage[c]	192.2	2.3		5.0	6
Medium cost					
Sewered aquaprivy	570.4	2.0	0.9	10.0	11
Aquaprivy	1,100.4	0.3	0.2	14.2	16
Japanese vacuum truck cartage	709.9	5.0		13.8	15
High cost					
Septic tanks	1,645.0	5.9	5.9	25.8	29
Sewerage	1,478.6	5.1	5.7	23.4	26

Source: J.M. Kalbermatten, D.S. Julius, and C.G. Gunnerson, *Appropriate Sanitation Alternatives: A Technical and Economic Appraisal*, World Bank Studies in Water Supply and Sanitation (Baltimore: Johns Hopkins University Press, 1982, p. 64).

[a]Assuming investment cost is financed by loans at 8 percent over five years for the low-cost systems, ten years for the medium-cost systems, and twenty years for the high-cost systems.

[b]Assuming average annual income per capita per capita of $180 and six persons per household.

[c]Based on per capita costs scaled up to household costs to account for multiple-household use in some of the case studies.

operating one; working foremen in Japan, Taiwan, and Korea reported that they could hire enough workers for the task. The changing value of nightsoil as a resource was more elusive. In Southeast Asia, it is frequently used as a fertilizer for fish ponds, and in both mainland and island countries it is used, sometimes with animal manures, to generate methane (biogas). Significantly, farmers in and around Kyoto, after having reportedly used chemical fertilizers for many years, are beginning to revert to the ancient custom of making private arrangements with householders to remove their nightsoil for use as fertilizer and presumably to restore or maintain tilth of the soil.[16] In 1977, 8,000 household vaults were served in this way.[17] The desire for modern convenience is real, and as long as costs are internalized, it is an appropriate goal.[18]

Alternative Waste Treatment and Disposal Alternatives

A variety of alternatives for waste treatment and disposal are available.[19] Two that are particularly suited to developing countries are composting and stabilization ponds.

Recent developments in the United States for treating raw sewage sludge include successful use of a composting method that is equally applicable to sludge from septic tanks, digesters, or biogas generators or to nightsoil. A reliable and least-cost process is the Beltsville Aerated Rapid Composting (BARC) system developed at the U.S. Department of Agriculture's Agricultural Research Service Laboratories in Beltsville, Maryland.[20] The process is based on mixing sewage sludge with wood chips. Sawdust is added as an additional bulking material to absorb the greater amounts of liquid in the nightsoil. The BARC system has been used effectively to compost nightsoil from the National Capital Park Service latrines. The estimated 1977 cost of sludge composting with the BARC system was $35.40 to $46.40 per dry ton in a 10 ton per day plant. The system is suited for developing countries because of its simple operation of limited inexpensive mechanical equipment and because of its highly effective and uniform heat inactivation of pathogens, which makes the final compost safe from a public health point of view.

Nightsoil use as a fertilizer in agriculture as practiced in China and other Asian countries for centuries has helped maintain soil fertility in intensively farmed areas. Recent reports indicate that one-third of the fertilizer requirements of agriculture in China has been provided by recycled nightsoil.[21] The public health problems in nightsoil treatment are severe, however; research has amply demonstrated that nightsoil and sewage sludge carry high concentrations of the full spectrum of pathogenic bacteria, viruses, protozoans, and helminths endemic in the community, many of which are

highly resistant to conventional nightsoil and sewage sludge digestion and storage.

From a survey of the literature on nightsoil treatment, it can be concluded that the only safe nightsoil treatment method that will ensure effective inactivation of helminths such as *Ascaris* eggs and all bacterial and viral pathogens is heat treatment to a temperature of 60°C for several hours or 50°C for several days.[22]

Stabilization ponds are indicated for treatment of sewage from pour-flush or cistern-flush sanitation systems or for diluted nightsoil. Space may be limited in areas of high population density. To ensure an essentially pathogen-free effluent requires five ponds and a total detention time of fifteen to thirty days. During this period, wastes are stabilized by bacteria and algae. Pathogens are removed from the water by ingestion into pond bacteria or by sedimentation. Sludge removed periodically can be stored for at least one year to ensure pathogen inactivation, or it can be composted.

Effluents from well-operated conventional secondary treatment plants discharged to streams cause generally minor local pollution. Discharges to lakes may create undesirable changes in aquatic life because of their fertilizer content. Land disposal for treatment or irrigation in industrial countries or for direct reclamation by sewage farming in developing countries is practiced throughout the world.

Ocean disposal is a viable alternative for coastal communities. Requirements for domestic waste treatment are usually met by screening, occasionally supplemented by flotation. Outfall locations, depths, and configurations are determined by site-specific beach use, initial dilution requirements, currents and travel time waves and tides, absence of shell fisheries, and the rates at which bacteria from the effluent disappear from surface waters. This disappearance depends primarily on sewage characteristics and treatment, followed by sedimentation and then by mortality factors, such as by sunlight, competition, and predation. Dilution in the open ocean, which follows initial dilution over the outfall, is a minor factor, and expensive determination of eddy diffusion coefficients is more of an exhilarating academic exercise than a study of a controlling factor. Lowest system costs may be realized by a series of outfalls rather than by assembling flows with expensive interceptors and then dissassembling them with expensive diffusers.

Ocean disposal is an inherently flexible option; it can be relocated, expanded by additional outfalls, or modified by additional treatment as funds permit and needs for upgrading require.

Reclamation Alternatives

Reclamation of energy by methane (biogas) generation from anaerobic digestion of animal or plant wastes is an increasingly viable option as fossil

fuel prices increase. At the household level, it may require too high a capital investment, and at the municipal level it may involve excessive methane transmission costs. The optimum size for neighborhood or community systems is probably site specific but as yet undetermined; in some cases it would properly include dung, otherwise used directly as fuel. Indirect fuel production from effluent irrigation and fertilization of grasses and fast-growing shrubs may be appropriate along desert margins.

Irrigation and fertilization of food or fiber crops is widely practiced, the main concerns being public health ones, which can be quickly dealt with by stabilization ponds and aerobic composting. Intermittent requirements for either water or fertilizer may necessitate storage facilities, however.

Fish ponds can be fertilized by human or animal wastes with sustained yields of 2 to 20 tons per hectare per year depending on the sophistication of design and operations.[23] Alternative approaches suggested by figure 8-1 provide both immediate improvements and the assurance of future upgradability. A few of these are listed in table 8-2.

In sum, many technologies and service levels are available to meet perceived water and sanitation needs. Engineering feasibility studies should include comparisons of a spectrum of service levels and alternative technologies, assessment of community willingness to pay, and economic as well as financial costs. Engineers should not design water systems and rate structures without regard to waste disposal requirements, nor should sewerage systems be planned without considering marginal costs of flushing water and unused capacity. Least-cost solutions are those in which capacity closely matches demand, a requirement that is met more easily in dispersed systems than in centralized ones.

Table 8-2
Some Alternative Upgrading Sequences for Sanitation Systems

Classification	*Technology*[a]
Off-site to off-site	Bucket latrine (20) to vault with manual removal (19) to vault with mechanical removal (18)
Off-site to on-site	Bucket latrine (20) to ventilated improved pit latrine (5) to pour-flush or sullage-flush with soakaway (8 or 12)
On-site to on-site	Pit latrine (3) to ventilated improved pit latrine (5) to Reed Odorless Earth Closet (4) to sullage-flush latrine with septic tank (12)
On-site to off-site	Ventilated improved pit latrine (5) to vault and vacuum truck (18) to small bore sewers (14)
On-site to off-site	Low-volume cistern flush with soakaway (14) to low-volume cistern flush with sewer (14)

[a]Identification numbers from figure 8-1.

Pigs provide for direct conversion of animal and human feces to protein and in some Central American, Southeast Asian, and South Asian communities, for collection and transportation and aesthetic (if not completely hygienic) factors as well. Less well documented are reports of similar saprophytic attention from goats, cattle, dogs, fowl, and birds. Both engineered and inadvertent recycling and reclamation of resources augment system (or ecosystem) stability.

Sanitation System Selection

The dependence of sanitation technologies on water service levels has been stressed throughout this chapter. The average costs of this dependence are clearly revealed in table 8-3. Costs of 20 lcd from standpipes at 1 meter or 50 meters radius from the household with on-site disposal are compared with 100 lcd from a yard or house connection and sewers. At 20 lcd, sanitation costs averaged 3.3 times water costs, and at 100 lcd, the ratio is 4.4 to 1. These ratios are consistent with those from Caminos and Goethert and from a number of more recent Bank projects for upgrading low-income areas.[24] An extreme case is found in one Middle Eastern capital city where plans are being implemented for initial construction of sewers at $1,000 per capita, some ten times the annual GNP per capita.

Problems may arise when gradual improvements are made to water system service levels to the point where there is too much sullage for on-site disposal; a $25 per capita water improvement may carry with it a future $250 per capita obligation to provide sewers or other drainage for sullage.

Table 8-3
Estimated Average Water and Sanitation System Costs in 1978
(U.S. dollars per household for water service levels of 20 to 100 lcd)

	Water Service Level		*Average Costs per Household*		
Population per Hectare	*lcd*	*Average Radius (meters)*	*Water Supply*[a]	*Sanitation*	*Total*
100	20	0	52	70	122
	20	50	116	70	186
	100	0	425	1,500[b]	1,925
350	20	100	23	70	93
	20	50	51	350	401
	100	0	310	1,500[b]	1,810
800	20	100	10	107	117
	20	50	25	355	380
	100	0	178	1,500[b]	1,678

Source: World Bank, 1980.

[a]Distribution costs only.

[b]Gravity sewers, no rock excavation, minimum treatment, and marginal costs of flushing water.

Notes

1. L. Squire and H. van der Tak, *Economic Analysis of Projects* (Baltimore: Johns Hopkins University Press, 1975).

2. I am indebted to former associates at Stanford Research Institute, Menlo Park, for this simplified model, many elements of which are restatements of the first and second laws of thermodynamics and their ecological derivatives that energy flows and materials recycle. Other sources include E.F. Schumacher, *Small Is Beautiful* (New York: Harper and Row, 1973); N. Jéquier, ed., *Appropriate Technology: Problems and Promises* (Paris: Organisation for Economic Cooperation and Development, 1976); and A.B. Lovins, "Scale, Centralization and Electrification in Energy Systems," in *Future Strategies for Energy Development* (Oak Ridge, Tenn.: Oak Ridge Associated Universities, 1977), pp. 88–172.

3. Lovins' "Scale," further characterizes sustainability as "more important than the momentary advantage of any generation or group [so that] long-term discount rates should be zero or slightly negative, reinforcing a frugal (though not penurious) ethic of husbanding."

4. Adequacy is subjective. Three liters per capita per day (lcd) will sustain life, 20 to 30 lcd provide all of the health benefits of a safe water supply, and larger amounts provide for convenience. Flushing of wastes is obviously to be preferred to earlier tossing them from Edinburg windows or wrap-and-toss systems of some East Asian and North African urban areas. However, flushing has historically been a luxury made possible during exceptional times such as the expansion of the Roman Empire from the fourth century B.C. through the first century A.D.; in nineteenth-century England when revenues of the East India Company were diverted to the crown; and during the twentieth century's unprecedented economic development of North America and northwestern Europe.

5. Edwin Chadwick, *Report on the Sanitary Condition of the Laboring Population in Great Britain* (1843; reprint ed., Edinburgh University Press, 1965).

6. John Snow, *On the Mode of Communication of Cholera* (London, 1855) reprinted in *Snow on Cholera* (London: Oxford University Press, 1936).

7. G.F. White, D.J. Bradley, and A.U. White, *Drawers of Water* (Chicago: University of Chicago Press, 1972).

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9. M. Elmendorf and P.K. Buckles, *Socio-Cultural Aspects of Water Supply and Excreta Disposal,* PU Report No. RES 15 (Washington, D.C.: Energy, Water and Telecommunications Department, World Bank, 1978).

10. White, Bradley, and White, *Drawers of Water.*

11. J.M. Kalbermatten, D.S. Julius, and C.G. Gunnerson, *Appropriate Sanitation Alternatives: A Technical and Economic Appraisal* (Washington, D.C.: Energy, Water and Telecommunications Department, World Bank, 1978).

12. R. Feachem, D.J. Bradley, H. Garelik, and D. Mara, *Health Aspects of Excreta and Sullage Management* (Washington, D.C.: Energy, Water, and Telecommunications Department, World Bank, 1978).

13. Kalbermatten, Julius, and Gunnerson, *Appropriate Sanitation Alternatives.*

14. R. Feachem et al., *Health Aspects of Excreta and Sullage Management,* op. cit.

15. This approach has been developed in part from that proposed by A.U. White and G.F. White, "Behavioral Factors in Selection of Technologies," in C.G. Gunnerson and J.M. Kalbermatten, eds., *Appropriate Technology in Water Supply and Waste Disposal* (New York: American Society of Civil Engineers, 1979).

16. M.G. McGarry, M. Stainforth, and T.L. Lee, eds., *Compost, Fertilizers, and Biogas Production from Human and Farm Wastes in the Peoples Republic of China,* Tech. Ser. 8a (Ottawa: International Development Research Centre, 1972); and M.G. McGarry, *Developing Country Sanitation* (Ottawa: International Development Research Centre, 1972).

17. See Kalbermatten, Julius, and Gunnerson, *Appropriate Sanitation Alternatives.*

18. Robert C.T. Lee, personal communication, Taipei, Taiwan, 1967, observed that when a country passes from agricultural support of industry to industrial support of agriculture, the nonfarm income of farm families begins to exceed their farm income, and they lose interest in using nightsoil. The opportunity costs of their labor increase and chemical fertilizers are more convenient.

19. *Appropriate Sanitation Alternatives: A Field Manual* (Washington, D.C.: Energy, Water, and Telecommunications Department, World Bank, 1978).

20. E. Epstein, G.B. Willson, W.D. Burge, D.C. Mullen, and N.K. Enkiri, "A Forced Aeration System for Composting Wastewater Sludge," *Journal of the Water Pollution Control Federation,* no. 48 (1976):688–694.

21. McGarry, Stainforth, and Lee, eds., *Compost.*

22. H.I. Shuval, C.G. Gunnerson, and D.S. Julius, *Nightsoil Composting*, N.P. Report No. RES 12(a) (Washington, D.C.: Energy, Water and Telecommunications Department, World Bank, 1978).

23. M.G. McGarry, *The Importance of Water Reuse* (Ottawa: International Development Research Centre, 1978).

24. H. Caminos and R. Goethert, *Urbanization Primer for Design of Sites and Services Projects* (Washington, D.C.: World Bank, 1975).

Urban Shelter and Community Development

Herbert H. Werlin

The urban population of the developing countries is expected to continue to grow by more than 4 percent a year in the next fifteen years, and in many large cities its rate of growth exceeds 6 percent, which corresponds to a doubling in the size of urban areas over a decade. To accommodate this growth with permanent conventional housing of even minimum cost standards is virtually impossible, given the limited resources that are available. Currently the supply of such housing is generally only a fraction of the increase in the number of urban families. Except in some of the richer developing countries, most urban families cannot afford conventional housing unless it is very heavily subsidized by public authorities, which will be able to pay for only relatively small programs.[1]

During the 1970s, the World Bank launched more than thirty urban development projects aimed at helping almost 6 million poor urban dwellers. These sites and services and slum upgrading programs have pioneered what increasingly appears to be a feasible alternative to conventional slum clearance programs and low-cost housing schemes. Sites and services basically involve the subdivision of urban land and the provision of a number of public utilities and services, as well as community facilities for residential and commercial use. Slum upgrading essentially is the improvement of that area's undesirable physical and social environment. Developing countries increasingly are adopting these two approaches of the World Bank to urban development problems, and this chapter describes some of these projects, which represent one of the largest-scale applications of appropriate technology. These two approaches are probably important social innovations in their own right. From a technological point of view, they are also interesting in that they show clearly the interdependence between the hardware of a project (physical infrastructures and equipment) and its software (organizational forms, pricing mechanisms, and legal arrangements, for example).

Evolution and Design of Sites and Services Projects

The primary reason for setting up sites and services projects is to provide shelter for urban dwellers unable to afford conventional public housing

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units. The number of people in such a situation is usually very high; in most cities of the developing countries, it represents between 50 and 80 percent of all residents. Systematic large-scale sites and services projects for the benefit of the poor are of relatively recent origin, and their development has been greatly influenced by the writings of such people as Charles Abrams, John Turner, and Otto Koenigsberger and by the initial experiments conducted in the 1960s in India, Latin America, and East Africa.

Many of the early projects were undertaken carelessly and reluctantly. They were seen as a temporary or intermediate stage between slum-clearance programs and public housing projects. Leaders feared that site and service schemes would perpetuate the slum conditions and shanty dwellings that they were anxious to discourage. Consequently these early experiences tended to be negative. The sites chosen were either difficult to develop or far removed from employment opportunities. In some cases, security of tenure was not guaranteed. In others, excessive arrears were allowed to accumulate. Administration and maintenance were often inadequate. As a result, projects tended to deteriorate, reintroducing hostile official attitudes.

Economic, administrative, and political problems continue to haunt site and service projects. Some countries are unable to acquire adequate and suitable urban land at a reasonable cost. The tendency also remains to provide too high a service level, given the income of the beneficiaries, or to impose inappropriate standards. The lack of experienced and qualified technical staff, the weakness of local government, the unwillingness or inability to delegate responsibility for decision making, and the failure of public communication have been factors in delaying action.

Recently, however, there has been a dramatic turnabout through much of the developing world in official attitudes toward site and service projects. For example, Kenya, heartened by the success of its initial efforts in this area, is now planning its second World Bank-supported project. This change in attitude largely can be attributed to better recognition of the types of problems likely to be encountered in such projects and to the consequent improvement in their design and execution. This is perhaps best illustrated by a few examples.

Zambia, among other countries, has shown the value of initially keeping standards as low as possible, while making provision for upgrading standards as household incomes increase. The so-called basic plots, consisting of communal water supply and pit latrines, cost only $750, compared to $1,320 for the least expensive normal plots, containing individual water and sewer connections. As such, they can reach the lower-income groups with the greatest need for housing. At the same time, they are viewed as an initial stage of phased servicing, which, depending on occupant demand, could lead to eventual normal servicing standard.

In Usulutan, El Salvador, the population showed little interest in a site and service project because it was easier and cheaper for people to buy an illegal plot from a local landowner. Since distances from the pirate subdivisions to town are short and water is easily available from shallow groundwells, the advantages of the official project, which included larger open areas, piped water, and waterborne sewage, were not worth the price difference. Based on this experience, the agency in charge of such projects (the Fundación Salvadoreña de Desarrollo y Vivienda Mínima, or FSDVM) now undertakes a market survey prior to each site development to determine alternatives and preferences to tailor supply to demand better. Typically these surveys cover the residents' capacity to pay, their locational and design preferences, their needs, and the land market. After market surveys have been completed, FSDVM offers eligible residents the opportunity to select within city limits the size, cost, and service level of their plots. In addition to various lot options, participants in successful recent projects are allowed considerable autonomy in building their homes.

To keep site and service projects within the financial reach of low-income urban residents, many countries include a mixture of income groups. In Korea's Gwangju site and service project, for example, nearly 30 percent of the larger plots were auctioned off to residents. The demand for these market-priced plots was so great that the city has fully recovered the land and infrastructure costs for the entire site through the sale of the larger plots. As a result, the lower-income families have been charged a substantially reduced cost for their plots, with the net profit going into a revolving fund that will be used for similar projects. Another practice is to sell centrally situated land within the site to businesses or shopkeepers. In Lima's sites and services project, 161 of the 867 serviced plots have been set aside for the construction by self-help or multipurpose expandable shop cores. The presence of upper-income groups and businesses within a site and service area not only generates income and jobs but also makes the project socially and politically more acceptable.

For many years, government authorities have faced the accusation that their public housing and plot allocation processes are ethnically or politically biased. The Kenya government therefore developed certain procedures for its first World Bank-supported site and service project to ensure public confidence in the allottee selection process. First, persons wanting to acquire plots must prove that they have lived in Nairobi for at least two years with their families. Applicants also must prove that their incomes are below the Kenyan equivalent of $90 a month. For this purpose, a variety of documents are acceptable, including a letter from an employer, social worker, administrative officer, or minister certifying the applicant's length of residence and income.

Second, applicants must agree in writing to fulfill the requirement of living on the lot and to erect an acceptable structure within a certain period of time. They are prohibited from selling, transferring, or otherwise disposing of their rights to tenancy, except to the Nairobi City Council, for the first five years after acquisition. This regulation is intended to prevent plots being acquired for speculation, a situation that existed in Nairobi's Kariobangi Scheme where most of the allottees had sold their plots within a few years.

Third, the selection of allottees from among qualified applicants is accomplished by a computer through a random number program. Each step in the process is given as much publicity as possible. Prior to the final selection, the list of certified applicants and their application number is posted, and, as soon as the selection process is completed, the names and numbers of the allottees are made public.

Finally, allottees are required to pay the equivalent of $77 between the announcement of allocations and the date they occupy their lots. This deposit covers water and sewerage connection fees and is credited against the allottee's outstanding loan principal. The deposit represents a tangible commitment by the allottee and provides minimal security against which the initial loans can be made.

The importance of providing credit to occupants of project sites is now generally recognized. This can facilitate the construction of permanent dwellings and as such decrease the time required for the start of occupancy. Where, as in Lusaka, the majority of households use contract labor, the availability of credit can generate considerable paid employment. This has also been the experience in El Salvador, where over 40 percent of households employ other people to help finish their dwellings. Here, loans of between $50 and $260 are available for materials or labor necessary to construct, complete, or expand the core units in the FSDVM site and service projects.

Technical assistance is provided in many projects. In Zambia, building plans and artisans skilled in masonry, bricklaying, and carpentry are made available to participants. Periodic inspections ensure that participants' structures conform to minimum regulations. Community development staff assist participants in completing and improving their homes. In the Nairobi site and services project at Dandora, technical assistance, supervision, and retroactive loans have been successfully combined, accounting for the fact that within six months, nearly two-thirds of the 954 plots initially allocated contained completed and approved houses with one or more rooms. Following the selection by the allottee of one of the thirteen available plans and the approval of the first two rooms, a series of phased loans totaling over $400 becomes available.

In El Salvador, successful use has been made of collectors to reduce arrears. These collectors receive a bonus of a small percentage of amounts col-

lected over a fixed minimum. Families showing debts of over three months are visited by FSDVM staff to arrange an adjusted repayment schedule. After six months, cases are passed to the Legal Department to initiate foreclosure proceedings. A clear and reasonable compensation policy governs resales in such cases. In Zambia, each section leader of the United National Independence party, the sole political party, has been made responsible for the payment records of about twenty-five households. For this purpose, section leaders are expected to cooperate with city treasury representatives, to whom payments are made directly. Other measures taken by the Zambian government to reduce payment arrears and defaults include making eviction of tenants legally less difficult and restoring the local council's eviction authority.

Lessons from Eastern Africa and the Second-Generation Projects

The experience of the World Bank with four urban development projects that were substantially completed in the 1970s in Eastern and Southern Africa (Botswana, Kenya, Tanzania, and Zambia) have set the pattern for new projects now being implemented in countries that face similar problems of rapid urban growth, limited financial resources, rudimentary institutions, and inexperienced or untrained staff.[2] These new projects form what might be called the second generation and differ from their first-generation predecessors on five main counts: the emphasis on construction loan programs, the availability of a wider range of housing and infrastructural options, the supply of more appropriate community facilities, the improvement of employment opportunities, and the provision of better technical assistance.

To promote self-help building, some of the earlier projects provided loans for bricks, cement, and sand. In Botswana and Zambia, the loans were large enough to build two rooms in the serviced site areas. The loans were handled by the local authorities and distributed through a system of materials depots. Experience revealed, however, that most households used small contractors to build a major part of their shelters because of a lack of building skills or the shortage of time for this work. Consequently, in more recent projects, there has been a shift from materials loans to construction loans, thus enabling the participants to hire labor. In situations where shortages and high costs occur for materials such as cement, borrowers are given the option of cash loans or vouchers redeemable at materials depots.

The earlier projects concentrated on providing a few standard features: serviced sites for dwellings with minimum on-plot features, relatively low-cost infrastructure, inexpensive layout of plots, and convenient location for

employment and transportation. By 1975, urban projects began to include a wider mix of options. In some cases, higher-income groups are allowed to buy larger plots for residential or commercial purposes at the prevailing rates. The profits from these sales are then used to reduce charges imposed on impoverished families. To reach the very poor, an increasing effort is being made to provide only basic surveyed plots together with a communal water supply. Such an approach is being used in Tanzania to meet the needs of the bottom 20 percent of the urban population normally excluded from sites and services projects. Because of the number of options offered, it has been increasingly recognized that allottees need more guidance from the staff in selecting plans. Demonstration houses and classes for those interested are becoming more common.

Primary schools, dispensaries, community centers, and markets built in the first-generation projects used conventional standards as to numbers and types of facilities. In many cases, the standards were significantly above the low-cost, affordable standards agreed on for the other components. Consequently, more attention is now being paid to the development of simpler, more functional, and lower-cost facilities. At the same time, an effort is being made to build community facilities within which a number of services can be provided or integrated. While officials have often maintained a rigid position regarding standards, some have gradually come to recognize the benefits of flexibility. In Kenya, the Nairobi City Council eventually agreed to accept a low-cost primary school specially designed for the project. Because local acceptance was so widespread, the council has now adopted this design as its standard for primary schools throughout the city. Another approach is to upgrade existing facilities, thereby minimizing requirements for additional personnel and expenditures. This is what has been proposed in Ethiopia, Tanzania, and Botswana. In these countries, innovation and experimentation have also been encouraged in the areas of nutrition and health delivery, and these projects include demonstration gardens, community lectures, staff training, and vehicles and equipment for follow-up home visits.

The first-generation urban projects were designed to be labor intensive and to provide significant employment in the construction and building industries, but they only indirectly promoted employment.[3] The extent to which attention is now being paid to stimulating direct employment and higher productivity among beneficiaries is indicated by the fact that on the average, 8 percent of second-generation project costs are devoted to such activities. These funds are directed toward components such as sites and sheds, business credit, and technical assistance for small-scale enterprises. Another approach is to encourage the informal sector within projects—that is, the income-earning activities of plot holders without an official license. The importance of this has been most apparent in Kenya's Dandora project,

where about 25 percent of the residents use their plots for small businesses, such as selling food and other goods, workshops, providing services, and brewing beer. Because these activities are so important, the Nairobi City Council and other Kenyan local authorities are reconsidering current legal restrictions and are also planning to expand markets and workshops to accommodate demand.

As the projects have become more complex, technical assistance has grown more extensive. The average percentage of total project costs going to technical assistance has increased from about 10 percent in the first-generation projects to nearly 15 percent in the second generation. At the same time, technical assistance has become more varied. The second Kenya project, for instance, includes technical assistance for studies aimed at strengthening institutions involved in urban development. Provision is made in the second Botswana project for a review of the national housing policy and a study of small-scale enterprises. More attention is also being paid to nutrition, sanitation, and general public health. With regard to such persistent problems as low-cost sanitation, maintenance, and cost recovery, more technical assistance may be needed. While pit latrines are unacceptable in some projects, waterborne sanitation is too expensive for the very poor, and efforts to find viable least-cost alternatives are continuing. Maintenance of infrastructure has also been a problem in most projects. And with the exception of Kenya, cost recovery remains a major issue in Eastern Africa projects, requiring an increased effort to help local authorities establish simple, workable, and politically acceptable mechanisms for the collection of fees and other dues.

Upgrading Slums: Social and Economic Problems

The sites and services projects described represent the first alternative approach to conventional urban development projects. The second, in which the World Bank has also played a pioneering role, is the upgrading of urban slums. What makes a slum, according to a growing number of experts, is not the poor quality of its housing but rather its undesirable physical and social environment. The solution is not to demolish the housing but to improve that environment. If one can rid existing slums of unsanitary human waste disposal, open drains and ponds, inadequate and polluted water supplies, litter, filth, and muddy unlit lanes, one need not worry too much about the shanty dwellings within them. It is remarkable to see, once the environment has been improved, how capable slum dwellers are of organizing themselves and improving their standard of living, given the right sort of encouragement. This has been clearly demonstrated in a slum upgrading pro-

ject in Manila (Tondo Foreshore) that began at the end of 1976, where the residents have chosen architectual styles of great vitality and individuality.

In many cities in developing countries, from one-fourth to one-third of the urban population lives in squatter and slum areas. Because of these vast numbers, efforts to clear and rebuild these areas almost invariably fail. In Madras, for example, the Tamil Nadu Slum Clearance Board, set up in 1971, managed to complete over 36,000 dwelling units during the first seven years of its existence, but this was inadequate to clear the slums of the city and rehouse the approximately 175,000 families living in them. Moreover, the entire capital cost of these units had to be absorbed by the government since the residents could afford to pay only maintenance expenses.

In addition to the expense of slum clearance programs, there are other reasons for the alternative approach of upgrading. The first is that given the scale and spread of slums in most cities, it is often politically not feasible to remove them. The second is that squatters or slum dwellers are generally among the poorest citizens, and any relocation attempt removes them farther from sources of employment, thereby reducing their capacity for economic survival. The third reason is that once occupants are given security of tenure and access to credit, their savings can be mobilized and directed into shelter. Finally, it should be noted that within many slum settlements are established community organizations that form the strong support system necessary for the social and economic survival of low-income urban squatters.

Slum upgrading is almost always a slow and difficult process.[4] Each country or city must develop its own solutions to the particular problems encountered. One of the most common problems is that of terrain. Slums are often located in precarious areas (ravines, hills, floodplains, beaches), which make them difficult to upgrade. Furthermore, the expense of providing services may make cost recovery impossible. The knowledge that such places might more practically be used for other purposes that would yield higher rates of return only increases frustration.

In many cities, particularly in Asia and Latin America, slums may not be large but are very densely populated. To upgrade such slums as the Tondo in Manila (with 900 to 1,200 people per hectare) or Klong Toey in Bangkok (250 people per hectare), some relocation is desirable in order to provide services. If attractive land is available nearby for overspill site and service projects, some of the residents may be persuaded to leave. However, usually they are reluctant to move, and relocation procedures must be developed that are efficient, equitable, enforceable, and also acceptable to each group within the community.

The ownership of slum land tends to be very complex. Seldom do residents own both the houses they live in and the land on which they live. Many residents are squatters, illegally occupying the land and paying little,

if any, rent. The situation is further complicated in many countries by the lack of adequate records and trained personnel to keep them. To upgrade slums without addressing this tenure problem may simply add to the wealth of absentee landlords. Yet if landlords are not given adequate compensation, they may create political and legal problems for the government. Moreover, there is the danger of encouraging future illegal invasions of property by giving security of tenure to squatters. But failure to give tenure to residents generally discourages self-help and mutual-help efforts to improve their property.

Unless governments can recover the costs of slum upgrading projects from beneficiaries, they may be discouraged from undertaking them, but cost recovery is often difficult. Because slum dwellers tend to be the poorest of the poor, they may not be able to afford to buy their land and houses or pay for services. Since so many are without wage-earning employment, their income tends to be erratic and undependable. They are not likely to be creditworthy, are likely to be unable to obtain loans for house improvements, and may also be unaccustomed to paying for dwellings or services. And what if slum dwellers refuse to pay for upgrading programs? To evict them can be financially, practically, and politically difficult. The situation becomes even more complicated in cities lacking an adequate tax assessment and collection system. If the affluent are not paying for improvements to their areas, can the poor be expected to do so?

Without substantial community support and initiative, slum upgrading is difficult, if not impossible. The participation of the residents is particularly important for the maintenance of these projects. Questions of tenure, mutual help, relocation, compensation, charges, tax or fee collection, and enforcement of requirements can be successfully resolved only with the help of the community. Community involvement is most effective when it operates through established leaders, groups, and organizations. When such leaders and groups exist, it is important to involve them from the start in the planning of the project. But in certain slum areas, there is no social unity. There may be divisions along racial, religious, linguistic, or class lines. When landlords and tenants live together within the slum, local decision making may be especially difficult. All of these divisions are likely to be intensified at times of political unrest and economic hardship. In addition, lack of education among slum dwellers frequently compounds the problem. Planners therefore have to work closely with people in the hope that the necessary organization and spirit of mutual help will develop spontaneously. Often, however, there is a shortage of professionals with training and experience in community work. Because of the persistence of these problems, countries need to be aware of them before undertaking slum-upgrading projects, but, as the following case studies indicate, they can be overcome with sufficient planning and determination.

The Philippines Tondo Foreshore Project

Manila's largest slum, and the one in most pressing need of basic urban services, is the Tondo Foreshore. This area was reclaimed from the sea in the late 1940s and squatters moved in shortly after. The community covers almost 180 hectares and has a population of roughly 27,000 families (180,000 persons) in 17,500 structures. The median family income is about $575 a year, 60 percent of the median income of the Manila metropolitan area as a whole. The Tondo's level of environmental sanitation is very low because of the high population density, lack of water and human waste disposal facilities, and very poor drainage. Partly as a result of these problems, the area's residents suffer from severe health problems.

Toward the end of 1974, the government undertook feasibility studies for the redevelopment of the Tondo Foreshore. The plan that was initially recommended allocated roughly half of the land area to commercial and industrial purposes and significantly reduced the density of the remaining land. This would have resulted in the vast majority of residents being dislocated to Dagat Dagatan, a large site located about 3 kilometers north of Tondo. Following public discussion and protests, the government decided in February 1975 to implement a modified plan. This plan, in contrast to the earlier one, was designed to provide services to families in place and to minimize dislocation to the level required for purposes of developing infrastructure.

The revised Tondo Foreshore Development Project demonstrates the extent to which squatter upgrading is an appropriate alternative to resettlement, which was previously the government's policy. It seeks to provide a water supply network, a sewage system, streets and footpaths, schools, health clinics, and loans for home improvement. Special loans are also granted to small businesses in the area, and a team of advisers identifies and promotes small business expansion. Among the services provided were sewage, drainage, water supply, streets and footpaths, schools and health clinics, loans for home improvement and small businesses, and technical assistance.

For the 500 families displaced in the Tondo and the 1,500 families displaced by the expanded international port complex, 2,000 serviced sites were provided in Dagat Dagatan, about 3 kilometers north of Tondo. Three options were presented to each of the Tondo's ninety blocks, allowing the residents to decide how their houses would be rearranged to ease construction and improve street access.

Development costs were covered with a twenty-five-year renewable lease, at an annual interest rate of 12 percent, with an option to purchase after five years. Upgrading costs were relatively high, each unit containing sinks and toilets, but over half of the expense was expected to be paid by the

industrial and commercial enterprises occupying about 16 percent of the land. Recent observers of the project have been favorably impressed by the progress made. According to one World Bank representative, the area has undergone dramatic improvement. Although reblocking proved to be expensive and time-consuming, it stimulated far more private investment than predicted. Residents undertook so much construction that the original core units provided by the National Housing Authority were soon unrecognizable. And according to a 1978 survey, 90 percent of the residents were satisfied with the project.

The Tondo project is a model of what can be accomplished by slum upgrading. Because of the historical importance of this success, the project is being studied by a special monitoring unit and a number of conclusions are beginning to emerge. The first is the major importance of tenure. While the significance of any one factor is difficult to determine in such a project, land security (even without formal tenure) appears to be one of the most important considerations to residents. In many cases, tenure seems to be even more attractive than the provision of basic services.

A second conclusion is the importance of the problem of reblocking costs, which in this case have been beyond the means of the poorest 25 percent of the slum's residents. Unaware of costs, residents have tended to select the most expensive reblocking option. Project teams have therefore recently been explaining more carefully the implied costs and encouraging families to select one of the less expensive options. Because reconstruction and repairs during the reblocking process have proved more costly than anticipated, the amounts available as loans to participants are being increased. More careful attention to road layouts, verification of tenure status, and cost analysis of engineering requirements have also helped cut costs. Reblocking has been made more efficient by the development of "superblock teams," consisting of block representatives who aid the residents in the various decisions about lot sizes and shapes, hence speeding the reblocking process.

A greater effort is underway to explain the costs of upgrading to residents and to get prior commitments from them to pay for the level of services they require. Instead of the original 48 square meter lots, 36 square meter lots have recently been proposed. This reduction would minimize the risk of default; however, there is growing recognition that about 20 percent of the households have difficulty in meeting monthly development charges. This suggests the importance of strengthening the income-generating components of the project; hence, small business loans and vocational skills training centers have been made increasingly available.

According to initial surveys, community satisfaction remained high even during reblocking disruptions. Much of this high spirit is thought to be due to the work of the Community Relations and Information Organization

(CRIO), which serves as a liaison between community residents and National Housing Authority (NHA) staff. CRIO is responsible for presenting the project's objectives and implementation schedule to the community, for assisting them at the time of relocation, and for discussing problems with community leaders. It also publishes a monthly newsletter about the project. While NHA has always maintained a close relationship with the leaders of the *barangays* (the country's smallest official political unit, comprised of 500 to 2,000 families), it has recently attempted to work more closely with the representatives of unofficial political, religious, and occupational groups. Community planning councils have been formed wherever slum upgrading is taking place. UNICEF is providing special assistance in community participation, sponsoring a number of seven-day planning seminars with up to fifteen participants from government agencies concerned with slum improvement, and up to twenty-five resident participants. These seminars have so far proved helpful and are expected to continue periodically.

The country's second integrated urban project, supported by a recently approved $32 million World Bank loan, will build on the lessons taught by this first project. In addition to meeting the basic needs of more low-income families in Metro Manila, it will develop affordable solutions to the problems of poverty, shelter, and sanitation in three regional cities of the Philippines: Cebu, Davao, and Cagayan de Oro. The strategies being developed now are expected to have a major beneficial effect over the next ten years on the lives of the country's poorest people. NHA proposes to devote about 50 percent of its funds to slum improvement, 25 percent to new sites and services, and 25 percent to fully completed housing units.

The slum improvement component in the regional cities is designed to fit infrastructure and social facilities into existing settlements without relocating more than 10 percent of the families. Displaced families will be relocated in adjacent areas and in no case farther than 2 kilometers from their present location. Minimum services will be offered to improve public health and safety, affordable to all but the destitute. A somewhat higher level of service will be available to communities willing to pay the extra price for it. The approach will be flexible, allowing gradual improvement of standards as they become affordable. Cost recovery will be made possible through leases and freehold titles, for which there will be clarifying titles; by providing security of tenure, the government expects to encourage significant economy. The economic rate of return from increased property values as a result of this project is estimated at about 37 percent. More important, about 48,000 people will benefit, at a cost of $83 per person, which is approximately one-third that of previous resettlement programs.

Indonesia's Kampung Improvement Program

Indonesia has the most ambitious slum upgrading program in the world. Much of this program has focused so far on a population of over 6 million

in Jakarta, a city growing at an estimated 4.5 percent annually. This rapid growth is putting an almost intolerable strain on the government's capacity to provide basic services. Until recently the city's low-income *kampungs* (neighborhoods) generally lacked piped water, sanitary facilities, solid waste management, flood control, and transport systems. Most of the population had to rely on contaminated wells or expensive water vendors for drinking water and had no alternative to drainage canals, ditches, rivers, and other open waterways for bathing, laundering, and defecation.

To cope with this situation, the Indonesian government began its Kampung Improvement Program (KIP) in 1969, with World Bank assistance since 1974. While the approach in Manila has been intensive and meticulous, providing complete services in one area before going on to the next, the approach of KIP has been more sweeping, providing minimum services to dramatic numbers of people. By the end of 1979, some 3.5 million people in Jakarta benefited from this program's provision of paved roads, footpaths, watertaps and drains, sanitary facilities, garbage collection, primary schools, and health services. During its third Five-Year Development Plan (1979–1984), Jakarta expects to provide minimum basic services to almost all of the existing low-income residential areas in the city.

The success of Jakarta's KIP has inspired efforts to extend it to other cities, beginning with Surabaya, Ujang Pandang, Semarang, and Surakarta. In all cities undertaking a World Bank-assisted KIP, *kampungs* have been chosen on the basis of environmental conditions, density, age, access to existing infrastructure, and popular support for upgrading. After household surveys, the *kampungs* are ranked on a point system, and an effort is made to ensure that the benefits are uniformly distributed in an equitable manner within the geographic limits of a participating city.

To keep costs low (about $40 to $65 per capita), only the minimum necessary services are being introduced, within the following quality-control standards: all dwellings must be within a maximum distance of 100 meters from a one-way road and 300 meters from a two-way road; pavement widths are 4 meters or 6 meters on right-of-way of 6, 8, or 10 meters depending on traffic conditions; footpaths are paved to within 20 meters of every dwelling not located on a road; narrow footpaths of 1 meter width are provided, where feasible, to link interior groups of houses to the main footpath system; primary drains are built as required, and open secondary drains are provided along roads and footpaths; each section of the *kampung* that contains twenty to fifty families will have at least one standpipe, and where sufficient supplies are available, private connections to the main city supply or deep wells are possible; pit privies for individual families and household groups are provided wherever appropriate soil conditions exist, and in other areas, communal toilet and washing facilities are provided for each twelve families; handcarts and bins are provided in all cities for solid waste disposal, and motor vehicles and trailers are to be made available for large cities; and primary schools with enough space for about 75 percent of school-

age children and small health clinics are to be provided, with necessary furniture and equipment.

To overcome persistent problems of land acquisition and tenure, each city undertaking KIP projects is allocated full-time Land Office staff. Their responsibilities are to register all public land occupation and tenure claims, arrange for public land occupants to purchase their plots, determine land and building values, acquire land for public access and facilities, and improve methods of compensation to those whose land has been expropriated.

Because current urban property records are inadequate, it is considered impractical to impose plot charges on KIP beneficiaries. Moreover, because the types of urban services provided under KIP are similar to those routinely provided without direct charge to higher-income neighborhoods, the government has agreed not to introduce a special tax into KIP areas. However, it has undertaken to improve the existing system of property taxes by training staff in property valuation, initiating a five- to ten-year property valuation program, and basing assessment on market values rather than currently unrealistic rental values. The increase in the land property tax to date has been highly encouraging.

Conclusions

The sites and services and slum upgrading projects carried out in the developing countries with the financial and technical assistance of the World Bank show convincingly that it is possible to meet the housing needs of the urban poor at a cost that is affordable by both the poor and the countries concerned. There is still a long way to go from the 6 million people who until now have benefited from such projects to the tens, if not hundreds, of millions of urban poor throughout the world. But the projects now underway, or recently completed, have helped to develop the organizational experience and knowledge critical to the long-term success of any major innovation of this type. They have also shown that appropriate technology, in the housing sphere at least, is neither a catchword nor an ideological gimmick but an effective and workable alternative to conventional capital-intensive technologies.

Notes

1. *Sites and Services Projects* (Washington, D.C.: World Bank, 1974).

2. These experiences have been summarized in a report, *Review of Urban Projects in East Africa*, by Carolyn Tager and Praful Patel of the World Bank's Urban Projects Department (Washington, D.C.: World Bank, 1980).

3. One exception in this respect was the Bank's first project in Botswana, where 5 hectares of commercial land and 11 hectares of industrial land were provided to encourage small-scale industries, artisans, and other employers to locate their activities in the project site.

4. See Stephen H.K. Yeh, and A.A. Laquien, *Housing Asia's Millions* (Ottawa: International Development Research Centre, 1979), and M.C. Hoek-Smith, *Institutional Constraints in the Development of Informal Housing Areas* (Nairobi: Housing Research and Development Unit, 1977).

10 Basic Education

Francis J. Lethem

Education is a service, just as is the provision of health or agricultural extension, and it might be defined as a delivery system, or combination of delivery systems, by which a country or a community can achieve one, several, or all of the following objectives: to ensure that some or all of its members are informed, functional citizens; to prepare its youth to be employable and trainable by the modern sector of the economy; to train adolescents or adults in the performance of specific productive activities; to advance knowledge; to preserve or disseminate cultural, religious, social or political values; and to develop each individual's optimum potential—intellectual, spiritual, emotional, physical or social—and technical or artistic aptitude. To achieve each of these objectives, there are a variety of ways in which educational systems can be structured, knowledge imparted, and target groups defined. Each way represents a technology.

The multiplicity of potential objectives that education systems aim at achieving suggests that the design of appropriate technologies in education has to be a complex matter. Furthermore, educational objectives are not always clearly stated, their priority is not always evident, and it may not always be possible to separate substance from technology or methodology.

Not surprisingly, therefore, educational planners have tended to focus their attention on formal education administered by the Ministry of Education, to the detriment of preemployment or on-the-job training activities carried out by the Ministry of Labor, other governmental agencies, or private employers. Other educational processes—such as those occurring through the work of agricultural extension agents, health or other community workers, the military, political parties, trade unions, or religious organizations—may have been largely ignored. In the process, the prevailing educational technology—formal education—has been accepted as given, regardless of whether it is appropriate to the needs, objectives, and capabilities of a particular country or community.

The recent focus of development thinking and efforts on specific target groups or target areas is challenging the conventional wisdom. The kinds of questions now asked of education systems are whether they meet the needs of the rural and urban poor, of women, of illiterate adults, of the unemployed, or of the farmers who will benefit from an irrigation scheme. Are they, in effect, meeting society's basic educational needs?

Appropriateness of Education

The concept of appropriateness in education implies a number of conditions:

1. That the educational needs of the target groups have been assessed (ideally with their help).
2. That a technology or a combination of technologies and delivery systems are available or can be developed to meet those needs.
3. That the final product, service, or knowledge thus acquired is useful, acceptable, and affordable by the intended users.
4. That the production and delivery process makes the most economic use of the available resources, at minimum social cost, and is compatible with local institutions, culture, and environment.

These conditions mean in practice that what is taught in primary school should be geared to the needs of the majority. As André Chervel suggests, the teaching of certain grammatical concepts in primary school was (and is) often inappropriate for learning to write the French language, an essential objective of the primary school.[1] This is particularly so when the grammatical subtleties are in reality a preparation for the teaching of Latin, a subject chosen in secondary school by only a minority. The concept of appropriateness also means that what is taught should meet the needs of the intended beneficiaries as they perceive them and that the delivery of the service should take into account the constraints under which the beneficiaries live or does not generate costs that they cannot bear, even though the cost of operating the schools may be borne by the government.

Although there are few instances where the recipient population is in a position to express its views unambiguously on the appropriateness of education to its needs, one such case came to light during the design of the educational component of a World Bank rural development project in Ghana's Upper Region. At that time (mid-1975), about 90 percent of the adult population in that region was still illiterate, and only 20 percent of the primary school-age group were in school (against 60 percent for the country as a whole). Primary school enrollments had been declining (from 42,000 in 1968–1969 to 31,000 in 1972–1973), and adult mass literacy programs, which initially generated considerable enthusiasm, had been abandoned.

Parents resisted formal primary schooling for a number of reasons: their unsatisfied expectations that schooling would lead to paid employment; their feeling that schooling had not helped to meet some of their other needs (for example, to obtain better farming results or to improve family health); the poor quality of instruction and inadequate supervision, which left the Upper Region at a disadvantage relative to other parts of Ghana in

terms of access to further education; the school year (September to July), which competed against farm work for the children's time during the brief period, starting around April, when the rains fell in the Upper Region; the perceived alienation of the pupils completing primary school from their homes and their parents' way of life, one of the factors contributing to the exodus of young people to the towns in the rest of the country; and the consequent lack of school leavers for essential farm work, thus requiring the use of younger children for such tasks as herding and bird scaring.

As for the mass literacy program, several factors seemed to be involved in its failure. As in primary school, literacy was erroneously perceived by the population as leading toward wage employment; furthermore, since primary schooling focused on reading and writing instead of arithmetic or weighing (which have immediate relevance to everyday life), literacy did not result in any improvement in local living standards. Although literacy was taught in some of the main local languages (Gurenne, Dagaari, and Kasem), these languages were never used in official administrative and commercial documents—hence the inability of the population to improve the ways in which it coped with the most elementary transactions affecting it. The teaching methods were too rigid, and the voluntary instructors, who received no financial and little psychological or social rewards, lost interest. The government changed its emphasis in 1956 toward physical rural improvements, such as well digging through self-help, and the Department of Community Development withdrew its material support for literacy training, including the essential follow-up represented by the rural newspaper, which was published in the Dagaari and Kasem languages.

These examples illustrate the concept of appropriateness of product as it applies to education. When education as a product or service is considered appropriate, there is a further need to ensure that its production (and delivery) process will be appropriate to the environment in which it is to be used. A striking case was provided by consideration of television (ITV) as the principal medium of instruction at the primary level in Niger.

ITV was an expatriate-financed and -operated educational research project. Administratively and pedagogically it was isolated from the mainstream of the Ministry of Education's activities: it reached only about 900 pupils in one cohort who otherwise would not have gone to school, used professionally unqualified classroom teachers (mature primary school leavers who were given special training in communication skills), and supervised them continuously since all were teaching within a radius of 20 miles from the production center. Pedagogically, however, the experiment provided a breakthrough, not only in relation to the pupils' performance in reading, writing, and arithmetic but also in terms of the relevance of the programs to the children's rural background and their personality development.

While this success led to the financing of ITV schemes in other countries, Niger's Ministry of Education had to conclude that in the Niger environment, the experiment was not replicable nationwide. Niger's population is widely dispersed. The road network was insufficient to ensure the maintenance of television sets and regular distribution of printed materials to the teachers and pupils. Capital and operating costs were too high for the country to bear; ITV would have substituted a foreign exchange, capital-intensive medium of instruction for a local, labor-intensive technology (the professionally qualified primary teacher) at a time when the absorption of secondary school leavers was becoming a problem. Pedagogically, ITV would have imposed the use of one language (probably French) in primary education at a time when the government's policy was to introduce national languages in the first grades (a pedagogically and culturally superior approach). Finally, the necessary reliance on expatriates for preparing the ITV programs without adequate local control might have resulted in broadcasts inconsistent with national goals, values, or political beliefs. Ultimately, ITV would have mainly benefited the already favored population in the main urban and semiurban areas, to the detriment of the rural areas.

Educational realities, however, are not always as clear-cut as the above illustrations might suggest. This becomes evident when one is attempting to work out criteria for the design of education and training programs appropriate, say, for rural areas. The World Bank Education Sector Working Paper published in December 1974 proposed the following, much more complex criteria for such programs:

(a) They should be functional. This means that they must serve well identified target groups (participants in particular crop or area development projects, health, population, nutrition program, etc.) and meet their specific needs (improved production and management, adoption of new methods of child care, etc.).
(b) Rural education projects should be designed as part of a total education delivery system. In Colombia, e.g., the SENA (Servicio Nacional de Aprendizaje) program is responsible for providing training for skills, on a national basis, for both adults and adolescents. It is governed by a council which includes the Ministries of Education and Labor, the National Planning Office, and management and labor organizations. Education projects can also become the focal points of coordinated action through the use of multipurpose centers to serve other activities, such as cooperatives, health and family planning services.
(c) Education in rural areas should be integrated with other rural development activities at both the national and local levels. At the national level development of a common framework of policy for various rural development activities is essential with emphasis on making productivity and welfare-oriented activities complementary. At the local level coordination or integration is necessary to ensure that education programs are functional and adapted to the needs and opportunities of the local milieu.

(d) Rural education projects should be replicable in terms of their costs and managerial requirements. For example, the national vocational training schemes in Colombia and Thailand have reduced costs through the use of mobile training units.[2]

To help meet the basic educational needs of the poor, it will be necessary to conceive both a product (basic education) and a delivery system appropriate to the purpose. Can this be done? Can the one be disassociated from the other?

Basic Educational Needs

Any attempt to define the concept of basic educational needs necessarily leads to a philosophical discussion of what education is about, for whom, and for whose benefit. Education—formal, nonformal, and informal—is an essential component of any society's fabric, a privileged means for the society to preserve and perpetuate itself.[3] Hence, depending on circumstances, education can be used to promote economic and social development, to preserve social stability, or to reinforce economic and social inequities. In that respect, basic educational needs have nothing in common with shorthand definitions such as the provision of four years of primary education. As vividly argued more than ten years ago by Ivan Illich, by teaching the poor subjects that are irrelevant to them, possibly in a language not their own, by judging their achievements through examinations reflecting urban middle-class values, and by lowering teachers' expectations of their performance, education systems in most countries have succeeded in persuading the underprivileged of their incompetence.[4]

The concept of basic educational needs is precisely the opposite: it involves the will of a society to determine what such needs might be, at a point in time, with a view to finding ways in which they can be satisfied. In general, basic educational needs should consist of a combination of three essential elements:

1. Communication and general knowledge skills, which at the basic level should include literacy, numeracy, and general civic, scientific, and cultural knowledge.
2. Living skills, including knowledge of health factors, sanitation, nutrition, family planning, the environment, cultural activities, management of the family economy, and how to create and maintain a home.
3. Production skills, embracing all forms of activity directed toward making a living or the production of goods and services.

The combinations of these essential elements vary with the intended beneficiary. From the point of view of the individual, education should provide

the means to achieve full potential within the environment in which he or she is living. This might mean acquiring the means toward self-development, self-reliance, and growth: learning how and where to acquire additional knowledge. Each social unit might define its basic educational needs in a different manner. Not all members of a family need to have the same skills, but the family unit needs to possess most of the living skills enumerated. Not all of the village community needs to be able to deal with government authorities in administrative matters, but each family should have the minimum communication and general knowledge skills necessary to verify that its interests are well represented. The actual combination would also vary over time. An individual's basic education needs would be satisfied over his or her lifetime, and as a society evolves and its economy develops, its basic educational needs would change accordingly, becoming more sophisticated or specialized. Thus, basic educational needs are a dynamic concept for the individual, the community, and society, in time and in space. The community must have the means to function both within its boundaries and in a wider context; the individual must be provided with a minimum of literacy and numeracy but must also have reasonable access to further education.

These considerations add up to this definition: the concept of basic educational needs represents, for each society, what it determines to be the minimum required—or the minimum it can afford—to achieve its priority economic and social objectives including as a minimum the satisfaction of society's other basic needs such as shelter, health, food, water, or employment; prepare itself for longer-term development objectives; and enable each individual to develop more fully as a human being.

What does such a definition mean in a specific context? Here is Father Balenghien's proposal, as a result of many years of experience with functional literacy programs in Mali, of what the country's basic educational needs might be:

1. Domain of health: Sufficient knowledge for the people to solve their problems themselves (for example, to prevent and in some cases to treat illnesses) and the knowledge necessary to improve their nutritional habits and their adaptation to the environment.
2. Economic domain: The knowledge and skills required to render their work more profitable through the application of more efficient production methods.
3. Sociocultural domain: Command of basic skills in the native tongue (reading, writing, and numeracy), understanding of the usages and customs governing social life in the community, and sufficient understanding of national or local culture and religion to facilitate integration into the community.

4. Domain of civil life: Functional knowledge required to enable the people to regulate their relations with the various administrative services and functional knowledge enabling them to fulfill their role as citizens and to participate actively in the life of the community.

Our colleagues from the UN Educational, Scientific and Cultural Organization (UNESCO), who were attempting to synthesize the experience of the Sahelian countries in meeting their population's basic educational needs, rightly felt that the preceding list should be qualified as follows:

> The specifications of minimum educational needs within each of the above categories may vary considerably in different regions of the same country in terms of requirements of the population, the level of its aspirations, often linked with the cultural level, the position already attained on the one hand and the available resources on the other. It also varies with the target groups. In other words, except in the case of "absolute poverty", the definition of these needs is a delicate job and an opinion poll would seem to be most useful. The people themselves should express their priority needs in the course of such an inquiry, and this can be quite naturally coupled with the evaluation of existing educational activities.[5]

Even in a national context, our definition remains theoretical as long as the priority target groups have not been determined and their basic educational needs assessed. Each society has to make its own decisions, and these will reflect the various forces at work. In all cases, the priority might be defined according to the following criteria suggested by Abdun Noor in unpublished World Bank materials:

1. Functional groups: If agriculture is the mainstay of the economy, then all the population connected with that sector.
2. Socioeconomic status: The poorest of the poor, the children of the middle-income group, and so on.
3. Development targets: All of the population covered by an integrated rural development project.
4. Age: On the rationale that the earlier training is imparted, the greater its contribution to development will be.
5. Multiplier effect: Education of women and other selected core groups.
6. Geographical criteria: Starting from rural to urban areas or vice-versa, but thinly distributing the resources, as was followed during the Cuban literacy movement.
7. Ethnic or special groups: Nomads, landless peasants, and others.
8. A mix of all or some of the above, which will reflect the right priority of needs in a society.

Whatever the mix of priorities, the needs of many cannot be met in the short run—hence the importance of fitting the programs adopted to meet the needs of certain groups into a broader strategy to ensure that those who have to be left out in the short term do not remain deprived. Various basic education programs should be integrated into a national strategy to meet basic educational needs.

Basic Education

Basic education is not as elusive a concept as that of basic educational needs, which basic education is supposed to meet. The educational establishment in many countries has naturally attempted to use the term interchangeably with *primary education,* give or take a few years of schooling. In a nonformal context, on the other hand, some people view basic education as a program exclusively for youth, leading either to employment or to better integration with rural society, while others perceive it as the preliminary step for adults toward a program of lifelong education. In other cases, it is equated with adult (or functional) literacy.

All of these views are erroneous as a general concept, even though they may be valid in terms of the target group to which they apply, if the proposed technology (both the knowledge or know-how taught and the delivery system) is not appropriate to the needs of the target group and the constraints. In other words, while basic education might be equated in certain countries with the completion of their compulsory cycle of formal elementary (primary or basic) schooling, in most countries basic education will have to consist of a combination of educational provisions—formal, nonformal, and informal—that together constitute a minimum package of attitudes, skills, and knowledge that a given society will require from every one of its members.

The essential ingredient of basic education is that there should be a national will to meet (though not necessarily in the immediate future) the minimum educational needs of its most deprived members. The country should organize itself to design a viable strategy to meet this objective and then undertake to implement it.

Only in recent years did such a will appear in the United States when Americans became aware that their standard educational provisions were still leaving a surprising number of adults unable to function effectively in their own society (for example, by filling out a job application, understanding a newspaper in English, or obtaining a driver's license) and even more so in the case of ethnic and linguistic minorities whose special needs had received little attention.

With the provision of basic education becoming an increasingly widespread goal, a number of educational innovations were bound to appear

worldwide to help those who were not being reached by formal schooling. To succeed, these innovations had to be appropriate in terms of content and delivery.

To illustrate what the provision of a basic education involves, let us consider the cases of Upper Volta and Mali where the World Bank made some of its early loans aimed toward the education of the rural poor.

Rural Education in Upper Volta

The concept of rural education launched in Upper Volta around 1960 was based on the observation that since only 10 percent of the school-age children could benefit from primary schooling during the foreseeable future, some useful but low-cost education should be provided to rural children (aged fifteen or above) who had been bypassed by the system.[6] This took the form of Rural Education Centers (CER) where basic agricultural techniques and handicrafts, together with literacy and numeracy, were to be taught over a three-year period by specially trained instructors appointed on a fixed term contract.[7] This program had a pioneering role; the evaluation of its weaknesses, which were well publicized, has contributed to major improvements that have benefited not only Upper Volta but many other countries faced with similar educational choices. The problems can be summarized as follows:

1. Initial misrepresentation by the local political authorities of the actual educational objectives.
2. Lowering of the minimum school entrance age, under the resulting parental pressure, which made the CERs a clearly inferior alternative education compared with the primary school and made the integration of the younger CER leavers into farm life more difficult.
3. Use of French as the teaching language although it was hardly used in the rural setting and not understood by the trainees.
4. Control over the teaching force by primary teachers instead of by agricultural extensionists and location of the program within the Ministry of Education instead of the Ministry of Agriculture and its regional administrative dependencies (regional development organizations, ORD).
5. A weak central administration.
6. Haphazard location of the CERs instead of in those communities where other productive investments were made.
7. Limited parental and community participation.

The government has now fully realized the potential of its rural education system as an element of its rural development policy. It is implementing

measures to correct all of these deficiencies and has already achieved a number of successes, notably in regard to the capability of the CER leavers, who despite their lack of formal qualifications, often show greater self-confidence, initiative, and entrepreneurship than primary school completers or dropouts, and to the impact of rural education on modernizing certain traditional village structures, and increasing the participation of women in a number of decisions from which they were previously excluded.

Upper Volta's rural education system can be considered an important component in the country's strategy toward meeting basic education needs. Once this system has solved its remaining administrative and logistical weaknesses, it might become the core for expanding basic education efforts toward the adult population. There will also be a need to determine whether some kind of articulation with the formal system, even on an exception basis, may be desirable.

Functional Literacy in Mali

While Mali is facing many economic and social issues similar to those of Upper Volta, its strategy toward meeting basic education needs is quite different. It developed from Mali's experience with functional literacy programs for adults and seems to aim first at meeting the needs of the producers and then at broadening its reach toward younger people.

Mali's functional literacy program blends the use of several complementary media (literacy teaching, printed materials, radio, rural press) with a model organizational structure in such a way that functional literacy has become an integral component of the extension function of several government-sponsored agricultural development schemes. Its impact is such that laws have been recently approved requiring that new investment projects include literacy as one of their components.

Whereas mass literacy campaigns are based on the assumption that literacy is a desirable good by itself and are therefore mainly concerned with the mechanics of reading, writing, and arithmetic and not with their uses in everyday life, functional literacy, by definition, aims at meeting certain elementary needs of specific adult target groups in relation to their professional activity. If its programs are properly designed, functional literacy has to be considered as an appropriate technology.

Functional literacy centers are established in priority zones for the extension services and only after the village itself makes the decision to embark on the program.[8] Such a decision implies several commitments: to create a committee to supervise the village literacy program, to appoint literates (or nonliterates) to be trained as instructors, to construct and furnish the center, and to support (in kind) the services of the instructor and

bear the cost of consumables. About 500 hours of instruction are required to achieve literacy and numeracy, spread over a two-year span to avoid the periods of intensive agricultural work. The farmers in the groundnut scheme, for instance, would learn to weigh and record their crop and its value, as well as the quantities of production factors purchased.

This example of the nature of functional literacy suggests that it will not remain neutral in terms of a village's socioeconomic development. Once peasants are able to verify the weight of their crop and the price they should obtain for it, they can prevent mistakes or abuses by purchasing agents; next, the village may create mutual self-help associations or cooperatives and eventually take over the responsibility for the collection and commercialization of the groundnuts; finally, farmers may better understand government regulations, especially those relating to the payment of taxes, and also better assert their position with local and regional authorities, thus acquiring a greater participation in managing their lives.

Functional literacy, although not indispensable for learning the relatively simple improved agricultural techniques taught by the extension agents, is nevertheless likely to reinforce the learning process by linking the timing of the two activities. It is likely that the combination of the work of the literacy instructor, the volunteer villager himself, and the extension worker would by itself represent a good mix at the village level.

The concept and content of functional literacy are well adapted not only to the needs of the farmers but also to the design of its delivery system. Functional literacy is taught in a village building constructed by the villagers from local materials and provided with simple handmade wooden furniture. A National Center supplies each village with four storm lanterns or two pressure lamps (instruction is given at night since peasants have other activities during the day), a blackboard, a radio set, initial writing material, and subsequent didactic materials.[9] These materials have to be tested with great care since the intended message can easily be misunderstood. In addition, the impact of the literacy program is reinforced by the Ministry of Information, which assists in the broadcasting of the rural radio programs to accompany the literacy classes and also edits and prints the Bembara-language newspapers, *Kibaru,* written by the National Center (one of the few reading materials to reach villages).

In recent years the National Center has been divesting itself of the day-to-day administration of functional literacy, which is being delegated to literacy staff placed under the authority of the management of the appropriate production scheme. Hence the latter can ensure that both the substance and timing of the literacy program reflect to the maximum the technical concerns of production. Reciprocally, the production scheme's administrative and logistical means are used for the accounting and materials distribution needs of the literacy programs.

An evaluation of the program emphasizes the importance of local capabilities for successful implementation.[10] For instance, in villages where the programs were sponsored by a traditional youth association (*ton*), attendance by students and instructors was better, the proportion of female participants was higher, and more financial resources were made available. The evaluation also reveals that in many villages, literacy is not yet an individually felt need. Although all participants seem to have acquired a better knowledge of agricultural and health practices than nonparticipants, only the small number who become entrusted with community responsibilities requiring literacy or numeracy skills retain these skills.

At this point, it is not clear whether, as originally intended, the functional literacy program should turn its attention to different age groups, such as adolescents or children. This question is now being studied with great care by all those concerned with education in Mali and other African countries.

The Search for Appropriate Technologies and the Mechanics of Delivery

The search for appropriate technologies to meet basic educational needs suggests that in many instances the collaboration, and sometimes the leadership, of ministries other than the Ministry of Education will be required. It has often been observed that an appropriate institutional design or the choice of an appropriate implementation agency may be a precondition for the adoption of certain technologies and the achievement of certain benefits.

In Mauritania, for instance, a pilot experiment financed by a World Bank loan attempted to fit traditional education, which is perfectly adapted to the environment and widely diffused, into a modernization process with respect to its content (literacy instruction in modern Arabic, practical calculations, useful knowledge) as well as the educational methods employed.[11] For the experiment to be meaningful, it had to have the support of the religious and political authorities, which it did. To meet basic education needs, Benin is exploring the potential of youth clubs (under the Ministry of Agriculture) for rural youth and a system of successive industrial and commercial learning modules (under the Ministry of Labor) for urban youth.

In Burundi, UNESCO recently suggested that the government experiment with a system of literacy centers similar to those now operated by the churches. Pupils would attend the centers two days a week and be expected to be literate in their language and have a minimal proficiency in arithmetic. The proposal argues that the government should establish a dual system of basic education as a temporary measure, with literacy centers gradually being converted into primary schools as resources permit. The best pupils in literacy

centers would also have the chance to transfer into primary schools. In view of the existing financial constraints, possible rejection of the proposed dual system would lead to denying further most children the access to any sort of education at all, and consequently the gap between literates and illiterates would continue to widen.

Although the right educational provisions and administrative arrangements may have been designed, the key to the success of any basic education system will be its acceptance by the intended beneficiaries. If parents want access for their children to formal primary education, it may be better to come up with a system of peripheral lower primary schools feeding into nuclei upper primary schools such as that established in El Salvador. To reduce costs, the schools operate on double shifts, and teachers often handle several grades in the same classroom. In these circumstances, physical planning becomes a crucial factor in the design of basic education.

The mechanics of delivery of basic education are important. School buildings, furniture, and equipment should be appropriate to the use requirements, the environment, and local resources. For instance, in El Salvador the primary school buildings financed by the World Bank in 1974 are of simple construction, relying insofar as possible on the use of locally available materials. Walls are either of brick or of ordinary plastered concrete block; however, because the schools are located in a seismic area, it has been found necessary to incorporate reinforced concrete posts, for which cement and steel must be imported. Roofing is generally of corrugated asbestos tiles, and windows are fitted with only wire screens and simple wooden shutters. Construction was carried out partly by contracts awarded on the basis of local bidding, but such tasks as site clearance and the provision of access ways, water supply, drainage systems, and site fencing were handled by the local communities under the direction and technical support of the government agency in charge of community operations.[12]

As early as 1969, the Bank-financed education project in Guyana required that prior to starting design work, in-depth studies compare the capital and maintenance costs of school buildings built either with locally obtainable wood or imported cement. Considerable attention was also given to environmental factors for the disposal of effluents and in relation with human comfort. Sergei Kadleigh, who was instrumental in the formulation of the design criteria, reported that design implementation actually exceeded his expectations and that the schools had proved not only to be educationally functional but also remarkably cool without any air-conditioning. In general, he recommends that school building designs—besides meeting user educational requirements, facilitating internal communication, easily accommodating future growth, and being structurally safe—should pay special attention to the following:

1. Climate and the environment: for instance, "open spaces between and around buildings should be furnished with trees, plants and water for the control of soil erosion, sound insulation, glare and reflection, solar radiation, temperature, screening from view, shelter from the wind, and air purification."
2. Human comfort and well-being: "The design of the building envelope should be such that it modifies the external climate to provide the occupants with year-round acceptable conditions of comfort and well-being for living and working, by natural means without the use of artificial aids. Mechanical [energy-consuming] methods of ventilation, heating, cooling or air-conditioning should be resorted to only when the results of the most effective use of natural conditioning need augmenting to provide acceptable conditions; such as might be the case when storing books, delicate instruments and equipment and perishable goods like food and medicine."
3. Appropriate technology: realistic performance standards for space, structure, and the environment (climatic and ecological design) should be established and quantified for design purposes.

   The economics of the building and allied industries should be investigated and analyzed in depth with particular reference to local manpower, skills, and employment needs on the one hand, and on the other hand, to the availability and nature of the resources (labor, materials, and energy) required for school construction. The results should be tabulated and evaluated in terms of the government's long- and short-term development economy and the particular needs of the local communities where the schools are located.

   Designs using alternative combinations of construction management, labor and skills (to benefit employment and reduce costs), and materials (to husband natural resources and energy both during construction and throughout the life of the completed buildings, as well as to reduce costs) should be explored and evaluated for each basic type of school and institution in the project. In each case, the most appropriate design for the local community in the larger context of the government's development economy should be selected, together with the most appropriate and economical methods of implementation. Buildings should meet the performance standards, be readily adaptable to different characteristic sites, take full economic advantage of repetitive elements, and by simplicity in planning, take into account developments in educational methods and media.

   Alternative sources of energy for light and power such as from the sun, wind, water, and the recycling of waste products also should be fully explored and evaluated against the prevailing sources. Designs should incorporate the systems of greatest benefit to the local community.

> Cost evaluation should include operation and maintenance costs (costs-in-use) as well as capital costs. Designs should reflect the optimum balance between these two orders of costs measured against the opportunity cost of capital over the life of the buildings.[13]

It might be useful to reflect on the importance of textbooks in the learning process, especially when this process has to occur in an environment where little written material is available and teachers are not qualified. As Stephen Heyneman stated:

> We should not forget what every rural primary school teacher in Africa or Asia already knows: that the textbook is an educational technology too. Though not new, books have never been widely diffused in less wealthy societies. When first introduced they can stimulate profound changes. Books have the capacity to deliver massive amounts of new information to the most remote locations. To operate they depend neither upon electricity nor consumable supplies. If the content is not understood, books can be studied again and again; if quickly understood, individuals can read ahead. Ideally, books can be delivered to all children equally, urban, rural, rich and poor alike.[14]

Basic Education and the Role of the World Bank

Is basic education a dream that no amount of technology or administrative skill might ever satisfy? Doesn't it imply that when a community or society comes close to meeting its basic educational needs, it would automatically set itself new and higher targets? This is quite logical, and this is precisely what life is about. Progress results from setting attainable goals. Success generates self-confidence, entrepreneurship, and creativity, as well as new, more ambitious goals. This is as true for individuals as it is for communities. Therefore it is my hope that the concept of basic education—and basic needs in general—will lead to major progress toward setting into motion a mechanism that will help to meet the poorest people's most elementary educational needs and be suitable for meeting society's increasingly sophisticated demands. At each step appropriate technologies and administrative arrangements will be required, and they will vary.

Now may be the time for groups of countries, regions, or communities facing limited resources and other constraints and with enough of a common cultural heritage to pool their efforts, to learn from each other, and to design their own strategies toward meeting what they define as their basic educational needs.

Since 1962, when the Bank financed its first project in the education sector, the provision of basic education increasingly has been recognized as a

central element in economic development. Although initial lending was largely restricted to hardware in projects designed to meet manpower needs directly, by 1970 it was accepted that the Bank should lend for education projects with important long-term significance for economic development. The Bank's 1974 education policy paper listed the provision of a minimum basic education, as fully and as soon as available resources permit, as a principle for its investments in education, and the number of loans with innovative components in both formal and nonformal education systems increased. This principle was repeated in the Bank's 1980 education sector policy paper, which explained that "the Bank's interest in helping to expand education opportunities for both school-age and adult populations is closely related to its efforts to promote a broad approach to development, and its desire to assist in meeting basic human needs. Appropriate basic education enables the majority of the poor, in both rural and urban areas, to lead productive lives and to benefit from social and economic development of the community."[15]

In the provision of educational opportunities to school-age children, this experience encompasses such innovative approaches to the provision of basic education as the use of educational radio and television in primary education (Malaysia), self-paced instruction (Bangladesh), production of textbooks and instructional materials (Indonesia), provision of a national network of workshops attached to primary schools (Rwanda), establishment of a nuclear system of primary schools, with several primary schools containing only the lower grades feeding into centralized upper-grade primary schools (El Salvador), and skill training related to employment opportunities for primary school leavers (Tunisia).

The Bank has financed many project components in nonformal education in an attempt to reach out to school children and nonliterate adults. These components involve the teaching of literacy, numeracy, and vocational and agricultural skills. Some examples of these components have been rural youth clubs (Benin), nomadic training centers (Somalia), national and provincial centers for lifelong education with coordinated administrative and program development support (Thailand), district-level learning funds to support income-generating learning activities at the village level, designed and carried out by the learning group members themselves (Indonesia), and village-level basic training schemes (Yemen Arab Republic).

The Bank will continue to support innovative projects and programs intended to improve the quality and efficiency of first-level education and improve access to learning opportunities for groups not equitably served.

Notes

1. André Chervel, *Histoire de la grammaire scolaire* (Paris: Payot, 1977).

2. World Bank, *Education Sector Working Paper* (Washington, D.C.: World Bank, December 1974), pp. 25–26.

3. Philip H. Coombs and Manzoor Ahmed in their pioneering work, *Attacking Rural Poverty: How Non-Formal Education Can Help* (Baltimore and London: Johns Hopkins University Press, 1974), p. 8, propose the following definitions: "*Informal education* . . . is the lifelong process by which every person acquires and accumulates knowledge, skills, attitudes and insights from daily experiences and exposure to the environment—at home, at work, at play; from the example and attitudes of family and friends; from travel, reading newspapers and books; or by listening to the radio or viewing films or television. Generally, informal education is unorganized and often unsystematic; yet it accounts for the great bulk of any person's total lifetime learning—including that of even a highly 'schooled' person.

"*Formal education* . . . is the highly institutionalized chronologically graded and hierarchically structured 'education system,' spanning lower primary school and the upper reaches of the university.

"*Nonformal education* . . . is any organized, systematic, educational activity carried on outside the framework of the formal system to provide selected types of learning to particular subgroups in the population, adults as well as children. Thus defined, nonformal education includes, for example, agricultural extension and farmer training programs, adult literacy programs, occupational skill training given outside the formal system, youth clubs with substantial educational purposes, and various community programs of instruction in health, nutrition, family planning, cooperatives, and the like."

4. Ivan Illich, *Deschooling Society* (New York: Harper and Row, 1971).

5. M. Botti, M.D. Carelli, and M. Saliba, *Basic Education in the Sahel Countries: A Study Prepared for the IBRD* (Hamburg: UNESCO Institute for Education, 1978), pp. 52–53.

6. This ratio is similar in most Sahelian countries. It is what can be accommodated within national education budgets, which already claim such a share of national resources—between 3 percent and 5 percent of gross domestic product (GDP)—that there is little margin for expansion (total public resources rarely exceed 15 percent of GDP). The main limiting factor is teacher salary (ten to fifteen times GNP per capita for a primary teacher against two times in a country like the United States or Japan).

7. This would exclude the instructors from the ranks of the civil service and allow a limiting of their contractual salaries to about $650 per year versus up to $1,900 per year for a fully qualified primary teacher.

8. This section is based on unpublished materials by my colleague, Michael J. Wilson, who was asked by the World Bank to appraise the financial needs of the literacy centers.

9. The National Functional Literacy Center, administratively under the Ministry of Education, operates as a source of pedagogical expertise for the research, development, and production of literacy materials, with the technical substance provided by the specialized ministry—the groundnut, rice, or cotton development schemes under the Ministry of (Agricultural) Production, for instance. It is also responsible for the evaluation of the results of its interventions.

10. Direction nationale de l'alphabétisation fonctionnelle et de la linguistique appliquée, *Rapport final de l'évaluation de l'alphabétisation fonctionelle dans l'OACV* (Bamako: Ministère de l'éducation nationale, 1978).

11. Botti, Carelli, and Saliba, *Basic Education,* p. 101. Traditional education refers to the country's Koranic school system.

12. David H. Lewis: "Appropriate Technology in Education," in *Appropriate Technology and World Bank Assistance to the Poor* (Washington, D.C.: World Bank, 1978).

13. Sergei Kadleigh, "International Consultancy," in *Proceeding of the Royal Institute of British Architects* (London: RIBA, 1977).

14. S. Heyneman, J. Farrel, and Manuel A. Sepulveda-Stuardo, *Textbooks and Achievement: What We Know,* World Bank Staff Working Paper No. 298 (Washington, D.C.: World Bank, 1978).

15. W.D. Haddad et al., *Education Sector Policy Paper* (Washington, D.C.: World Bank, 1980).

Part III
Technology Transfer

Technology transfer has become one of the central objects of international negotiations, as well as a major bone of contention between industrialized and developing countries. This political phenomenon can be attributed to a number of factors, the most conspicuous of which is the growing realization of the dramatic imbalance in the distribution of the world's scientific and technological resources. The developing countries, taken as a group, account for little more than 3 percent of the world's research and development expenditures and around 12 percent of its total research manpower. There is strong evidence that this imbalance is likely to persist for a very long time, despite the efforts made by many developing countries to build up their own scientific and technological infrastructure. These countries have, in effect, become structurally dependent on technologies from the industrialized nations. The issue at stake is not so much that of redistributing the world's scientific and technological resources—an impossible task in the best of circumstances—but that of helping to build technological capacity to buy, adapt, or copy the most appropriate among the available technologies and to obtain equitable terms when the technology has to be bought.

The five chapters in this part examine the ways in which development projects prepared and financed by the World Bank have served as a major channel of technology transfer from industrialized to developing countries and, to a lesser extent, between developing countries themselves. Three of the five chapters deal with sectors that until recently were the mainstay of the Bank's lending activities: the development of water resources, power generation and distribution, and the production of fertilizers. A fourth chapter deals with the support to basic manufacturing industries by the IFC, an affiliate of the World Bank. The fifth chapter deals with a sector relatively new to the Bank, the engineering industries, but with a number of common characteristics with the other four, notably the basic or infrastructural nature of its projects.

The technology transfers that have taken place in the sectors presented here (with the exception of the engineering industry) should be seen as a side effect or precondition for the operational success of specific development projects. When the Bank finances a major power generation project or an important water development scheme, for instance, the main object is not to transfer technology but to carry out a clearly identified development project that is likely to have a positive economic and social impact and to ensure an adequate financial return on the large investments devoted to it. All projects call for important transfers of technology in the form of both hardware and software, but what is ultimately more important than the efficiency

of the transfer process itself is the complete mastery by the borrowing country or institution of the knowledge transferred through the project.

On the basis of a number of specific case studies, the authors of the five chapters presented here show how the process of transfer operates and how the borrowing institution gradually came to master the organizational, managerial, and more narrowly technical aspects of the project. Their implicit definition of the term *technology* tends to stress the transfer of operating technology and, to a lesser extent, design capability more than the transfer of an ability to generate indigenous technological innovations.

These chapters suggest a number of important lessons. The most conspicuous is that, at least in the sectors analyzed here, large amounts of technology are being, and have been, successfully transferred to the developing nations. Another lesson is both the simplicity and the complexity of the transfer process. The transfer is simple in the sense that it is essentially a learning process that involves the training of workers, technical personnel, and managers, drawing on experience and past mistakes and gradually building up an ability to operate machines and run a complex production system. In this respect the Bank has an experience that is probably unrivaled elsewhere in the world.

Technology transfer, however, is also a complex and multifaceted process. It does not simply involve a supplier's selling a specific piece of technology to an often inexperienced buyer in a developing country but rather a whole galaxy of actors working in different capacities at various stages of the project. These include the governmental agencies (or, in the case of IFC, the industrial corporations) that identify and propose a project, the consulting firms that prepare it in detail, the manufacturing firms that are pitted against one another in the bidding for the supply of equipment, the financial institutions that cofinance the project, and the institution that is set up or reorganized to run it. And when the World Bank is involved, it acts not only as a financier but also plays the part of an adviser and sometimes promoter of the project.

There are also other lessons that stand out from the case studies analyzed here. In chapter 11, P. Kirpich shows that in the development of water resources, one of the critically important elements in a successful technology transfer is organizational continuity and the lifelong commitment of individual institution builders to the project. Foreign experts have an important role in the early stages, but ultimately such schemes are viable only if they are controlled and operated by local people.

In chapter 12, R.H. Sheehan and S. Ramachandran also point to the crucial importance of institution building and dispel a number of myths about the appropriateness of technology and the difficulties of making the right technology choice. In their view, the most appropriate technology is the least-cost technology, and although the Bank has generally tended to

choose fairly conventional types of technology in its power generation and distribution projects, there is no evidence to suggest that this was either the second-best technology or one that was inappropriate to local conditions.

In his analysis of fertilizer development projects in chapter 13, C. Pratt brings to light the incremental nature of the technology transfer process. It begins with such simple things as the bagging of fertilizers imported in bulk from abroad and ultimately ends with the development of an indigenous capability to design, engineer, construct, and possibly export complete fertilizer plants. What is particularly interesting about Pratt's presentation of this technology transfer continuum is his thesis, backed by solid economic and technical considerations, that developing countries cannot and will not all move up through this technological continuum, from simple processing operations to the indigenous design of turnkey plants. The reason is not so much the absence, present or anticipated, of a capability to move up the ladder of technological sophistication as very nature of the technology involved. Fertilizer projects tend to be exceptionally large and bulky, productive units must become larger if unit costs are to be kept competitive, and it makes little sense, except for the largest of the developing countries, to try to build a complete technological capability ranging up to the design of complete plants. In effect, the technology transfer taking place in the framework of a fertilizer project is often a one-of-its-kind transfer. But even if, as in most other cases, it does not have any direct multiplier effects on local technological capabilities, it is nevertheless economically very important, if only because of the savings on foreign exchange and the likely increases in agricultural output resulting from a greater availability of fertilizers.

In chapter 14, H.G. Hilton examines a wide range of industries built up with the financial and technical assistance of the IFC. All of these industries—pulp and paper, textiles, iron and steel, cement—belong to the private sector and are in some way basic to the industrialization process. Like the other authors in this part of the book, Hilton stresses the importance of training in the technology transfer process and points to an important yet largely neglected fact: any transfer of technology is meaningless if the user of that technology is not able to maintain productivity levels above certain minimum standards. Plants operating at 10 or 20 percent of their rated capacity are ultimately much more costly to a country than all of the foreign exchange their output was intended to save.

The engineering industries examined in chapter 15 by F. Moore represent a fairly new field of investment for the World Bank, but they are extremely important because of their technological multiplier effects on other industrial sectors. The author shows that the projects financed by the Bank in countries such as Thailand and Korea are aimed not simply at transferring technology—either as a primary or as a subsidiary goal—but rather

at building up indigenous technological capability. These projects are still in their early stages, and for this reason it is difficult to evaluate them. But the work carried out in preparing and designing them already suggests that one of the first and most rewarding steps in building up such a capability is to improve what already exists, and such improvements often can be carried out with only minor capital investments.

Water Resources Development

Phillip Z. Kirpich

Water resource planning has always been a key concern of the World Bank and its borrowers. Given the critical water shortages in many developing countries, as well as the growing flood, soil erosion, and pollution problems, it is likely that sound water planning will become even more important in the future. Several characteristics of sound water planning have emerged from such planning. It has become increasingly clear that it is not only the physical factors (water quantity and quality, aquifer characteristics, soil properties) that must be considered but also the economic and social elements. To mention just a few examples, investments in rural areas directly concerned with water too often have retained a bias toward heavy construction or industry. Many large dams have been built primarily to provide hydroelectric power for industry. When irrigation has been the major purpose, a dam could be fully completed before a single farmer's channel had been dug, or it could have been in existence for ten years without agreement on water costs, distribution, types of cultivation, and the institutional arrangements for financing, storing, moving, and selling the food produced.

Twenty years ago, the term *project* had a narrower meaning than today; it meant physical works or facilities for limited objectives, such as a canal system for irrigation, a waterworks for potable water, a power plant, a highway, a school building, or an industrial plant for a specific product. Economic and financial analyses were made to determine the project's justification from national and local viewpoints. Today the physical works are much more varied and are no longer considered in isolation. This is so not only because of the environmental effects, which in recent years have received much public emphasis, but also because software elements must be included as integral parts of a particular project. These elements can be extremely important, as can be seen from the data in table 11-1, which show the relative importance of the various components in two typical integrated rural development projects financed by the World Bank.[1]

Practitioners now accept that in the initial stages of the project cycle (which includes the identification, selection, and preparation of projects but not their detailed design, construction, or operation), some general principles should be used.[2]

Adopt a multidisciplinary approach, making use of a team composed of engineers, economists, agronomists, chemists, financial analysts, and sociologists, as appropriate. Public works departments traditionally have been

Table 11-1
Typical Components of Integrated Rural Development Projects
(percentage of total budget)

	Papaloapan Project, Mexico	*Tungurahua Project, Ecuador*
Irrigation works	25	58
Feeder roads	20	5
Potable water and sewerage	15	2
Rural electrification	7	1
Schools	8	
Health clinics	7	1
Community centers	2	1
Agricultural credit		24
Agricultural technical assistance (including rain-fed agriculture)	15	7
Marketing assistance	1	1

Source: World Bank, 1978.

dominated by engineers, but they are quickly learning that they must have a minimum understanding of the other disciplines for effective teamwork.

Improvement in channels of communication among planners in various government agencies is essential, as well as between them and the politician. If public works departments are dominated by engineers, other key agencies—public health, agriculture, finance—are not. This tends to make interagency cooperation difficult, especially when communications are impeded by jargon incomprehensible to those in other disciplines or to politicians.[3]

Contacts and dialogues between the project planners and local people (officals, urban dwellers, individual farmers, or groups of farmers) should be established early in the planning stage and maintained continuously. Ways should be worked out together for making use of local knowledge and securing local participation in planning, construction, and implementation. It is surprising how many excellent ideas and suggestions the local people can come up with. It is, moreover, elementary good psychology to get participation on the part of local people rather than to spoon-feed them.

Unemployment and underemployment are grave problems in such situations, so it is obvious that labor-intensive methods are to be preferred. This is so not only for economic reasons but also as a means of unemployment relief and as a way of obtaining vital local participation in the implementation of the project at an early stage. At a recent international congress, much time was devoted to advanced methods, mainly involving electronic gadgetry, for improving operating efficiency while reducing labor requirements for water distribution networks. Commentators pointed out that the economic worth of these gadgets had yet to be proved, even for

advanced countries. The doubt would be even greater under conditions of labor surplus.

Methods of demonstrated success are not necessarily transferable from one country or locality to another. This may seem obvious, and yet it is a common mistake to assume that they are. Conventional gravity irrigation canal systems of the arid or semiarid zones do not work well in the humid tropics of Latin America or in Bangladesh, a humid-zone country where landholdings are unusually small.[4] In the Punjab (India and Pakistan), the green revolution in a way perplexed planners because almost spontaneously tens of thousands of shallow wells were installed by private farmers in the space of a few years. These were mostly electric-driven, low-capacity centrifugal pumps, which, in physical terms, are far less efficient than large-capacity deepwell-turbine pumps; yet the former are clearly superior in economic and human terms.

Seemingly obtuse stubbornness on the part of the poor, subsistence farmers (generally a majority or a sizable minority in many developing countries) when they refuse to adopt readily modern methods of irrigation or to use improved seeds, fertilizers, or pesticides is usually justified because they cannot afford to take risks. This fact is of fundamental importance in planning water control schemes for agriculture, since the nature of the physical works and their sequence and speed of construction are directly affected. A difficult preliminary task thus is to persuade subsistence farmers of the value of the new methods through demonstration on a relatively small scale, at least to start.

Water users should pay charges to cover two items: project operation and maintenance and the capital investment made to construct the project. Even small farmers or small urban consumers should pay the first in full (to ensure continued effective operation of the project) and as much of the second as possible, taking into account the repayment capacity of the water users and the needs for incentives to discourage waste of water, for disincentives to discourage pollution, and for revenue to assist in retiring indebtedness.[5] In regions where water is scarce or becoming so, block systems, whereby charges per unit of volume increase as the volume increases, are receiving growing attention.[6] Pricing policies for water obviously have many political overtones. The Bank, by insisting on reasonable financial performance targets for agencies that distribute water, has been able to relieve local officials of some of the agony of politically difficult pricing decisions while at the same time reducing the burden on the national budget.[7]

Project Leadership

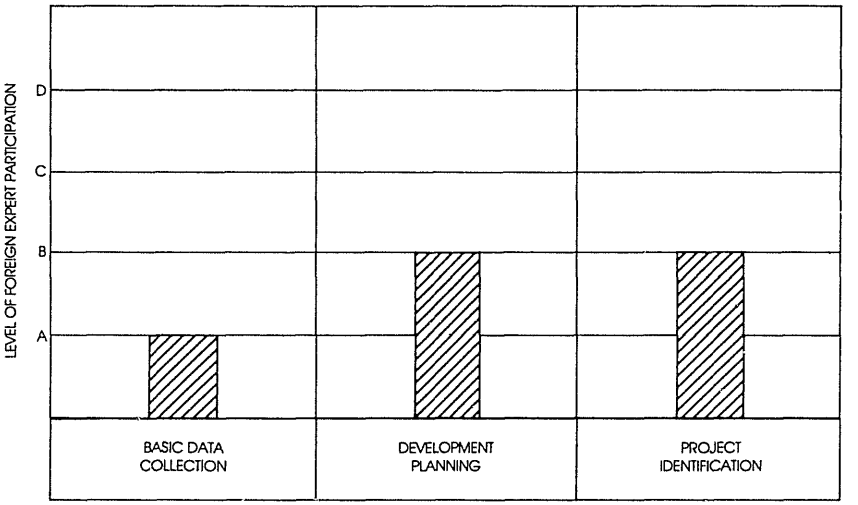
Successful project execution requires effective leadership, since, in addition to an interdisciplinary team, a leader is necessary to coordinate the efforts

of the separate disciplines and provide linkages with outside agencies and with the local people. In my opinion, the ideal leader is one who has mastered one of the disciplines mentioned and in addition has acquired considerable understanding of the other disciplines; he or she should also keep up with local and world events. Such leaders are rare because the educational systems of most countries provide technical training that is too narrowly oriented toward a single discipline. Insufficient time is given to related disciplines and to the humanities; people lacking such training should be called technicians and not professionals.

Technology Transfer through Foreign Experts: Advantages and Limitations

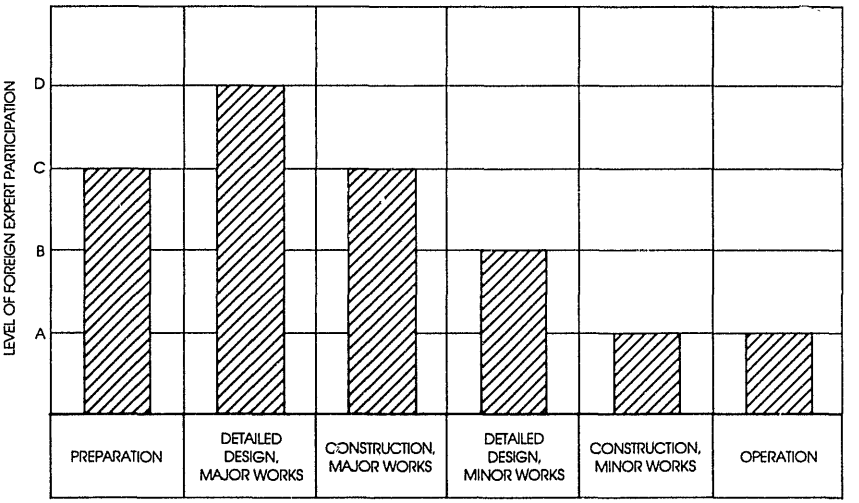
If a country lacks leaders of the kind described, it can import them, but such an expedient may be of only limited and temporary value since planning must go on continuously for many years and since foreign experts require a long time to acquire sufficient knowledge of local conditions.

In discussing the role of foreign experts, the various stages of the project cycle need to be considered. Following identification and preparation, a project proceeds to detailed design, construction, and operation. As figures



Key: **A**, foreign experts provide guidance but primary responsibility is with authority; **B**, foreign experts participate but primary responsibility is with authority; **C**, foreign experts take the lead but authority participates to ensure coordination with long-range plans and proper operation following completion; **D**, foreign experts take full responsibility.

Figure 11–1. Long-Range Planning



Key: **A**, foreign experts provide guidance but primary responsibility is with authority; **B**, foreign experts participate but primary responsibility is with authority; **C**, foreign experts take the lead but authority participates to ensure coordination with long-range plans and proper operation following completion; **D**, foreign experts take full responsibility.

Figure 11-2. Project Execution

11-1 and 11-2 illustrate, foreign experts may have an important role in these various phases, which are not always clearly distinguishable from one another. The precise role of such experts is, in fact, a rather neglected question that has not been the object of much systematic or detailed study.[8] Yet the answer is important since good development experts are too rare and valuable for their services to be wasted.

If the role of the foreign expert is to be studied as it deserves, the complex processes of bringing a development project into being have to be examined stage by stage, and the work done in each stage has to be examined and analytically divided. In the design and construction of large-scale water resource projects, we must, moreover, make a distinction between major works and minor works. Large dams, transmission lines, pumping stations, processing plants, and major canals fall in the first class and require different treatment from minor structures—distributary lines and canals, small bridges and buildings, and the like.

Large-scale water resource projects for developing agriculture usually involve a larger total effort in minor works than in major. An irrigation, drainage, or groundwater project typically contains many miles of small canals and drains, as well as many wells and ancillary structures. Rural roads

must often be added, and sometimes farm works as well, such as clearing, leveling, and other kinds of land preparation. The aggregate cost of such minor works can easily exceed that of the major works on which the project is based. Individual large dams are, of course, conspicuous triumphs of civil engineering, but it is a great mistake to allow them to have all the publicity. Take, for example, the large irrigation-drainage-flood-control schemes in the Indo-Pakistan subcontinent, where, in the long run, the expenditures on minor works and agricultural ancillaries will greatly exceed the expenditures for major works. The minor works here involve a formidable interplay of a large number of variables of a complexity more than great enough to challenge the ingenuity of the finest technical brainpower.

If minor works are characteristically extensive, they also have another feature that is important. Their planning requires close contact with local farmers, whose number will depend on the size of the average farm and area in the project. In parts of Latin America where farms are large, only a small number may be involved, but even there land subdivision and settlement schemes are tending to increase the number. In parts of South Asia, a project of 50,000 hectares with average landholdings of 1 hectare affects 50,000 families. With such large numbers, the problems of land acquisition and rational layout of minor works become increasingly complex, not only because of the physical factors such as topography and property lines but also because of the need for a suitably timed program in which the minor works are properly phased with respect to the software elements (such as credit, extension, marketing, and improved seeds and fertilizers). Besides, the entire effort must be properly managed, with adequate incentives provided to the farmer.

Where will the directors of the project find the people who can handle such a complex of ancillary works and obtain the cooperation of the farmers in the process? All experience shows that only local people can deal on a massive scale with other locals. It would be impracticable (and excessively costly) to bring in foreigners to the extent required, and even if they could be brought in, it would take them too long to get acquainted with local habits and customs. To find local people who already have, or who can be provided with, the necessary technical training means a great deal of planning at a very early stage, even before the stage of what is technically known as project preparation.

Another compelling reason why the major part of the planning effort must be carried out by local rather than foreign experts concerns the continuity that is vital to sustained success. Major development schemes in the world—the valleys of the Mississippi, the Nile, the Rhine and the Rhone, land reclamation in the Netherlands and Italy—were carried out over many decades, even generations, by people who made this work their career. It is in the nature of such developments that one must live with them for a long

time to come to understand the many ramifications of works dealing with waters, land, and people. Unless a foreigner is prepared to live in the country or can find some other way of continuously identifying with the particular development, he or she cannot take primary responsibility but can be only an adviser on limited aspects of the development.

On the other side of the coin, there will be many fields where, through lack of previous experience with works or projects of the type and scope contemplated, the necessary expertise cannot be found in the country. In this case, foreign experts should be employed. Such experts should be selected with care, taking into account whether their expertise covers technologies that are in fact applicable and transferable. For example, experts on water control in arid-zone agriculture should not be assigned to humid-zone agriculture nor should water supply experts on advanced treatment methods be assigned to deal with village water supplies based on groundwater.

Foreigners cannot participate as fully in long-range planning as they can in project execution. The maximum effective foreign participation is reached in the phase of detailed design. Large and complicated structures, such as high dams, major diversion dams, large pumping stations, power stations, processing plants, and high-voltage transmission lines, require large, sophisticated engineering design organizations. In countries with little previous experience, these can be developed only at high cost and over a long period of time. Moreover, even though the investment is made to create an organization to design, say, a high earth-fill dam, such an organization will most likely be unsuitable for the next dam to be constructed, which may be one of concrete-gravity or thin-arch type.

It is thus in the detailed design of major works that properly selected foreign experts are the most valuable. Such works usually can be isolated from the other works involved so that the problem of coordination with local factors, so characteristic of minor works, is generally not serious. The detailed design of major works can thus be performed anywhere, even outside the country—for instance, at the home office of a consulting firm where all the necessary expertise is already assembled.[9]

Examples of major water resource development with which the World Bank has been concerned are described briefly in table 11-2. The Bank's participation has taken the following forms: review of consultants' terms of reference and reports, advice and monitoring of the effort of national groups, and direct participation through dialogues with national groups over an extended time period. The first form is the most common. It is argued that the second two forms should be used more often; however, the Bank has limitations with respect to its available manpower, and the Bank (rightly, in my opinion) does not wish to push its own ideas too hard as there is a danger that the resulting project(s) will bear a World Bank label rather than a national label.

Table 11-2
Representative Examples of Major Water Resource Developments Involving the World Bank

Name of Development	*Location*	*Nature of Development*	*World Bank Role*[a]
National Water Plan	Mexico	See text	Advice and monitoring
Tropical Lowland Development	Mexico	Drainage and rain-fed agriculture, carried out by national team aided by foreign experts (FAO) paid by UNDP	Advice on F, PI, and PP
Nile River Basin	Egypt	Master Plan for Water Resource Development and Use, by national team aided by foreign experts (UNDP project)	Advice and monitoring on F
Indus River Basin	Pakistan	Irrigation, drainage, flood control, and hydroelectric power, carried out by national agencies aided by foreign consulting firms	Assisted in negotiating treaty with India (1960) and administering subsequent Indus Basin Development Fund
Mekong River Basin	Southeast Asia	Long-range plan for flood control, irrigation, hydroelectric power, and navigation, by international team financed by UNDP	Advance on F, PI, and PP, including review of Basin Plan and development priorities at request of UN
Senegal River Basin	West Africa	Long-range plan by foreign consulting firms	Advice on F, especially on possible phasing
Land and Water Development	Bangladesh	Medium-range and long-range plans for irrigation, drainage, and flood control, carried out by national agencies aided by local and foreign consulting firms	Advice on F, PI, PP, and PO
Lower Magdalena River	Colombia	Flood control, drainage, and rain-fed agriculture, by national team with advice of foreign experts	Advice and monitoring on F and PI
Mahaweli Ganga	Sri Lanka	Irrigation, flood control, and hydroelectric power, by national team supported by foreign experts (UNDP)	Advice and monitoring on F, PI, and PP
Montaro Development (trans-Andean Diversion)	Peru	Hydroelectric power and water supply for Lima, by foreign consulting firm	Advice on F and PI
Lower Guayas River Development	Ecuador	Flood control, drainage, and rain-fed agriculture, by national team supported by foreign experts	Advice and monitoring on F, PI, and PP
Santiago Region Development	Chile	Water supply, irrigation, drainage, flood control, and hydroelectric power, by national team supported by foreign experts	Advice on F
Chao Phya Basin	Thailand	Irrigation, power, municipal/industrial water supply, and flood control	Financing of study for future water allocations; advice on consultants' terms of reference and review of consultants reports

[a]Abbreviations are as follows: F, framework planning; PI, project identification; PP, project preparation; PO, project operation.

When the construction phase for the major works has been reached, foreign experts will be still required to ensure proper execution of the design. But at this stage, local technicians should play a larger part for reasons of economy so that they may have sufficient acquaintance with the works to operate them when the time comes.

The construction of minor works and the operation of all works should be primarily the responsibility of the local authority set up for the ultimate operation of the project. The construction of minor works is something that, if not already within the capacity of local contractors and technicians, should become so at an early date, since, with any development of consequence, the same kind of minor works are repeated many times. The operation of the project should be undertaken by local authorities, with only the occasional guidance of foreign experts as might be found necessary.

Whatever the immediate role of the foreign expert—whether in planning, design, construction, or operation—his or her contribution will have little lasting effect unless on-the-job training of local experts for these tasks is an essential part of the assignment.

Training of Local Manpower

In many countries, the availability of local experts, without whom no major development effort can succeed, is far short of the need. The difficult task of creating an adequate corps of such experts in a reasonable time must be attacked on several fronts. Education at all levels, vocational as well as professional, is one means. On-the-job training is another; such training is another fruitful field for the foreign expert.[10]

In construction, some spectacular successes have been achieved on such large concentrated operations as the Mangla Dam in Pakistan and the Aswan Dam in Egypt. When activities become more dispersed, results are not usually too good; indeed, up to the present, efforts to train local experts for planning and management, and for dealing with local inhabitants on a massive scale, have fallen short of their objectives.

In Bangladesh, for example, there has been some development of local know-how in project preparation, but in execution and management, as measured by the needs—admittedly very large—progress so far is disappointing. This is true despite the presence of large numbers of foreign experts for more than two decades. Fortunately, the authorities in Bangladesh, in cooperation with foreign aid and foreign financing agencies (including the World Bank), are now engaged in working out a solution, following studies of the proper role of foreign experts. These studies have focused on how such experts can be most effective in carrying out training of local experts and how to develop and maintain adequate sources of local experts.

Although examples of successful on-the-job training in water resource projects are disappointingly few, there are some notable successes. The

development of consulting firms in Colombia is one. Educational standards have always been relatively high in that country. In the late 1940s and early 1950s, several promising young Colombian engineers started their own firms, after a period of employment with foreign (mostly U.S.) firms. The Colombian firms are now entirely independent, although some find continued association with the foreign firms to be advantageous.

Although formal education and on-the-job training are valuable means of developing local experts, they can succeed only where potential experts are available, and they are not likely to be available in the absence of an auspicious climate that will attract the vigorous and intelligent among the population to follow the pursuits involved. How can this be achieved? Salary scales are one answer, but possibly more significant is the prestige connected with working on a project of high national purpose and importance. Here is where government at its highest level comes in. Government should first establish prestige by giving the project concerned high priority. Second, it should establish an organizational framework along with personnel policies that will maintain prestige and morale. The Ministry of Hydraulic Works of Mexico, the Waterstaat of the Netherlands, and the Tennessee Valley Authority in the United States are examples of world-famous agencies that have attracted high-caliber people and kept them at high levels of performance. The rewards offered comprised national recognition and feeling for a job well done rather than monetary compensation, although it is true that the latter was above generally prevailing rates.

Organizational and Institutional Factors

In the less developed countries the organizational and institutional framework concerned with water resource development is generally weak—more so in the agriculture and water supply sectors and less so in the power sector. The weakness in the case of the agricultural sector stems largely from the low priority traditionally assigned to agriculture. Although attitudes are changing, agriculture still suffers from insufficient funds, lack of skilled manpower, and economic policies unfavorable to agricultural development. In the water supply field, institutional as opposed to engineering improvement is relatively more difficult to achieve, particularly where services are poor and deteriorating.

Another typical problem in developing countries is the lack of coordination between the implementing ministries, on the one hand, and the so-called core ministries that handle overall national planning and finance, on the other. Often the only way to proceed is to push actual projects that have been well prepared even though the plan has not been fully defined.

These institutional problems also prevail in the developed countries, although the nature of the institutional problem in the developed countries is different from that in the developing countries.[11]

The government designated the Secretaria de Recursos Hidraulicos (SRH) as the main agency responsible for the study. SRH established a special Plan Commission to organize and manage various multidisciplinary planning groups composed of staff from SRH and other concerned agencies to carry out the work program. The government also established a coordinating committee organized by SRH but including representatives of the Ministry of Programming and Budgeting (Secretaria de la Presidencia, SDP), the Ministry of Finance (Secretaria de Hacienda y Credito Publico, SHCP), the Ministry of Industries and Commerce, the Ministry of Agriculture, and the Department of the Federal District to assist and guide the work of SRH and ensure full cooperation of all concerned agencies. At the highest level, a directive council consisting of three Mexicans and three foreign experts in planning, provided policy guidance.

The deputy minister for planning of SRH was designated to head both the Plan Commission and the coordinating committee. The planning groups were composed of about fifty specialists from Mexican consulting firms. A UNDP project with a grant of about $1.1 million was approved to assist in carrying out the study through the provision of five international experts on a full-time basis, resident in Mexico, and about twenty part-time nonresident experts. The UNDP grant covered the cost of the international experts, as well as fellowships and visits abroad of Mexican staff, and seminars conducted in Mexico by visiting expatriate university professors and other experts.

In accordance with a government request, the World Bank acted as executing agency for the UNDP project, and the Bank assigned four professional staff members to assist in recruiting the international experts and in monitoring the progress of the study. The corresponding tripartite agreement stated that the National Water Plan emerging from the study "should provide a reliable frame of reference for future lending programs in the field of water resources," without, however, interfering with loans already being processed.

The work of the Plan Commission culminated in the issuance of a document in early 1976 entitled "Plan Nacional Hidraulico 1975." The following accomplishments of this study deserve to be highlighted:

1. General acceptance, for the first time, of the need for a continuing, institutionalized planning effort covering the entire project cycle (framework planning, project identification, project preparation, project implementation, and project monitoring).
2. Assessment of the deficiencies and unreliabilities of existing data bases and determination of the need for more detailed field studies (groundwater, drainage in humid tropical lowlands, and check of agricultural statistics through satellite pictures, for example).[12]

Long-Range Planning: The Case of Mexico

Typically, in most countries, water resources projects (irrigation, water power, flood control, drainage, water supply, waste disposal, navigation, soil conservation, and watershed management) are identified, evaluated, financed, and constructed on a piecemeal basis. To avoid this undesirable situation, long-range, continuously updated national and/or regional water plans are necessary, although proceeding with actual projects cannot always wait for the preparation of such plans. The appropriate timing for proceeding with preparation of national and regional water plans should depend, first, on a commitment by the government of adequate leadership and technical manpower resources (usually seriously limited in less developed countries) and, second, on a determination of how critical the water resource factor is with respect to national objectives and priorities.

Mexico provides an example of a developing country in which water availability is a limiting factor and where the government has provided adequate leadership and manpower, including some international experts, to carry forward national and regional water planning in an effective manner. Mexico's investment in water projects in the public sector amounted to $2.7 billion in the 1971–1976 *Sexenio* (presidential administration). In addition, the private sector has been investing considerable sums in groundwater development under government-sponsored credit schemes. The water resources of Mexico are scarce compared to the needs, and conflicts over their uses are becoming serious. In order to develop a sound water policy for the efficient utilization of available water resources, while taking into account sectoral priorities and the objectives of more equitable income distribution and regional development, the government proceeded in September 1972 to carry out a National Water Study. The long-range objective of this study was to formulate and institute a systematic process of water resource planning for the rational selection of programs, projects, and policies concerning water so as to help attain the country's objectives of socioeconomic development. The immediate objectives of the study were the following:

1. Formulation of policies concerning water development and control, with recommendations for the institutional measures required.
2. Formulation of alternative water development programs for the short, medium, and long term, including preliminary identification of projects.
3. Design of an information system to cover immediate data needs and to ensure the flow of data needed for systematic planning.
4. Establishment of a systematic training and instruction program covering the additional staffing needs of all the areas and activities included in the plans, programs, and projects for water resources development.

3. Initiation of studies and evaluations that measure existing and potential water use inefficiencies, particularly in irrigation, together with an analysis of potential alternatives to reduce such inefficiencies, including an analysis of present water pricing practices in agriculture, as well as other sectors, with proposals for changes in order to bring about greater efficiency and equity pricing practices.
4. Development of mathematical models for major hydrologic basins as tools for analyzing alternative regional hydraulic development projects.
5. Identification of present and likely future water use conflicts and preparation of proposals for solution, including the transfer of available water from low-value to higher-value uses, conjunctive groundwater-surface water systems, and new means to deal with the resolution of such conflicts.[13]
6. The first systematic attempt to evaluate the implications of the proposed medium- and long-term development programs on the current and future SRH budgets.
7. Establishment of better liaison with the core ministries (Programming and Budgeting, and Finance) and with other agencies concerned with water resources.
8. The first attempt to evaluate skilled manpower needs within and outside SRH, including an evaluation of existing educational structures (and their required changes) to overcome manpower training deficiencies.
9. With respect to agriculture, recognition that the vast but hitherto largely neglected humid-tropical lowlands in the Gulf Coast must now receive priority attention, that the traditional approach (large-scale irrigation) is inappropriate for this region, and that, instead, the emphasis should shift to drainage, flood control, and small-scale supplemental irrigation.[14]
10. Growing recognition in several other water-short Latin American countries with knowledge of the Mexican effort (Chile, Peru and Ecuador) that the time may soon be ripe to undertake a similar activity.

Framework Planning

Frequently there is a lack of interaction between long-range plans, whether national or regional, and specific projects. The best way to overcome this problem is to proceed by successive approximations. The term *framework planning* has been used to describe this device, which may be viewed as a series of approximate, periodically updated, and improved studies of available data on physical and human resources, socioeconomic conditions, multiple objectives for a region, and alternative development plans.[15] The

concept seems obvious, and it is not at all new; what is surprising is how often it is not used. There are many examples worldwide of overly perfect master plans, which are not only excessively rigid but also make use of inadequate or erroneous data.[16] The term *master plan* has, moreover, a sense of finality that is inappropriate for the evolving, multifaceted activities embraced by water resource development.

Long-range plans have a number of other defects. As far as specific projects are concerned, they often suffer from inadequate downward linkages with local residents and politicians. In seeking such contacts, selectivity should be practiced so as to identify influential local leaders without whose support time and effort will be wasted.

Long-range plans often also suffer from inadequate upward linkages—inadequate contact between the project-implementing agency and the appropriate national planning agency. When goals are poorly defined, the project development agency may not be able to wait for the clarification of such goals. On the contrary, by proceeding with the project, a feedback will take place, and it may, in fact, help to define national goals. Finally, long-range planning may become quickly obsolescent. Thus, plan updating should be a continuous process, carried out by a well-qualified multidisciplinary group.

Since framework planning, like all other planning, requires intuition, imagination, and seasoned judgment, it is a field for neither the narrow-minded nor the novice. Here again the problem confronting developing countries is to find the best combination of local and foreign expertise to carry out both long-range planning (including framework planning) and project preparation. In most instances, framework planning has been carried out using river basin divides as the problem boundaries. Such boundaries, however, are not always appropriate, as shown by several examples of major water resource developments with which the World Bank has been concerned.

The Application of New Techniques

Space age techniques have a place in water resource planning in the developing countries. These techniques include remote sensing and mathematical models that make use of computers. If intelligently used, these new techniques can save much time during both the reconnaissance phase of planning and during the operating phase.

Computerized mathematical models of hydraulic systems (for example, river basins involving several reservoirs or large groundwater aquifers) are often useful, although their applicability in the developing countries would be the exception rather than the rule. Moreover, there is a danger inherent in overcommitment to mathematical models that stems from the fact that

reality cannot always be represented by quantifiable factors. Nonquantifiable factors may be even more important in the decision-making process. Consider, for instance, the risk that farmers must take in anticipating their markets for commodities by several months, the social instability resulting from increased unemployment if labor-saving technology is used, or the fact that poor subsistence farmers will not try out the new high-yielding varieties of seed because failure can mean starvation. Mathematicians familiar with the manipulation of models are rarely in a position to identify such key variables, and since models are often allowed to develop a life of their own rather than remain a limited tool, there is a tendency not to rely enough on professionals from other disciplines who cannot provide computerizable statistical information.[17]

Since planning is an art as well as a science, we must allow scope for intuition, imagination, and judgment, which can never be fitted into mathematical models, categories, and coefficients. We have learned that the level of professional competence and judgment of an experienced interdisciplinary team is crucial and transcends in importance the skills in mathematical modeling.

The term *systems analysis* has tended to become synonymous with the use of mathematical models. In my opinion this meaning is incorrect since all the term signifies is a logical and orderly approach to the analysis of a system (and there is nothing new in such an approach) while taking into account all relevant factors, some of which are quantifiable and some of which are not. Since nonquantifiable factors, according to my definition, are included, systems analysis transcends and is not synonymous with mathematical models.[18]

Notes

1. On this point, see David J. Bates and Graham F. Donaldson, "Changes in Emphasis in Rural Sector Lending," *Finance and Development* (June 1975); Albert Waterston, "A Viable Model for Rural Development," *Finance and Development* (December 1974); and Arturo Israel, "Toward Better Project Implementation," *Finance and Development* (March 1978, vol. 15, no. 1, p. 27.30).

2. Confusion often arises as to what is meant by *detailed design* and how much design is included at the project preparation stage. By *detailed design*, I mean construction drawings and specifications for civil works and equipment, in sufficient detail to solicit tenders leading to contract awards. The project preparation stage should, in my view, culminate in the form of a feasibility report; such a report should include enough preliminary design on which to base reasonably accurate cost estimates of the costs of both hardware (civil works and equipment) and software (administration, tech-

nical assistance, training, and so forth). Decisions on whether the project should proceed and, if so, how it should be modified should be based on a review of the feasibility report. Detailed design should then start without delay.

3. When politicians have pet projects—a not uncommon situation—planners should be ready with alternatives that weigh the pros and cons in economic and social terms. The planners must then try to persuade the politicians regarding the most desirable course of action—a difficult task that is not always effective.

4. See P.Z. Kirpich and H.P. Dugan, "Province-Wide Irrigation and Drainage Planning and Development in East Pakistan," paper presented at the Eighth Congress of the International Commission for Irrigation and Drainage, Varna, Bulgaria, 1972.

5. For a discussion of the advantages and limitations of economic incentives and disincentives, see Sterling Brubaker, *To Live on Earth: Man and His Environment in Perspective* (Baltimore and London: Johns Hopkins University Press, 1972), pp. 172, 186.

6. See Marshall Gysi and Daniel P. Louks, "Some Long Run Effects of Water Pricing Policies," *Water Resources Research* (December 1971):1375.

7. See *World Bank Operations—Sectoral Programs and Policies* (Baltimore and London: Johns Hopkins University Press, 1972); *Rural Development—Sector Policy Paper* (Washington, D.C.: World Bank, 1975); *Village Water Supply—A World Bank Paper* (Washington, D.C: World Bank, 1976), pp. 35-36.

8. That it is not only a neglected question but also an urgent one is the view of C. Gordon Thether, *Financial Times*, 26 April 1967, commenting on P.Z. Kirpich, "Foreign Experts: Their Advantages and Limitations," *Finance and Development* (March 1967).

9. Suggested techniques for the selection and engagement of consultants (including foreign experts) can be found in *Guidelines for the Use of Consultants by the World Bank as Executing Agency* (Washington, D.C.: World Bank, 1981).

10. For a longer discussion of manpower problems, with special reference to water resource planning and implementation in Mexico, see Gunter Schramm, "Human Institutional Factors," *Natural Resources Journal* 16, no. 4 (October 1976).

11. For discussions of institutional aspects of water management in developed countries, see *Water Management—Gestion de l'Eau* (Paris: OECD, 1972), and Gilbert F. White, *Strategies of American Water Management* (Ann Arbor: University of Michigan Press, 1969).

12. A common fault to be guarded against is to collect an excess of data that are either irrelevant or premature in that they will become obsolete before being used.

13. The Lerma River basin in the central plateau is the zone of most internal conflicts over water use (urban and industrial versus agricultural) and over pollution. The Lerma basin is adjacent to and provides important sources of water for Mexico's two largest cities (Mexico City and Guadalajara) and contains within its limits eight medium-sized cities, important industries, and about 200,000 hectares of irrigated land. Water demand has already outstripped the available supply in dry years, and serious contamination of underground aquifers is occurring.

14. Vast areas with good soils elsewhere in tropical America that are similarly underutilized—even though they are ecologically similar to the productive rice areas of South Asia—include the Lower Magdalena basin in Colombia, the Lower Guayas basin in Ecuador, and the Pantanal (state of Mato Grosso) in Brazil. See P.Z. Kirpich, "Development of Lowland Tropical Flood Plains in Latin America" (Paper presented at the Regional Preparatory Meeting for the World Water Conference, Lima, August 30, 1976), and Kunio Takase and Toshihiro Kano, "Development Strategy of Irrigation and Drainage," *Asian Agricultural Survey, Part VII* (Manila: Asian Development Bank, 1969).

15. According to this description, a framework plan would resemble in many respects the Level B studies of the Water Resources Council of the United States. See "Establishment of Principles and Standards for Planning," *Federal Register*, September 10, 1973, p. 92.

16. There is a need for flexibility not only in framework planning but also in project preparation and implementation, especially for new-style projects with large software components; see Israel, "Toward Better Project Implementation."

17. Several writers have warned of the danger of faddism associated with mathematical models. See John Kenneth Galbraith, *Economics, Peace and Laughter* (New York: Houghton Mifflin 1971), p. 43; *World Bank Operations—Sectoral Programs and Policies*, pp. 428, 453, 455; and Ven Te Chow and S.J. Kareliotis, *Water Resources Research* (December 1970): 1580, who note, "A systematic theory for the formulation of a stochastic system model is unavailable because the formulation of the model requires practical knowledge of the physical characteristics of the process and the system that is usually lacking in the mathematician."

18. For further references on the advantages and limitations of systems analysis as applied to water resources planning, see Myron B. Fiering, "The Role of Systems Analysis in Water Program Development," *Natural Resources Journal* (October 1976, vol. 16, no. 4), and Gilbert F. White, "Introduction—World Trends and Needs," *Natural Resources Journal* (October 1976, vol. 16, no. 4); Warren A. Hall, Systems Analysis in Irrigation and Drainage," *Journal of the Hydraulics Division, ASCE* (April 1973), and discussion by P.Z. Kirpich; and Asit K. Biswas, ed., *Systems Approach to Water Management* (New York: McGraw-Hill, 1976).

Power Generation and Distribution

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The electric power sector is one of the three largest areas of Bank lending (the other two are transportation and agriculture). By the end of fiscal year 1983, the cumulative lending in the power sector reached $18.6 billion, accounting for almost a fifth of all the Bank Group operations.

In the early 1950s, when the primary focus of the World Bank's operation was the transfer of resources to the war-devastated countries of Europe, the power sector offered an especially appropriate channel for a quick and efficient transfer of resources on the massive scale that was required. After the setting up of the Marshall Plan, the Bank focused its lending activity on the developing countries. Power again played an important role in the lending strategy primarily directed to the industry sector. In recent years, the Bank's philosophy has emphasized rural development and lending directly to provide for basic needs. Despite this change in policy, commitments in the power sector have continued to grow. Between 1978 and 1983, power sector loans amounted to $10.1 billion, more than 15 percent of the total Bank lending over the same period.

Although a somewhat smaller proportion than in the past, current levels represent a greater dollar amount than ever before. The Bank recognizes that power is necessary not only for the development of the manufacturing sector but also in agriculture to drive water pumps and for agro-based industries; it is also required for the general development of the villages through rural electrification.

Power Sector and Its Development

The growth of the power sector in many developing countries tends to follow the same general pattern. Three broadly defined stages may be identified. In the first stage, electricity is introduced to the country, most often starting in the urban areas. Small scattered plants, often installed to meet the needs of a particular industry, also generate power for the needs of nearby consumers. The plants are sometimes privately owned and operated, but municipalities and city or state governments may be involved. If the World Bank starts to lend for power in the country at this stage, it tends to be involved with relatively small, isolated projects.

The second stage arises as the demand for power grows, the area of coverage expands, and larger plants are built. The Bank's role at this stage is not only to finance generating plants, transmission lines, and distribution facilities but also to help develop an effective organization. Where the management of the sector is fragmented, resulting in poor planning and inefficient operation, the Bank frequently advocates consolidation and sometimes makes its loan conditional on centralization. The government is sometimes urged to pass the needed legislation and clear the way for mergers where such actions would increase the efficiency of the sector operation.

Often the countries are encouraged to create an electricity authority at the national level. With the creation of a central authority, the power system of the country may be planned more efficiently. Sophisticated techniques are introduced to help plan for the growth of power generation facilities to meet a growing demand. This ensures the most economical expansion and also helps schedule sufficiently in advance the availability of financial and human resources needed for the construction of the system.

The third stage is the institutional development of the sector. Although an electricity authority may have been created, it may take some time before the organization begins to function effectively. Procedures that were adequate for smaller, fragmented organizations are usually found to be inadequate for large-scale operations with widespread interconnections. The Bank helps with technical assistance in the planning and building up of institutional capacity. This sometimes requires reinforcement of existing institutions or advice to the borrowing country on how to create new institutional structures appropriate to the nation's power sector development. Frequently at the Bank's initiative, the expertise is provided by consulting firms, which are hired to conduct diagnostic studies or offer other kinds of technical assistance, such as improved management information systems or better ac counting techniques. Funds are also made available for the training of personnel in the techniques of management and power sector planning. Institution building remains one of the primary goals of the Bank in its power sector lending program.

The Bank's Role in Technology Transfer

In power, as in other sectors, the choice of technology is of great importance. There are usually several possible ways to produce the desired output. Some options generally will employ more of the needed inputs to produce a given result and are therefore inefficient relative to other techniques. Common sense often rules out some technically inefficient technologies, but other choices are less obvious. In many cases, there are several different

techniques, all technically efficient and each using different amounts of the various inputs. The choice among these techniques is an economic one and should take into account the scarcity of the required inputs and the costs and benefits of the investment. The determination of the least-cost technology is mandatory in the evaluation of projects in the power sector. The term *least cost* means the minimum long-term combined capital and operating costs of the system (excluding sunk investments), which are discounted at an appropriate interest rate.

The Bank does not have set views on proper sector technology. It does not suggest the use of large rather than small generating units, or capital-intensive methods of construction instead of labor-intensive methods, or the reverse. For example, there are considerable economies of scale in the generation of power, and when large-size thermal units are chosen, it is a reflection of scale economies. Similarly, the use of capital-intensive construction techniques may well be the most appropriate, even in labor-abundant developing countries, if their use results in large savings of money.

In the preliminary assessment of a power project, the demand for power is first projected in considerable detail, including the magnitude and frequency of peak loads. The various ways of meeting this demand in the actual country context are then evaluated with as close to the same degree of reliability as possible. If the project is feasible, the Bank then strives to help the borrowing country select the most technically and economically efficient technology in relation to the specific objectives, constraints, and circumstances of a project. As a matter of policy, the Bank does not advocate the installation of prototype facilities or the use of untested technologies in developing countries. This does not mean that the Bank is opposed to new techniques, but it does not wish to see scarce development capital used for experimental purposes. The Bank has, however, financed geothermal plants and lignite-fired steam plants that were among the first of their kind in the world.

There have been instances where the Bank has considered, but not chosen, the most modern technology. In one country, for example, extra high voltage direct current transmission was studied for a large power project, but it was finally decided that the more appropriate choice was alternating current. In another country, a lower voltage transmission system was preferred to a more sophisticated high voltage system because of the special circumstances of the project. When the situation is warranted, however, the Bank does not hesitate to recommend the very latest technology, the leading edge of the state of the art. This has been true particularly in the case of transmission systems where transferring large blocks of power over long distances is necessary.

The Bank has not endeavored to transfer technology in the abstract, nor has it sought, at least in the power sector, to cultivate new technologies

through its own program of research and development, although in one case it has partly financed a power research facility. Rather, the role of the Bank has been that of a catalyst, helping its borrowers identify priority sectors of development and assisting in the choice of proper facilities and the most appropriate technologies.

"Technology involves a great deal more than the mechanical processes."[1] In addition to the rather obvious engineering aspects of technology, financial and economic expertise, as well as organizational know-how, are also transferred. Technology transfer is, however, a slow and complex process. Beginning with the right questions being posed to the entity seeking the loan, the transfer of technology proceeds through the various stages of project appraisal, negotiation, implementation, and operation. Techniques of system planning and economic appraisal are transmitted in the early stages of project definition and preparation. Most of the engineering know-how gets transferred during the actual construction and start-up phases, and organization skills are developed as operations begin. In most countries where the Bank has lent for power projects, the relationship has been a continuing one with a series of lending operations over long periods of time.

While the beneficiary of the loan—the power entity—is the main recipient of the technology transfer, some know-how spills over to others. Local suppliers and construction contractors acquire new expertise as the project is carried out. In order to stimulate such transfers, the Bank encourages local manufacturers of equipment and local construction firms by using them where possible. Local equipment suppliers are granted a margin of preference of up to 15 percent over foreign suppliers; local civil works contractors in very low-income countries are allowed a margin of 7.5 percent.

With few exceptions, the Bank finances the portion of power project costs that involve foreign exchange. This component tends to be higher for projects in the power sector than, for instance, in the agricultural sector, but there are also big differences within the power sector itself. The proportion of foreign costs for a hydroelectric complex may reach only 50 percent of the total because civil works for hydro projects have a large domestic content, including labor and locally available materials such as cement and reinforcing steel. For steam-electric plants, which are much more dependent on equipment manufactured outside the country, the proportion of foreign costs can go up to 75 percent. In countries where manufacturing capacity is limited, the foreign exchange component of transmission and distribution facilities may be even higher.

The most important element in the implementation of a project is the arrangement for construction. Delays in completion result in delays in realizing benefits. A competent and experienced contractor can usually be relied on to plan the work and mobilize resources to meet the construction schedule. Because the most experienced firms are often based in the indus-

trialized countries, local firms tend to win fewer contracts, and it is difficult for them to break out of this vicious circle; they do not get the job because they do not have enough experience, but they cannot get the experience without the job. One way out of this situation is for local firms to form consortia with foreign firms when bidding for projects. The Bank has encouraged this in several instances and has also favored the hiring of local firms for the construction of auxiliary works, such as access roads, construction camps, maintenance facilities, etc. These components often account for a substantial portion of a large and complex project and usually have fewer complications. In recent years, local firms have been widely used in the construction of power projects in several middle-income developing countries.

The diffusion of technology among developing countries has attracted much attention, and the Bank is in a good position to act as a broker in the technology market, especially in the transfer of technologies from one developing country to another. But the problem here is a basic one: in many cases, there is little new technology in the developing countries themselves. Where the production capability exists in developing countries, the Bank has encouraged the purchase of such equipment by its borrowers, but results have been mixed. In some cases, deliveries have been late, or the equipment did not meet specifications. The effect may well make it even more difficult for suppliers from developing countries to gain a significant share of the international market. Greater attention must be given to quality control and reliability if developing countries are to become major suppliers or contractors in other countries.

One important aspect of technology transfer is the dissemination of the cumulative knowledge and experience gained from all Bank projects. The lessons learned in one country are used to good advantage in other countries by both the Bank and by various firms involved in the projects. While this cannot really be thought of as a conscious and deliberate technology transfer, it does constitute a substantial benefit for borrowing countries and can be viewed as a kind of transfer of technology between developing countries.

Transfer of Engineering and Organizational Capabilities

Two general types of technology are transferred in the power sector. The first comprises technical and engineering capabilities, and the second relates to organizational and managerial skills. Beginning with the first loan made for an electric power project—to Chile in 1948 where it financed a high-head hydroelectric generating plant, which at the time was the highest in the Western Hemisphere—the World Bank has helped to transfer engineering

know-how. In that same country, it helped to introduce arch dam technology when it financed the Rapel hydroelectric project in 1959, and seven years later, new underground construction methods were introduced at the El Toro hydroelectric station.

Several of the extra high voltage (EHV) transmission lines financed by the Bank introduced new technology to the country. Brazil's first 345 kilovolt line was begun in 1958; EHV technology was introduced to Iran and Yugoslavia in 1972, and in Argentina a 500 kilovolt line was adopted for the Chocon hydroelectric project transmission system in 1968. Direct current transmission was employed for the connection between New Zealand's North and South Islands in 1962. The Bank also helped build Ireland's first pumped storage facility. Italy's first nuclear power plant, the Senn nuclear project approved in 1958, was supported as a training facility.

The Bank has had a major role in the transfer of organizational capabilities in the power sector in several countries. Brazil is one of the Bank's main power borrowers and has a large and rapidly growing power sector. After financing individual projects for several entities within the country, the Bank realized the importance of a comprehensive strategy for the development of Brazil's hydro resources. In the 1960s the Bank acted as the executing agency for a study financed by the UNDP to evaluate the hydroelectric potential of the south and southeastern regions. This so-called CANAMBRA study, completed in 1969, formed the basis for the development strategy of the power sector during the 1970s.

The Bank also played a major role in drafting the legislation that has made the Brazilian power sector financially viable. The power sector regulatory body in the Ministry of Mines and Energy, the Departamento Nacional de Agua e Energia Electrica (DNAEE), and ELETROBRAS, the government holding company, have been assisted by the Bank in carrying out their tasks, and Brazil is now well advanced toward an integrated planning and operation of major sector facilities.

In Thailand in 1968, the Bank helped with the formation of the Electricity Generating Authority of Thailand (EGAT), now largely responsible for the generation of power in the country. Although it is not the sole authority in Thailand (the Metropolitan Electricity Authority and the Provincial Electricity Authority are responsible, respectively, for distribution in Bangkok and the rural areas), EGAT has sufficient authority to plan and expand power generation effectively.

Panama provides an interesting example of Bank-induced transfer of organizational know-how. The Instituto de Recursos Hidraulicos y Electrificacion (IRHE) was created in 1961, prior to the Bank's involvement in the power sector of the country, and was charged with the coordination of power development in Panama. The first Bank loan to IRHE was made in 1962 to construct a 6 megawatt hydroelectric plant to serve the Central Pro-

vinces. It was found, however, that the IRHE operated under considerable political pressure, which resulted in mismanagement and financial difficulties.

The more sizable second loan to IRHE in 1970 to finance the 150 megawatt Bayano hydroelectric plant, the 40 megawatt Las Minas steam-electric plant, and the transmission line to Panama City was not made until much-needed organizational changes were instituted. New legislation permitted IRHE's operation as an autonomous agency and made the position of director general a nonpolitical one. The director general was made solely responsible for day-to-day operations, and the board of directors' role was limited to policy matters. The Bank loan also provided for the hiring of management consultants and for the training of IRHE's personnel.

In mid-1972, IRHE's role changed significantly when the Panamanian government nationalized the Compania Paneméña de Fuerza y Luz (FyL) and transferred its assets to IRHE. FyL had received concessions for the operation of electricity, telephone, and gas services in Panama City and Colón. This transfer increased the scope of IRHE's operations several-fold and imposed a strain on the existing organization. The Bank persuaded IRHE to appoint a technical director and, together with consultants, helped IRHE to develop its organization and institute better management and control systems.

The Bank's third loan in 1973 helped finance diesel generating plants, transmission, distribution, and load dispatch facilities, but it was found that further organizational changes were needed if IRHE was to fulfill effectively its enlarged role. Prior to the approval of the fourth loan (for the La Fortuna hydroelectric project), the consultants appointed at the Bank's suggestion undertook a diagnostic study of IRHE's organization to help identify areas that needed to be strengthened. The Bank has financed the consultants whom IRHE has since hired to help implement the recommendations.

The Bank played a major role in the development of IRHE's organization and in urging the Panamanian government to pass the necessary legislation. Although it was the management consultants who actually trained IRHE's personnel and instituted the management information system, it was the Bank's involvement that aided IRHE's continued development.

The Bank's efforts have not always been successful. In Turkey, for instance, the results have been less than expected. Prior to 1970, four state organizations, a half-dozen or so private companies, a large number of private industrial firms, and more than 600 municipalities and villages were involved in generating, transmitting, and distributing electricity. The four state organizations included a planning and statistical organization responsible for all planning in the sector, the State Hydraulic Works (DSI) responsible for the development of hydroelectric projects, Etibank, and a State

Economic Enterprise whose power group constructed and operated all major thermal plants and transmission lines in Turkey.

Today there are only two state organizations: Türkiye Elektrik Kurumu (TEK) and the DSI. TEK is responsible for the major part of the generation and transmission of electricity, and DSI is responsible for the planning of hydropower development. Municipal authorities buy most of the power from TEK, except for Ankara which still generates part of its requirements. The largest private utility provides only 9 percent of the energy consumed in the interconnected system. This institutional framework under Turkish law is different in several respects from that suggested by the Bank and at least partly responsible for the inefficient operation of the sector. The Bank, however, is still trying to assist TEK overcome these difficulties and become an effective electricity authority.

Tariffs and Finance

Perhaps the greatest obstacle to the growth of the power sector is inadequate finance. Few utilities generate sufficient revenues to finance their expansion programs completely. The power sector is a voracious consumer of investment capital and is expensive to operate. To some extent, borrowing invariably will be necessary, but tariffs must be set to reflect the costs of supply.

The laws and regulations applicable to power companies often contain clauses that permit them to earn a fair rate of return. The return is calculated on net fixed assets, but accounting techniques usually value assets on the basis of historical costs. Inflation causes this historical value and the cost of replacement to diverge considerably. When electricity tariffs are set at levels that yield a fair return on the original value of assets, they fail to generate sufficient funds; and it is unrealistic to look to the government for the difference since governments are always hard pressed for funds to finance other development projects not capable of producing revenues.

The Bank believes that power utilities should be allowed to generate enough funds to finance a reasonable portion of their own expansion. Public ownership of the electricity company or authority, either in part or whole, alleviates the fear of exploitation, but it also tends to make the electricity authority more susceptible to political pressures than are private companies.

The demand for electricity, within limits, is usually found to be relatively inelastic with respect to price. While electricity is a major input in certain electrochemical and electrometallurgical industries, in general it accounts for less than 3 percent of the total industrial production costs in developing countries. As a consequence, the welfare loss of higher tariffs is unlikely to be very large.

In most countries, the greater opposition to tariff increases stems from a fear that such increases will increase inflation. This is rarely the case. Increases in the price of electricity generally will have a minimal effect on the rate of inflation because the share of electricity costs in relation to the total cost of living is relatively small. Indeed, it can be argued that failing to raise tariffs may be inflationary because low tariffs would stimulate too much demand and the consequent dipping into the government budget to finance the expansion of the sector could cause deficits to be larger than otherwise. Regulating authorities are often reluctant to accept this viewpoint. The temptation to meet these needs by increasing the money supply may prove too difficult to resist, thus fueling inflation. In any event, it is common for some governments to exert pressure on public utilities to hold the price line. Frequent tariff increases are probably required in most countries to achieve adequate revenues.

Another area in which the Bank has become involved in recent years is the structure of tariffs. Ideally the rate-of-return criterion determines the level of tariffs, and the electricity authority (or regulating body) has a fair amount of flexibility to set the tariff structure. In the past, some form of average accounting cost has been used as the basis for electricity pricing. The Bank now believes that tariffs should be made to reflect marginal economic costs insofar as practicable.

The pattern of load demand typically involves one or more daily peaks, and the system capability must be adequate to meet the maximum demand. As a result, some of the generating units are used for only a fraction of the time. Providing for peak capacity therefore requires installing units that can be started up quickly. Hydro plants with sufficient storage are useful for this purpose and so are gas turbines. The former usually have high capital costs, while the latter are usually expensive to operate. In either case, electricity tariffs can be structured to reflect the greater cost of providing for peak capacity to discourage electricity use during peak periods and reduce the need for reserves. This concept of peak load pricing is not new. Great Britain and France have long used tariffs of this nature and have altered the pattern of electricity demand, thus making the peak less pronounced. Utilization of generating capacity is likely to improve as a consequence.

Studies have revealed that marginal-cost-based tariffs are often easier to administer than the maze of existing tariffs. The Bank has initiated courses and seminars to explain the principles of marginal-cost-based tariffs. Thailand and several states in India have completed such studies of their systems. It may be some time before tariffs reflecting economic marginal costs are actually introduced, however, because of perceived political consequences of raising prices.

System Planning Technology

An adequate and dependable supply of power requires far more than simply installing new generating units as demand increases. The pattern of demand, the occurrence and duration of peaks, and the reliability of the system in terms of outages all have an effect on the manner in which power is generated. Short duration peaks, for instance, would favor the installation of gas turbines; seasonal variations of river flows and the need for irrigation often determine the operation of hydroelectric plants; and the cost and availability of fossil fuels affect the type of thermal plant used.

The least-cost method of power generation may be determined from various programming models. Fairly sophisticated models, which take into account rate of load growth, outages, generating costs, and other such factors, are now available and enable one to plan the expansion of facilities while taking into account resource constraints. The Bank has helped introduce these methods in several countries, including Malaysia, Argentina, Mexico, and, currently, Indonesia.

Transfer of Technology through Training

Although outside help may be necessary to design and construct power projects, it is the borrower who operates and maintains them. Therefore operational and maintenance capacity must be developed, a process that almost always requires the training of personnel.

Projects financed by the Bank often include a specific and sizable training component. The borrower sends key persons at various levels to courses in foreign countries, sometimes for extended and specialized training. Firms are also hired to conduct short courses and seminars in the borrower's country. Better accounting systems and planning methods are often introduced in this way.

A considerable portion of the training, however, does not come from specific courses or education programs but through the implementation of the project. The borrower is involved at every stage of the design and construction of the project and learns from it. The funds specifically allocated to training therefore greatly understate the training of personnel that actually occurs. In addition, engineers and other technicians visit suppliers and learn directly about the equipment and its use. Participation in the installation of facilities also provides them with a great deal of knowledge about the equipment. Periodic visits by the supplier's technicians during the initial period of operation also contribute to the transfer of skills and know-how in the early stages of production.

Evaluation of the Bank's Role

The Bank's contribution to the growth of the power sector in the developing countries is significant and includes a broad transfer of technology. While large commercial banks and banking consortia can, and often do, provide funds on the scale required for power projects, the World Bank is in a unique position to provide a comprehensive package of technical and financial services in addition to the loan. The value placed on these services by many countries was demonstrated in one case when Thailand borrowed from the Bank at an interest rate higher than available elsewhere in order to avail itself of the Bank's expertise.

A major contribution of the Bank has been the institution building involved in the creation and development of the organizations dealing with the power sector. The need for developing engineering capacity and the building of a competent electricity authority are of key importance in power sector development. It is in this area that the Bank has rendered a major service.

In summary, the Bank's role in the transfer of technology for the power sector development has been that of an active catalyst, and it is probable that the power sectors of several countries would not have developed as rapidly or as efficiently as they did without the Bank's involvement. In these cases, however, the real credit ultimately must rest with the host governments and their receptivity and willingness to change.

Merely because the borrowing agency has acquired new technology after the Bank's involvement does not necessarily mean that the Bank was responsible for it. Nor can the Bank claim credit for technology transfers effected in projects where its support was mainly financial. In such cases, the transfer of technology undoubtedly would have taken place anyway. The development of the power sector, or for that matter any other sector in a country, depends on the enthusiasm, persistence, courage, and dynamism of the nation's leaders to mobilize resources.

Note

1. Amartya Sen, *Employment, Technology and Development* (Oxford: Clarendon Press, 1975).

13 Fertilizer Production

Christopher J. Pratt

One of the critical problems facing the developing countries is the need to increase food production so as to satisfy the basic needs of their expanding populations and reduce their growing dependence on food imports from a small number of highly industrialized countries. The provision of fertilizers, in association with other agricultural inputs (such as water, mechanical energy, improved seeds, and extension services) is, in this respect, essential. Although overall fertilizer use in the developing countries is still fairly small, in the last twenty years it has accounted for around 30 percent of their total increases in food production and for over half their yield increases in cereal production.[1] In the next two decades, it is anticipated that an even larger share of the needed increases in food production in these countries will have to come from the application of fertilizers. Building up a fertilizer production capacity is therefore essential.

Excluding the socialist countries, it is estimated that some 70 percent of the nitrogen and phosphate fertilizer production capacity that will be installed worldwide until 1990 will be located in the developing countries. Estimated investment needs, number of new plants, and production capacity for the three main fertilizers—nitrogen, phosphate, and potash—are shown in table 13-1.

If investments in fertilizer production were to make the developing countries self-sufficient in food, the additional capital needs for nitrogen plants alone probably would have to be 50 percent higher than the figures shown. Increased requirements for phosphate and potash being roughly of the same order means that the projected cumulative investment needs for the 1980–1990 period would have to be raised from the present $26.5 billion to nearly $40 billion. This does not take into account additional needs for plant replacement and for new investments in the fertilizer industries of the developed countries, which could approach an additional $20 billion by 1990.

The Role of the World Bank

The World Bank has assisted with the financing of fertilizer projects in numerous developing countries and has played the leading part of all lending institutions in helping these countries to plan, finance, and install new fertilizer production units. It is estimated that in the 1980s, around 30 percent

Table 13-1
Developing-Country Fertilizer Plant Investment Requirements, 1983-1993
(1980 U.S. dollars)

	1980-1985	*1986-1993*
Nitrogen		
New nitrogen capacity (million tons)	9.8	11.7
New plants required	43	52
Investment requirement ($ billion)	11.3	13.6
Phosphate		
New phosphate capacity (million tons)	6.7	7.7
New plants required	22	26
Investment required ($ billion)	7.7	10.7
Potash		
New potash capacity (million tons)	1.5	1.5
New plants required	1	1
Investment requirement ($ billion)	0.7	0.7
Total investment required ($ billion)	19.7	25.00

Source: W.F. Sheldrick, "The Changing Structure of the International Fertilizer Industry," paper presented to the Fertilizer Society, London, March 17, 1983.
Note: These figures exclude the centrally planned socialist countries.

of all new nitrogen projects, 20 percent of all new phosphate projects, and possibly some potash projects will be financed with the assistance of the World Bank. A list of typical fertilizer projects financed in part by the Bank between 1968 and 1983 is given in table 13-2.

To an increasing degree, project planners in the public sectors of developing countries periodically study the need for fertilizers, and when a forthcoming demand for a new or expanded fertilizer plant appears sufficiently large, a report is prepared and submitted for government consideration in the country concerned. If the report is favorable, it may be passed to the Bank Group for review. Alternatively, a feasibility study may be prepared by the private sector in a developing country and sent to the IFC for study and possible financing. In other cases, Bank staff may identify the likely need for a fertilizer plant during an economic mission.

If the potential for a fertilizer project appears favorable, a preappraisal team visits the country to make an initial survey of the envisaged project and to collect information. Typically, such a team might consist of specialists in marketing, fertilizer technology, and economics or finance. Meetings with government officials, industrialists, and others are held, which form the basis of a prefeasibility study. If this study is favorable, the prospective project is eventually examined in considerably greater detail, and several more visits may be made to obtain accurate data and to refine existing information.

A feasibility study is then prepared that defines the role of the Bank and other lenders in financing the project, as well as the amount of engineering, staffing, foreign exchange, domestic costs, and benefits likely to result. At a time appropriate with the availability of funds, the project is presented to the Loan Committee for study and comment. If it is favorably received, it is subsequently sent to the Executive Committee for review and discussion before ultimate approval by the president of the Bank of the loan or credit desired. This is normally expressed in U.S. dollars, while domestic currency requirements are financed by local banks and other investors.

Invariably the processes and products have been well defined beforehand, together with intended outputs, and a short list of experienced engineering designers has been proposed. In many cases, these have been U.S., European, or Japanese firms, and this can be expected to continue for some time to come. After a project has been approved by the Bank and the domestic government, the most suitable engineering firm or group is appointed and promptly commences detailed design and procurement, as well as site preparation studies. The project is then constructed, together with housing and other offsites, by approved foreign and local contractors. Experienced engineers and others are sent to the site to supervise project erection, which may take at least three years. Much civil work is normally undertaken by experienced local firms, which helps to reduce the project's foreign exchange costs. Meanwhile, a fertilizer seeding program may have been started with advice from the Bank, and this, together with the main project, will need periodic supervision visits by the project officer, who reports his or her findings to the Bank in detail for comment, followed by action if necessary. Small teams of erectors and specialists eventually visit the site to supervise installations of major equipment, excellent opportunities for technology transfer. Eventually the project is completed and brought on stream, each section being subjected to its performance guarantee run prior to acceptance. A period of gradually increasing additional output then often follows, which may take many months, during which the plant is brought up to full sustained capacity and the project can be considered completed. Expatriate staff, by then usually few in number, eventually return home.

All of the fertilizer projects in which the World Bank has participated have involved a substantial transfer of operating technology to the borrowing country. The type of technology thus transferred and the effects of such transfers on the economy of the borrower have been rather different from country to country, and it may be useful to describe three typical situations. The first is that of a country with a fairly small domestic market whose fertilizer requirements can be met primarily through imports. The second is that of a country whose large domestic market or abundant supply of natural resources (phosphate rock or natural gas, for instance) warrants the

Table 13–2
Fertilizer Projects Financed by the Bank Group from 1968 to 1983

Region or Country	*Project*	*Amount (U.S. Million)*	*End Product*	*Year Approved*	*IBRD, IDA, or IFC*
East Asia					
Indonesia	Pusri II	30.0	Ammonia/urea	1970	IDA
	Pusri II (supplemental)	5.0	Ammonia/urea	1973	IDA
	Pusri III	115.0	Ammonia/urea	1975	IBRD
	Pusri distribution	68.0	Distribution	1975	IBRD
	Pusri IV	70.0	Ammonia/urea	1976	IBRD
	Subtotal	288.0			
Europe, Middle East, and North Africa					
Egypt	Talkha	20.0	Ammonia/urea	1974	IDA
	New Valley Phosphates	11.0	Technical assistance	1979	IBRD
Jordan	Fertilizer Industry (Engineering Credit)	3.1	Phosphoric acid/DAP	1975	IFC
	Arab Potash (Engineering Credit)	1.0	Potash engineering	1975	IDA
	Fertilizer Industry	70.0	Phosphoric acid	1978	IFC
	Arab Potash	35.0	Potash	1978	IBRD
Morocco	Maroc Phosphore I	50.0	Phosphoric acid/MAP	1974	IBRD
	Maroc Phosphore I, expansion	50.0	Phosphoric acid	1978	IBRD
Portugal	Quimigal	58.0	Ammonia/ammonium Nitrite	1979	IBRD
Rumania	Bacau	60.0	Ammonia/urea	1974	IBRD
Senegal	Industrie Chimique du Sénégal	25.0	Phosphate fertilizers	1981	IFC
	SEFICS	19.3	Fertilizer transport	1981	IBRD
	PHOSUALOR	7.7	Phosphate engineering	1983	IDA
Togo	Dagbati phosphates	5.7	Phosphate engineering	1981	IDA
Tunisia	Gafsa	23.3	Phosphate rock	1974	IBRD

Turkey	Igsas	24.0	Ammonia/urea	1973	IBRD
	Igsas (Supplementary)	18.0	Ammonia/urea	1975	IBRD
	Fertilizer industry	110.0	Various debottlenecking	1981	IBRD
	Fertilizer industry	44.1	Rehabilitation	1982	IBRD
	Fertilizer industry	4.0	Phosphate engineering	1982	IDA
	Subtotal	639.2			
Latin America					
Brazil	Araucaria	50.0	Ammonia/urea	1976	IBRD
	Sergipe	64.0	Ammonia/urea	1977	IBRD
	Valefertil	82.0	MAP/TSP	1977	IBRD
	Sotave	16.0	Mixed fertilizers	1980	IFC
	Fosfatados	45.0	Phosphate rock	1982	IFC
Mexico	Fertimex I	50.0	Urea/pesticides	1975	IBRD
	Fertimex II	80.0	AN/DAP/NPK	1979	IBRD
Peru	Bayover phosphates	7.5	Phosphate engineering	1980	IBRD
	Subtotal	394.5			
South Asia					
Bangladesh	Ashuganj	33.0	Ammonia/urea	1975	IDA
	Industry credit	29.0	Various debottlenecking	1980	IDA
	Fertilizer transport	25.0	Rail and storage	1981	IDA
	Chittagong fertilizers	15.0	Ammonia/urea	1982	IDA
India	Cochin II	20.0	NPK	1971	IDA
	Gorakhpur	10.0	Urea	1972	IDA
	Nangal	58.0	Ammonia/urea	1973	IDA
	Trombay IV	50.0	NPK	1974	IDA
	Sindri	91.0	Ammonia/urea	1974	IDA
	IFFCO	109.0	Ammonia/urea	1975	IBRD
	Industry Credit	105.0	Various debottlenecking	1975	IDA
	Hazira	400.0	Ammonia/urea	1980	IDA

Table 13-2 *(continued)*

Region or Country	*Project*	*Amount (U.S. Million)*	*End Product*	*Year Approved*	*IBRD, IDA, or IFC*
Pakistan	Dawood Hercules	34.9	Ammonia/urea	1968	IBRD/IFC
	Multan	35.0	Ammonia/NP/CAN	1974	IBRD
	Fauji	55.0	Ammonia/urea	1978	IDA
	Imports credit	50.0	Purchase of fertilizers	1980	IDA
	Fertilizer industry	38.5	Rehabilitation	1982	IBRD
Thailand	Potash project	8.9	Potash engineering	1981	IBRD
	Subtotal	1,167.3			
	Total Bank Group	2,489.0			

Source: W.F. Sheldrick, "The World Bank and Its Role in the International Fertilizer Business," *Fertilizer International* no. 171, September 1983.

Note: Abbreviations:
MAP: Monoammonium phosphate
TSP: Triple superphosphate
AN: Ammonium nitrate
DAP: Diammonium phosphate
NPK: Nitrogen, phosphate, potassium
CAN: Calcium ammonium nitrate

establishment of a fertilizer plant. The third is that of a country that, in addition to the erection of fertilizer plants, may also be in a position to develop a local equipment manufacturing industry to make, and possibly export, the machinery used in fertilizer plants.

Technology Transfer Based on Fertilizer Imports

The first and simplest case we shall consider here—and the one most typical of a developing country with limited experience—is the importation and use of bagged fertilizers. This can be done effectively only after careful tests by agronomists and cooperating farmers have shown a repeated need for specific fertilizer materials. Frequently the soil is deficient in nitrogen (or soon will be), as well as in phosphates and potash, and perhaps also in secondary elements such as sulfur and magnesium. After careful years of cropping, even virgin lands may develop increasing shortages of certain micronutrients such as iron, copper, or manganese. These must be applied periodically and precisely to avoid toxicity to plants and animals.

In such cases, the process of technology transfer can start with the purchasing of recommended grades of fertilizer in bags, which, after initial storage at the importing site or close to it, are transported to the points of use. The training of unskilled people in the correct methods of storage and handling of bagged materials is essential; otherwise much of it may be lost by burst bagging, spoilage due to weather, and pilferage. These fertilizers often are applied by hand to specific crops before and after planting under the guidance of local extension and service people who have received training from experienced agronomists. In this way and by use of the appropriate technology transfer mechanism, farmers with little or no prior knowledge of fertilizer use can rapidly be taught how and when to apply the proper fertilizer to the soil, how to buy, transport, and apply it, and subsequently how to profit from its correct use. Simultaneously, they will learn how to prevent burst bags plus other wastage and can quickly be taught the need for judicious applications of water, compost, lime, and related materials to their crops at appropriate times. Typical high-grade fertilizers that may thus be imported include nitrogen, phosphorus, and potassium compounds, such as urea, diammonium phosphate, triple superphosphate, and potash. Some low-analysis fertilizers, such as single superphosphate, have largely disappeared from the export market, although they continue to be produced for local consumption in several developing countries.

When fertilizer sales have grown to several thousand tons annually, importation of raw materials or semifinished goods in bulk, followed by mixing and bagging near the port, may become practical. The process of dry mixing is simple, but it presents to a developing country the basics of manu-

facture, such as receipt and proper storage of bulk raw materials and intermediates, conveying, weighing, rotary mixing, screening, and crushing of oversize for reuse, as well as bagging, storage, and dispatch to dealers and farmers. With a simple process and a few bulk materials such as diammonium phosphate, urea, potash, and perhaps one or two intermediate products, a wide range of fertilizer mixed goods becomes possible. This also considerably increases the versatility of manufacture and allows an astute producer to take advantage of seasonal price reductions on imported materials as they arise, providing sufficient working capital is available from local sources.

At the same time, a considerable increase in technology transfer takes place. Operators must learn how to handle and store imported bulk materials, how to convey, weigh, and mix them, and how to bag them properly for sale to dealers and farmers. They must also be taught how to keep the machinery clean and in good repair. Eventually large farmers will begin to use tractors and fertilizer spreaders, which will require additional technology transfer by people trained in the skills of using and maintaining such machines. Simultaneously the need for experienced soil testers and agronomists will expand, as will requirements for seasonal financing, fertilizer, seed and crop storage, and sales. Thus, an entire new industry will be created in which technology transfer, as well as experience in financing, demonstrations, and fertilizer sales, are essential components.

Generally the storage and mixing plant is built to the designs of an experienced company by a local contractor who may import much of the mechanical and electrical equipment needed. A few skilled people on the designer's staff may be resident at the site during construction to supervise erection and start-up. This is an opportunity for local people in various fields to participate in technology transfer, in both erection and operation of the mixing plant. Sometimes granulation is also undertaken in conjunction with mixing, producing fertilizers in the form of granules, say 2 to 4 millimeters in diameter, by combining two or more materials under the action of moisture, rolling, and heat. A rotary granulator or pugmill is used in conjunction with a drier, and sometimes a cooler and coating drum are added. The material in process is normally recycled and screened to remove undersized and oversized granules before being sent to storage and bagging. Crushing oversized material invariably produces dust, which must be removed in scrubbers, thereby increasing the complexity of the process.

The financing required for simple mixing and granulating plants is relatively small, and the World Bank does not normally take part in such projects except for occasional small loans or credits for fertilizers and other agricultural materials that may be granted under special circumstances.

The Building of Fertilizer Plants

The second and considerably more complex case of technology transfer is the building of a fertilizer manufacturing plant. When the demand for fertilizers in a developing country steadily increases, the possibilities of local production instead of imports may be considered. These may include the manufacture of ammonia and its derivatives from natural gas, naphtha or other refinery products, the production of phosphate from phosphate rock, as well as the production of sulfur and possibly potassium salts in some commercial form. Alternatively, although local demand might be small, as in some Middle Eastern countries, the export potential may be an attractive consideration.

With few exceptions, investments in basic fertilizer plants are large and involve sophisticated technology. Normally the minimum economic size of an ammonia or a phosphoric acid plant, especially if required for export purposes, is 600 tons per day. In the last decade, the customary size of an ammonia plant has been 910 tons per day, and such plants are often built in conjunction with a urea plant producing at least 1,400 tons per day, since this effectively uses otherwise surplus carbon dioxide.

Alternatively the plant can be designed to produce ammonium nitrate, usually made in solid form or perhaps in conjunction with calcium nitrate to make a calcium ammonium nitrate product containing 25 to 30 percent nitrogen, as in Pakistan. Larger plants based on 1,350 to 1,500 tons of ammonia per day and designed to produce 2,000 tons or more of urea per day will be built in India and elsewhere.

Such large plants making ammonia and its derivatives under high pressures and temperatures can be hazardous to start up and operate unless the staff has received adequate training and experience. Therefore it is vital to ensure that technology transfer has been thoroughly built into the system as an essential and continuous operation of its own. Otherwise the dangers of explosions and fires, plus lengthy shutdowns, will increase tremendously, as accidents in recent years have demonstrated even though large sums were spent on training staff and labor. One effective way of providing good training and technology transfer for a new project is to send the key operators to a similar plant elsewhere for several months of rigorous, practical learning and experience, in conjunction with frequent written and oral testing. On their return, they are able to put into practice what they have learned and are also able to train other people.

If the installation of an ammonia plant, plus appropriate offsites, a power plant, and a downstream urea or ammonium nitrate unit are considered justified on the basis of careful feedstock and market studies, its optimum location and required financing can be sought with confidence.

When required funds have been obtained from agencies such as the World Bank and/or other sources, the project can be designed and constructed within the lenders' rules and guidelines. Thorough training usually must be given to most or all of the new staff and labor well in advance of project start-up. Many of these steps are critical to the safety and performance of the plant, which operates at high temperatures and pressures in several sections. Therefore key trainees are usually taught by lectures and hands-on shift experience in a similar plant of a cooperating producer. This training may last from three to twelve months and forms a major part of the technology transfer accorded to senior plant operators and staff in large, modern, complex projects. On their return, they are expected to train junior personnel and maintain their own expertise through plant commissioning and afterward by frequent meetings plus simulated shutdowns and emergencies, as well as smooth starting-up procedures.

Modern ammonia, urea, and other plants operate on a control room basis where complex instrument integration makes continuous production virtually automatic. Early-warning visual signals of a minor upset are given, which are followed by audible warnings of an increasing problem. If the problem cannot be promptly corrected within a given time, the affected section or perhaps the entire plant may then be automatically shut down. Associated power generation, boiler feed water, water cooling, and other units operate similarly. Therefore plant operators must be trained to respond quickly to imminent or sudden upsets and take appropriate corrective action at once. In case the action is ineffective, they must also be trained to assist the plant to shut down in an orderly manner, as well as to start their section again, after a fault has been diagnosed and corrected. Operators of large, modern ammonia and urea plants thus have great responsibilities. Usually they are few in number per shift yet virtually in charge of complexes costing $250 million or more. Therefore the technology transfer they have received, which increases with experience, must be up to date, precise, and instantly effective in emergencies. Furthermore, restarting a large plant may be much more difficult than shutting it down.

Similar conditions exist for operators producing urea, nitric acid, and nitrates and also for those in charge of boiler and power plants, water treatment, and effluent units. Urea and ammonium nitrate are usually prilled in tall towers from which the solid products are conveyed and sent to storage for later shipment in bagged form. Frequently bagging is undertaken on a day or a two-shift basis, which means temporary halts in bagging and transportation; however, these do not create problems compared to stoppages in producing ammonia or its derivatives. The technology transfer required for product handling and bagging is straightforward and normally imparted as part of on-the-job training. All operators should be experienced in emergency fire drills, accident prevention, and avoidance of plant

spillages. The best way to maintain this technology transfer is by realistic demonstrations, unscheduled to the extent possible, after training has been given. Similar precautions, though of a different nature, apply to ammonia and nitric acid handling, transfer, and safety procedures, which can be properly learned through periodic demonstrations in which everyone concerned takes part. First-aid training and firefighting are also essential items of good emergency plant procedures, and their practice should be encouraged by management.

The majority of Bank-assisted fertilizer projects to date have been nitrogen-based, such as ammonia and urea. It has also participated in financing phosphate and sulfuric acid plants, where the same principles of technology transfer apply. In one plant in Morocco, sulfuric acid is made from imported sulfur and used to attack phosphate rock obtained from domestic sources. The phosphoric acid-gypsum slurry is filtered, and the recovered acid is concentrated and exported, as well as used at the plant to produce solid phosphate fertilizers. Power is also generated for internal use by waste heat from the sulfuric acid unit. Although phosphoric acid production was not new to Morocco, extensive technology transfer from experienced operators to new employees took place before and during plant commissioning. This was successful, as indicated by the ordering of a second large plant.

In Pakistan, the first Bank-financed nitrophosphate plant has recently been commissioned. This is designed to produce 1,000 metric tons per day of NPK fertilizer (nitrogen, phosphate, and potassium) plus 1,500 tons per day of calcium ammonium nitrate containing 26 percent nitrogen. The transferred technology is considerable; the complex includes a new, large natural gas-based ammonia plant, plus two nitric acid units of 600 tons per day each, as well as the fertilizer units, plus power and steam generation and all offsites. Some 200 tons per day of urea from an existing plant are also made. Additional problems included the shutting down of several old units and phasing out nearly 1,000 operators. In this case, a direct technology transfer from old units to new ones was insufficient. Accordingly, key operators were sent overseas for retraining and were then given opportunities to train their colleagues by imparting the necessary technology to operate the new units as they reached completion. Managers and supervisory staff were also given appropriate instruction in modern plant administration and operation.

The Bank participated in the pilot production of potash by the government of Jordan from Dead Sea brine, and results were sufficiently encouraging to justify full-scale production of at least 1 million tons per year. The project has been financed and is making good progress. Although based largely on established technology, some modified methods will be used, such as the continuous recovery on a large scale of precipitated carnallite by

semisubmerged machines. After conversion to potash, the finished product will be transported daily by road to Aqaba port for shipment overseas. For this project, new or applied techniques for dike and solar pond construction were developed and were proved satisfactory before the full-scale project could be considered. This has meant straightforward training and technology transfer could not be used because these techniques had to be first invented and approved after demonstration. An appreciable proportion of the total technology eventually employed will probably be developed and used in this way. Accordingly, this unusual project will offer numerous opportunities for technology transfer at many levels of operation and supervision in both existing and new techniques. The Bank, as a leader in the project, has participated in a thorough search for organizations and individuals who can ensure greatest possibilities of success for this large undertaking.

Some operations now being developed for subsequent technology transfer to others on this project include selecting optimum present and future locations for input brine pumps in the Dead Sea, building self-sustaining dikes on weak marls and quicksands, constructing solar ponds of sufficient size, laying adequate salt bottoms in the pans, building stable dikes with long lives, providing reliable carnallite harvesting methods, producing products of acceptable grade and purity, ensuring reliable bulk transportation from the plant to the storage and shipping terminal, providing adequate power, water, and housing in a remote area, and providing adequate, trouble-free effluents disposal. These are prime responsibilities of the designers and constructors; however, the Bank is very much involved directly and indirectly with the successful transfer of technology in all cases. For example, it proposed the names of acceptable major consulting and contracting organizations who were considered experienced for specific purposes. It took part in meeting advisers and consultants, accountants and auditors who, after selection by Arab Potash Co. (APC), would be responsible for working on the project. It also reviewed many specifications prepared by the engineering consultants for major critical items of equipment and gave its comments and advice to APC.

As the project proceeds, the Bank will continue to receive regular reports from the company and its consultants and to give its advice until full production and sales have been attained. It is anticipated that senior operating staff will be sent overseas for on-the-job training and technology transfer. On their return, they will impart this knowledge and experience to others.

Development of Indigenous Equipment Manufacturing Capabilities

All of the Bank-financed fertilizer projects discussed and summarized in table 13-2 have used foreign technical assistance in conjunction with local

technological capabilities to a greater or lesser extent, depending on experience. The size and complexity of an ammonia plant in the 1,000 ton per day category, for instance, usually makes such help essential in all phases of the project, from design through equipment fabrication to field erection. This is true of most other types of fertilizer plants.

In the case of a developing country with a large internal market and a substantial industrial infrastructure, the transfer of technology in the form of turn-key fertilizer plants can gradually lead to the local design and production of equipment for such plants. India and Brazil, for instance, are typical examples of major developing nations increasingly able to design and construct much of the fertilizer equipment and plants they need. The production of such equipment in developing countries arises from a simultaneous desire to reduce the foreign exchange costs of such projects and to achieve some form of industrial and technological independence, and it may ultimately lead, as the case of India shows, to the export of competitive equipment and design services.

One of the first steps in the building up of such an equipment design and manufacturing capability is to select an approved foreign manufacturer—U.S., European, or Japanese in most cases—that is willing to have its machinery manufactured abroad under license by a well-established local company. As a rule, this requires several months of training at the manufacturer's plant in which skilled operators and managers from the developing country are taught the necessary technology. They then return to their own plant and set up domestic manufacture, perhaps with the initial guidance of experienced people from the overseas licensor. In turn, new operators and staff are trained, and the transfer of appropriate technology continues. Many manufacturing organizations in developing countries have achieved total independence in this way and are able to compete with their former associates in supplying equipment and plants, as well as machinery, drugs, and chemicals for numerous industries.

The building up of such a design and equipment-producing capability generally takes a long time, requires a strong industrial base as well as substantial efforts in research and development, and entails significant direct and indirect costs. For several developing countries, technological self-sufficiency in fertilizer plants and equipment may be several decades away, primarily because of the relatively small size of the market for equipment such as large centrifugal compressors, reformers, reactors, and on-line computers.

Investments in fertilizer plants are considerable, but once a major plant has been built with foreign assistance and financing from the World Bank, it may be sufficient to meet domestic market requirements for many years. From this perspective, it may not be worthwhile to develop an indigenous design and equipment-manufacturing capability unless, as the case of Mex-

ico seems to suggest, the availability of major natural resources (oil, gas, and phosphates), coupled with a strong chemical engineering background, can serve as a major incentive for the development of an export-oriented design and equipment industry.

The availability of natural resources, the size of the internal market, and the sophistication of the existing industrial infrastructure thus appear to be determinant in the development of an indigenous design and equipment-manufacturing capability. The erection of fertilizer plants with foreign assistance, which involves a substantial volume of technology transfer and is probably a necessary first step in the development of such a capability, does not thus necessarily lead to the growth of such a capability. In this sense, the technology transfer accompanying a new fertilizer plant remains in many cases a one-of-a-kind type of transfer.

The Process of Technology Transfer

The process of technology transfer in the fertilizer industry differs widely from country to country. The simplest process of transfer is through the importation of bagged materials, which are either used directly or are mixed by shovel, rebagged, and broadcast by hand on the field requiring fertilizer addition. Verbal instructions should suffice. The use of imported bulk materials followed by hand bagging and distribution should also need only simple verbal instructions and one or two demonstrations in application.

Producing granulated mixed fertilizers from bulk materials requires considerably more training and experience. The bulk materials must be unloaded and conveyed to storage, then withdrawn, weighed, mixed, and granulated before screening and also drying in some cases. To a considerable extent, good granulation is still an art in which teaching and experience are necessary to support knowledge gained during technology transfer courses. This also applies to crushing and returning oversized and undersized product for regranulation and dust removal, to give maximum use of plant, operators, and raw materials.

The production of ammonia and related compounds such as urea and ammonium nitrate from natural gas requires highly sophisticated technologies, which must be designed and used by groups of skilled specialists. For example, plant designers require several years of college training, followed by several more years in a design office and in the field before being competent to assume responsibility for a large project. The required background for plants designed to operate on other fuels such as naptha, heavy oil, or coal may be even greater and also necessitates years of experience and technology transfer on actual plants from others thoroughly familiar with this work.

Table 13-3
Basic Fertilizer Technology Required in Developing Countries

Raw Materials Availability	*Method*
Initially only bagged, mixed bagged fertilizers used	Import and store mixed fertilizers in form to agronomist's specifications; transport to cultivated area and apply by hand
Initially only bulk, mixed fertilizers used	Import and store mixed fertilizers in bulk to agronomist's specifications; bag and transport to cultivated area and apply by hand; later by tractor-spreader when justified by quantity
Bulk importation of basic materials such as diammonium phosphate, urea, potash, and compounds	Produce mixed and granulated fertilizers to suit agronomist's bag and transport specifications to cultivated areas; apply by hand and/or tractor-spreader, as justified
Natural gas	Convert to ammonia and related compounds such as urea, ammonium nitrate for domestic use, and/or export sales; or pipeline the gas to a more developed region or country for conversion to ammonia and related products
Naphtha and other refinery products; coal	Convert to ammonia or related compounds for domestic use and/or export sales; or pipeline or bulk transport the raw material to a more developed region or country for conversion to ammonia and related products; coal is also used to make ammonia in some cases (for example, in India, South Africa, and probably the United States)
Phosphate rock	Mine, beneficiate, and sell the rock to a more developed country for fertilizer use; or mine, beneficiate, convert to phosphoric acid or a phosphate fertilizer for domestic, and/or export use
Potash	Mine, beneficiate, purify, sell potash for domestic and/or export use
Sulfur	Mine, purify, sell for domestic and/or export use for producing sulfuric acid for fertilizer and other purposes; also recover from sour oil and gas
Hydropower	Used in a few cases, such as in Nangal, India, to produce hydrogen by electrolysis; mostly used for electrical power generation
Transportation	Pipelines and ships, plus railroad cars, are used, respectively, for natural gas and naphtha, other liquid fuels, ammonia, and nitrogen fertilizers; solid fertilizers are shipped in bulk and bagged form; sulfur is also transported as a molten liquid.

Similar situations exist in designing, constructing, and operating large phosphoric acid, phosphate, and potash plants. The operations manuals of these installations, like those for producing ammonia and its derivatives, normally comprise several volumes and cover basic theory, start-up, operation, shutdown, and equipment problems in considerable detail. For skilled operators, acquiring this level of technology requires months of daily experience, punctuated with frequent tests and simulated plant corrections. After meeting the required training standards, they return to the nearly completed project and assist in training their subordinates. This continues down to the semiskilled or unskilled labor force, which may be able to receive only verbal instructions. Effective technology transfer, by instruction manuals and on-the-job training, plus subsequent experience and supervision, have thus become essential for safe and productive factory operation.

The type of technology transfer in fertilizer projects is determined to a large extent by the nature of the raw materials available, and it may be useful here to try to illustrate this by summarizing the various technology transfer options open to developing countries for each of the different raw materials that may be available to them (see table 13–3).

Appropriate and Alternative Technologies

A large number of fertilizer plants in the developing countries have been built with the assistance of the World Bank Group. This raises a number of important questions about the appropriateness of the technologies thus transferred and the availability or nonavailability of alternative technologies that allow the use of smaller sizes of plants or of resources other than oil or natural gas.

Most of these plants are very large and require heavy investments—although normally about half of the investment is required to provide the infrastructural facilities. Typically, ammonia plants have been in the 1,000 tons per day category, based on natural gas, naphtha or fuel oil. However, recently some large-scale gas-based plants in India, supported by the Bank, have achieved a production capacity of 1,350 tons per day of ammonia. Based on 330 days per year operation, this amounts to an annual production capacity of 450,000 tons of ammonia.

However, for many developing countries where the internal market and the annual consumption of fertilizers are considerably smaller than in either India or Brazil, a fertilizer plant with a daily capacity of 300 to 400 tons per day would be needed to meet domestic needs. Sometimes where there is cheap natural gas available for a country, it is then economic to build a large plant and export the remaining product after meeting domestic needs.

Although there has been considerable interest in the application of small plants to meet the specific domestic fertilizer needs of developing countries, it is only in special circumstances that such plants can be justified economically. The benefits that arise from going to large-scale units in reducing total production cost per ton can be very significant.

In the last twenty years, the major change in ammonia plant technology has been the transition from reciprocating compressors to centrifugal compressors. Because this technique particularly favors large plants, it is one of the factors that encouraged the rapid development of large plants in recent years. Another development that has become increasingly important in ammonia plant technology is the improvement of energy usage, and new plants are specifically designed to achieve this. The Bank has been very active in the last few years in assisting developing countries to retrofit their old ammonia plants to achieve energy conservation.

Although most of the ammonia plants in operation today use natural gas or petroleum derivatives, there are alternative technologies, sometimes based on obsolete technologies, that may become competitive, given sufficient investments in research and the likely increases in the cost of petroleum derivatives and natural gas. In India, for example, lignite has been the principal raw material used at the Nyeveli plant, water electrolysis is still undertaken at Nangal, and until a few years ago, coal was used in Pakistan. The government-owned plant in South Africa makes ammonia from coal on a large and growing scale, while in the United States and India, the existence of extensive coal reserves, plus improved technologies for beneficiation, gasification, and waste disposal, have prompted a new interest in this hydrocarbon. Recently, India has brought on stream two large coal-based fertilizer plants at Talcher and Ramagundam, and the Tennessee Valley Authority in the United States has constructed a 250 ton per day coal-based ammonia demonstration plant at Muscle Shoals in Alabama.

Several large U.S. companies and organizations are also building small demonstration or semiworks plants to produce pipeline gas, liquid fuels, and chemicals from coal. Such plants will be based on high-technology processes that are expected to be the forerunners of large future projects. These will increase steadily in number, as the supplies of natural gas in the United States and elsewhere diminish and because solid fuels are expected to outlast liquid and gaseous hydrocarbons by several centuries.

These few examples indicate that a vigorous search is in progress for alternative technologies in the fertilizer industry. It will take some time before these alternative methods reach the international market, but several developing countries with a significant fertilizer equipment manufacturing industry may become the future technological leaders in some of these new areas.

Note

1. *World Fertilizer Review and Fertilizer Requirements of Developing Countries 1979* (Washington, D.C.: World Bank 1979) quoting original figures from James P. Grant, Overseas Development Council, International Superphosphate Manufacturers Association Meeting, Paris, France, December 1977.

The International Finance Corporation

H. Geoffrey Hilton

The International Finance Corporation (IFC) was established in 1956 as an affiliate to the World Bank, and its member countries are limited to those of the Bank itself. Its objectives, as described by article 1 of its Articles of Agreement, are

> to further economic development by encouraging the growth of productive private enterprise in member countries, particularly in the less developed areas, thus supplementing the activities of the International Bank for Reconstruction and Development. . . . In carrying out this purpose, the Corporation shall (i) in association with private investors, assist in financing the establishment, improvement and expansion of productive private enterprises which would contribute to the development of its member countries by making investments, without guarantee of repayment by the member government concerned, in cases where sufficient private capital is not available on reasonable terms, (ii) seek to bring together investment opportunities, domestic and foreign capital, and experienced management; and (iii) seek to stimulate, and to help create conditions conducive to the flow of private capital, domestic and foreign, into productive investments in member countries.

IFC's operations, summarized in table 14–1, show that between 1957 and 1983, 76 percent of the total value of commitments was made in the manufacturing industries. The corporation finances roughly 17 percent of the projects in which it invests, which means that during this period, it has been associated with manufacturing investments amounting to around $13 billion.

The IFC's interest in technology transfer arises from its constitution; it is first and foremost a development agency, and this role implies that it must seek to do things that are new and likely to have a developmental impact. It would not, for example, be content to assist in the financing of a fourth or fifth textile mill in a particular country. It would have to be satisfied that something new was being achieved in addition to the flow of resources, and it might consider participating in the development of a synthetic fiber plant in a region where textile plants already exist and that proposed to supply new materials for use in the existing plants.

As a financial institution that is required to bring together investment opportunities and domestic and foreign private capital, the IFC must attach considerable importance to the preparation of a project's financial projec-

Table 14-1
Facts about the International Finance Corporation, June 1983

Purposes for Which Investments, Standby and Underwriting Commitments Have Been Made	*U.S.$ Million*	
Development finance companies		$249
Money and capital market institutions		191
Industry		
Manufacturing		
Cement and construction materials	844	
Iron and steel	358	
Chemical and petrochemical products	420	
Pulp and paper products	372	
Textiles and fibers	263	
Food and food processing	241	
Motor vehicles and accessories	217	
Fertilizer	217	
Nonferrous metals	47	
Machinery	33	
General manufacturing	427	
	$3,442[a]	
Nonmanufacturing		
Mining	$467	
Tourism	121	
Utilities	36	
Others	41	
	$665[a]	$4,104[a]
Grand total		$4,548[a]

[a]There may be discrepancies in these totals because the figures have been rounded per million dollars.

tions, since it is on the basis of these that funds can be expected to flow, both from the corporation and from other financial institutions. These projections must be based on a careful analysis of the costs of establishing a project and its expected operating performance during the time when production operations are being established. On the basis of these projections, economic justifications can be prepared and a reliable assessment made of the extent to which the project is economically desirable for the host country. Determination of the expectations for both the construction and the operating period requires considerable technological skills, and it is important that in both cases these skills be identified and their availability at the site and at the time be carefully evaluated.

An assessment of the developmental impact of a project also requires a considered appreciation of the technological circumstances. In the initial stages, it is important that those working on a project be aware of the limi-

tations that existing technology may place on its feasibility. It is not possible, for instance, to produce high-strength paper such as multiwall sacking paper from indigenous raw materials derived from cellulosic sources of inherently short fiber. No technology exists that can produce such an improvement in natural properties. The opposite situation can also occur: the technology may be available, but its application could be economically unattractive. It would be possible, for instance, to take an indigenous iron ore with a relatively low iron content (somewhere about 30 to 35 percent), to beneficiate the product, and by using local noncoking coals to operate a direct reduction process to produce sponge iron. This could be used in arc furnaces to produce steel. There is nothing technologically infeasible in this process, but it is very likely that the result would be economically unattractive, even if a substantial demand existed. Considerable operating costs would be incurred at all stages, and unless existing price structures were to change drastically, the protection needed to keep the company viable would probably be regarded as economically unattractive.

The initial assessment of a project's feasibility demands a certain familiarity with the capabilities of technology. This may not always be available in developing countries but can be supplied to some extent by members of the Bank Group working on preappraisal missions and on project promotion.[1] It is also possible to increase the awareness of technology and technological potentials in developing countries through the activities of the World Bank's Economic Development Institute (EDI), and other specialized agencies, such as the UN Industrial Development Organization (UNIDO) and the UNDP, are funded and staffed to develop this awareness of the potentials and limitations of technology.

The fact that the preliminary exploration of a project's technological possibilities has been completed does not mean that the project as first presented to the IFC can always be accepted as a basis for an investment. Considerable emphasis is now placed on what is termed appropriate technology. This is somewhat of a coded phrase since it is almost axiomatic that anyone proposing a project based on some particular technology must believe it to be appropriate. In this sense, the development and specification of the most appropriate technology can become a retrospective rather than a prospective activity. The IFC has accumulated considerable experience of industrial operations in developing countries and makes use of it in determining the acceptability of the technologies that new projects expect to employ. The examination of alternatives in employment of labor or capital is particularly important and is routinely included in the work of appraisal.

The technological feasibility of a proposed project must always be considered as a necessary but not a sufficient condition. The technology adopted must also be appropriate when judged by the criteria adopted by the Bank Group. These are not technological but economic, and the technological

input is concerned with the exploration of feasible alternatives. The determination of appropriateness involves certain assumptions about capital costs and operating costs, and these are the essential inputs into the financial and economic analysis on which the IFC's investments and those made by others associated with it are based. The technological problems thus focus on two main areas of concern: that the project can reasonably be expected to be constructed in the time that has been assumed in the projections and for a capital cost substantially in line with that on which the financial and economic forecasts have been based, and that it can be operated at the levels of efficiency anticipated in the financial forecasts.

Technology Transfer in the Construction Phase

Developing economies generally have no highly experienced construction companies, but a project can always be regarded as an opportunity to improve the experience of those that do exist. It is therefore necessary during the appraisal phase to ascertain what local engineering resources are available and to what extent they need to be improved and how such an improvement may best be fostered. The work of institution-building and increasing the pool of knowledge in the host country can never be overlooked. This is of particular importance in industries such as chemicals, which involve high pressures, high temperatures and corrosion resistance, and which may therefore require erection and welding techniques new to the country. It is then necessary to determine what technological skills are locally available and the extent to which expatriate assistance is required to supplement them. It must never be forgotten that practical applications and demonstrations are produced by people who are experienced practitioners of the technology that is to be transferred. The Bank and the IFC's experience clearly indicate that the preparation of manuals cannot serve as an adequate substitute for the availability of experienced people.

Should a transfer of technology be necessary, local organizations must be associated with the work so as to provide them a learning experience and develop a domestic technological capability. One illustration of this can be found in the field of welding technology. Special welds are needed for the field assembly of such project components as cement kilns. Because kilns cannot be shipped in a fully completed state, welds must be performed on the spot. This is a special technique that must be developed by the supplier of equipment. The situation is more acute in the case of large chemical plants, where high pressures are encountered. Corrosion-resistant steels that need special welding techniques are commonly employed, and the process must be performed to high standards by certified welders before the plant can be considered safe. In such a case, the certification standards may be

transferred from outside the host country—for instance, by API, Lloyds, or Bureau Veritas.

In the more industrialized developing countries, a substantial proportion of the goods and services required for the implementation of a project will be supplied by local resources. It is always necessary to ensure that if particular services are required, maximum use is made of appropriate local institutions and that if goods are to be supplied, they are checked for suitability by the project engineers. The capital goods manufacturing industry of a developing country is likely to be operating close to its level of capacity, and delay problems and quality control problems are common. Therefore it is necessary to make sure that the project has available specialists in the fields of project control and of equipment expediting. The progressing and expediting efforts required for projects in the more industrialized developing countries are generally appreciable. Successful projects built to a timetable and without appreciable budget overruns invariably require such controls. The staffing of the project must therefore make it possible for the customer to provide to the suppliers advice that would not be required in a mature industrialized economy.

During its developmental stages, a project is a bridge between what is available and what is desired, and the determination of what is available is made by using specialized technologies. Mineral resources, for instance, have to be sampled to determine their quality and their properties and how these properties are likely to change as the deposits on which the project is based are exhausted. This phase of work can give rise to problems in technology, and in some cases, it may not be possible to transfer the technology in its entirety. For example, there are only a limited number of places where wood pulping trials can be carried out to determine pulp characteristics, and few of these are in developing countries. Similarly, ore dressing experiments are unlikely to be carried out in the host country unless there already is a substantial and well-established mining industry. If a project is concerned with the financing of a new mine in a country where mining is just beginning, it is almost axiomatic that this particular technology will not have been established there. The properties so determined are, however, of limited utility unless they are carefully linked with the resource from which the samples were taken; that is, the locations in an ore body from which the samples have been taken must be carefully specified. Similarly, wood samples taken for pulping must be associated with species counts on the ground and possibly with aerographic surveys. These types of activities must be performed in the host country and are likely to require some importation of technical skills. If counterpart personnel from the host country are associated with the work, a worthwhile transfer of technology can occur during this phase of project preparation.

During the development phase of the project, it is also essential to get an idea of what the market will require. This is fairly straightforward in the case of a commodity such as cement, which is normally required in one or two qualities only. But when a project is concerned with consumer goods, such as cotton textiles, an accurate determination of market preferences is critical. If such a project has a developmental nature, it is likely to be replacing imports. These may well be very diverse since they come from a large number of exporting countries, and local consumers would be accustomed to having a wide range of choice. A local textile mill may not be well suited to produce such a wide range of products, and the determination of what could be an acceptable range to the customer and of what would be sufficiently restricted to be feasible to manufacture is extremely important.

The determination of consumer buying characteristics is always difficult in a developed economy since fashion and individual choice play an important part. It is equally, if not more, important in a developing economy, where consumer preference can be quite volatile and severe financial problems can result if a textile mill is designed to supply a particular range of fabrics and comes into production just as changes in fashion initiated outside the country occur. For instance, it is difficult for a textile mill originally designed to produce bleached and piece-dyed cotton shirtings to succeed in a market where a change in fashion suddenly requires striped shirtings. The mill will have neither the yarn dyeing capacity nor the preparation equipment required to make the striped warps.

If the available resources have been properly determined and the product range and market requirements correctly assessed, the appropriate equipment can be specified and the project launched on the basis of its expected performance. The skills transferred in this phase are not of permanent concern to the project, but they are necessary to ensure that it does not carry for the rest of its life an unacceptable cost burden. This type of technology transfer primarily benefits consulting firms and construction contractors, both of which are external to the project. These transfers, however, occur regularly, and many small businesses have started as subcontractors in the implementation of a larger industrial project. Not all enterprises, of course, are of equal importance for the external development of such capabilities. Some projects may involve only light buildings and nothing more than the installation of relatively straightforward machinery. Others may introduce new skills in heavy machinery erection or foundation work, but as far as the particular project is concerned, these transfer benefits are a by-product of successful implementation and should not take precedence over it. No one could justify a cement project solely as a means of transferring the technology of heavy machinery erection or of field welding of heavy plate. Yet both technologies must be transferred if the equipment is to be erected, and both will have to have been demonstrated and passed on to local specialists.

An examination of the projects in which the IFC has been involved points to two general principles concerning the technologies that are used and have to be transferred to the operating phase. The first is that few projects are operating on the basis of proprietary technology. Most of them employ technologies that are well established and widely understood and about which journals and proceedings are continually reporting. Second, and possibly more important, the success of a project is rarely determined by the transfer of a single technology. It is often found that while the core technology can be adequately transferred, the important problems of the operating enterprise are found in the peripheral technologies—that is, in the maintenance of the equipment, the testing of raw materials, and the adjustments of the manufacturing process to market requirements. These are separate but associated technologies, and they must also be transferred if the project is to be successful.

Technology Transfer in the Operating Phase: The Case of Iron and Steel

The problems of technology transfer in the operating phase perhaps can best be illustrated by looking at a number of industrial sectors in which the IFC has been involved. The first industry, in terms of value of commitments, is iron and steel. This is a very basic industry, which has been well known and successfully transferred internationally for well over a century. Historically, the transfer of iron-making and steel-making technology from Europe to North America was accomplished for the most part through migration. Skilled workers and technicians (at the time, the two were virtually indistinguishable) emigrated to the United States, where they established iron and, later, steel plants. A similar pattern had also operated within Europe. To a lesser extent, expatriate advice was used in the formative years of the development of the Japanese steel industry at the beginning of this century.

The use of oxygen converter steel making in the developing countries today testifies to the importance of local conditions on the success or failure of process transfer. The oxygen converter, working on liquid hot metal from a blast furnace, must be able to operate on the basis of analyses provided by local resources. Cases have been encountered where the phosphorus content of the ore, which is inevitably reduced and so is found in the hot metal, made a single slag operation in the oxygen converter infeasible and the task of transferring the alternative technology (the double slag method of working) is appreciably greater, not so much from purely metallurgical considerations but from process control problems. An adverse effect on investment return is also quite possible.

The use of the basic oxygen path points to an important issue: the interdependence of applied technologies. The successful operation of a converter is highly dependent on a regular analysis of the hot metal under treatment—i.e., that its composition remains unchanged in day-to-day operations—and this, because the blast furnace is limited in the modifications in analysis that it can produce, depends primarily on the regularity of the raw materials fed into it. To ensure such regularity requires a careful planning of the mining operations and of the exploration of iron ore deposits so that mining can be carried out in a manner that regularizes the analysis of the raw materials received by the steel works.

The linkage with mining is also essential to the process of direct reduction, the most recent development in steel production. This process, which takes iron ore directly and reduces it in the gaseous phase by suitable reductants, is dependent on the characteristics of the raw material. A high iron content in the raw material must be achieved, not so much because it could not be reduced if it were lower but because the reduced product must be passed to the succeeding process, and high process costs are associated with high gauge contents. Although the raw material costs may be reduced through the use of screened and sized ore, plant production rates can be adversely affected by decrepitation, and only operating trials can determine the ore's susceptibility. Any technology that is to be introduced for direct reduction work therefore must be well suited to the raw materials that are to be used. This again implies a backward linkage since it is extremely important to determine both the characteristics of the raw material and the prospects for maintaining the expected characteristics of the deposit throughout the operating life of the steel plant.

There are a number of technologies now available that differ as far as the reductants are concerned. The majority of current installations employ the reforming of hydrocarbons to provide the reducing gases. These are chemical operations, which can frequently pose a new learning task for an established and experienced steel company. Here a new technology would have to be transferred to a company that has extensive experience with the other types of technology.

The mini-steelworks route to steel, normally made up of a scrap-based furnace, continuous casting, and a rod mill producing reinforcing bars, can be particularly vulnerable in developing countries. Local supplies of scrap may be scarce and not of prime quality. Nonferrous contaminations are not entirely removable in the process of arc furnace steel making, and the residual elements may adversely affect the continuous casting operation; the problems may also persist in the subsequent rolling operations. Continuous casting, therefore, may be inappropriate in the early years of operation of a new plant based on scrap, but it could be introduced at a later stage when the collection of scrap and its sorting and control had become better or-

ganized. It could also be introduced if local scrap can be used to provide a smaller proportion of the charge in the furnaces and if the residual, or tramp, elements can be diluted by the relatively pure iron of reduced iron sponge produced by a direct reduction process.

The rolling operations in a mini-steel plant can also involve the transfer of associated technologies. Earlier rolling mills, which were relatively crude, did not pose considerable maintenance problems, but the mills now used for the production of reinforcing bars require considerable expertise in control technology for the electrical drives, in mechanical technology for the maintenance of the mill itself, and in machine shop skills for the machining of the rolls and for the maintenance of the guides and bearings used in the rolling mill. These technology transfers do not normally present insurmountable problems but do point to the fact that the establishment of a steel works requires the transfer not only of metallurgical technologies but also of many others, notably in equipment maintenance and refractory development. The transfer problems can be reduced if labor-intensive rolling technologies are used, but other problems may then arise. Working conditions are difficult in hot and humid locations, and double or triple mill crews may be required when rolling flats by labor-intensive methods in high ambient temperatures.

Textiles and Fibers

The textile industry uses a wide range of technologies, most of them well established. The spinning of cotton yarn (primarily ringframe spinning), for instance, has changed little in its essentials in the past hundred years. There have been detail improvements in machinery, which have simplified the production processes, and these improvements have produced better intermediate materials, which in turn have facilitated the improvement or development of subsequent processes.

Currently two major technological innovations are available in the textile industry: open-end spinning in yarn production and shuttleless weaving machines, the latter used instead of the loom in the weaving operations and the production of fabric. These two new technologies frequently are introduced by personnel provided by the machinery suppliers, but it is necessary to be satisfied that both the raw materials and the way the products are used are appropriate. The characteristics of the yarn are different now because of the different arrangement for the fibers produced by the open-end spinning process, and the fabrics produced by shuttleless weaving machines differ in some respects from those produced by the conventional loom.

The technologies used in the textile industry are governed to a large extent by consumer demand for the end product. One exception, often considered attractive by many textile mills simply because it is an exception, is

the production of military uniforms, which can be made without worrying too much about changes in consumer preferences. Textiles represent fashion, and fashion can never be overlooked in considering technologies in this industry. It is also an industry where the issue of capital and labor intensity frequently arises. At first sight, there may appear to be little connection between fashion and capital-labor substitution. There is, however, a considerable interaction between them. It arises from the fact that in both spinning and weaving, human intervention is required because of discontinuities in the production process. A spinning machine will continue to spin uniform yarn without any intervention until the yarn breaks or the supply package in the creel is exhausted. Then the spinner must piece the package, and a discontinuity is apparent in the yarn thus produced. Similarly, when a loom is weaving fabric with the automatic weft replenishment, it will not stop and will not require the attention of a worker until a thread breaks or until there is a failure to replenish the weft. In both cases, a discernible fault can easily be produced in the fabric.

At one pole of the textile industry are hand spinning and hand weaving, where the nonuniformity of the fabric can be regarded as one of its attractions. At the other extreme is the production of fabric for low-cost, ready-made garments where uniform quality and low fault incidence are required. When cheap ready-made garments, such as shirts and slacks, supplant more traditional dresses, the local textile industry must respond to this change in market. A labor-intensive technology may not be entirely suited to this new market, and a technology designed to satisfy a particular market demand may be inherently machine oriented and therefore capital intensive rather than labor intensive.

The finishing activities of a textile mill are the sectors where there is the greatest interaction between technology and the wishes of the consumer. Some interaction does take place in the weaving and spinning processes, but in the modern textile industry, the greatest impact is generally in finishing, the phase in which colors or prints are added to fabrics. In parts of the world where a traditional dress or color is known, a highly specialized technology may be necessary to produce exactly the shade of color desired in the fabric. In other countries, prints are worn, and it is then necessary to assimilate both the technology of actual printing and the art of designing prints that will appeal to consumers. This has always been a very specialized activity, and it is not always easy to transfer, although it might well be supposed that local artists are best able to design fabrics that will appeal to local consumers. This is an extremely important technology; textile mills can frequently produce fabrics that are quite satisfactory from the technical point of view but have the inherent disadvantage of being difficult to sell—at any price—in the market for which they were intended.

The textile industry can use either natural or synthetic fibers. In the past, IFC's activities have not been much concerned with synthetic fibers, and it seems unlikely that they will form a substantial part of its activities in the future. Synthetic fibers can, however, confer additional and useful properties to fabrics and have been important in the corporation's activities in the more industrialized developing countries. The technologies in this area are relatively new, although easily available commercially, and in general no monopoly exists in the supply of technology for either polyamide or polyester.

Regardless of the type of technology employed, synthetic fiber plants are high-technology, capital-intensive units. They involve chemical operations, which require careful controls and precise high-speed machinery of considerable strength for the processing of yarns and fibers. Maintenance problems at the higher ends of technology are important, and the transfer of these peripheral technologies may have a greater bearing on the success of an enterprise than the transfer of the core technology itself. The implications for backward integration and for cross-linkages with the petroleum and associated petrochemical industries are very important. Some form of technological anticipation may be required in the selection of the appropriate process technology, and the probable developments in the petroleum refining and petrochemical sectors of the host country must be taken into account.

Construction Materials

By far the greatest part of the IFC's experience in the construction sector has been with the production of cement. The raw materials are frequently, but not always, available in developing countries, and the technology is mature and well established. Efforts are being made, however, to scale down this technology and to develop smaller regional plants. The IFC has had no direct involvement with any of these efforts, but developments in this area are being kept under close review. The considerable importance attached to technology and technology transfer in the IFC's operations requires a wide knowledge of potential technological alternatives, which may be suitable in particular projects.

Although cement technology is well developed and widely understood, it is raw-material sensitive (as in the case of the reduction operations in iron and steel), and technology selection must take this factor into consideration. Some years ago, the choice between wet and dry processes was not always clear, but now the problem has become straightforward. As technology progresses and as energy costs change, new technologies are introduced to economize fuel consumption in the burning process of cement manufacture. Therefore it is necessary to consider the raw material and fuel

characteristics more closely and to take a critical look at such problems as the use of air suspension preheaters on the cement kiln.

The cement industry involves considerable heavy erection during the construction period, but the equipment suppliers are well able to supply the specialized field erection staff. The transfer of operating technologies is not particularly difficult, but the maintenance requirements remain important.

Other important building materials are clay products. Here also there have been few changes in technology for a very long period, but detail improvements in equipment and minor technologies are constantly taking place. The suitability and availability of raw materials must also be taken into consideration, and the possibility of variation as deposits are worked must always be kept in mind. The transfer of quality control technologies to ensure consistency of the constituents is essential.

Involvement in new construction materials is likely to require the transfer of both production technologies and utilization technologies. In developing economies, building techniques are often traditional. Labor-intensive methods are usually prevalent and dependent on the use of local raw materials. Newly developed materials can be suggested as substitutes for these traditional materials, but one must not overlook the impact of such innovations on the existing construction industry. In the same way, careful consideration must be given to the impact of novel materials on the industry that would produce them and on the industry that will have to use them.

Pulp and Paper

Technology transfer problems in the pulp and paper industry are more acute than in many other sectors. This is not so much because of novelties in equipment (paper machines are reasonably standardized and differ chiefly in terms of their end products) but because the raw materials out of which paper can be produced are varied. This is the same problem as with cotton. But whereas cotton is a warm climate product, which has been long exported and has benefited from production technologies developed in the equipment-exporting countries, cellulosic raw materials are rarely exported, and the development of pulping technologies has suffered in consequence.

The properties of the pulp depend on the characteristics of the species from which it is produced, and technology can do nothing to lengthen the inherent fiber length of the cellulose; however, an inappropriately selected technology can result in reducing fiber length. In the tropical or subtropical developing countries, the naturally occurring species of trees rarely provide the long fiber cellulose necessary for the production of high-strength papers. Natural forests, moreover, contain many different species, and

selective cutting is rarely economical. The operations of a pulp mill running on a mixture of tropical hardwoods are thus difficult to control, and the quality of the end product is generally not as high as might be desired.

Sources of cellulose other than trees are available, however. Two in particular, bagasse and bamboo, can produce a satisfactory pulp with short to medium fiber lengths, but both can pose problems in the operations of a pulp mill's chemical recovery system. This system is needed not only for economy in the use of chemicals but also for environmental protection. Here there is a real need for development programs. Equipment suppliers are generally located in the developed countries, and the pulping industries in those countries are not dependent on the use of tropical raw materials. On the other hand, a number of developing countries have taken the technology of pulping such materials as bagasse and bamboo further. In this industry, there is a real opportunity to extend the sources from which technology may be transferred.

These difficulties with naturally occurring cellulose sources or other readily available sources have prompted the establishment of plantations of exotic tree species on which a paper industry can be established, which gives rise to questions as to the suitable technologies for arboriculture. Pulp and paper-making operations must be located close to the source of cellulose and close to sources of process water. Like other continuously operating industries, the operations of a pulp and paper mill pose considerable maintenance problems. The operation and maintenance of the chemical recovery system also demands a high degree of expertise. It is not uncommon in developing countries to find that available local personnel with the necessary technical skills may be unwilling to relocate themselves and their families to the new plant, which is often remote and may lack such amenities as schools, shops, and entertainment. This problem is more acute today now that the convenience of urban life is better appreciated.

Technology Transfer Mechanisms

Almost all transfers of technology depend to some extent on written instructions. It is a common requirement that new equipment be supplied with the necessary documentation, which includes handbooks, drawings, and lists of parts. This widely applied principle can be effective under suitable conditions, but in everyday life, such written transfers frequently fail, even in the case of activities less complicated than industrial operations. Too often the instruction pamphlets and handbooks supplied with automobiles and cameras, for instance, are not adequately studied by the purchasers, and the inability of purchasers to assemble knocked-down items according to the instructions is notorious. In contrast, some companies are able to sell kits of

electronic components, which are then assembled by purchasers who have little or no electronic knowledge, and the results are generally satisfactory. Correspondence schools have managed to teach a number of disciplines successfully, and both technical instruction and academic teaching are now able to augment the written instructions with audiovisual presentations.

Equipment suppliers do not always pay enough attention to the development of training manuals and training aids, and the use of unfamiliar languages poses particular problems. Those familiar with a technology and who are best equipped to determine what has to be transferred are not always lucid writers. Conversely, able writers are frequently unfamiliar with technology and with technological usage, even in their native language. If a translation is required, difficulties are compounded, and the checking of the foreign-language version by the technological originator is likely to be ineffective.

Technology transfers concerned with the procurement by an existing enterprise of improved machines to increase its production capacity often rely entirely on such documentation. It should never be forgotten, however, that some technology transfers must reach organizational levels in the host country where familiarity with a foreign language is rare. Even if language difficulties do not exist or have been overcome, the dissemination of technology to the organizational level, where it can be used effectively, is sometimes defective. It is not unknown, for example, for maintenance workers doing their best to adjust a machine to be unaware of a carefully prepared manual that specifies the exact procedures but is kept in the manager's office.

Written and audiovisual presentations are an important part of technology transfer, but they are limited in scope and frequently need to be supplemented. All such supplements involve personnel training, and this can take place at the source of the technology or at the point of employment, or at both. Both formal instruction and exposure to opportunities for learning by experience are used. Although there is frequent use of such terms as *technology package* and the *unbundling of technology*, this jargon should not obscure the fundamental reality that effective transfers require that some people acquire knowledge and skills that they previously lacked. The problems and methods of transfer can be greatly simplified if this is kept constantly in mind.

For technology to be transferred within industrialized countries, both training and documentation are required. Training can be carried out in the equipment supplier's plant or, occasionally, in another plant where similar equipment is in daily use. There can be problems of confidentiality here, but in general the method is effective, particularly when the supplier of technology has established specialized training facilities and developed a full-time training staff.

In developing countries, the two most obvious obstacles are language and expense. Personnel trained for a development project are unlikely to have had extensive industrial experience, and learning cannot be as rapid as with people from industrialized countries with a more extensive exposure to industrial operations.

Trained personnel do not always remain with the company that originally arranged for their training. Their attractiveness to other employers and their own ambitions are likely to increase. If they have been trained in the peripheral support technologies, other local enterprises may hire them away, and, occasionally, when their language skills are particularly useful, they can be hired by organizations in the developed countries.

A weakness of both the instruction manual and the formalized training approaches to technology transfer is that they can deal effectively only with determinate matters. They must be based on the conventional wisdom familiar to the writers and lecturers, and the comprehensiveness of this will depend on the existence of effective feedback from established operations. A transfer must serve as a basis for an extension of the technological principles into a novel environment. Problems are likely to arise that are not easily anticipated, and solutions must be devised during the process of transfer.

What is not always realized by those not directly involved in them is that industrial operations continuously present a succession of problems. There tend to be a smaller number of large problems and a larger number of small problems, and the success of an enterprise depends on the extent to which the incidence of such problems can be reduced.

The elimination of problems require a knowledge of their causes and the feedback from established operations, which makes it possible to include such knowledge in the formalized transfer of technology. By contrast, when problems develop as operations proceed and must be solved as novelties when they arise, something beyond formal transfer is required. Examples of problems that are not easily anticipated are variations in ore bodies encountered as extraction proceeds, changes in consumer preferences in the textile industry, and, common to virtually all industries, changes in the operating characteristics of the installed equipment produced by wear and tear. These factors, coupled with restrictions imposed by cost and the short duration of training, places a limit on the transfer capabilities of the written and the source-located training procedures. Therefore it is frequently necessary for an additional transfer capability to be provided. This can be regarded as a form of on-the-job training coupled with some evolutionary capability for extending and adjusting established technology to comply with particular conditions. This commonly involves the employment at the site of expatriate staff with long experience in the required technologies. Their task is to train local successors and to develop solutions to operational problems just as they would if they were working in a developed economy.

Such employment is common in the construction and start-up phases of projects. The erection of the more complex pieces of equipment is normally supervised by specialists from the suppliers, and they usually remain on site until the equipment has been put into operation. Similarly, technical staff from process vendors can be employed during the project development phase. These are short-term assignments, but they are effective in supplying the guidance needed. They are likely to be quite adequate when the new technology is supplied to an existing plant where the required supporting technologies are well established.

In developmental industrial projects, the transfer of peripheral and supporting technologies is frequently of equal or greater importance than the transfer of the core technology. Shorter-term appointments cannot deal so effectively with activities that, unlike erection and start-up, persist and, not infrequently, grow in importance throughout the life of the investment. Equipment maintenance, production planning, and management accounting are examples. The technological content of these activities varies. Experience, however, indicates that successful operations are markedly influenced by them; serious shortfalls in capacity utilization, which in turn cause financial problems, nearly always result from deficiencies in this area. These activities are not only essential but permanent, and they must be transferred. One solution is to employ staff from similar industries in the country or from similar plants in other countries if local sources are inadequate.

The technologies of equipment maintenance are of special importance and pose particular problems in a developing economy. In developed countries, specialized assistance is available since the volume of work permits specialization, skilled workers can be hired away from equipment producers, and delivery times of spares can be short and inventories consequently small. Furthermore, since labor is expensive and spares cheap, maintenance practices involving replacement rather than repair are feasible. Developing economies can provide few, if any, of these advantages. Maintenance by replacement is likely to be less attractive, and there is a frequent tendency to recondition, using available local resources as a substitute for replacement. But with many types of repair, reconditioning needs special skills and quality controls if downtime is to remain low, and the loss in productive time of the main investments must be taken into consideration when reconditioning is being considered. There are thus considerable opportunities for local initiative in the development of appropriate technologies and procedures for maintenance. It is, however, very much a practically oriented activity and does not seem to have received the attention it deserves. Greater consideration of maintenance practices and related technologies would not only improve the performance of current industrial investments but would also assist in building up indigenous technological capabilities.

Sources and Costs of Transferred Technology

The analytical work leading to an investment decision includes the determination of a project's technological requirements and the means required for the transfer of technology. These transfer requirements fall into two separate but closely related categories: those associated with the design and construction phases of the project and those associated with its subsequent operation. Although there is some overlapping between the two, they are very different, and practitioners generally cannot be assumed to be freely interchangeable. In industrialized countries, companies whose main business lies in operations are unlikely to possess in-house capabilities for the design and construction of new facilities unless they are large and so successful that they can contemplate a more or less continuous program of expansion. They must, of course, have extensive internal resources of operational technologies. At the other end of the technological resource spectrum, organizations that specialize in design and construction activities are unlikely to be fully experienced sources of operational technologies.

If a project is to operate successfully—and it must be stressed that operation is the pay-off since all the benefits expected to flow from it are conditional on its satisfactory operation—then the plans on which it is to be built must be endorsed by responsible representatives of those who will have to operate it and who will be responsible for its success. A plant that has been constructed according to proposals drawn up by design institutions and equipment suppliers and where the inputs of the operations technologies have been postponed until production is almost due to start is likely to encounter unnecessary problems and rectification expenses. The difficulties are exacerbated if, as is frequently the case when a project has a developmental context, the top management of the new enterprise is not familiar with the day-to-day practical operating problems. If the new enterprise to be established is associated with an existing industrial company, it is possible to give experienced staff the opportunity to study similar activities abroad and to entrust them with the responsibility for endorsing the design proposals, fully aware that they will also be responsible for the ultimate success of the new investment. Such a strategy can be very successful but is feasible only in the more industrialized developing countries.

If a project is to be carried out by a completely new entity, staff must be recruited and similar opportunities for acquiring experience arranged for them, but the links of responsibility in this case are likely to be more tenuous. For large and complex projects aimed at establishing a new industry (and that usually means the establishment of a new corporate entity), something more is required. The fundamental problem is that worthwhile experience of production operations exists only within the enterprises in that industry. This means that for a developmental project, this experience is likely to exist only outside the host country.

A newly established company can advertise and recruit the required expatriates on its own account, but such an attempt might easily fail to attract good personnel from their present employment. Experience also suggests that such collections of expatriates do not readily work as a team and that success is then very dependent on the coordinating talents of the top management of the new enterprise.

For all these reasons, it may be preferable to obtain the operating advice from a foreign firm that has practical experience of the activity under consideration. Such firms may not, and indeed for their own best interests ought not to, have appropriate staff immediately available, and the ultimate staffing, if not also the initial staffing, is likely to require some measures of promotion and recruitment. With a single source of personnel and a central responsibility for performance, coordination is much easier and the operation of the project is likely to be more satisfactory. It does, however, raise special problems as far as payment and performance incentives are concerned.

Simpler arrangements do not pose such problems. Expatriates can be recruited either directly or through an agent, and the expenses are straightforward. Depending on the attractiveness of conditions in the host country and the going rates in the countries where recruitment is undertaken, some sort of proposal can be developed, and the responses to it provide a justification for the ultimate costs.

If projects are large and sufficiently important, such competitive principles can be used to select an operating company to provide the operating advice required by the new enterprise. The most suitable pattern of reward for such services might be a fee related to the performance of the enterprise to be established. The development of a suitable incentive basis for such a fee is not, however, as easy as it might seem. Great care is needed to avoid suboptimizations, and the big weakness in such a system is that it is difficult to introduce negative fees for substandard achievement.

These difficulties suggest that a technical partner that has a real investment in the newly established enterprise, that profits by it only as and when other investors also prosper, and that sees the value of its investments decrease just as they also do when the outcome of operations is unattractive, is likely to provide the appropriate practical operating advice for as long as it is required.

This need for a technical partner with an associated investment can be justified on the following grounds: there is a need for experience in operating technology, this experience must be obtained from similar industrial operations, and there are major difficulties in designing simple and effective incentive payments for a company that undertakes to provide such operating assistance. The effectiveness of such an approach is lessened if the equity investment is, in effect, a deferred payment of the profits resulting from the supply of goods and services to the project.

The circumstances of a particular investment determine the technology transfers required for its successful implementation and operation. Requirements are variable even within a sector, and, consequently, useful quantitative generalizations as to transfer costs cannot be made. The justification of an expense by comparison with other projects can be meaningful only if both their scope and costs are known. Costs can be quite easily and compactly described, but what is included cannot be expressed so readily. Without adequate specifications, two transactions whose cost appear identical may be considered to be in line, but a knowledge of what has indeed been included in them often suggests that they are really different.

The acceptable level of technology transfer costs can be determined only once the type of services supplied, the method of supply, its timing, and its duration have been specified. Once the amount of man-years of work has been reliably estimated and quotations of cost per man-year obtained, an informed appreciation of a large part of the costs of technology transfer can be made.

The costs should always be compared with the benefits received. Estimates that compare the cost of purchasing proprietary know-how with that of developing a new alternative are encountered infrequently, if at all. The great majority of transfers are concerned with technologies that facilitate or improve construction, start-up, and operation. All are important, and the benefits of improvement generally can be expressed in financial terms. Financial and overhead expenses depend on time, either in the construction phase or in the time from start-up to breakeven, and estimates of time, savings, and associated benefits can be compared with the estimated costs of attaining them through other means.

Of far greater importance in most cases are the additional costs that can be incurred and the earnings forgone by failures to transfer adequately the technologies of plant maintenance, production planning, and cost control. These deficiencies are encountered in virtually all sectors and all too frequently are characteristic of industrial operations in developing economies. Greater emphasis on internal technology transfers and on the development of local capabilities is likely to produce very worthwhile improvements. Yet suggestions to stimulate research to extend technology are more frequently encountered than suggestions to improve the ability to employ effectively the technologies that already exist. If seed falls on stony ground, plant breeding experiments are not the best answer. Removal of the stones offers a better prospect and might provide more employment for the lesser qualified.

Note

1. The Bank Group comprises the World Bank, IDA, and IFC.

1 The Engineering Industries

Frederick T. Moore

A number of activities have been undertaken to raise the technological capabilities, and hence the competitive position, of industry in several developing countries; the primary emphasis in this chapter is on the engineering or capital goods industries.[1] These are primarily the machine-building industries and include three large groups of electrical and nonelectrical machinery and transport equipment. Their typical product lines include agricultural machinery, engines and turbines, metal-working and woodworking machinery (including machine tools), shipbuilding and railroad equipment, motor vehicles, and scientific equipment.

Many characteristics of engineering products make them attractive in development. First, many such products can be produced reasonably efficiently on a small scale. This category includes products that are typically produced in small batches or in a "one off" fashion and where the production processes are simple and standard and have a relatively few machine operations. Under such circumstances, the amount of fixed investment is modest, which means that many of the enterprises would fall in the classification of medium-scale or smaller firms. In other cases, however, large-scale production is required because of the interdependent nature of complex production processes, and the size of the investment in plant and equipment is substantial. We do not have good empirical estimates of the minimum efficient scale of output for the heterogeneous engineering products or information on whether the cost curve is relatively flat bottomed over a range of output.

A second characteristic of these industries is that they tend to be labor intensive and hence offer opportunities for absorption of labor. Offsetting this is the fact they also tend to be skill intensive. Although their potential for labor absorption is attractive to countries concerned with employment creation, a shortage of skilled technicians and engineers can be a major impediment to their development.

Third, the technology employed in these industries is, in large part, well known and often has been in use for many years. Within the past fifteen years, there has been a virtual explosion in the art of metalworking as more complex jobs are undertaken in a single operation (such as working on several axes at the same time), but the dimensional accuracy required in much of the work has not changed greatly. Many products are still made in much the same way now as before. This means that the ability to master the

basic technology is not impaired by rapidly changing methods across a wide spectrum of products. The lack of a flow of information on technical processes down to the operator level may, however, be an impediment.

Fourth, the external economies among the engineering industries are typically extensive; that is, there are strong linkages both backward and forward among the products so that it is possible to find families of products that are mutually supportive. In order to take advantage of this, however, development programs must be planned as an integral and interdependent whole.

Fifth, the engineering industries tend to be the carriers of technological change, and there are numerous opportunities to borrow the ideas, to copy, and to make changes that have effects beyond the confines of the engineering industries themselves. This may be a means of stimulating domestic research, development, and engineering programs in a country as well, and the spillover effects throughout industry are usually substantial.

Finally, there are a number of products (parts, components, and subassemblies but also some end items) that developing countries can successfully export. International subcontracting of parts also can be a significant stimulus for export, particularly in the case of products where labor costs in industrialized countries are high. Many of these export markets are differentiated because of the product characteristics, and exports do not run into the same problems of quotas and controls that frequently face traditional goods.

These characteristics are strong arguments in favor of a more rapid development of the engineering industries in the developing countries. Although there are a number of specific obstacles and problems, the favorable aspects offer a strong rationale for the expansion of this particular industrial sector.

The Rate of Growth of Engineering Industries

Substantial research has been done on the typical or normal patterns of growth of major sectors in the economy (agriculture, industry, and services) and of specific groups within the industrial sector (such as food, textiles, metals, and machinery). On the basis of this research, it is possible to obtain some comparative guidelines on the typical pattern of growth of the engineering industries, given different levels of development (measured here in terms of per capita GNP) and their relative importance in the manufacturing sector.[2]

Table 15-1 shows that the typical share of GNP originating in manufacturing varies from 17 percent at a per capita income level of $330 to 27 percent when per capita income reaches $1,285. The engineering industries'

Table 15-1
Relative Size of the Manufacturing and Engineering Industries

Per Capita GNP at 1978 Price Equivalent	*Share of Manufacturing Industries in GNP*	*Share of Engineering Industries in GNP*	*Share of Engineering in Manufacturing*
$ 330	17%	3%	18%
1,285	27	8	30
5,000	30	11	37

Source: V. Prakash and S. Robinson, "A Cross-Country Analysis of Patterns of Industrial Growth," draft World Bank Paper (Washington, D.C.: World Bank, 1979).

Note: Income has been adjusted from a 1970 to a 1978 base. The data present a time series and cross section sample of countries around the world.

share in GNP is only 3 percent when per capita income is $330 but almost triples at an income level of $1,285.

Engineering industries typically grow much more rapidly than the manufacturing sector as a whole. At a per capita income level of $330, the growth elasticity for all manufacturing (the percentage increase in manufacturing value added per 1 percent increase in real GNP) is about 1.6, but the growth elasticity for engineering industries is typically over 2.3 and is higher than for any other industrial group. These are the dynamic growth industries even at this relatively low level of per capita income, and the same is true as per capita income increases. Clearly this is an important reason for concentrating development policies on the engineering industries.

Measuring the Efficiency of the Engineering Industries

Bearing in mind the importance of the engineering industries in the process of economic growth and industrial development, the World Bank has tried to evaluate the technological level of these industries in selected countries and, on this basis, to prescribe the elements of a development program, including preparation of feasibility studies for specific projects aimed at improving technological capabilities in the engineering sector of two countries, South Korea and Thailand. None of the projects described here has yet been carried through the complete cycle, and the conclusions that can be drawn from them are therefore tentative. This story does, however, show the ways in which the World Bank acts as a technological institution and how action-oriented research provides the basis for broad development policies and for specific industrial projects aimed at promoting the growth of indigenous technological capabilities in the developing countries.

The measurement and evaluation of current technological capabilities in the engineering industries was based on visits by Bank staff to a sample of individual plants covering a wide variety of product lines in the two countries concerned. Technological capabilities were first addressed in terms of the efficiency of current operations using existing equipment and labor (that is, X-efficiency, to use the technical term). In the second phase, an attempt was made to determine those product lines in which the country had some comparative advantage or could readily acquire such a position with additional investment in equipment, training of labor, and reorganization of production methods.

The sample of plants to be visited was chosen in conjunction with knowledgeable people in industry and government. The visits were made by engineers with extensive experience in production and plant management. After each visit, an individual analysis and assessment of the facility or of individual product lines was made. In order to arrive at an accurate and uniform analysis, the engineers making the evaluation were asked to consider specifically seven major factors and to award points or to score each of them.[3] The seven factors assessed were the following:

1. Plant layout and flow of work: This includes the layout of machinery and equipment to permit the optimum flow of material and the minimum amount of handling in processing the product from receipt of the raw material to the finished product. Factors considered were flow of work, storage, material-handling facilities in plant, and other logistical arrangements.
2. Operating practices: These cover principally the application of production engineering techniques to the manufacturing processes, including the processing of materials, preplanning methods for producing the component, work measurement, tooling setups on the machines, jigs and fixtures, assignment of tasks to the machines, the use of metal-cutting and metal-forming tools, as well as safety procedures and practices.
3. Maintenance of plant and equipment and conditions of machines: This includes how the production machinery, ancillary plant, and service equipment are maintained in order to avoid shutdowns of the manufacturing processes, the procedures such as planned preventive maintenance schemes that may be carried out to keep the operating plant in good condition, and the age and accuracy of the machines and equipment in the plant.
4. Labor use and productivity: This factor covers the manner in which management employs its labor force, which, in a larger context, may dictate how effective or productive the labor force is in the operations. It will also include such activities as on-the-job-training or specific training for production or machine operations.

5. Quality of product: In this context, product quality refers primarily to the product's acceptability in the international markets and to the in-plant systems for setting, monitoring, and maintaining product quality.
6. Engineering design, testing, research and development: This factor refers to the existence of in-plant facilities and capabilities to design, redesign, and retool or otherwise adapt or modify existing product lines to meet changing demands or conditions in the plant.
7. Management systems: This includes the normal business controls such as costing, marketing, and sales, as well as controls of production processes such as inventory control, production control, and labor and output statistics for planning and control.

For each of the seven factors to be evaluated, a score was awarded on a scale ranging from 60 to 100. There was a minimum differential of five points between each evaluation (60, 65, 70, 75, and so on) so as not to impose too exact a measurement on the engineer. A figure of 90 to 95 corresponds to efficient production processes, comparable to those of industrialized countries, and a score below 75 indicates deficiencies in production and management systems that, if not corrected, probably would lead to the failure of the firm. An intermediate score of 80 to 85 indicates acceptable practices for expansion within local markets, and a score of 85 to 90 suggests that the exports are possible to less developed countries but not to the more sophisticated markets of the industrialized countries.

Clearly there is always some injustice in trying to portray the overall capabilities of an industry in such a way. An industry is made up of a large number of individual firms, and the potential of each may vary quite considerably. This is particularly the case of Korea, where the machinery industry is rather dualistic in nature. The new generation plants built in Changwon after 1975 are much more advanced than those built earlier (and were the only ones covered in this survey). Although the same elements of comparison, with one exception, were used in both Korea and Thailand, the average scores (shown in table 15-2) cannot be compared for the two countries. There is general agreement that the enterprises in Korea are more advanced than those in Thailand.

In Thailand, it very quickly became apparent that there are significant differences among the sample group of firms and that they should actually be subdivided into three distinct groups. The first group of Thai companies, financed by domestic entrepreneurs, have no significant engineering or technological capability in the management and do not appear to have ready access to technological information. Consequently these companies generally displayed poor use or understanding of technology, which was frequently accompanied by obsolete and inefficient equipment. About half

Table 15-2
Summary of Scores from Plant Visits in Korea and Thailand

	Korean Firms	*Thai Firms*			
		Without Engineers	*With Engineers*	*Joint Venture or Foreign*	*Weights (%)*
Plant layout	70–75	72	78	82	8
Operating practices	70	65	83	88	18
Maintenance	75	65	80	86	8
Labor use and productivity	75	75	85	84	17
Product quality	80–85	77	87	89	20
Engineering design	75–80	76	81	80	18
Management systems	n.a.	69	69	78	11
Weighted average	n.a.	72.0	81.6	84.3	100.0

of the companies visited by the mission fell into this category. The second group are indigenous Thai companies, where day-to-day management decisions are in the hands of engineers or technically trained personnel. Generally these companies were profitable, they were frequently expanding fairly rapidly, and they seemed to provide a good foundation for the development of an indigenous Thai industry. These companies, however, appear to be in a distinct minority. The third group of companies comprises joint ventures and foreign firms; their technology and equipment have usually been imported, and their products are often comparable in quality with those made abroad. Management is usually in the hands of foreigners. The majority of these enterprises have been established in Thailand only over the past seven or eight years, and some are still in the process of adjusting their operations to the market.

The summary of the point scores is given in table 15-2 for both the Korean and Thai firms, the latter subdivided into the three groups. In Thailand, the seven factors identified in this survey have been weighted according to their relative importance so as to arrive at an average score for each group of firms. This weighting system was derived by the engineers carrying out the survey and is based on their judgment and experience as to the relative importance of each of these factors in the successful operation of a factory. Four factors (operating practices, labor use, product quality, and engineering design) account for approximately 75 percent of the total weight.

The average score for all factors provides a rough measure of the extent of inefficiencies in management of resources, but of greater operational significance are the conclusions and recommendations for each of the factors taken separately.[4] One of the most significant conclusions emerging

from this analysis is that in many cases it is possible to improve operations significantly with little or no increase in investment. In Korea, for instance, it appeared that increases in productivity of around 10 to 20 percent were readily attainable through the relocation of machinery to improve the flow of work and through improvements in operating practices. In a standard gear-cutting operation, the idle time on the machine could have been decreased by over 50 percent by the use of a simple jig. In both countries, the production practices in removal of metal were judged seriously deficient, with adverse effects on costs and product quality.

The examples drawn from the individual plant evaluations can be used to show the extent and characteristics of the inefficiencies in present operations. Each instance of a technical inefficiency can be translated into an effect on costs of production and an impairment in competitiveness, but it is not easy to make this kind of calculation with any precision when there are numerous technical inefficiencies. Accurate cost records are jealously guarded by management, and in many cases such records do not even exist for many of the plants visited. It was, however, feasible to form an opinion as to the kind of technical assistance required to correct the major deficiencies, and that type of calculation has provided the first element of a development program for the industry in both Korea and Thailand.

Local Technological Capabilities and Their Linkage with National Policies

Plans for expanding output of engineering goods and increasing the variety of products must take into account the ability of domestic firms to produce at costs and qualities competitive with imports. An analysis of existing or potential comparative advantage is, however, difficult in situations where the market conditions are changing, the available information is unreliable, and the policy environment has already created differences in treatment among firms.

A number of criteria were taken into account to help determine whether, in a dynamic growth situation, a comparative advantage was likely to exist or could readily be achieved. These criteria included the conditions of the domestic and export markets, the relative composition of material inputs and labor costs, and the existence of strong linkages within a group of product lines, which may make it possible to take advantage of external economies through joint development of the group. In some cases, there are possibilities of economies in small-scale operations or batch production, and in other cases certain product lines may be uniquely suited to a specific regional location.

In Korea the development of the engineering industries is being undertaken under the pressure to expand exports. Between 1976 and 1991, the output of the most important machinery products is expected to grow at a rate about 50 percent higher than manufacturing output as a whole, and over half of all exports are expected to originate in these industries. In these circumstances, it was necessary to try to identify some specific items where there is likely to be a window in the international market and to identify other less specific product groupings where the general conditions for development appeared favorable.

In Thailand some general principles for choosing priorities for development were derived from the plant visits and a survey of local financial and economic conditions. These principles included an emphasis on labor-intensive products (but with a need to raise efficiency wages through labor training), an initial priority on domestic market needs, the avoidance of highly complex items or those requiring a high level of precision in machining, an emphasis on products involving sheet and plate work in fabrication and simple standardized machinery and assembly, and the avoidance of products that require high volumes of output in order to achieve low production costs. These principles are very pragmatic and have been made deliberately so since we do not think that at this point in the elaboration of a development plan for the engineering industries it would be prudent to try to derive fine specifications on product possibilities. Some basis for an initial rough cut is required, however, and at a later point specific investment projects will be evaluated in terms of their economic, financial, and technical feasibility. As a beginning point, these general principles nevertheless are adequate.

Based on a listing of factors reflecting demand, cost, and existing market structure, the analytic team of economists and engineers then pooled their information and in lengthy sessions talked through a long list of products, evaluating each element in turn, using the available qualitative and quantitative information. This resulted in a fairly extensive list of products for which the various factors in Thailand seemed favorable. This list included hand tools and cutlery, selected small agricultural equipment, small industrial engines, certain types of pumps and valves, architectural and construction hardware, shipbuilding and repair (coastal and fishing boats), certain standard machine tools (center lathes, hacksaw machines, bench drills), small transformers and switchgear, and some automotive parts. Other products were recommended for deferral until later.

At this point, an economist might point to the fact that a better way to derive a priority list would be simply to compute the effective rate of protection of the products or the domestic resource costs and use this as a basis for determining policy choices. A special study of effective rates of protection for the engineering industries was in fact carried out in Thailand, but

such data, while extremely useful, do not use all the information available and have the drawback of being rather static. Furthermore, they are subject to substantial variations when there are slight changes in basic conditions and do not incorporate such factors as the potential for price decreases brought about by technical assistance, the extent of differentiation in international markets, or the knowledge that a change in product mix can make the difference between profit and loss.

A comparison between the conclusions derived from the study of effective rates of protection and those achieved on the basis of the judgment of the team of experts showed that the structure of protection (tariffs and taxes) discriminated against the production of many engineering goods, which, on technical and other grounds (such as the degree of labor productivity), probably should be favored, and gave high protection to products such as motor vehicles that were likely to be produced inefficiently and at high cost. The study of effective rates of protection led, in fact, to recommendations for a revision of the tariff structure of protection and served as a check on the list of promising product lines established by the team of experts.

This selection of product lines was meant to be the starting point for a development program, and individual investment projects will have to be subjected to careful analysis. The designation of products to be given preference is primarily a way of signaling to the private sector those areas that are likely to be attractive and to receive incentives in a government program. The analyses derived from the plant visits and the preliminary list of product groups can serve as a basis for the design of a program to assist enterprises in improving their technological capabilities.

Development Projects for the Engineering Industries

The projects being developed on the basis of these surveys of the engineering industries in Korea and Thailand will have four major components: technical assistance, funds to support new investment, training of the labor force and management, and reform of the government incentive system. At this point it may be useful to focus on each of these project components so as to show the ways in which they can contribute, directly or indirectly, to the development of local technological capabilities in the borrowing countries. At a more general level, this description of project components shows some of the ways in which the World Bank is acting as a technological institution in the projects it finances.

The first of these project components is technical assistance, channeled through experienced production engineers and management personnel who are to work with the owners and managers of the local enterprises and help

them raise the level of efficiency of current operations. This may result in changes in the layout of machinery in the plant, the number and output levels of products, operating and maintenance practices, the use of labor, and management practices. Through this effort, a diagnosis of the problems will be made, and prescriptions for correction will be agreed on and carried out. In many cases, such changes can be accomplished in a relatively short period, and experts should be able to demonstrate to the owners' satisfaction that the changes will improve their capabilities.

Experience tends to indicate that the expectations about the effectiveness of technical assistance can be realized. In one country, following a World Bank industrial mission, the government contracted with a private group of consulting engineers and about fifteen specialists who spent one month working with a selected group of some thirty enterprises. They brought with them a variety of scientific equipment and key production items. They were able to make some changes on the spot, gave demonstrations of how to use equipment more efficiently, left sketches of how to make other changes, and provided information on tooling and equipment that was not known to the local firms. Other information was sent after the visit. This technical assistance operation uncovered problems that will take time to iron out and some difficulties were encountered (for example, frustrations over the inability to supply instant solutions), but the overall assessment is that this type of arrangement can be effective.

The technical assistance component of these projects in Thailand and Korea will also produce plans for future investment in facilities and equipment. These plans should emerge directly from the diagnosis of current operations and will include the replacement of obsolete equipment, the purchase of new machines to break bottlenecks in processing, as well as more extensive plans for expansion of capacity that are justified by market and technical conditions. The plans are expected to be of a sufficient quality and thoroughness to justify the approval and support of new investments.

The second project component is the provision of funds for new investment. It is anticipated that technical assistance efforts probably will identify opportunities for a larger volume of investment than can be supported with the available funds and that these engineering industry projects will attract funds from sources other than those provided in the projects themselves, notably from commercial banks and other financial intermediaries. One of the side effects of the projects will thus be to broaden both the financial system and the source of support to the engineering industries.

Project funds will be committed only on the basis of detailed investment plans prepared during the technical assistance phase. It will not be possible for an enterprise simply to apply for financial support without vetting of its plans prior to application. For a financial institution, this is a way of reducing risk, and it is also a means of helping to channel investment into areas

that are critically important to the industrial development of the country. This procedure may not, at first sight, seem very different from normal lending operations, but it shifts the emphasis of project preparation to the technical assistance stage. This may help overcome one frequent problem: the fact that it is not a shortage of funds that limits industrial development, though that may be a contributing factor, but rather a shortage of viable high-priority projects.

The third project component is the support for the training of the labor force and management. As the plant surveys clearly showed, the lack of skill and knowledge in the operation of the machinery often resulted in low levels of performance. Management systems, which include such items as production scheduling, inventory management, and cost control, received about the lowest scores, and most of the plants visited considered the shortage of skilled personnel and technical manpower one of the major obstacles to their operations. These industries are labor intensive, but they are also skill intensive. Yet the statistics on the composition of the typical labor force in the enterprises show a preponderance of unskilled labor and a shortage of managerial and technical personnel. In Thailand, the share of unskilled workers in the labor force exceeded 50 percent in twenty-five firms out of thirty-eight, and only five had less than 20 percent of unskilled workers. Similarly, only two firms out of forty-one had more than 20 percent of their labor force composed of managerial and technical personnel, while twenty-nine had less than 10 percent.

Although wages are low, this advantage is offset by the fact that physical productivity is also low, so that in many product lines efficiency wages are low, and there are no cost advantages compared to countries where wages are high but productivity is proportionately higher.

Training will raise both productivity and wages, although in some cases the owners or managers may be in a position to appropriate for themselves the productivity gains because of the poor bargaining position of labor. Much depends on whether the wage is based on a daily rate or a piecework rate. Because of the shortage of skilled labor, the labor force in these industries also tends to be rather mobile and does not seem to have too much trouble moving where opportunities are better.

In the projects, it is proposed to include a program and funds for training of labor in those firms that are receiving technical assistance and investment funds. This is envisaged as a package program since success can be reasonably assured only through a multiple attack on all of the main problems.

It is also planned that most of the training will be on the job within the plants. Entrepreneurs do not like to release labor for outside training because it reduces the available labor, and in some sense it appears lost to the enterprise. They are much more willing to have training in the plant, even though it may disrupt operations temporarily. It also has the advantage

that the training is directly related to the job that the worker is doing, and the payoff is more immediate and more visible. In this type of training, the operator does not become a craftsman capable of performing on a wide variety of machines—he or she learns how to operate a specific machine to do well-defined jobs—but the benefits can still be substantial, and it is a great deal easier to sell such a program to the managers. For both labor and management, the training is learning by doing in the best sense, and this can help each of them to view labor training as a normal part of plant operations.

The fourth and final component of these engineering industry projects involves a reform of the incentive system (such as tariffs, taxes, subsidies, and licensing practices and other arrangements). In most developing countries, the incentive system has been built up piece by piece, with little systematic reflection on overall development objectives. Since governments typically derive much of their income from customs duties, tariffs are often set in a way to increase revenues rather than to serve development purposes, and policy instruments could more readily be replaced by more effective tools that have fewer unintended side effects.

The infant industry argument to provide some extra incentives or protection to selected product groups can be applied, though this should normally be done on a limited basis and should gradually decline. Encouraging the growth of industries that can survive only in the long run behind a high wall of protection is not in a country's interests.

It is also better to undertake a reform of the incentive system across the board rather than to do it separately for the engineering industries since this may create other types of inefficiencies. In cases of gross discrimination, some temporary relief may be warranted. For present project plans, a reform of incentives is highly desirable but not essential prior to the projects.

Importance of the Institutional Framework

One of the keys to success or failure of a program to increase technological capabilities lies in the institutional arrangements for direction and control, including the recruitment and scheduling of technical assistance, the negotiation of arrangements with participating enterprises, the preparation and review of proposals for new investment, and the monitoring of training and coordination.

These functions cannot readily be assumed by a group of foreign experts, though their assistance will almost certainly be required. The management functions must be exercised by an institutional group in the country if the program is to become an integral part of the development effort. Therefore it is necessary to find, modify, or create an institution that will have the vision, the competence, and the authority to direct the activities. This is the most difficult part of the program.

In our limited experience, my colleagues and I have not found a single case of an existing institution that had the mandate, the personnel, and the philosophy to assume immediately such a management role. Perhaps surprisingly, it is just as rare to find existing institutions that can be strengthened and redirected; they are usually too involved in other tasks that require different skills and are aimed at different objectives. To change them to focus on technological development is extremely difficult. The alternative is to create a new institution with the proper focus and responsibility, but the planning horizon for achieving significant progress in the program is at least five years.

The organization of such a new institution poses a number of problems. The government must supply some leadership and have some management responsibilities. But if the program is regarded as a purely governmental undertaking, it is unlikely to evoke complete enthusiasm among private enterprises. It should ideally be perceived as a joint affair between government and industry. This may be achieved by ensuring that both private industry and the government are represented on the board of directors and within the managerial structure.

Another problem is the selection of participating firms. It is impossible to include, in an initial effort, all the firms in the engineering industries. In any country, they are counted in the hundreds or even thousands. The greatest need for support is among the medium- and smaller-scale firms that produce parts, components, and the simpler end items of products. The large firms usually can obtain technical assistance or investment funds on their own.

It is estimated that in a typical project, around 100 firms can be accommodated in an initial program. How are they to be selected? The list of product lines to be given priority treatment helps to narrow the range, but it can be expected that the participating firms will, to a large extent, be self-selected. The brightest and the best of the entrepreneurs will most quickly perceive the potential advantages of the program; many others will reserve judgment and hold back.

Notes

1. Although *capital goods* is somewhat more inclusive than *engineering industries,* the overlap is extensive. The engineering industries are technically classified in the International Standard Industrial Classification category 3800 and also include a few others, notably foundries and forging operations.

2. V. Prakash and S. Robinson, "A Cross-Country Analysis of Patterns of Industrial Growth," draft World Bank Staff Paper (Washington,

D.C.: World Bank, 1979); *Engineering Industry,* UNIDO Monographs on Industrial Development, no. 4 (Vienna: United Nations Industrial Development Organization, 1969).

3. This system of evaluation was first developed and used in a study of machinery industries in Korea. See *Korea: Development of the Machinery Industries—A Case Study in Strategy and Tactics,* World Bank Report 2130-KO (Washington, D.C.: World Bank, 1979). In the Korea study, only the first six factors were considered; the seventh was added to the study carried out in Thailand. See *Development of the Engineering Industries in Thailand,* World Bank Report 2647-TH (Washington, D.C.: World Bank, 1980).

4. The conclusions and recommendations emerging from these surveys have been presented in detailed World Bank reports.

Part IV
Global International Research Systems

An increasing number of scientific and technological problems confronting the developing world require research too large in scale and scope for any single country to fund or carry out and therefore demand some form of coordinated international action. Problem areas in this category include research on food crop production, human reproduction, tropical diseases, weather forecasting in tropical areas, and commodities such as cotton, wool, and rubber. These areas are natural subjects for the union of money and technological ideas.

The three chapters in this part describe a new institutional device, the global integrated research network, that has enabled several organizations of the UN system to respond to the needs for research in these areas. The World Bank has played a key role in several of these networks—in some cases as a financial contributor, in others as a coordinator, but most importantly as a mobilizer of funds from other sources, and notably from bilateral aid agencies.

The three international research networks examined are those in which the Bank has been most closely involved: the Consultative Group on International Agricultural Research (CGIAR), presented in chapter 16 by J. Coulter; the Special Program for Research and Training in Tropical Diseases, jointly sponsored by the UNDP, the World Bank, and the World Health Organization (WHO), which is described in chapter 17 by A. Lucas; and the Cotton Development International (CDI), a proposal that was jointly sponsored by UNDP, the Bank, and the Rockefeller Foundation, and whose history is presented in chapter 18 by W. Lepkowski and C. Weiss.

These three programs or networks share a number of common characteristics. The most conspicuous of these is the very wide scope of the problems each of them is attempting to handle. To give an idea of this, it may be worth noting here that the thirteen international agricultural research programs sponsored by the CGIAR are doing research on crops that represent some 75 percent of total agricultural production in the developing nations and provide a livelihood for more than 1.5 billion farmers. As for the six tropical diseases tackled by the Special Program, their victims number in the hundreds of millions. Compared to these figures, the number of people living off the cultivation of cotton is much smaller, around 125 million (to which should be added some 45 million in the cotton textile industries), but these are still very large figures.

Another common characteristic of these three networks is that they all involve effective and genuine cooperation among researchers, institutions,

policymakers, and funding agencies in both developing and industrialized countries. At a time when developing nations are seeking to promote technical cooperation with one another, these international programs are among the largest and possibly among the most successful examples of scientific and technological cooperation among developing nations.

The three networks also testify to an important, yet largely unnoticed, phenomenon: the emergence of what might be called an international or worldwide science and technology policy that is aimed at bringing the power of modern science and technology to bear on some of the developing world's major social and economic problems and in the formulation of which developing countries are fully represented. In a sense, these networks might be viewed as one of the building blocks of a new international technological order.

The development and day-to-day operations of these international research networks raise a number of important questions. How does one identify major fields for international cooperative research? How can such networks be most effectively financed? What is the role of institutional entrepreneurship in their development? How can the research results be most effectively disseminated to their users? What are the elements that make an international program a success or a failure?

In chapter 16, devoted to an analysis of the CGIAR, Coulter provides a number of answers to these important questions, and his presentation might be seen as a major lesson in the art of managing international research programs. While clearly pointing out that agricultural research is one of the most profitable investments that can be made from both a social and economic point of view and that it can make an important contribution to the building up of indigenous technological capabilities in the developing countries, he also raises a number of important strategic issues that remain to be solved. One is the tendency of the research system to focus on subject areas that are economically important, such as irrigated rice or wheat, rather than on those that might be viewed as socially more desirable, such as subsistence crops for poor farmers. Another issue is the difficulty and vital importance of linking research with the agricultural extension system and with credit mechanisms and price structure. A third is the difficulty of expanding research fast enough to meet growing needs. Much more research could be done, but to translate the possible into the workable is far from easy, even if, as Coulter clearly demonstrates, we already have the political and scientific skills to do so.

All of the agricultural research programs sponsored by the CGIAR are carried out in international research institutions. Some of these institutions—the International Rice Research Institute, for instance—are very large, and their origins antedate the creation of the CGIAR. Others are much smaller and younger and are, in effect, a creation of the CGIAR;

this is the case of the Nairobi-based International Laboratory for Research on Animal Diseases.

These examples, important as they are, should not lead readers to believe that international research institutions coordinating their activities in the framework of a consultative group such as the CGIAR constitute the only mechanism for carrying out research on problems of worldwide importance. The Special Program for Research and Training in Tropical Diseases (TDR), examined in chapter 17 by A.O. Lucas, shows that another approach, based on national rather than international research centers, can be equally effective. TDR is one of the most interesting illustrations of the ways in which existing knowledge available in the developing nations can be mobilized for the benefit of all.

This concerted attack on six major tropical diseases coordinated by the TDR suggests that research alone is not enough, even though it may be very important in certain specific cases (we do not yet have any operational vaccines against malaria or bilharzia, for instance). What is critical is the effective mobilization of existing knowledge and new knowledge. Lucas shows that the knowledge required is not only medical or scientific but organizational, social, and economic. He also shows the major importance of training and health planning, and he demonstrates that the success of an international network of this type lies more in the software than in the hardware.

Chapter 18 by W. Lepkowski and C. Weiss describes the conception and evolution of a proposed international research network, the CDI, that ultimately failed to win political approval. The CDI proposal addressed itself to a major problem of developing nations—the declining competitiveness of cotton relative to synthetic fibers—and rightly recognized that much more research is needed on all aspects of cotton, from the development of better plant varieties to the blending of cotton fibers with synthetics. The need for international action rested on the fact that most cotton-growing countries are too small or too poor to carry out the needed research, and all would stand to benefit from an internationally shared and funded research effort. In examining the rationale for the establishment and organization of CDI and the history of the now defunct proposal, the authors show some of the difficulties of institution building in an international environment.

16 The Consultative Group on International Agricultural Research

John K. Coulter

The developing countries and the agencies concerned with them are giving high priority to increasing food production as a means of improving the lot of the rural poor. The gains from increased food production accrue not only to those who produce food but also to those who consume it. Low-income consumers typically may spend more than 80 percent of their income on food, and any reduction in food cost benefits them directly.

Historically, increasing the cultivated areas has played the major role in raising food production. This has been done both through expansion into new lands and through intensifying production under shifting cultivation by shortening the fallow period (a short-term gain but probably a long-term loss). In the past couple of decades, growing pressure on land has meant that around two-thirds of the increased production in Asia, the Middle East, and North Africa has come from increases in output per unit area.

A recent World Bank report estimates that only about 57 percent of the world's potentially arable land is cultivated, but much of the better land is already in use. Many of the 1.4 billion hectares of unused arable land present serious biological and physical constraints to cultivation and are often inaccessible to both farmers and markets. Furthermore, there is very little unused land in regions where food needs are the greatest; in Asia, North Africa, and the Middle East, for instance, more than 80 percent of the potentially arable land is already under cultivation.

The additional food production capacity required in the developing countries to meet their growing needs has been calculated at 450 million tons of cereal equivalent per annum by the year 2000. To achieve this goal, production would have to increase by about 4 percent a year, compared with an actual average of around 2.7 percent between 1960 and 1975. A growth rate of 4 percent per annum has not been achieved anywhere on a sustained basis. If progress is to be made toward this goal, it will require not only the cultivation of more land but the provision of a much larger quantity of such inputs as labor, water, fertilizers, power, and improved seeds, as well as better infrastructure like roads and markets to supply these inputs. The unique role of agricultural research is to generate the new technologies that will make these inputs more efficient.

The development of improved agricultural technology in the tropical areas is not new. It has been underway for much of this century on such

crops as tea, sugar, rubber, and oil palm, and application of this technology has led to spectacular yield increases in the farmers' fields. The picture, however, is very different for most food crops, with the exception of rice and wheat, which have witnessed substantial yield increases, mainly in the more favorable areas where irrigation has been available.

The poor record of yield improvement in food crops in the tropics is often attributed to the lack of investment in agricultural research on these crops. This view is probably correct, although the quality of the research on cash crops has usually been better because of its more stable long-term funding and because the producers have often constituted a more articulate group, which has insisted that research funds be used effectively.

The poor record of yield improvement in food crops led to another deduction by those involved in agricultural development: that the primary need in food crop production was not so much one for agricultural research as it was one for adequate extension services to diffuse the technology already in existence to the farmers. Many recent experiences, however, have indicated that this view is not correct. Rather, the lack of impact of research on production is often due to its failure to provide the right kind of technology package.

The Emergence of an International Agricultural Research System

The disappointing record in yield improvement of food crops and the apparent ineffectiveness of much of the existing research led to the creation of the first international agricultural research center, the International Rice Research Institute (IRRI), set up in the Philippines in 1960 by the Ford and Rockefeller foundations. This was followed in 1966 by the creation, through the evolution of earlier Rockefeller programs, of the International Maize and Wheat Improvement Center (CIMMYT) in Mexico. These two centers had a narrow focus on specific crops of critical importance to world food supply, and this paid off handsomely. Within six years of its creation, IRRI had developed the first tropical ecotype of fertilizer-responsive dwarf variety of rice; the Rockefeller program, the predecessor of CIMMYT, had earlier developed similarly successful dwarf varieties of wheat.

The foundations then decided on the creation of two more institutes, the International Institute of Tropical Agriculture (IITA) in Nigeria and the International Center for Tropical Agriculture (CIAT) in Colombia. The decision to establish these two centers was taken in 1967, though construction was completed some time later.

These international institutes had several unique attributes. They recruited widely for their international staff, were devoted to the solution of

practical problems, established partnerships with their host countries, were governed by an independent board of trustees, were designed to encourage the work of first-class scientists, and were assured of long-term financial support.

As the cost of funding them increased, the two foundations sought other help, and individual national agencies came to their assistance. It was always understood, however, that one of the cornerstones of agricultural research was long-term funding, and the international community was therefore asked to devise a mechanism for this support. The result was an organization unique in the history of international cooperation: the Consultative Group on International Agricultural Research.

The Role of the CGIAR

The CGIAR was organized at the initiative of the World Bank in May 1971 to broaden the support for international programs of research and training aimed at increasing the quantity and improving the quality of food production in the developing countries. It was established as an association of international and regional organizations, national governments, public and private foundations, and representatives of developing countries. Currently the CGIAR is supporting programs of research and training that encompass crops and animals accounting for three-quarters of the food supply of the developing countries. Over 5,000 people, including 500 senior scientists, are working at the centers supported by the CGIAR. Virtually all of the support scientists come from the host countries of the centers, but the senior staff members, about a third of whom are from the developing countries, belong to more than forty different nationalities.

The CGIAR is jointly sponsored by the Food and Agriculture Organization of the United Nations (FAO), the UNDP, and the World Bank. The Bank provides the chairman and the executive secretariat. The CGIAR is advised by a panel of experts, the Technical Advisory Committee (TAC), whose secretariat is provided by FAO. The CGIAR has grown from twenty-three to thirty-seven members, the international centers and activities it supports from four to thirteen, and the contributions from $20 million in 1972 to approximately $145 million in 1982 (in current dollars).

Early in its existence, the TAC reviewed the needs for international agricultural research and training and identified the most serious gaps and shortcomings in terms of both food crops requiring attention and ecological zones in the developing world on which farming systems research was needed. As a result, the CGIAR sponsored the establishment of several new international centers and programs, and members are currently supporting thirteen international agricultural research centers, each governed by an international board and each with an international staff. These are:

1. International Center for Tropical Agriculture (CIAT), based in Colombia, which deals with cassava, field beans, maize, and rice, as well as production systems for cattle and swine.
2. International Maize and Wheat Improvement Center (CIMMYT), located in Mexico, which, in addition to its main research on breeding improved varieties of maize and wheat, conducts some research on barley, triticale (a cross between wheat and rye), and sorghum.
3. International Potato Center (CIP), based in Peru, which serves potato-growing regions throughout the developing world.
4. International Center for Agricultural Research in the Dry Areas (ICARDA), with a principal station in Syria, which deals with crop improvement (barley, broad beans, lentils and durum wheat), soil and water management, and farming systems (including sheep husbandry) for dry, winter-precipitation areas.
5. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), based in India, which deals with the development of farming systems in semiarid zones and with the development of improved varieties of groundnut, sorghum, millet, chick-pea, and pigeon pea.
6. International Institute of Tropical Agriculture (IITA), based in Nigeria, which is concerned with the development of farming systems for the humid tropics, as well as with cassava, cowpea, soybean, and local adaptations of internationally and nationally developed strains of maize and rice.
7. International Livestock Center for Africa (ILCA), located in Ethiopia, which deals with systems of livestock production, particularly cattle.
8. International Laboratory for Research on Animal Diseases (ILRAD), based in Kenya, which studies two major protozoan diseases of cattle in parts of Africa, trypanosomiasis and theileriasis (East Coast fever).
9. International Rice Research Institute (IRRI), based in the Philippines, which has worldwide responsibility for the development of improved varieties of rice and related farming systems.
10. West Africa Rice Development Association (WARDA), established in Liberia, which deals with rice research and development in fifteen west African countries.
11. International Board for Plant Genetic Resources (IBPGR), with headquarters in Rome, which seeks to stimulate and coordinate the collection, preservation, evaluation, and exchange of a wide range of genetic materials of many species of potential interest to plant breeders in the developing countries.
12. International Service for National Agricultural Research (ISNAR), with headquarters in the Netherlands, provides assistance to the developing countries to plan, organize, and manage research more effectively.

13. International Food Policy Research Institute (IFPRI), based in Washington, D.C., which works on analysis of world food problems to determine those actions and policies that could be adopted by governments and international agencies to increase the supply of food.

Financial Growth of the System

The rapid increase in the size and scope of this international system of agricultural research centers required equally substantial increases in human and financial resources. Between 1972 and 1983, total operating expenditures of the centers increased from $47.5 million to $164.7 million (measured in constant 1983 dollars). (For 1983 estimated amounts are included in the totals.) Over the period 1972 to 1983, real growth in total expenditures annually was at a compound rate of almost 12 percent, and growth in operations was over 5 percent annually. These figures fail to show a tapering in recent years, however. Between 1979 and 1980, growth in operations was about 10 percent. Between 1980 and 1981, it was only about 0.2 percent, between 1981 and 1982 it amounted to about 5 percent, and between 1982 and 1983 it looks as if growth in operations will be about 6 percent.

Between 1972 and 1983, total donors' contributions to the thirteen centers supported by the CGIAR amounted to $1.3 billion in constant U.S. dollars, resulting in a real rate of growth of over 15 percent for this period. The rate of growth in donors' contributions has diminished over the years as old donors, because of various budgetary constraints, have increased their contribution in real terms more slowly, if at all, and fewer new donors have joined each year.

The work of the centers is generating multiple benefits for millions of people in the major ecological zones of the developing world. New rice varieties developed by IRRI have the potential to double and triple yields in comparison with yields of the varieties previously available to many rice farmers in developing countries. For such work IRRI has recently been awarded the Third World Prize. The new varieties are now grown on 40 percent of the total rice areas of those countries, generating about $1.5 billion a year in increased rice production. Other centers, through their research and training activities, have also made significant contributions toward increasing food production in developing countries. Besides more food, the adoption of new crop varieties of rice, wheat, sorghum, millet, barley, cassava, and other root crops and of new farming systems has meant increased job opportunities, less drudgery, and a higher standard of living for millions of people in the developing countries.

The Mandates of the Centers

Each center or program is an independent organization governed by an independent board. The members of the CGIAR contribute to one or several centers of their choice and not to the group itself. The World Bank, as the residual donor, tries to fill any remaining gaps in funding to ensure that the needs for the centers are met. The research programs of the centers are governed by their mandate. Some centers have a commodity mandate (they work on one or several crops or livestock), and others have both a commodity mandate and an ecological area mandate (for example, humid tropics, semiarid tropics).

Although the mandates differ from center to center, the crop-based institutes have the following in common:

1. Collection, evaluation, maintenance, manipulation, and distribution of germ plasm and of improved plant materials for use in breeding, improvement, and production program at the regional and national level.
2. Publication and dissemination of research results.
3. Organization of periodic conferences and seminars.
4. Training of scientists for research and production programs.
5. Establishment and operation of an information center.
6. Assisting national and regional research programs through cooperation and support.

Several centers also have the mandate to develop farming systems that will help to increase and stabilize agricultural production and improve the use of natural and human resources and to identify socioeconomic and other constraints to agricultural development and evaluate ways to alleviate them.

In summary, the objective of the system is to develop technologies that will improve production, especially by small, resource-poor farmers in the less developed countries. The system is concentrating on food supply since an improvement in quantity and quality will improve human welfare in both rural and urban communities and raise their living standards.

The Research Programs of the Centers

The general mandate of the system broadly defines the goals of these international agricultural research centers, but the strategy for reaching these goals has changed over time in each institution and is different from one center to the other. The original mandate of IRRI, for instance, was to carry out basic and applied research on the rice plant to develop high-yielding, nonlodging varieties that respond to high rates of fertilizer application.

CIMMYT had commodity mandates for wheat, maize, triticale, and later barley. Although it is located outside the major wheat-growing areas of the developing world, it had a very well-established research foundation on which to build and an ecological environment in northern Mexico similar to that of the major irrigated wheat-growing regions of Asia. Mexico is also a region where maize is a major food crop. Wheat, maize, and rice had already been the object of a large amount of research in the developed countries.

The mandates of the more recently established centers include both ecological regions and commodities. CIAT works on livestock forage, as well as on several different food crops, and IITA works both on crops and farming systems. The crops for which these centers have worldwide mandates—tropical root crops and grain legumes—are usually those grown by poor subsistence farmers, who often cultivate the poorest soils. Because they are vegetatively propagated, root crops present additional hazards of disease spread. They also suffer from other handicaps. Since they are the dominant crops in only very few of the developing countries, national governments have given them low priority in their research programs. And unlike rice and wheat, they are seldom grown as sole crops and are usually part of a complicated mixed cropping system. In its work on the potato, CIP is concerned with a crop that has an excellent potential but is highly susceptible to diseases and requires a well-organized seed production system to achieve this potential. Increases in yields of grain legumes through plant breeding have proved more difficult than with cereals.

The mandate of ICRISAT is the improvement of agriculture and crops (such as sorghum and millet) in a harsh environment where rainfall fluctuations between and within seasons lead to major difficulties in stabilizing production. Such an environment will usually set a limit on the average rate of yield increase. ICARDA will also concentrate on the harsher environments, and its systems research component will include livestock, with the attendant sociological problems where livestock and land are controlled by different groups of people.

The two livestock centers have very different mandates. ILRAD has a difficult technical problem in its research on trypanosomiasis and theileriasis, and ILCA has to concern itself with socioeconomic as well as technical constraints. ILCA's research program is, in fact, centered on systems research.

Although the goals of the older international agricultural research centers are generally the same, some of those of the more recently established institutes may be more difficult to attain. Furthermore, reaching them will require a longer time span and may have less impact on total food production. On the other hand, reaching these goals will benefit the poorer farmers more directly.

Research strategies change over time. The early strategies of IRRI and CIMMYT were to produce new types of rice and wheat that would be very

responsive to improved fertility, insensitive to day length, and resistant to some of the most serious diseases. The scientists working on wheat and rice were highly successful in producing short-strawed, nitrogen-responsive, day-length neutral varieties that spread rapidly in certain parts of the world. Such varieties were, in fact, bred for relatively well-defined ecological zones (essentially the irrigated areas), though some of the modern wheat varieties have done well in rain-fed areas of the Middle East. The modern rice varieties have about the same yield levels as the traditional varieties under conditions of poor water supply so the farmer without access to this input has been unable to benefit.

This lack of impact has been increasingly recognized by the centers. IRRI has pointed out that less than 20 percent of the ricelands of the world are irrigated and has defined its major task in the future as that of developing varieties that will give better and more stable yields over the wide range of rain-fed conditions under which rice is grown. This is a task with a virtually unlimited time horizon. Irrigation undoubtedly will reach much additional land over the next few decades, but at the same time a number of countries (Indonesia is one) are expanding their areas of rain-fed rice. Breeding for pest and disease resistance is also a continuing battle to keep one step ahead of constantly changing strains of pests and diseases. The latest IRRI rice varieties are resistant to at least seven pests and diseases that are common in Asia, whereas the first IRRI varieties were resistant to only one or two. To achieve this, the center has progressively widened its germ plasm base. In fact, most centers have now established world germ plasm collections for their particular crops, and this program has given them some unique advantages.

In a national program, the emphasis is usually on breeding varieties for relatively well-defined ecological conditions, but an international center has to provide materials for a wide range of environmental, pest, and disease situations. Thus, the more recent approach of the centers is directed toward aggregating genes essential for widely varying adverse situations such as acidity, salinity, drought, low fertility, and a wide range of pests and diseases. It is also often directed at providing a plant type that is day-length neutral and with a favorable grain-to-straw ratio. This pyramiding of desirable genes is being done by testing large numbers of crosses in many locations, thus increasing the probability that some of the crosses, at some of the sites, will be subjected to intense disease, pest, or environmental pressures. This approach also exploits the unique advantages of the centers, their wide germ plasm base, the resources to make large numbers of crosses, and the opportunities to test segregating materials worldwide. Wide adaptability is a highly desirable characteristic since a genotype with a high degree of adaptability across locations will also have a high degree of stability over time at a given location.

Mechanization, Farming Systems, and Technology Transfer

Although the ultimate goal of agricultural research is the same in developed and developing countries (more efficient production in the farmers' fields), two somewhat different philosophies are being followed. In the developed countries, the approach has been to remove as many of the constraints as possible by other than biological means; for example, acidity is corrected by liming, low fertility by adding fertilizers, salinity by drainage, drought by irrigation, and pests by pesticides. A corollary has been the strong emphasis of research on methods of making these inputs more efficient. The international centers of the CGIAR, in their philosophy of developing a low-risk, inexpensive technology, now are attempting to circumvent these constraints by biological means.

Farmers, however, can achieve substantially better yields only by improving the overall level of their farming practices. Genetic improvements can help to stabilize yields at low input levels and can make the crop more adaptable to erratic rainfall and more resistant to pest and disease pressures, but the potential for increased yields can be realized only through farming systems that increase the availability of water and nutrients. Thus, the emphasis of the research programs is on maximizing the benefits of such inputs used as sparingly as possible.

Although the centers work mainly on producing better plant types, one factor-oriented program in which several of them are involved is the design of farm implements that can be constructed locally at the village level. Although many developing countries have surplus rural population, labor may be short at critical times of the year, and the adoption of new technology may require an additional energy input, either through mechanical or animal power. Some of the centers have thus become involved in mechanization programs using motorized power, the most advanced of which is that at IRRI. Other centers are developing animal-drawn equipment and better hand tools.

Commodity improvement is a common aim of both international and national agricultural research programs, but another area in which the international centers have developed a particularly strong program is that of farming systems research. Most national centers have some elements of this in their research programs, but very few of the national programs (mainly those in the largest countries) are giving a major emphasis to this type of research.

Farming systems research aims at understanding the physical and socioeconomic resources within which agricultural production takes place. It attempts to evaluate existing farming systems and to improve the research workers' understanding of why farmers behave as they do. It helps in

problem identification and assists research organizations in deciding on priority issues, thus leading to research on them. Finally, it can evaluate new or improved practices in major production areas and can assess the benefits and impacts of new technology.

Farming systems research is of a long-term nature and deals with a complex subject. Methodology has to be developed, and it is likely that the impact on production will be evolutionary. Nevertheless, the potential long-term impact of this research seems to warrant the continuation of support.

Within the farming systems research work, several centers have specific aims. IITA, for example, is developing techniques for eliminating the bush fallow resting period and for intensifying the use of the better watered valley bottom land. It has been calculated that between 1900 and 1965, about half the forest area in developing countries was cleared for agriculture and that if shifting cultivation expands at the present rate, most of the remaining forest may be destroyed in the next forty years.

ICRISAT's farming systems research is directed to the conservation and better use of water and that of IRRI to intensifying production on the ricelands where the new technologies, such as shorter-season varieties and direct seeding of the crop, would allow additional crops. CIMMYT's work has been directed to the more productive use of the fallows between the wheat crops and CIAT's to increasing the productivity on poor soil through production of a high-value cash output, beef.

The third area in which the centers are operating is the transfer of their technology to the farmers. The two aspects of this activity are the validation of their technology in the real world of the farmer and the improvement of the ability of national programs to convey their technology to the farmer, in either its present or a modified form. The latter aspect of the centers' work involves technical assistance in the form of training, short-term advisory visits to national programs, raising the awareness of national program decision makers, and the supply of long-term advisers.

CGIAR centers have thus followed many of the paths of traditional agricultural research but have also pioneered new approaches. No national programs have attempted to use such a wide germ plasm base or tested their materials over such wide ecological conditions. Nor have any national programs been so specific about working under and for low input conditions of the poorest farmers. The farming systems programs of the centers are more comprehensive than any of those at the national level, and their training programs seek to give the trainees a thorough understanding of every aspect of the commodity in which they are doing research.

The Outputs of the System

The output from a research system comprises information, intellectual capacity building, and influence. Information may be in the form of new

knowledge or new technology that can be embodied, for instance, in higher-yielding varieties. Although some of the centers suggest that their achievements be measured by the uptake of new technology by farmers and its value thus demonstrated by increased yields, most centers take the view that there are many steps in this process over which they have no control. They consider their function to be that of delivering a technology that is demonstrably better than that currently available to farmers, but they also consider that their direct clients are the national systems rather than the farmers.

Most research organizations devote some effort to building an institutional capacity—that is, the development of their intellectual resources. This means some diversion of resources from the production of information or materials for immediate use, but these centers have given high priority to the training programs for nationals of developing countries. No figures are available on the number of agricultural scientists the developing countries will need from now until the beginning of the next century; however, in view of the rapid growth of population and the need for research and for the education of farmers in the use of improved systems of agriculture, there will certainly be a requirement for tens if not hundreds of thousands of such scientists and technicians. The centers are training both production agronomists and research scientists, but the total is probably fewer than 500 per year so that their major impact is likely to be on the training of trainers.

The Impact of Research on Production

Since new technology is a major output of this research system, its uptake by farmers can be used as a measure of the quality of that technology and of the return on investment in research. So far, the uptake and impact on production can be assessed for two crops only, wheat and rice. Table 16-1 shows the uptake of the modern varieties of wheat and rice developed by the CGIAR centers in the four major developing regions of the world.

Table 16-1
Percentage of Total Area of Wheat and Rice Sown to Modern Varieties, 1976-1977

	Wheat	*Rice*
Asia	72	30
Near East	17	4
Africa	23	3
Latin America	41	13

Source: World Bank, 1980.

One of the salient features of the diffusion of modern varieties of wheat and rice is the rapidity of the innovation process. This comes out clearly from the figures in table 16-2, which show the share of the total wheat growing area devoted to new varieties of wheat in five typical countries.

The impact of these modern varieties must be measured not only in terms of increased areas planted to them but also in terms of increased yields per unit area. The magnitude of these increases varies greatly from country to country and from one area to another within a country. Table 16-3 shows the yield increases that have occurred in the Philippines, where the modern rice varieties have been most widely adopted.

Overall, the modern varieties averaged about 13 percent more output per hectare than the traditional varieties in the irrigated areas and 9 percent in the rain-fed areas. Even such modest increases have a major effect on total production, but the impact of modern varieties of wheat on yields has been more spectacular, as can be seen from the case of India summarized in table 16-4. Much of the wheat belt in India, however, has a large degree of agroclimatic uniformity and a better infrastructure, especially as far as irrigation is concerned, than wheat-growing areas in other countries.

These figures suggest that the return to investment on research on rice and wheat has been very high. It has been calculated that the increase in rice production due to investment in rice research has been 1.5 percent per annum between 1972 and 1975. Attributing one-third to IRRI would produce an annual benefit flow of approximately $280 million and an internal rate of return on investment on this research of about 80 percent.

The impact of new technology is not confined to improved crop yields. It has wide social and economic impacts in terms of employment, agricultural wages, income distribution, and other factors. Much has been written about the green revolution. The information available does not substantiate

Table 16-2
Rate of Adoption of New Varieties of Wheat
(percentage of total area under wheat)

Year	*Afghanistan*	*India*	*Nepal*	*Pakistan*	*Tunisia*
1966-1967		4	5	2	
1967-1968	1	20	13	16	
1968-1969	4	30	26	38	2
1969-1970	5	30	34	43	7
1970-1971	9	36	43	52	11
1971-1972	10	41	52	57	6
1972-1973	15	51	66	56	9
1973-1974	16	57	76	59	6
1974-1975	17	62	85	63	6

Source: World Bank, 1978.

Table 16-3
Paddy Yields in the Philippines
(kilos per hectare)

	Irrigated Areas			*Rain-fed (Lowland) Areas*		
	Modern Varieties	*Other Varieties*	*Area Sown to Modern Varieties (%)*	*Modern Varieties*	*Other Varieties*	*Area Sown to Modern Varieties (%)*
1967-1968	1,967	1,613	34	1,307	1,239	17
1968-1969	1,778	1,617	62	1,125	1,089	31
1969-1970	2,155	1,886	61	1,487	1,527	39
1970-1971	2,023	1,930	67	1,614	1,580	45
1971-1972	2,053	1,723	73	1,443	1,350	55
1972-1973	1,950	1,741	70	1,276	1,110	60
1973-1974	2,051	1,887	80	1,531	1,525	64
1974-1975	2,222	1,879	79	1,430	1,179	64

Source: Bureau of Agricultural Economics, Department of Agriculture of the Philippines.

the view that the modern varieties are inherently suitable only for larger farmers. Where varieties have fitted the ecological conditions, large and small farmers, whether landowners or tenants, have had about the same rate of adoption.

While the size of the farm has apparently made little difference in percentage terms, it has obviously enlarged the difference in gross income. The new varieties have resulted in some additional use per hectare. This increased demand seems to have had little effect on wages, but real values of land have tended to rise; however, the extra income generated by the new production has had an important secondary impact on employment. Another positive factor has been the benefit to consumers. In Colombia, it has been calculated that the lowest income quartile of the population captured 28 percent of the benefits of increased rice production.

Table 16-4
Wheat Yields in India, (1964-1965 to 1971-1972)

	Area (thousands of hectares)		*Yield (kilograms per hectare)*		*Annual Compound Growth Rate in Yield (%)*
	1964-1965	*1971-1972*	*1964-1965*	*1971-1975*	
Bihar	636.3	1,397.4	636	1,785	14.45%
Gujarat	444.1	574.5	937	1,562	8.13
Haryana	722.4	1,172.0	1,274	2,043	8.29
Madhya Pradesh	3,157.9	3,509.0	627	868	6.80
Punjab	1,563.0	2,320.0	1,510	2,413	9.32
Rajasthan	1,183.4	1,524.4	932	1,249	5.14
Uttar Pradesh	3,965.4	6,045.8	1,058	1,249	4.45
All India	13,422.1	19,162.5	913	1,382	7.63

Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

On the negative side, the modern varieties of rice and wheat have increased regional disparities because these varieties were adapted only to certain ecological regions. This negative effect is particularly obvious in those regions where the larger farmers tend to own the better land and the smaller farmers tend to live on the poorer soils and/or in more extreme climatic zones.

This survey of the impact of research conducted by the international centers demonstrates the positive benefits of this research and the large payoff that has been obtained. Although this research has been directed primarily toward improving agriculture in the developing countries, there have been and will continue to be benefits to agriculture throughout the world. The germ plasm collections of such crops as potatoes, rice, maize, and sorghum are of value to rich as well as poor countries, and the increases in production have helped alleviate the burden on developed-country producers and lowered food prices for consumers in these countries.

The Potential Long-Term Impact of Research

Maize is the only other crop on which research at an international center has been in progress for a substantial period. CIMMYT is working on both quality and yield improvement, and notably on providing better-quality protein by improving the amino acid balance in the grain. The value of this work has already been demonstrated in both human and animal nutrition, and the high-quality protein will be particularly important for those people living primarily on a diet of maize. The work on high-lysine maize promises to have a major impact on maize production throughout the developing nations during the next decade. Maize varieties from IITA with tolerance to maize streak virus, a serious disease in Africa, are now being distributed through the government of Nigeria's accelerated food production program.

Sorghum and millet are the two other cereals with major research programs. ICRISAT is working not only on producing varieties that will have high yields in favorable conditions but also in breeding varieties that will give stable yields in hostile environments. The semiarid tropics, with which ICRISAT is concerned, are characterized by irregular rainfall within and between seasons. In such areas, farmers try to spread their risks by planting a relatively large area of the crop, but as population pressures mount, this becomes more difficult. Varieties that will guarantee the farmer some yield even in bad seasons are thus a major goal—hence the emphasis in ICRISAT's program on varieties with drought-tolerance or drought-escape mechanisms.

Progress in this area is likely to be quite slow, but the breeding programs for resistance to important diseases and pests, such as downy mildew, shoot

fly and the parasitic weed *Striga* on sorghum, and downy mildew and ergot in millets, are making good progress. Resistant varieties from these programs should be available in the not-too-distant future.

Work on tropical root crops, particularly cassava, is designed to improve these crops in two major areas, Africa and South America. Work at CIAT has shown that yields can be doubled when simple and cheap improved cultural practices are used to grow the best local lines. Selections from superior germ plasm increased these yields substantially. IITA has produced cassava material with resistance to cassava blight and cassava mosaic, both serious diseases in Africa that can cause yield losses as high as 80 percent. Some of these resistant materials are being distributed to national programs, and a technique for rapid multiplication of this vegetatively reproduced plant has been developed. These improved varieties will, however, require a much longer time to reach large numbers of farmers than the high-yielding rice and wheat varieties.

Several of the centers have programs on grain legume improvement. CIAT, working on field beans, a staple in the diet in Latin America, has been testing varieties through the International Bean Yield and Adaption Nursery; the best of these have shown yield increases on the order of 30 percent over the best local varieties. These trials and the work on improving yields of nonblack beans indicate that some improved materials should be available fairly soon for distribution by national programs.

Pests cause serious damage on cowpea, particularly in the humid tropics, and IITA has had a major program aimed at reducing these losses by breeding resistant varieties, combined with minimal insecticide treatment, techniques referred to as integrated pest management.

In several areas of noncommodity-oriented research, there has been sufficient progress to indicate that the technology can be moved into the farmers' fields in the fairly near future. The water management techniques developed at ICRISAT promise some early developments in the intensified use of the black soils in India, which at present are often fallowed during the rains. Work at CIAT has shown that the medium- and low-activity rock phosphates, common in South America, have considerable potential as a cheap source of phosphates for pasture on the highly phosphate-deficient soils of the llanos.

The work on nitrogen fixation in rice fields at IRRI, in the root system of sorghum and millets at ICRISAT, and on grain legumes at IITA and CIAT is a promising line of research, and some of the results should be applicable fairly soon. Multiple cropping at IRRI is another program where some elements are being taken up by farmers. Direct seeding of modern varieties of rice, for example, has enabled Philippine farmers to grow two crops of rain-fed rice where they grew only one crop previously.

Another aspect of factor-oriented research is the mechanization programs. The first IRRI power tiller designs were made available in 1972 and between then and 1976, about 10,000 units had been built. The IRRI portable thresher gained rapid acceptance, and over 800 units were made in the first year of production. The impacts of factor-oriented research cannot be measured in terms of area or yield of crops, but their contribution to increased production is considerable and likely to grow.

The Future Development of the CGIAR Research System

Analyses of some successful research projects show the very high rate of return to investment and imply that more investment in research would be generally profitable. Indeed, some calculations have shown that the CGIAR system might invest two or three times the present amount and still obtain a very good return. But even these amounts would not cover all of the research gaps that exist in the agriculture of the developing world. Several important food and cash crops, such as cotton, coconuts, and bananas receive no research support from CGIAR. There are areas like Southeast Asia where the main attention is given to rice yet where several other crops are also very important; livestock in Latin America is a major component of farming systems but receives only scant attention. Finally, there are the input factors like fertilizer use, water, and soil management on which only a limited amount of CGIAR-sponsored research is carried out.

The problem thus facing the CGIAR is to decide on priorities, notably those concerning its future range of activities. It can invest additional resources in ongoing activities, take up new activities, or direct research to the least favored areas and to the poorest people whose needs are greatest, but the payoff of this research in terms of increased production is likely to be smaller. These areas constitute some of the major research gaps because national programs, often very short of staff and funds, have tended to concentrate on the more favored areas or on cash crops where the potential payoff is greater.

Managing ongoing research programs is also difficult; it is easy to start new projects if funds are available but extremely difficult to run down ongoing programs. Their momentum ensures that some interesting information is always forthcoming, thus supporting the belief that just a few more years of work may produce a breakthrough.

Until now the CGIAR's centers and programs have grown in a somewhat uncoordinated manner because their individual budgets have been funded by the group without reference to any priorities among the ongoing activities of the different centers. This can result in distortions over time,

and there is a responsibility on the system to ensure that its resources are not too widely dispersed and that opportunities for effective use of international agricultural research funding are not being missed. Clearly managing the growth of the system over the next decade will provide many challenges.

One measure of the success of this unique system are the attempts to emulate it by setting up other consultative groups. Its achievements in mobilizing international funding, in bringing together a very informal but highly flexible group of donors, and the promotion of a group of highly competent research institutes have demonstrated the will and the mechanism for international collaboration in this important activity. It faces many challenges in the future, not least of which is the danger of growing into a bureaucracy that could stifle the creativeness of those on whom its success depends—the research scientists. Thus, it must be ready to drop some activities and take up some new ones, to be bold in exploring new opportunities but not to lose sight of its major objective: providing a series of alternative technologies that would benefit the poorer countries' least-endowed citizens.

In concluding this discussion, it is appropriate to emphasize the role of national agricultural research systems. The first international centers were started when much of the national agricultural research was weak, but it was never intended that the centers would substitute for weak national research. At best, they could help them speed up the development of technology while building up their institutional capacity. To do so inevitably is a long-term undertaking, and the international center-national program interaction brought about production results that the latter could not have accomplished alone. The investment in the international centers was well justified, but there has also been a growing realization that investment in national research systems is also essential. This is demonstrated by the developing countries themselves, which now invest about $1.4 billion (in 1977 dollars) in agriculture research, by the investments of the World Bank and bilateral donors, and by the creation of the International Service for National Agricultural Research. As the national research systems become stronger, the role of the centers will change, but the synergistic effect of the one on the other will become even more important.

The Tropical Diseases Research Program

Adetokunbo O. Lucas

The general poor state of health of the people in many developing countries is a matter of continuing concern, not only because of the humanitarian desire to relieve pain and suffering but also because the widespread occurrence of disease can be a significant barrier to development. It is widely recognized that poverty is one of the important determinants of some of these diseases, and yet disease may constitute a constraint to development, thereby creating a mutually reinforcing vicious cycle.

Such situations are often complicated by the ecological effects of major development projects. Some of the large-scale projects for crop irrigation or the production of hydroelectric power, for instance, have intensified the transmission of disease by expanding the breeding sites of the vectors of malaria, schistosomiasis, and other parasitic infections. Other major problems encountered in the field of public health are the emergence of strains of anopheline vectors of malaria, which are resistant to commonly used insecticides, and the occurrence and spread of drug-resistant parasites. Although technical problems do not entirely account for the failure of some of the antimalaria programs, they have contributed significantly to the difficulties.

There have been some outstanding successes in the control of specific diseases: the reduction in the incidence of yaws and other treponematoses and the dramatic eradication of smallpox. Apart from reduction in the incidence and prevalence of certain endemic diseases, a steep decline has occurred in the mortality rate in many developing countries, an indication of improvement in the general health of the population. The decline in mortality has not occurred in all developing countries, however, and within each country, the changes have not occurred uniformly in all population groups. Furthermore, although a steady decline occurred initially, in some countries the mortality rate is no longer falling appreciably.

One of the major characteristics of the situations where the health of the population has improved significantly has been the broad application of existing knowledge about disease prevention and the promotion of better health in the context of total community development. It has included not only specific health interventions like immunizations against prevalent communicable diseases but also broad noncategorical inputs such as education, better nutrition, and improvements in environmental sanitation.

In spite of the advances, certain specific health problems of the developing countries continue to prove difficult to solve, particularly the major par-

asitic infections such as malaria, schistosomiasis, and onchocerciasis. For some tropical parasitic and infectious diseases, relatively simple control measures are available. For others the available tools for control are crude, cumbersome, and costly, and it is clear that in many endemic areas, these diseases cannot be brought under control with the available technology. Therefore a two-pronged approach is necessary: there must be vigorous applications on existing knowledge, including field research to determine the optimal methods for applying such tools, and it is necessary to undertake research designed to discover new and improved tools for the control of these diseases. The general specifications of these tools are effectiveness, safety, simplicity of application, and relatively low cost.

Tropical Diseases Research in Historical Perspective

The history of research in tropical diseases shows many interesting features. At the turn of the century, there were the exploits of the great entrepreneurs such as Patrick Manson, Ronald Ross, and Aldo Castellani. Much of this early research, sponsored through public funds, was related to the colonial medical services of the imperial powers, and the activities of field teams were carried out in the colonial territories and backed up by basic research in the great European schools of tropical medicine.

This research was motivated by both humanitarian concerns and the need to solve the health problems that threatened the thriving commercial enterprises in colonial territories. In the extreme situation of West Africa, the occurrence of malaria, yellow fever, and other tropical infections constituted an insuperable barrier to European settlement, and in the early colonial days it was a major constraint to commerce. Another feature was the intensification of tropical diseases research in relation to military efforts. In both world wars, malaria and other tropical infections assumed strategic importance in some theaters of military action. This increased wartime effort resulted in the significant clustering in time of the discovery of new antimalarial drugs in the 1920s and later in the 1940s and 1950s.

Although research continued in both universities and pharmaceutical firms, the overall effort has been relatively small compared with that devoted to other medical problems, such as cardiovascular diseases and cancer. Although data are difficult to obtain on a global scale, it was reckoned a few years ago that no more than $30 million was being spent each year throughout the world on tropical diseases research, whereas in one country alone, thirty times that amount was allocated to cancer research. Following independence, many of the former colonial territories did not have the capability to undertake medical research on a significant level, and for most of the research and development aimed at control of

parasitic diseases, they remained dependent on the activities carried out in the nonendemic areas. Although the pharmaceutical industry has contributed to the development of new technology for controlling tropical diseases, there was some indication of declining interest on its part in this field of activity.

The Objectives of the Program and the Role of the World Bank

In response to these challenges, WHO initiated in 1977 the Special Program for Research and Training in Tropical Diseases, following a 1974 resolution in its governing body, the World Health Assembly, which called for the intensification of research on malaria and other tropical diseases. The Special Program, which is cosponsored by the UNDP and the World Bank, has two interrelated objectives. The first is the development of improved tools needed to control tropical diseases. This includes new preventive, diagnostic, therapeutic, and vector control methods specifically suited to prevent, treat, and control selected tropical diseases in the countries most affected by them. The second is the strengthening of biomedical research capabilities in tropical countries, specifically in the countries most affected by tropical diseases, through training in biomedical sciences and various forms of institutional support. This capability must be strengthened because major activities in the specification, development, and testing of new tools must take place in the countries where the diseases are endemic so as to ensure that these tools are effective in controlling the target diseases.

These two objectives are closely interdependent. It is important to secure and expand the involvement of scientists and institutions in the developing countries so that they may participate in the identification of the local problems and the definition of their determinants, both behavioral and environmental, in the specifications of the new technology to be developed, in the testing of the new products, and in their adaptation to local conditions in order to facilitate adoption. The long-term goal is to promote self-reliance in medical research so that these countries can identify and define their problems, initiate the research for solutions, and collaborate meaningfully with others in developing new technology.

The World Bank is beginning a major lending effort in the field of public health. It is also sponsoring a number of global multilateral research and development programs, focused on the production of technologies for the health care systems of the developing countries. The Bank contributes to these programs through its expertise in project management and in the application of research results through its lending activities. In addition, the Bank acts as the financial manager for a number of programs. Through its

own activities, it is also able to influence a wide spectrum of national ministries dealing with planning, finance, health, and development.

It is in this context that the Bank acts in its capacity of cosponsor of the Special Program for Research and Training in Tropical Diseases, of which WHO is the executing agency. As a cosponsor and member of the Standing Committee of the Special Program, the Bank provides a bridge between international health organizations and development agencies, a link now recognized as a prerequisite to the success of health programs.

After extensive consultations among the cosponsors, various governments and agencies that were interested in promoting the program, and representatives of the developing countries concerned, agreement was reached about the content and the mechanisms of the program. Initially a package of six diseases was included in the program: malaria, schistosomiasis, filariasis, the trypanosomiases (both African sleeping sickness and the American form called Chagas disease), leprosy, and leishmaniasis. Each disease was selected on the basis of three criteria: that it constitutes a major public health problem, that existing tools for control are inadequate, and that there is some indication that basic research could contribute to the solution of the problem. The criteria for the control methods are that they be susceptible to implementation at a cost that can be borne by developing countries, that they require minimal skills or specialized supervision, and that they can be easily integrated into the health services, and in particular into the primary health care services, of developing countries.

The Role of Research and Development

The activities of the program are directed toward the development of practical tools to solve the problems of the six selected diseases. They focus on the development of new drugs, the modification of existing drugs, the search for vaccines, new methods of vector control, and improved diagnostic tests.

In the search for new tools, four approaches have been considered for each disease: drugs, vaccines, methods for the biological control of vectors, and simple-to-perform diagnostic tests. The research therefore concentrates on chemotherapy and chemoprophylaxis, immunotherapy and immunoprophylaxis, biological control of vectors, and diagnostic aspects, especially immunodiagnosis.

The research activities are carried out by multidisciplinary groups of scientists formed on a worldwide basis. These so-called scientific working groups (SWGs) focus on both the specific diseases and on transdisease research areas. In addition to SWGs for each of the six diseases with which the program is concerned, SWGs have also been formed in four transdisease

areas: epidemiology, the control of vectors, basic biological sciences, and social and economic aspects.

An SWG comprises all the scientists who plan and/or carry out research on a specific aspect of the program. Members of the group define the research objectives, devise a strategic plan to achieve them, carry out the research according to the plan, and review the plan and the research as the work progresses.

To develop such a plan and operate an SWG, the scientists must describe or formulate the detailed objectives of the SWG (for example, the specifications for a malaria vaccine applicable and effective in rural India), the current state of the art in relation to the objectives, the problems that remain to be solved, the possible research approaches and disciplines, and the feasibility, sequence, and cost of the activities, or projects, in each line of research. They must also formulate a clear strategic plan, including each research approach and its line(s) of research, leading toward the final objectives.

One or more SWGs are now operating for each of the diseases selected by the program. In general, three areas are covered for each disease, either by separate SWGs or by subgroups of one SWG: chemotherapy and drug development, immunoprophylaxis and immunodiagnosis, and, where relevant, epidemiology and vector control. Within this broad framework, the priorities in each component of the program have been selected on the basis of a careful analysis of needs and opportunities, always in consideration of activities on the subject already undertaken by other agencies.

The overall strategy of the program is to identify and attempt to fill gaps in the efforts directed toward the development of new tools for the control of these diseases. Investigations showed, for instance, that a number of pharmaceutical companies were actively engaged in the development of new schistosomicidal drugs but that one major constraint was the clinical evaluation of the promising compounds. The SWG on schistosomiasis therefore accorded high priority to the promotion of well-designed, multicenter clinical trials of schistosomicidal drugs. On the other hand, in the case of filariasis, where the SWG had identified the need for a macrofilaricide that is effective against the onchocercal worm as a top priority, a major constraint was the lack of validated biological screens. The SWG on filariasis has therefore supported the development and validation of these screens for testing potential filaricides in a network of academic centers stretching from the United States, through the United Kingdom, Germany, and Japan to Australia. Selected compounds supplied by various pharmaceutical companies are now being tested in order to identify useful leads. In addition, clinical trials are being promoted in endemic areas. Each component of the program is being designed in such a way as to match needs with opportunities in the most rational manner.

Because the Special Program represents a new experiment in the international organization of research, it is useful to examine the operation of the network mechanism of the SWG. This can best be illustrated through the example of the SWG on the immunology of leprosy (IMMLEP), the oldest group of the Special Program. Established in 1974, the IMMLEP group devised a plan for the development of a vaccine and for diagnostic tests. Its activities were designed to exploit an earlier breakthrough outside the program, which made available for the first time relatively large quantities of the leprosy bacillus from infected armadillos. The first requirement was to secure a steady supply of bacilli derived from armadillos. Contracts have been awarded to several institutions, and currently over 300 infected armadillos are being kept in the various laboratories for the production of leprosy bacilli. One important constraint is that the susceptible animals are found in a restricted geographical area (the southern part of the United States, and Central and South America) and so far connot be bred in captivity. In order to make the bacilli available to the global network of institutions collaborating in the IMMLEP program, the material harvested from the infected armadillos is stored in a central bank. A series of protocols have been devised and tested for the extraction of the bacilli from the armadillo tissue, and now a technique has been developed that combines high purity with minimal damage to the bacilli. Through research grants awarded by the IMMLEP group and the biological materials available, research institutes in several continents are actively collaborating to achieve the objectives of this group. The network is operating in such a way that armadillo tissue derived in one continent may be subjected to immunological studies in another continent and the purified antigens tested in the field in an endemic area in a third continent. The SWG is now able to report sufficient progress in its search for a vaccine so that detailed consideration can be given to the design of vaccine trials. Similarly, with regard to serodiagnosis, significant progress has been made, and some promising new test systems are being further developed.[1]

The malaria component of the program illustrates another feature of the operation of the network system, the interaction of SWGs. The research and development work on malaria is carried out by three SWGs: one in the area of chemotherapy, another in immunology, and the third in field research. The emergence of drug-resistant strains of the parasite is one of the challenging problems tackled in this component.

The field research SWG has developed a program of global surveillance and monitoring of the distribution of these resistant parasites. This mapping will provide the basis for planned containment of the problem and its eventual control. Test kits for in vitro detection of drug resistance are the main tools used in this epidemiological survey. The SWG sponsored regional courses in which participants from developing countries were trained

in the use of the technique. Next came national workshops and finally national surveillance programs, which are now being developed and implemented in endemic countries of Asia, Africa, and the Americas. The kits are being produced for the program in an institution in the Philippines.

Recently a microtest modification was produced by Professor K.H. Rieckmann, who developed the original technique. The new method was tested in parallel with the original and was shown to have several advantages. The Special Program is sponsoring a collaborative effort through thirteen institutions to develop the microtest and manufacture new diagnostic kits for field use.

The chemotherapy SWG, in collaboration with the Walter Reed Armed Forces Institutes of Research and a pharmaceutical company, is conducting clinical trials in Thailand, Brazil, and Zambia on a new drug, mefloquine, that is effective against strains of the parasite that are resistant to other drugs. The new test kit will be used to monitor sensitivity to this new drug. Basic research on the mechanisms of drug resistance is supported by the section, which is jointly run by the chemotherapy and immunology SWGs. Studies are being conducted on the biochemistry of drug-sensitive and drug-resistant strains, and isoenzyme studies are being used to characterize the genetic basis for resistance. The mode of action of drugs in sensitive and resistant strains is being studied to determine how the latter escape drug action.

Other biochemical studies aim at discovering biochemical differences between the parasite and the host that can be exploited in novel approaches to drug design. New drug delivery systems such as the use of liposomes are being explored in the hope of obtaining more effective and safer drug action through specific targeting to the parasite. Thus, in tackling the problem of drug resistance, a broadly based program ranging from basic biological research to field studies is being managed by the three malaria SWGs.

Collaboration with the Pharmaceutical Industry

Early experience indicates that the program can identify useful modes of cooperation with industry. Four main mechanisms are in effect: participation by industry-related scientists in SWGs, the provision of agents for screening, contracts for technical services, and clinical evaluation of new drugs and vaccines. There are currently some sixty projects involving the participation of pharmaceutical enterprises.

The contractual arrangements with industry are designed in such a way as to protect the public interest and to ensure that any products that are developed with support from Special Program investments will be made available to the affected populations on the best possible terms.

Social and Economic Research

Although the Special Program has invested considerable effort in biological research, it clearly recognizes that social and economic factors are also important in determining the occurrence and distribution of tropical diseases. It is further recognized that if the tools devised for their control are to be effective, they must be capable of application in the social and economic circumstances of the communities in which the diseases occur. These circumstances will determine such aspects as cost, acceptability, and practicability.

This component of the program will be developed by the SWG on social and economic research. Following initial consultations, four major areas of research were identified: behavioral issues, problems associated with the delivery of disease control, the relationships between development activities and disease, and decision analysis and disease control. This component is in an early stage of development. Extensive consultations are taking place with site visits to institutions in developing countries. Literature surveys are also being carried out, supplemented by data from unpublished reports, and an initial field workshop to standardize water contact studies for schistosomiasis control has taken place.

Institution Strengthening and Manpower Development

Intimately related to the search for new tools is the second objective, equally important and interdependent: the development of manpower and the strengthening of research institutions in the endemic countries of the tropics. This area of the program is rightly regarded as the one that promises the most important long-term benefits from the program.

To accomplish this task, the Special Program has established a Research Strengthening Group (RSG), which, together with its executive subgroup, plans the strategy and guides the implementation of this sector of the program. The objectives of the RSG are to strengthen research and training institutions in these countries so that they can better respond to their own national as well as Special Program needs, to support the training of persons from the tropical countries to help meet national manpower needs, and to contribute to a rapid transfer to the affected countries from the industrialized world of the knowledge, technology, and skills relevant to their health objectives and within the sphere of the Special Program.

A strategic plan for institutional strengthening has been drawn up to enable institutions in tropical countries to assume appropriate roles in analyzing and solving local and regional health problems. The institutional support and training opportunities provided through the Special Program

ensure an increasing involvement of research scientists and institutions in tropical countries in the research and development activities of the Special Program. A further benefit of such strengthening is increased national competence in health research, equipping countries to tackle other health problems of high national priority.

Thus, with regard to promotion of research, the Special Program assists research institutions in tropical countries in playing their essential role in developing, testing, and applying new control methods or refining existing ones, and it tries to strengthen the national capability of tropical countries for health research.

The program focuses on the training of individuals at all of the levels needed for research to identify the problems and develop the new tools required to improve prevention, diagnosis, and treatment of tropical diseases; on research training programs to meet national needs within health service manpower development programs; and on appropriate national programs for biomedical research and training. The strengthening of institutions and training of research manpower are interdependent, and the program therefore operates in such a way that one is used to promote the other.

The need for involvement of the tropical countries themselves in all phases of the research and development process, as well as in the planning and implementation of programs for training and the strengthening of research institutions, is manifest if the technology that is developed is to be effective in the places where it is needed. If the new tools are to be of value, they must be applicable to disease control in endemic areas. Thus, scientists and health planners from the endemic areas must be involved in drawing up specifications for potential new tools and in assessing the problems that must be overcome to develop tools with such specifications.

A new method of disease prevention or control—a new drug, a vaccine, a diagnostic test, or a vector control method—requires careful testing in endemic areas. Although the fundamental biomedical research necessary to develop new tools initially takes place chiefly in sophisticated laboratories outside the endemic areas, clinical and field trials can take place only in the endemic areas. Scientists in the endemic areas must be brought in to participate increasingly at all levels of this research.

The adaptation of new methods to local situations often requires local operational studies prior to application. Epidemiological, clinical, genetic, and other differences may necessitate some modifications, for instance, in dosage of drugs or in schedules of immunization. Differences in the local systems of health care and in local cultural and social factors may also require special assessment, work often best carried out by local scientists.

The use of existing institutions in the endemic area is usually a more cost-effective and rational approach than the creation of new facilities. Selected existing institutions may be suitably strengthened and expanded

to carry out research and development and thereby strengthen the basis of national research. If institutions are nationally supported, they will have a higher probability of continued operation should there be, in due course, a phasing out of the support from the Special Program.

The involvement and training of local scientists in the endemic areas at all levels of research and development is designed to enable the tropical countries to assume increasing responsibility for health research. Each country should undertake a significant part of the epidemiological and operational research relevant to its own national health problems, whereas the developmental research to fill essential gaps in scientific knowledge can often best be carried out if responsibility is undertaken on a regional or global basis. Furthermore, epidemiological and operational research work can be carried out with relatively simple tools, while developmental and laboratory-based research usually demands expensive, sophisticated equipment and highly skilled manpower.

A rational strategy is to strengthen national research capabilities to enable each national health authority to analyze its own health problems and choose the best options for applying its own health care resources. The required development work and the more fundamental research will be promoted through national, regional, or global efforts in a network of collaborating centers. The institution-strengthening and training activities of the Special Program in return will ensure an increasing involvement of scientists from the tropical countries in the program's research and development effort.

There can be no stereotyped plan according to which the Special Program should cooperate with all tropical countries, varying as they do in social, economic, and environmental circumstances and in scientific development. The only prerequisite is the conformity of the activity to national requirements and plans for the development of research.

Among the terms of reference of the Research Strengthening Group is the planning and development of an informal network of collaborating centers in tropical diseases. These centers, which must be able to make a significant contribution to the program, may be located anywhere in the world, but only those in tropical countries are eligible for institution-strengthening support from the RSG. Groups of centers in tropical countries will be able to collaborate in serving regions with common disease problems.

Various types of grants are available from the Special Program to assist network centers. Grants for long-term support (for periods of up to five years) may include core support for such items as equipment, supplies, salaries for full-time personnel, the employment of consultants, and staff training. They may also contain special linkage agreements between the institute and a more developed research center, including exchange of research staff, joint research projects and training programs, and secondment of staff

from their regular positions at the more developed center for temporary assignments in the less-developed one. Short-term support takes the form of capital grants to assist well-established institutions needing a single capital sum to enlarge their research capability. Small grants are intended to assist promising young scientists from tropical countries who are engaged in or starting research relevant to the Special Program objectives but not supported by the program. Training grants for scientists are also available, chiefly to complement institution-strengthening activities and to meet the needs of the SWGs.

A model of a successful Special Program activity was provided in April and May 1978 when training courses were held at the Faculty of Science of Mahidol University in Bangkok, Thailand, under the sponsorship of the SWGs on the chemotherapy and immunology of malaria. William Trager, from Rockefeller University in New York, coordinated a course on the technique achieved in his laboratory for the continuous cultivation of *Plasmodium falciparum*. Participants from the local faculty, from other parts of Thailand, and from Burma, India, and Korea were experienced researchers who had the necessary facilities for setting up the technique in their own laboratories. In the second of the two courses, much of the training was carried out by the newly trained members of the local faculty. A later course was run exclusively by them, representing a completely successful transfer of a new technology.

Evaluation Mechanisms

Mechanisms for evaluation have been built into every aspect of the program. Individual research projects are evaluated by the steering committees of the SWGs. Each SWG in turn is evaluated by the Scientific and Technical Advisory Committee, a body of fifteen to eighteen scientists who review the entire program annually. An in-depth evaluation of the program as a whole is planned for the end of the first five years of operation.

Conclusion

The Special Program is operating in an area of major concern to developing countries. It is tackling diseases that have been selected because of their deleterious effects on a sufficiently large scale to be recognized as major public health problems. In its search for solutions, the program has selected mechanisms aimed at rapid technical advances while at the same time providing the opportunity for promoting self-reliance in the developing countries. The institution-strengthening and manpower-training component of the program focus on the rapid transfer of technology to the affected countries.

The orientation is not solely from the developed to the developing countries, however. Rather, there is a strong element of technical cooperation among developing countries built into the program through promotion and support of regional workshops, through regional collaborative studies, and through the exchange of scientists.

There was much discussion initially as to the appropriate scope of the program. Some favored investment in basic research, and others felt that the emphasis should be on applied field research. Some believed that the research and development component should be dominant; others recommended that priority be given to the strengthening of research capabilities. The present balance within the program has been adjusted to take into account these different concerns. Through the various mechanisms, the question will be continuously examined, and adjustments will be made to ensure that the objectives remain relevant and that they can be achieved in the most cost-effective manner.

Since 1979, the program has made considerable progress. As planned, a quinquennial review was carried out after five years of operation, the External Review Committee found that the program was making an "important contribution to the world-wide efforts against the six diseases that are its target." Some of the products of the research and development effort are now in an advanced stage of clinical and field evaluation or in operational use.

Note

1. See *Third Annual Report of the Special Programme for Research and Training in Tropical Diseases* (Geneva: World Health Organization, 1978), chap. 7.

Cotton Development International

Charles Weiss and
Wil Lepkowski

The UNDP, the World Bank, and the Rockefeller Foundation for six years promoted the establishment of what came to be known as Cotton Development International (CDI). CDI was to have been a new intergovernmental organization, controlled by the governments of cotton-producing countries and run along business lines, with the purpose of carrying out an integrated international program of cotton market development, including research, development, promotion, and technical and commercial services to industry and trade. CDI was to have built on the efforts of an existing organization, the International Institute for Cotton (IIC).

The effort failed totally, but honorably and instructively. The failure illuminates the difficulty of promoting and organizing an international, and especially an intergovernmental, program to apply modern science and technology to a global problem of interest to a large number of developed and developing countries. It also illustrates the specific issues involved in applying modern science and technology—integrated with up-to-date marketing—to an agricultural export commodity whose production is shared by farmers in dozens of countries.

The IIC had already pioneered in achieving necessary integration among research, development, and the commercial structure of the crop. But it had been unable to expand its membership beyond a small minority of the cotton-producing countries and suffered from a limited financial base. Indeed, 73 percent of its budget was paid by the United States. Moreover, IIC is not an answer to cotton's overall technological problem because it concerns itself only with industrial research on end uses and manufacturing processes of cotton. The CDI promoters therefore attempted to design an integrated approach that would meet the needs of both the developed and the less developed countries and would be financed by both the producers and the consumers of cotton.

CDI was to take advantage of the technological and marketing lessons already drawn by IIC from the history of polyester development. This synthetic fiber cut severely and quickly into cotton markets because of its advantages in the manufacturing progress, its wash and wear capabilities, and its crease and wrinkle resistance. Its manufacturers, all large chemical companies, were able to combine fiber research, research on textile manufacture, marketing, and promotion into a single integrated product strategy,

which, despite cotton's initial price advantage, quickly captured a large share of the textile market. Polyester manufacturers presented the textile industry with a complete package of spinning, weaving, and dyeing technology, extending even to design and fashion servicing.

They not only offered to share the costs of promoting the synthetic fabrics but also gave textile manufacturers the added cost advantage of having their brand names used in advertising, paid for by the chemical firms. Such subsidies were offered with the proviso that the finished textile product use a high percentage of synthetic. Cotton therefore found itself at a distinct economic and technological disadvantage. Up to that point, textile manufacturers had paid for their own research and promotion. Now, with the fiber manufacturers offering research, development, and promotion, cotton began to fade from priority.

Polyester cannot match cotton for comfort, and the practice has been to blend the two fibers into a fabric that combines the best properties of the two. Thus, cotton is able to compete with polyester as both a pure fabric and a constituent of blends, which may vary in the relative proportion of the fibers used. Cotton producers, however, misjudged the speed with which blends were to take over the market and were unaccustomed to sponsoring market-oriented research. Rather than seek to defend their product in the market or to maximize the share of cotton in the new blends, they lost nearly a decade in an attempt to match the easy-care properties of polyester with the chemical technologies then available.

Background

Many export commodities produced by developing countries have benefited from production research and extension support that was much stronger than that provided for domestic food crops. Cotton, coffee, tea, oil palm, cocoa, and sugar are examples of such export commodities. Staple food crops were neglected by colonial regimes and only recently have received major attention from developing-country governments and from the international community. In general, however, even nonfood agricultural commodities have never been a keen subject for large-scale integrated research and development on all aspects of the commodity, including industrial research on end uses. The exception to this rule is rubber, for which an integrated research and marketing program exists but which is limited to a handful of exporting countries.

Unlike basic food crops, cotton is an export crop that faces competition on world markets from alternative fibers. This market discipline imposes the need for research to increase yields, raise fiber quality, and lower production costs, regardless of the level of research effort being devoted to other

crops. The research base for cotton has been hurt by "closing of the Cotton Research Corporation of the United Kingdom, the contraction of production development support by international trading firms, and the shift in textile institute research emphasis from cotton to the man-made fibers."[1]

Approximately 140 million people in the developing countries make their living from growing cotton, with another 40 million earning their income in the cotton textile industry, according to the IIC. Cotton producers in developing countries range from large plantation owners in many parts of Latin America to some of the poorest farmers in the world in India, Pakistan, and Central and West Africa. For many of these poor farmers, cotton is an essential element in a crop rotation system and a source of cash income for clothing and other indispensable purchases and for payment of taxes. For still others, who are constrained by distance from markets or unfavorable weather or soil conditions, cotton is the only possible crop.

The 1979–1980 annual world production of cotton lint and cottonseed was about 14 million tons and 26 million tons, respectively. The value of the year's lint production exceeded $19 billion; the value of the annual seed production was about $5 billion.

The dependence of the developing countries on cotton for growth, foreign exchange, and employment is illustrated by the statistics in tables 18–1, 18–2, and 18–3. To cite three of the most dramatic country examples, cotton lint in the late 1970s accounted for 9 percent of the GNP and 46 percent of the exports of Chad and contributed to the cash income of 71 percent of its population; cotton lint and manufactures, taken together, accounted for 41 percent of the exports and 24 percent of the GNP in Egypt and 10 percent of the employment, 26 percent of the exports, and 10 percent

Table 18–1
People Dependent on Cotton for Their Livelihood, Selected Developing Countries, 1970

Country	*Millions of People*	*Percentage of Total Population*
Chad	2.6	71.4
Nicaragua	0.7	35.4
Guatemala	1.0	19.8
Syria	1.0	16.0
Sudan	2.0	12.7
Ivory Coast	0.5	11.2
Pakistan	5.5	10.3
India	45.0	8.4
Mexico	3.0	6.1
Peru	0.7	5.2

Source: International Institute for Cotton, "The Importance of Cotton and Cotton Products to the Developing World," June 1973.

Table 18-2
Cotton Yarn and Fabric Manufacture and Exports in Developing Countries, 1977

	GNP Per Capita (U.S.$)	*Manufacture of Yarn and Fabric (U.S.$ million)*	*Manufacture as a Percentage of GNP*	*Exports of Yarn and Fabric (U.S.$ million)*	*Exports as a Percentage of Total Exports*
Africa					
Egypt	340	1,744	13.5	238	13.9
Ivory Coast	770	n.a.	n.a.	35	1.6
Asia					
Hong Kong	2,620	1,030	0.9	329	3.4
India	160	6,757	6.7	342[a]	5.4
South Korea	980	598	1.7	204	2.0
Malaysia	970	42[b]	0.3	1[b]	0
Pakistan	200	707	4.7	271	22.8
Thailand	430	491	2.7	54	1.6
Latin America					
Argentina	1,870	223[c]	0.5	25	0.4
Brazil	1,410	n.a.	n.a.	187	1.5
Colombia	760	n.a.	n.a.	54	2.2
Mexico	1,160	612	0.8	61	1.3
Southern Europe					
Greece	2,950	452	1.7	175	6.4
Portugal	1,840	665	3.8	98	4.8
Turkey	1,110	1,194	2.6	161	9.2

Sources: World Bank Atlas, 1979; FAO trade tapes; International Financial Statistics, 1979.
[a]Excludes hand-loomed fabric.
[b]Yarn only.
[c]Fabric only.

of the GNP in Pakistan. Even allowing for the unreliability of the employment figures, these are impressive statistics.

World cotton consumption, according to a World Bank report, rose from 9 million tons in 1955 to 13.6 million tons in 1976, a 2.1 percent average annual growth rate.[2] Population and income projections indicate that by 1990 consumption should rise to 17.5 million tons, with the fastest growth taking place in the developing countries.

Synthetic fiber consumption will grow even faster than consumption of cotton, according to the same report. The market share of cotton is projected to fall from slightly over 50 percent in the mid-1970s to 42 percent in 1990.

Productivity is improving in the poor countries. Third World cotton yields rose 1.6 percent per year between 1961 and 1977, compared with a 3.4 percent rise in the centrally planned economies and only 0.6 percent in the developed countries.

Table 18-3
Importance of Cotton Lint Production and Exports in Developed and Developing Countries, 1977

	GNP Per Capita (U.S.$)	*Cotton Lint Production (U.S.$ million)*	*Lint Production as a Percentage of GNP*	*Lint Exports (U.S.$ million)*	*Lint Exports as a Percentage of total exports*
Africa					
Chad	130	49	8.7	58	46.0
Ivory Coast	770	43	0.7	21	1.0
Mali	120	65	9.0	57	45.7
Nigeria	510	120	0.3	6	0.1
Sudan	330	361	6.4	378	57.3
Tanzania	210	83	2.4	66	12.1
Middle East					
Egypt	340	1,316	10.2	466	27.3
Iran	2,060	271	0.4	107	0.5
Israel	3,760	103	0.8	57	1.8
Syria	860	263	3.9	212	19.9
Southern Europe					
Greece	2,950	256	0.9	31	1.1
Spain	3,260	80(E)	0.1(E)	0	0
Turkey	1,110	799	1.7	209	11.9
Latin America					
Argentina	1,870	233	0.5	88	1.6
Brazil	1,410	654	0.4	41	0.3
Colombia	760	258	1.4	113	4.7
El Salvador	590	100	4.0	76	7.8
Guatemala	830	149	2.8	155	13.1
Mexico	1,160	500	0.7	183	4.0
Nicaragua	870	153	7.3	149	23.5
Paraguay	750	100	4.7	80	0.2
Peru	720	164	1.4	47	2.9
Venezuela	2,630	28	0.1	0	0
Asia					
China	410(E)	2,405	0.6	85	n.a.
India	160	1,450	1.4	12	0.2
Pakistan	200	835	5.5	39	3.2
Developed Countries					
United States	8,750	4,947	0.3	1,536	1.3
USSR	3,330(E)	3,821	0.4	1,368	n.a.

Sources: World Bank Atlas, 1978, 1979; FAO trade tapes.
Note: E = estimate.

The developing countries have raised their share of the cotton market from 37 percent to 43 percent in a twenty-year period. Almost all of this increase occurred before the food grain shortages of the early 1970s. During the 1970s, substantial cotton acreages were shifted to food crops, especially in Africa.

Since 1961, world production of cotton lint has grown at an average annual rate of 1.7 percent. The 1979–1980 season produced nearly 14 million tons, more than twice as much cotton lint as the 1950–1951 season. The increase in production has been general, but there has been some change in the shares of output among producers.

Per capita consumption of all fibers in 1961 was 5.0 kilograms. In 1978 it was 6.7 kilograms. Cotton's share of the fiber market stood at 85 percent in 1920, falling to 75 percent in 1940, 71 percent in 1950, and 48 percent in 1978. Man-made fiber penetration rose from 0 to 47 percent in the same years.

Parallel with the advent and growth of man-made fibers was a marked shift in the geographical distribution of cotton manufacturing capacity. In 1950, industrial countries accounted for 69 percent of world cotton spindles and 64 percent of all cotton looms. Those countries have been reducing their spindles and looms for several decades. By 1977, they accounted for only 33 percent of all spindles and 34 percent of looms. In contrast, many developing countries have initiated or expanded their textile capacities since 1950. Their share of world cotton system spindles and looms increased from 16 and 17 percent in 1950 to 38 and 35 percent in 1977. Even more spectacular has been the growth of cotton textile exports from the developing countries—from $550 million in 1960 to $2.7 billion in 1978.

The trade potential looks good for the cotton-producing countries. Best assessments are that if international trade policies continue to be no more restrictive than they are today, the developing countries' share of cotton textile markets is likely to increase in the 1980s.

The Bank projects that the world demand for cotton in the 1980s will grow to around 17 million tons.[3] This indicates a need to expand production by 2.5 million to 3.5 million tons above recent outputs. No single producing nation alone can meet this rise in demand. Moreover, although this total increase in cotton production can be achieved through rising yields alone, investments in irrigation systems, machinery and equipment, and other input supply systems will be needed to obtain the required productivity gains.

Cotton production is by far the largest user of agricultural pesticides in both developed and developing countries. Not only has indiscriminate use of pesticides caused severe environmental damage, but it has raised production costs and, through ecological backlash (destroying natural predators and elevating hitherto minor pests to the status of major scourges), actually destroyed the cotton industry in several places where it once seemed to have great promise.

The shift of world textile manufacturing capacity has brought with it important ramifications for world trade policies. Fearful of unemployment caused by the lack of competitivenes of their domestic textile industries, developed countries have negotiated a series of treaties, called Multi-Fiber

Agreements, to limit the amount of textiles that can be imported from developing countries. Several developing countries, notably Hong Kong, Singapore, Taiwan, and Korea, have quickly filled their quotas and been forced to curtail their plans for textile expansion. In other countries, there remains room for expansion before the quota limits are reached.

The developing countries have sought to place limits on the extreme fluctuations of cotton prices during recent years. For example, the price of a widely traded variety of cotton ranged from 60 cents to 91 cents per pound between August 1975 and July 1976. Developing countries pressed for the establishment of an internationally managed buffer stock, to be purchased when the world supply of cotton exceeded the demand and sold off when the reverse was the case. The stable prices and reliable supply that would result from such a buffer stock, it was argued, would provide more predictable foreign exchange earnings to cotton-exporting countries and would also greatly increase the attractiveness of cotton for textile manufacturers.

Negotiations on the so-called International Cotton Agreement, which would establish such a cotton buffer stock as one of a series of reserve stocks for commodities exported by developing countries, have been underway under the auspices of the UN Conference on Trade and Development (UNCTAD). In international forums, many developing countries have voiced the general conviction that the world prices of natural commodities exported by developing countries are declining relative to the prices of the manufactured goods that they import, an argument that played an important role in the original establishment of UNCTAD. Most developed countries have opposed the creation of such a buffer stock on the grounds that it would be impractical and expensive to maintain and might be managed in such a way as to raise prices to consumers.

CDI was not to have had any role in establishing or sustaining any such buffer stock arrangements. It would, however, have been designed to benefit from support from the so-called UNCTAD/Common Fund second window account, a special fund that is to be supported by voluntary donations, mostly from developed and oil-exporting countries, that would support efforts to improve the market competitiveness of LDC exports through programs of marketing and technological development.

While neither the Multi-Fiber Agreements nor the proposal for an international buffer stock directly affects the rationale for an international program of research and development, they did contribute to a political atmosphere that tended to hinder dispassionate consideration of the technical merits of the CDI proposal. For example, the positions of some governments on the CDI proposal were affected by a broader strategic position that CDI might (or that it must) serve for diplomatic purposes as a substitute for a broader cotton agreement. These cross-currents were ultimately decisive in defeating the CDI proposal.

Recent Developments Affecting Cotton

Three recent developments have brightened the outlook for cotton on world markets. The first of these is the explosive increase in the use of cotton, especially in the form of denim, as a fashion fabric and the general trend in clothing markets toward natural fibers. To these developments the promotional efforts of the IIC and of Cotton Inc., in the United States, made a significant contribution. Second is the rise of oil prices. Although price increases have raised the costs of cotton production, higher oil prices have brought about an even more serious increase in the cost of petrochemical feedstock, with the result that during part of 1980, synthetic fibers became even more expensive than cotton in the cotton-importing markets of Western Europe. The third of these developments is directly traceable to the Utilization Research Program of the IIC and to the work of its technical director, Frank Burkitt, as well as to the work and collaboration of coworkers and scientists around the world. Drawing on the strategic lessons of the failure to produce a 100 percent cotton easy-care fabric by cookbook resin treatments during the 1950s, Burkitt and his collaborators undertook to learn enough about the fundamental structure of the cotton fiber to understand why cotton reacted to the chemical resins that produced easy-care properties by losing its strength and wear resistance.

Working on a very limited budget in collaboration with European researchers in several laboratories, IIC researchers found that traditional techniques of cotton finishing caused the chemicals used in easy-care treatment to be distributed nonuniformly. These techniques, moreover, did not allow complete relaxation of physical strains introduced into the fabric by earlier processes such as spinning, sizing, and weaving. IIC recognized that treatment by liquid ammonia allowed these strains to be dissipated and that the new minimum application systems for easy-care finishing gave a more uniform and improved product. The new systems of application also provided major savings in energy and chemicals.

The research revealed that either liquid ammonia treatment or minimum application easy-care finishing, used alone, gives improvements. Used in combination, 100 percent cotton products having the easy-care performance of blends, as well as adequate durability and strength, can be produced. The magnitude of this achievement is illustrated by the fact that as recently as 1976, one of the authors of this chapter was told by the director of research of a leading U.S. textile company that easy-care 100 percent cotton was an unfeasible technological objective.

This signal success of the IIC program shows that cotton can, if backed by a modern program of research and market development, defend its market niche against synthetic competitors. The success of natural rubber in retaining its market volume (although not its market share) lends further credence to this assertion.

A fourth development that may affect cotton's long-term future is the possibility that cotton eventually may become a major food or energy crop in addition to being a major source of fiber. Up to now, cottonseed, which comprises 60 percent of the cotton crop by weight, has been crushed to produce oil and animal feed. Recent increases in the price of petroleum have led to widespread interest in the possibility of using vegetable oils as substitutes for diesel fuel. Also, until recently the use of cottonseed protein for human consumption has been prevented by the presence of a toxic impurity, gossypol. In recent years, two different technological approaches were developed that raise the possibility of a gossypol-free cottonseed meal suitable for human food. Cotton breeders have succeeded in producing varieties that produce the same yield per acre as regular varieties but whose seeds do not contain the glands that produce and store gossypol. Technologists have developed a so-called liquid cyclone process for physically separating these glands from normal cottonseeds after harvesting and ginning. For a variety of reasons, neither of these technologies has progressed or spread as fast as their proponents had hoped.

How the CDI Concept Was Born

The idea of CDI emerged out of a suggestion from the IIC. Based in Brussels, Belgium, IIC is currently funded by eleven countries that grow cotton, eight of them developing countries. Its programs include promotion, economic and market research, industrial research, technical services, public relations, and industrial and trade services for European and Japanese industrial markets.

The majority of cotton-producing LDCs, many of them very poor countries, have not chosen to become members of IIC. IIC's programs include no cotton production research and only very limited assistance to cotton textile manufacture or cotton marketing in developing countries. In addition, during the past several years, it has experienced problems in raising funds to support its programs. Until 1979, IIC's membership fee was one dollar per bale of raw cotton exports to Europe and Japan. Under this formula, the IIC's base of funding was declining because of the general erosion of the dollar at the time, global inflation, and the increased exports of cotton textiles (rather than raw cotton) in the member countries. Recently IIC's membership formula has been revised, but its financial situation is still critical, and its program has had to be reduced in the last few years because of lack of funds.

In 1970, IIC knew that it had to expand and therefore sought additional sources of support. It approached the UNDP for assistance in expanding its work in utilization research and promotion. The request resulted in a decision to explore the total situation of international cotton since cotton's problems

ranged across production, end-use research, marketing, and promotion in both developed and developing countries, a scope that extended beyond IIC's expertise and, some might say, its ambitions.

Why an International Cotton Research and Development Effort was Needed

In 1972, UNDP established a fact-finding mission in which IIC staff participated. The findings of this mission formed the basis of the CDI proposal. The UNDP reported that the importance of cotton to the developing countries was crucial but that its production was fragmented. It said a major effort would be needed to meet the competition from polyester, but the developing countries were neither financially nor organizationally able to mount such an effort on an individual basis. Thus it urged a joint program involving the major cotton-producing countries in a long-term effort requiring greatly increased financial support and technical guidance from the international community. It noted the availability of high-quality technical assistance for production research in the LDCs from such agencies as the Institut de Recherches du Cotton et des Textiles Exotiques in France and from such multilateral sources as FAO, as well as utilization research and promotion conducted by IIC in Western Europe and Japan and by Cotton, Inc., in the United States.

But the mission found notable and wide gaps. As IIC had pointed out in its request for funds, there was a need for substantially more resources for utilization research and for marketing and promotional activities. There was also a lack of formal international coordinating and information exchange machinery to help address such issues as common production research problems, lack of plans for utilization research geared to the growing needs of developing countries, lack of an integrated program and strategy for cotton with which developing countries could jointly maintain their interests, and lack of a planning mechanism for supervision and control of research and for obtaining and allocating research funds.

Not more than five developing countries, the mission reported, had well-balanced, multidisciplinary research programs in cotton production. Most of the research institutes in developing countries lacked expertise in relevant research disciplines, especially entomology and soils science, and lacked important equipment and funding. There was (and still is) a great need to train developing-country nationals for research and to furnish opportunities for travel and exchanges through visits and conferences.

These conclusions were repeated and reinforced by a second report, financed by the Rockefeller Foundation at the request of the Bank and UNDP, and chaired by the late George Harrar, former president of the foundation.

The development of the CDI program and proposed structure was an intricate technical task requiring the efforts of several Bank and UNDP staff and five expert working groups over a period of a year and a half. The large number of governments that would have had to be involved with the cotton issue and the complex internal structure of each government led sponsors to decide not to consult with governments until the proposal had been fully worked out, despite the obvious advantages of having involved them from the beginning while the proposal was being formulated. A formal prospectus for establishment of CDI was issued in July 1977 by the UNDP, Rockefeller Foundation, and World Bank. The concept of CDI was contained in that proposal.

CDI's purpose was to have been to:

1. Promote the greater use and production of cotton and cotton products, including blended fabrics.
2. Improve the overall efficiency and productivity of cotton manufacture in developing countries through consulting services to industry.
3. Increase the competitiveness of cotton through industrial research and market development and promote the transfer of new cotton technology to industry.
4. Improve the yield and quality of cotton production in developing countries through agricultural research and development.
5. Improve the capacity of developing countries to carry out promotion, extension, marketing, and industrial research and development.

In other words, CDI was to integrate all elements of a cotton market system and link agricultural research to industrial processes, product research to marketing needs, and to build institutions to strengthen each single element. Besides the IIC, its models were to be the International Wool Secretariat, the Malaysian Rubber Research Institute, and Cotton, Inc., which carry out similar functions for wool, rubber, and U.S. cotton, respectively. It was to build on the nucleus provided by the staff and program of the IIC and retain the location of the IIC headquarters in Brussels, Belgium, which is close to the center of the European textile industry and a hub of global communications.

The CDI program was to include international agricultural research, industrial research, technological services to the developed- and developing-country textile industry, economic analysis, marketing, and promotion.

In agricultural production research, CDI was to have established regional production research teams to carry out a global program of research on cotton production problems. Initial priorities were to be yield, fiber quality, integrated pest control, improved varieties, and low-cost farming systems. CDI was also to have assisted national research programs in such areas as the following:

1. Improving varieties and developing germ plasm collections for high-yield qualities, insect and disease resistance, and tolerance to cold, heat, salinity, and drought.
2. Reducing losses from cotton pests.
3. Improving productivity through changes in farming practices, such as dates and rates of planting, crop rotations, soil fertility and management, water management, weed control, and evaluation of varieties under different conditions.
4. Improving engineering systems, such as seedbed preparation, insecticide application equipment, and ginning.

In industrial research, CDI was to have absorbed and expanded the research now underway in the IIC utilization research laboratory in Manchester, England, in such areas as easy-care cotton, adaptation of cotton to new textile technologies such as open-end spinning, and responses to consumerist and environmental legislation in developed and developing countries concerning such issues as pollution, flammability, and worker health and safety (specifically freedom from brown lung, or byssinosis, a serious disease caused by accumulation of cotton dust in millworkers' lungs).

CDI would have benefited textile manufacturing industries in both developing and developed countries. It would have offered them technical assistance and programs of research, development, and promotion designed to increase the demand for cotton goods in export markets and to increase the proportion of cotton used in textile mills throughout the world. Projects were to include the following:

1. Improving the quality of cotton-containing textile products in regard to easy-care performance, stability to laundering, and similar characteristics.
2. Ensuring that cotton can be processed economically on new processing systems and is compatible with developments in knitting machines, open-end spinning equipment, and high-speed bleaching and scouring ranges.
3. Minimizing the problems caused by impurities in raw cotton by economic methods of cleaning and nonpolluting systems of dyeing and finishing.
4. Advising on the organization and management of textile centers elsewhere.

Regional centers were also to have been established for coordinating technical assistance to the textile industries in developing countries to increase the amount of cotton they use. They were to have helped build capacity for carrying out promotional activities on behalf of cotton, for

commissioning or executing programs of transfer and adaptation of cotton technology to meet regional needs, and for helping build research and development capacity at the national and regional level. Market research and economic analysis were to have played a key role. Assistance would have been given to the development of market intelligence, projecting the impact of international social, economic, and political developments on the cotton economy.

In the original proposal, CDI was to be an organization of the governments of cotton-producing countries, many of them developing countries. These governments were to take the responsibility for financing the CDI program according to a formula that reflected both their production of cotton and cotton textiles and their per capita income. This structure was based on the principle that only the producers of cotton could be expected to take responsibility for its future.

In summary, the basic principles of the CDI proposal were as follows:

1. The need for a large increase in the funding of cotton research and development to raise it to a respectable fraction of the sum being expanded by synthetic competitors for similar purposes.
2. The need for an effort controlled and financed by producers, who alone had a direct interest in the competitiveness of cotton.
3. The need for an integrated approach combining agricultural research, industrial research, and marketing.
4. The need for a development-oriented approach in which the needs of poor cotton farmers in developing countries would receive appropriate attention.

To the sponsors, these principles were critical to any effort to bring modern science and technology to bear on a commodity that was both a major export earner and a major source of income to farmers in developing countries.

The Effort to Promote CDI

The formal presentation of the CDI prospectus in July 1977 was followed by a one-year program to explain the CDI proposal to the governments of producing countries (who were invited to become dues-paying members) and nonproducing countries (who were asked to make financial contributions). This effort was needed because of the novelty of the CDI proposal and the need to inform the government of forty-five or so countries, each of which had several ministries concerned with cotton. The donors then convened an informal meeting at Bellagio, Italy, financed and hosted by the

Rockefeller Foundation, where the proposal received encouragement from leading cotton experts from developed and developing countries. Active promotion of the CDI proposal followed. An intensive lobbying effort was initiated, culminating in three intergovernmental working groups at which government representatives formally discussed the CDI proposal with each other and with representatives of the sponsoring organizations.

The CDI proposal was not easy to explain to governments. Export crops like cotton in many developing countries are regarded as a hangover from the colonial past, whose economic role is to finance the development of the country through industrialization. Perhaps for this reason, government policies for the promotion of cotton normally take the form of trade promotion rather than science, technology, and marketing.

For many years, international cotton diplomacy has centered on the negotiations for quotas under the various multifiber agreements that regulate textile trade between the developing and the developed countries and on efforts under the auspices of UNCTAD to establish a buffer stock and reference prices to assure cotton producers of stable and satisfactory returns. Many of the foreign policy officials in developing and developed countries have participated in these negotiations, which focus on efforts to win trade concessions from one side or the other rather than on development-oriented discussions seeking areas for constructive cooperation. The idea that developing-country producers need to take financial and management responsibility for a modern program of market-oriented science and technology to defend the competitiveness of this export crop was in many cases a novel message to this constituency.

No country is purely a producer of cotton; all developing countries consume cotton, and many developing countries are promoting their own cotton textile industry. Each government has several ministries concerned with cotton, some as an item of agricultural production, others as an item of export trade, and others as an input to textile manufacture. All of these ministries have to come to a consensus before a governmental position is reached. For this reason, no government can identify itself solely with the interests of the cotton producer.

In the negotiations that followed the Bellagio meeting, the CDI proposal changed in fundamental ways that reflected the desires of the participating governments. Developing countries, however much they appreciated the need for CDI, felt they could not afford its cost. The sponsors argued in vain that cotton was a major producer of foreign exchange so that research money should be considered an investment off the top and that the dues of cotton producer countries for CDI's program to protect cotton's competitiveness would be, in any case, less than their premiums for fire insurance.

As the CDI negotiations proceeded, the prospects for funding of the UNCTAD second window improved. UNCTAD indicated that proposals

from CDI would receive sympathetic consideration from the management of the second window when it becomes operational. The working group therefore indicated its desire to change the structure of CDI into an organization composed of the governments of both producer and consumer countries in order that it might be eligible for second window funding. The prospect of a second window funding increased the political attractiveness of the CDI proposal but at the cost of undercutting the argument that the developing-country producers should themselves assume the financial and substantive responsibility for the work of CDI.

The Failure of CDI

CDI's prospects for success rested on three requirements: that IIC members, especially the United States, agree to join CDI and to allow IIC to serve as the nucleus of the new agency; that several major producers of cotton which are not IIC members agree to join; and that donors support CDI with enough funds to draw additional support from member countries. Two of these requirements failed to be accomplished.

The major success of CDI's promoters was to gain strong U.S. support for the proposal. This was not an easy task. U.S. involvement could be justified in two ways. The United States is a major cotton exporter, is already a member of IIC, and has a strong interest in expanding the overall market prospects for exported cotton. Second, the United States is a rich country with money to spend in support of foreign aid projects offering good prospects of benefiting poor people in developing countries.

The Carter administration gave CDI its firm support. The interests of the United States as a cotton producer, however, ran counter to any U.S. contribution to production research. They agreed, however, to support CDI, albeit reluctantly, as the best way to help the IIC programs of industrial technology and marketing, which they wholeheartedly supported, to survive and expand. Throughout the negotiations, the United States held to a position of strong support for CDI but with the proviso that it was precluded by congressional action from spending funds appropriated for market development (such as are now being used to support IIC) for production research. This restriction was taken into account in the design of CDI's financial structure.

Support of the IIC was also essential to CDI since IIC's membership, staff, and facilities were to be the nucleus around which CDI was to be built. IIC gave its backing to the general concept of an expanded program for cotton, and many of its members stated that they wished to be founding members; so did several key producing countries, such as the Sudan, that were not members of IIC. Support from IIC to the CDI proposal was never

wholehearted, however, reflecting as much as anything the reluctance of any well-established organization to embark on new and uncharted waters at great risk to itself. What is more, the support CDI received from non-IIC countries was muted by political developments originating far from the domain of science and technology.

The final blow to CDI's prospects for success started with the organization of a group of developing-producer governments at a meeting held in Izmir, Turkey, in March 1980. The major purpose of the so-called Izmir group was to assist producing developing countries to adopt common positions in the negotiations over buffer stocks and reference prices in the regular meetings held under the auspices of UNCTAD. The governments of the Izmir group also agreed to speak with one voice at meetings of the working groups discussing CDI. The group decided to use the CDI proposal as a bargaining chip in the UNCTAD discussions, in the belief that the United States was strongly committed to CDI and would make concessions on the larger issues in order to achieve its establishment. In the end, the group deemed even the tiniest prospect of the most minute concession sufficient to justify acceptance of a very strong probability of scuttling the entire CDI proposal, despite its repeated formal protestations that CDI was technically sound and advantageous to the developing countries. Individual countries in the Izmir group, including several important producers that strongly supported CDI, were constrained to keep silent in formal sessions in order to maintain group solidarity. The United States, for its part, held firmly to its opposition to any such arrangements.

As the world slid into recession, the costs of the CDI proposal loomed larger and larger, both to prospective donors and prospective members. Even with the promised support of the UNCTAD second window, the most optimistic projection of the financial base for CDI was only a little more than one-third of that projected in the prospectus.

Some prospective donor countries that had enthusiastically backed the CDI proposal retreated from their earlier positions of strong support and voiced support for only an administrative budget to cover the costs of a small staff, which would prepare individual proposals for research projects, an approach quite incompatible with the integrated approach that formed the heart of the CDI proposal. Some of these donors were represented by officials in charge of commodity negotiators who seemed motivated at least as much by the desire to divert discussion on buffer stocks as by a wish to help poor farmers or developing countries. This attitude was the mirror image of the position of the Izmir group.

At the end of the third working group meeting in October 1980, four years after the publication of the prospectus and after the expenditure of more than $1 million, the sponsors decided that the prospects of launching CDI as an effective organization did not justify further time and expenditure. They with-

drew their sponsorship and turned over the responsibility of promoting it to UNCTAD. Their action in effect killed the proposal in the form it had been presented.

On April 23, 1982, the governments of the Izmir group, meeting in Kaduna, Nigeria, agreed to establish a new International Cotton Producers Association to "intensify economic cooperation and coordination among all developing cotton producing countries." Secretariat support for the new organization is to be provided by UNCTAD, and support is expected from the UNCTAD second window when and if this is funded. Many of the stated objectives of the new association are the same as those of CDI.

The history of CDI shows the great difficulty encountered by technically oriented international civil servants dealing with the political dimension of launching a new kind of intergovernmental organization based on scientific and technological principles that are still unfamiliar in the international community. The history of the CDI proposal shows the dangers of allowing proposals for research and development to be tied too closely to the much more contentious and expensive proposals for buffer stocks and reference prices. It also shows fundamental contradictions in the notion, basic to the framework of commodity negotiations, that measures to improve the competitiveness of commodities should be taken jointly by producers and consumers. The interests of producers and consumers on most issues do not coincide; on the contrary, they are opposed. In commercial life (and this is surely the world of the export commodity), the proper defender of the competitiveness of a produce is its producer, not its consumer. Developing countries cannot expect consumers to take responsibility for this function.

We therefore suggest that the principle of support on a substantial scale of development and market-oriented research by producers is essential if commodities like cotton are to benefit from the application of science and technology in their modern, commercial context.

CDI was to have given the developing countries the power to mobilize science and technology for their own benefit. Control of CDI was to have been in the hands of the producing countries, most of them developing countries. The obverse of this power was the responsibilty to pay for the organization, a difficult responsibility in hard economic times but an inescapable one.

Notes

1. M. Elton Thigpen, "International Cotton Market Prospect," in *Price Prospects for Major Primary Commodities*, Report Number 814–82, (Washington, D.C.: World Bank, 1978), vol. 3.
2. Ibid.
3. Ibid.

15 General Conclusions

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The chapters of this book have shown that technology is an important element of the work of the Bank as a development institution. Indeed, the World Bank is a technological institution in the sense that it contributes to technological innovation, promotes the transfer of technology, and directly or indirectly helps to build up technological capabilities in the developing nations. It differs in important respects from more conventional technological institutions, such as national science councils, technological institutes, technology-oriented consulting firms, and large-scale research centers.

The first difference is that in the World Bank, technological activities are an element of development rather than an objective in their own right. From this point of view, the Bank is closer to an innovative corporation or investment bank than to a conventional technological institution. For the latter, the promotion of research, the development of new products, or the transfer of technology are central features of their day-to-day activities and their long-term development strategy.

A second difference is that the World Bank's importance in technological development is only beginning to be recognized by governments, development experts, and the banking community. In fact, the idea that an international development bank should also be an important actor on the technological scene may strike many readers at first as something rather new, although on second thought it should be acknowledged as a natural consequence of the important role of technology in overall development.

The cases presented in this book are aimed primarily at showing how the World Bank operates in practice as a technological institution, but this experience has significance far beyond the confines of this particular institution. The regional development banks, notably the Inter-American Development Bank and the Asian Development Bank, also carry out important technological activities, and the same is true of many local development banks in such countries as Mexico, Brazil, Colombia, India, and Korea. These banks, like the World Bank, have had a major impact on the technological capabilities and orientations of the countries in which they operate. Therefore the experiences presented in this book should not be viewed as something totally new or exceptional but rather as an illustration of a much broader and more important phenomenon, the growing role of financial institutions in the process of technological development.

The fact that policymakers are not yet fully aware of the role played by development banks as a major force in the technological system of the developing nations has meant that they have not paid attention to the ways of making these institutions more effective instruments of technological development. A better understanding of the technological role of financial institutions would also enable policymakers to minimize the contradictions that often exist between technological development objectives and economic and developmental priorities. Greater self-reliance and the development of indigenous technological capabilities are important goals, but major development projects need to be operationally successful and financially acceptable, and this often calls for a choice of technology or a pattern of implementation that does not necessarily make the optimum contribution to these longer-term technological objectives.

The technological activities of the World Bank raise a number of questions, not all of which have been fully addressed in this book. In what way, for instance, do Bank-financed projects contribute to the building up of indigenous technological capabilities? Does the Bank tend to be rather conservative in the technological field? Do the project design and preparation procedures of the Bank tend to favor foreign technology at the expense of locally designed technology? Before attempting to answer these important questions, it may be useful to try to assess the effective size of the Bank's technological activities and show how they fit into the organization's overall operations.

The Size and Nature of the World Bank's Technological Activities

The Bank's technological activities can be divided into two broad categories of unequal importance. The first comprises all of the activities specifically geared to technological development. This includes the Bank's financing of the international research network of the CGIAR, its participation as fiscal agent and financial contributor to the Tropical Diseases Research Program (TDR), specific project loans devoted exclusively or principally to the support of education and research institutions, the research-oriented components of conventional projects in areas such as agriculture and industrial development, assistance to governments in building up their consulting and engineering industry, technical support in energy planning, and research on appropriate technology in such fields as sanitation and civil works. The second category includes the vast array of technological activities that form an integral part of virtually all Bank projects. These activities range from the training of the technical and managerial personnel needed for the success of a project to the international transfer of equipment-embodied technology

and from the design of sectoral technology strategies to the upgrading of the borrowing agency's institutional capabilities.

The funds applied to the first group of activities are of the following order of magnitude:

$5.0 billion in loans and credits for education in the period from fiscal years 1963 to 1983.

Loans and credits totaling $1.4 billion for agricultural research projects or project components through fiscal year 1983.

Loans totaling $118 million for upgrading industrial technology at the enterprise level through fiscal year 1983.

Grants to CGIAR totaling $105 million, of which the most recent, for the year 1983, was $19 million.

$4 million for research on appropriate technology in sanitation and labor-intensive civil works construction.

To put these sums into perspective, we may compare them with a lending amount of $14.5 billion in fiscal 1983, net income of $752 million for the same period, and a cumulative total lending of $80.5 billion in the period from July 1970, the year of the first agricultural research project, until June 1983.[1]

Activities in which science and technology are the primary elements (with the possible exception of education and agricultural research) clearly do not have a major claim relative to other World Bank operations on its financial resources or staff time. But the sums invested by the Bank in science and technology, when compared to the sums available from other organizations in the field, are far from negligible, and their multiplier effects are often considerable since the Bank frequently acts as a catalyst that helps to mobilize funds from other institutions.

The Bank's financial contribution to international agricultural research, for instance, is relatively small. But the Bank's active involvement in the management of the CGIAR, reinforced by this contribution, acts as an imprimatur which helps assure other donors that the research of the international programs financed by the CGIAR is a sound investment of their aid resources. The Bank's technical assistance to local technology policymakers and consulting firms also involves relatively small sums of money, but its long-term impact may well be much greater than what these figures would suggest. In the same way, much of the Bank's research on appropriate technology has been carried out in cooperation with many other donors and research organizations (many of which rely on the Bank for technical judgments), but the projects based on this research often do not appear in the

statistics on the Bank's technological activities since they are funded by other development agencies.

The second category of technological activities of the World Bank—the technological elements of loans and credits for directly productive activities—is by far the more important. They are not always specifically recognized as technological activities and are difficult to single out from the overall contribution of the Bank to the preparation and supervision of projects, the conception of sectoral development strategies, and the review of a country's economic situation. For this reason, it would be extremely difficult, if not meaningless, to try to measure their size relative to the Bank's overall lending commitments.

The importance of these technological elements in the Bank's operation varies from sector to sector and from project to project. Some sectors are by nature more complex and more technology intensive than others; this is the case of exploration and exploitation of petroleum and natural gas resources, for instance, or of major power generation and distribution schemes. There are also major differences among projects within the same sector: a project involving a whole set of fairly new technologies is obviously more complex than a project that is in essence a replication of other projects carried out elsewhere.

Project hardware (machines, tools, equipment, and physical infrastructure) is often less critical to the success of a project than its software elements (the institutional structures, the managerial tools, the quality control procedures, the training mechanisms, and, more generally, the understanding of the ways in which technology in the hardware sense fits into the culture and social structure of the community in which the project is carried out). The balance between hardware and software differs from project to project and from one sector to another. Even in projects that use large amounts of equipment—fertilizer plants, large-scale water development schemes, or power generation and distribution networks, for instance—these software elements are considerable. They are even more important in the projects aimed at alleviating urban or rural poverty or meeting basic human needs, where a large amount of effort must often be spent in designing and testing new types of organization and new management and training procedures.

When trying to appreciate the size and nature of the Bank's technological activities, it is important to keep in mind that the Bank is a very large and diverse institution. This diversity, largely the result of a long evolution spanning more than three decades, accounts to a large extent for the fact that such concepts as technological development, technological capacity, or even technology tend to be defined and applied in rather different ways within the various departments of the Bank. It also explains major differences in emphasis in projects.

In the more traditional sectors of the Bank's activities—for instance, power generation or fertilizer production—where much of the technology is available on the international market in the form of equipment manufactured by well-established suppliers and the technical services that go with it, building up a local technological capability in the borrowing countries consists in large part of formulating project objectives, assessing resources and alternative project designs and technologies, selecting, acquiring, and implementing the technology, and operating it efficiently. In such sectors, the Bank's work as a technological institution focuses primarily on the process of technology transfer rather than on the creation of an indigenous innovative capability. This process begins in the project's early phases with decisions as to the project's overall technical characteristics, continues in the preparation phase with the work of the consulting and engineering firms, which is carried out in close cooperation with the Bank and the borrower, and ends once the borrower has mastered the organizational, managerial, and technical skills necessary to the successful operation of the new productive unit.

By contrast, in many of the newer sectors of activity, where there is much less institutional experience within the Bank (or for that matter in other development agencies and in the borrowing countries' government departments) and where locality-specific circumstances are likely to be critical to the design of a project, technological and organizational innovation is a necessity. One of the indirect effects of such projects is the development and diffusion of important new technologies (hardware and software) within the borrowing country or institution.

The Appropriateness of the Bank's Choices of Technology

Technology is widely recognized today as one of the important instruments of development, and considerable attention has been given by researchers and policymakers alike to the problem of choice of technology. The assumption underlying this concern is that the developing countries, which require vast amounts of foreign technology in order to achieve their development goals, do not always choose the technology that is most appropriate to their resources and capabilities.

Can the World Bank contribute to better technical choices in the developing countries? When considering this question, it is important to keep in mind that for a conventional technological institution such as an industrial research center or a government laboratory, the promotion of innovation is not only a major goal but its raison d'être. For the World Bank—or for that matter any other international or national development bank— technological activities at the project level are governed by priorities

other than the need to innovate or to promote the most sophisticated technology. The crucial determinant is the success of the project, and a balance must be struck between the risks inherent in any new technology and its potential benefits.[2]

This need to minimize risk from a technological point of view does not rule out innovative technological solutions, particularly in areas where existing technology is inadequate; however, it would probably be fair to state that in the majority of projects, notably those in areas where the Bank has traditionally been involved, the technologies chosen are up to date but fairly conventional and do not necesarily represent the latest state of the art.

This general pattern in the process of technology choice might be viewed as a form of technological conservatism. If in practice the Bank does show a strong preference for well-tested technological solutions, this is largely because such choices are imperative if the project is to meet its objectives. The well-tested solution of today is often very different from the well-tested solution of yesterday. As a result of its wide experience in the design of projects, its contacts with industry and the technological community, its institutional knowledge embodied in its staff, and its constant monitoring of technological developments in a wide number of areas, the Bank is probably in a better position than many countries, and many government institutions dealing with technology and development, to assess the quality, reliability, and likely effectiveness of a technology proposed for a project. This capacity to monitor innovation and technological developments worldwide, and hence to know fairly well what will work and what will not, can help to avoid major technological risks in a project. For the borrowing country, this involvement of the Bank in the process of technology choice is an important assurance of the project's ultimate success. It can also help to avoid the very high costs and long delays often associated with the importation of highly sophisticated but still largely untested foreign technologies and ensures that the borrowing country will not be serving as the proving ground for a foreign supplier of equipment.

In many of the Bank's more recent projects, which address complex socioeconomic and organizational issues for which there is little previous experience in the Bank or anywhere else, the goal that a project be replicable within the cost constraints typical of a particular country has led to a considerable amount of technological and organizational innovation. This emerges clearly from the chapters in this book dealing with agriculture and rural development, sites and services, water supply and waste disposal, and basic education. These are domains where the Bank has not only been innovative but more than once has been the leading institution in pushing the state of the art.

The risks of such innovations are not only economic and financial but social and political. If major technical problems arise in the process of building

a cement plant or a hydroelectric dam, they usually translate into cost overruns, delays in start-up time, or lower productivity, problems that can generally be corrected. But if a slum-upgrading program goes awry or becomes involved in broader political issues not directly stemming from the project itself, the result may be greater unemployment, rioting, and loss of confidence on the part of the people whom the project is intended to benefit; no amount of money can correct this.

The Decision-Making Process in Technology

Any discussion of the Bank's role in the process of technology choice—whether the technology is simple or advanced, conservative or innovative—must take into account the fact that practical operations are rather different from the models of economic theory.

One of the central features of the abundant economic literature on technology choice is the high degree of sophistication of the analytical tools (such as shadow pricing, sensitivity analysis, consideration of factor endowments, and combinations of different technological subcomponents) used in evaluating possible technological alternatives. The development of these tools has made a major contribution to our understanding of the role of technology in the economic system and has contributed to opening the eyes of many policymakers to the importance of the problem of technology choice. These tools now play an important part in the evaluation of projects and are widely used by development finance institutions such as the World Bank.

The availability of such tools should not obscure the fact that the process of making decisions about technology involves far more than the one-time application of sophisticated analytical tools. In practice, such decisions are the result of an iterative process that develops over a long period of time and involves complex interactions among policies, objectives, experience, technological opportunities, economic considerations, and social priorities. This can perhaps best be understood by looking at the ways in which the project cycle interacts with sector work and country economic work. The first important stage in the cycle is that of project identification. Here government officials of the borrowing country and World Bank staff members work in close cooperation within the broad framework of the borrowing country's priorities and development objectives and define the main parameters of a project.

Project identification may be viewed as the earliest phase in the process of technology choice. The choices here are implicit rather than explicit and consist essentially of a gradual narrowing down of technological options. If a project is conceived from the beginning as a large productive unit, for

instance, rather than as a much smaller one or as one whose output will have to conform to one set of specifications rather than another, this will rule out some types of technology. It is also important to keep in mind that this process of gradual exclusion, or narrowing down of technological options, is colored to some extent by the professional backgrounds of the people who carry it out and by their experiences with similar types of projects undertaken elsewhere.

In this process of interaction between the Bank and the borrower, the scope of the project and its technological parameters are influenced by the borrowing country's technological sophistication and level of development. In conventional projects carried out in an advanced developing country, the borrower tends to play a more important part than the Bank in determining broad technological options. In totally new types of projects or in projects carried out in much less developed countries, the Bank tends to have a greater role than the borrower in the definition of these early technological options and the choices among them.

The second important stage in the cycle as far as technology is concerned is that of project preparation. This work, carried out by the borrowing country, often with the help of foreign or local consulting firms, consists essentially of making a detailed presentation of the project, its objectives, its technical specifications, its relevance to the country's development priorities, and alternative approaches to its design. The two main partners here are the government of the borrowing country and the individual consultants or engineering consulting firm that may be hired by the government with the funds provided by the World Bank as a normal part of the project's overall cost.

The Bank deliberately tries to foster the participation of local consultants in this preparation stage. The possibility of doing so varies from country to country and from one sector to another. Even in relatively undeveloped countries, much preparatory work in some sectors (such as education) is done by government officials and by local consultants, sometimes in collaboration with foreign firms. In other sectors by contrast, such as ports or basic industries, many borrowing countries do not have the consulting firms to perform what is, in most cases, a rather large, complex, and novel type of job. As a result, the core of the preparatory work tends to be carried out mainly by big international consulting firms.

Based as they are for the most part in the industrialized countries, foreign consulting firms tend to be more familiar with the technologies, equipment, standards, and ways of doing things in their own country and, to a lesser extent, of other industrialized countries than with those of a developing nation. As a result, projects tend to be prepared in such a way that the technological options left open at the end of this phase are generally those prevailing on the international market, which in practice means those of the highly industrialized countries.

This is not to say that the consulting firms from industrialized countries have an inherent bias against technologies originating in developing countries. In fact, precisely because of their international exposure and worldwide experience, they have the technical capacity to compare different alternatives and are often less influenced by the standards and values of their own home country than a smaller local firm, which has always been working in its home environment. The problem is not so much that of the size or nationality of the consulting firm as that of the terms of reference given to the firm. If it is not asked to investigate alternative technological approaches, it will not do so. The preparation process therefore should include a detailed analysis of the alternatives before all but one are finally rejected.

The third phase in the project cycle is that of appraisal. This work, which requires a considerable amount of time and effort on the part of Bank staff members who carry it out and which in many respects is the most important in the whole cycle, is finally embodied in a staff appraisal report submitted to the Bank's board of directors in support of the management's recommendation that the loan be approved. This report contains a detailed description of the project, sets forth its economic and financial rationale, and examines such aspects as institutional structures, managerial organization, and technological options. Once a project has reached this stage, it cannot generally be modified substantially, although some projects, particularly in fields relatively new to Bank staff, may have to be modified during execution. The function of the appraisal is to examine the justification for the project as it emerges from the preparation phase and set forth the reasons for selecting a particular technological alternative. When the appraisal work reveals unexpected problems that require a complete redesign of the project, this is done; however, major problems are generally identified in the preparation stage, and unjustified or poorly designed projects are usually eliminated before reaching the appraisal stage.

This rather schematic view of the ways in which technological factors come into play in the project cycle illustrates the fact that the process of technology choice is a continuous process operating throughout the project cycle.

Technology in Economic and Sector Work

The decision-making process in technology is also intimately linked with, and to some extent conditioned by, the Bank's country economic work and its sector work. The detailed analyses of specific sectors or problem areas, carried out at both the country level and a more general policy level, form the general framework within which projects are identified and developed.

These analyses suggest the most appropriate development policies for the different sectors and in turn have an important influence on the identification of projects and on their more general design features. In some cases—rural development, forestry, fisheries, urban development, or small industries, for instance—considerable attention is paid to technological factors, and these analyses, distilled from the World Bank's experience, positive and negative, amount in effect to the technological element of a sectoral policy—that is, a rational, action-oriented view of the ways in which technology can contribute to the development of the sector in question.

These explicit sectoral technology policies are a fairly recent development in the Bank's activities and do not yet cover all of the fields of activity of the Bank. They arose as the Bank staff organization grew in size and complexity and hence needed to explain formally to itself and to the outside world what it was doing and why it was doing it. They are important in that they testify to the Bank's growing awareness of its technological role and seek to identify both the ways in which technology can contribute to development and what might be the most effective technological strategy to meet particular goals. They are also an important instrument in setting the general framework for new projects and in determining their main technological parameters.

The emergence of technological issues in the Bank's sector work and the gradual development of sectoral technology policies can probably be considered as important innovations in their own right, but they are also important for a number of other reasons. First, these policies are being developed by an institution that has the ability to translate policies into investment projects. One of the major problems facing many developing countries is the absence of effective linkages between the technological system and the production system.

Second, they are important because they focus on broad problem areas, or sectors, rather than on conventional economic and technological categories. This integrated, problem-oriented approach could well be a better instrument in mobilizing technology for development purposes than the discipline-oriented approach favored by conventional technology policies, which tends to stress manpower and research needs for each discipline and each sector, together with sectoral and cross-sectoral infrastructure.

The third reason for the importance of this technological work at the sector level is its influence on the policies of member countries. These analyses carried out by the Bank are in effect a major channel of communication between the Bank and the development community and often represent the state of the art concerning the ways in which to mobilize technology for development in specific sectors.

The Bank also spends a considerable amount of time and effort on country economic work, broad macroeconomic analyses of the general

economic situation and policies in each of the borrowing countries. These analyses are relatively sophisticated and generally carry a lot of weight with both the country and lending agencies. For the former, they amount in effect to an international evaluation of its economic performance; for the latter, they give important indications as to the borrower's investment needs and ability to repay loans.

Building Local Technological Capabilities

One of the major objectives of many developing countries is to strengthen their indigenous technological capabilities, to reduce their growing dependence on foreign technology, and to acquire a greater degree of autonomy in technology choices. These goals may be elusive; they may also be difficult to balance with other development objectives such as growth or equity and must take into account the complex interdependencies between industrialized and developing nations. But the concern that underlies them is a very real political and developmental issue, and one of the important questions to raise at the end of this book is that of the World Bank's role in helping to meet these objectives.

This question perhaps could be formulated in more specific terms: Do Bank projects tend to favor the use of foreign rather than indigenous technology? Are specific efforts made in the design of projects to foster the building up of local technological capabilities? Do the Bank's international competitive bidding procedures discriminate in practice against local suppliers or suppliers from other developing countries? Does its preference for liberal trade policies inhibit indigenous technological development?

In this connection, two important points must be kept in mind. The first is that as an international financing institution, the World Bank was designed to lend foreign currency at reasonable rates for projects that could not normally be financed otherwise. The second point is that the main imperative at the project level is that the project itself be successful and meet the objectives outlined in the appraisal report.

Building local capability is an important part of most projects financed by the Bank. In many sectors, it is a prerequisite to their success, even as measured by targets of physical output. And in most cases, it can proceed in stages so that it reinforces project success. It is, however, important to bear in mind that there is sometimes a trade-off between helping to build a local technological capability and getting the project on stream. If a fertilizer project, for instance, is delayed in order to give design experience to local engineers or in order to use a locally developed technology, this will have a direct impact on agricultural production.

Building up local technological capabilities, promoting locally designed innovations, and encouraging greater self-reliance is a long, difficult, and

expensive process, the cost of which generally has to be borne by the country itself. For example, using local consulting firms in the preparation of development projects can help to build up the professional experience of these firms, an important contribution to the development of indigenous technological capabilities.[3] In the same way, purchasing equipment from local suppliers can be vitally important in giving the latter direct access to a technologically sophisticated market and in raising their standards.

The promotion of local technology through such means may entail short-term costs. Inexperienced consultants may be nominally inexpensive, but their mistakes can be costly. Locally designed and manufactured equipment may not give satisfactory performance and may be more expensive as well. Many governments recognize this and are prepared within reason to accept these costs for the sake of fostering greater technological autonomy. Protective tariffs and preferences for local suppliers of equipment or technical services are legitimate instruments of national policy, and the costs they entail must be balanced against their long-term contribution to the development of local technological capabilities.

For this reason, the Bank's rules on international competitive bidding and its general adherence to liberal trade policies deserve special attention in a book devoted to the role of the Bank as an instrument of technological development.

The Bank's rules on international competitive bidding attempt to assure each member country the opportunity to compete on equal terms for the business generated by goods and services financed by the Bank through its projects. Such equal access is in the interest of economy and efficiency; it is also essential to the political support for the Bank by governments and business communities in the developed member countries.

International competitive bidding, moreover, gives developing countries access to a wider variety of technology and equipment at prices that are more favorable than would otherwise be obtainable. There are many examples of projects the Bank has financed in which equipment and services were obtained at much lower prices than had been the case in previous, essentially similar projects in the same country, where supplies or equipment had been procured under less open procedures. In the telecommunications sector, to cite a notable example, procurement under World Bank rules typically takes place at about three-quarters of the usual noncompetitive price for the same equipment. Similarly, there are many examples in which open bidding on the international market has given developing countries access to new sources of improved technology.

The World Bank in practice has espoused a variety of arrangements intended to make the process of international competitive bidding flexible and responsive to the aspirations of developing countries to build up their own local industry. It allows the borrowing country to add the prevailing tariff,

up to a maximum of 15 percent, to the bids of foreign suppliers of manufactured goods. Very poor countries may also add 7.5 percent to the bids of foreign contractors.

The Bank also makes considerable efforts to ensure that the standards and quantities of equipment specified in international tenders do not exclude local firms from bidding when they would otherwise have been able to participate. It allows smaller firms to bid on only part of a large procurement package so that they may participate to the extent their capacity and competitiveness allows. All of this having been said, the promotion of technological development depends much more on the ways in which a project is conceived and designed than on the rules and regulations governing the procurement of equipment.

In practice, developing-country suppliers have won an increasing percentage of Bank-financed procurement under the Bank's rules of international competitive bidding as a result of their own development and of the shift in Bank projects toward less sophisticated equipment. To put matters in perspective, it should be remembered that Bank projects account for only a small percentage of government-financed procurement in any developing country.

The Bank's adherence to liberal trade policies is frequently criticized on the grounds that such policies inhibit technological development, which for the supporters of this position can take place only behind protective barriers. Such barriers, it is argued, should protect not only local manufacture but also local design and technology.

It is easy to show that protective barriers do not in general preclude technological development. Many Latin American countries have achieved an important degree of industrialization behind protective barriers and now export technology to other developing countries and sometimes to developed countries. Indeed, the industrialization of the United States itself and of many other countries that are now industrialized took place behind high tariff walls.

What is not clearly established, however, is how much tariff protection is necessary or how long it should extend beyond a brief initial period needed to protect infant industry and technology. In other words, it may be possible to enjoy technological development without suffering the costs of diminished growth rates that are imposed by protection.

Many economists argue that protection from the rigors of international competition, whether at the project level or the macroeconomic level, actually inhibits technological development by insulating domestic industry from the pressure to achieve international quality standards and price levels. In addition, these economists argue, domestic consumers pay dearly for the industrialization of the country under a protectionist regime because of the higher costs of local production. As a result, the country as a whole

will suffer diminished growth compared to what it would have enjoyed with a less distorted economy.

Whatever the virtues of modest protection for infant industry, it is probably fair to state that existing levels of protection in most developing countries are much in excess of those needed to promote healthy industrial development. In this connection, researchers on technology policy in many countries have found that the protection and other incentives granted to local manufacturers are so high that it is difficult to provide special incentives for local technology. Both liberal and protective trade policies have defenders, and research on this issue is still far from being conclusive.

Several chapters of this book describe projects financed by the Bank that have the promotion of local capabilities for design and manufacture—and hence a lessening of technological dependence—as a major objective, and some have been outstandingly successful in so doing. It is important to keep in mind, however, that the Bank as a development agency is concerned with economic and social development taken in the broadest sense. Technology is an important dimension in this process, and in recent years this dimension has been the object of increasing attention on the part of the Bank in the design of policies and the conception of projects. Still, science and technology is only one of the many important dimensions of overall development.

Even in countries where the Bank's commitments have been very large, the total value of its loans remains small relative to overall investments. In this sense, the Bank is but one of the many actors that account for the success or failure of a country's development effort. What is more, it has relatively little, if any, influence on the many social, political, and cultural factors that ultimately condition a country's success in building up its internal innovative capabilities and creating an environment congenial to science and technology.

Conclusion

The Bank's technological function is an inevitable, and indeed necessary, component of its activities as a financing institution and development agency in the conception and execution of projects and in the formulation of sectoral development strategies.

Its organizational objectives and its interactions with the science and technology system are rather different from those of more conventional technological institutions, such as research laboratories, ministries of science and technology, or industrial corporations, which are concerned with research, the development of new products and new technologies, and the organization and day-to-day operations of a science and technology

system. The World Bank, by contrast, does not itself carry out scientific or technological research; its internal research activities are very largely socioeconomic and serve as a support for individual projects or for the Bank's country work and sector work. Its involvement in scientific and technological research is nevertheless considerable, but it might be characterized as a second-order involvement. The Bank operates as a funding agency, as a coordinator, as an initiator, and as a problem identifier. What is more, this work is carried out at the world level and in a multinational perspective. In this sense, the World Bank is a rather original type of technological institution. It may not fit easily in the familiar geography of the science and technology system as it has been studied by historians of technology or analysts of national science and technology policy, but it nevertheless has an important role to play.

This book has presented a general picture of the ways in which the World Bank operates from a technological point of view. It has not suggested that this is the right way or the only way to work, nor has it attempted to outline the ways in which this technological function of the Bank could be made a more important instrument of development. The main ambition of this undertaking has been to show what is happening in practice and to sensitize policymakers, bankers, development specialists, and political scientists to the important technological role that this major financial and development institution is playing.

The experiences of the Bank in the technology field are of relevance to a large number of other financial institutions: international development banks, development finance corporations, and industrial development banks. These institutions operate in a somewhat similar way to that of the World Bank, and several of them could become or are in the process of becoming technological institutions.

The potential role of financial institutions as major actors in the technological system of the developing countries is important not only as a political and sociological phenomenon but also—and this is much more significant—as a pointer to new policy instruments in the development process. A bank's investment capacity and operational experience, combined with its access to technology sources, is potentially one of the most effective bridges between the production system and the innovation system and could help to overcome one of the basic structural problems in the economies of the developing nations: the weakness of the linkages between their indigenous innovation efforts and their productive activities. If financial institutions were more widely recognized by themselves and by others in their actual or potential role as technological institutions, this technological role could almost certainly be made more effective, and they could evolve in the next ten or twenty years into a new type of development institution, better attuned to the needs and challenges of development.

Notes

1. Figures are according to the U.S. system of numeration.

2. This discussion refers to risks bearing on the success of the project, not to the risk that the Bank loan or credit might not be repaid. The risks involved in a project financed by the World Bank differ from those involved in a loan from a commercial bank. A commercial bank normally insists on collateral to guard it against the risk that the project will fail. The borrower, typically a commercial firm, may therefore be reluctant to use the loan to finance a risky project.

By contrast, World Bank loans and credits are guaranteed by the government of the country that benefits from the project. Its concern for the soundness of the project is part of its role as a development institution. The safety of the loan itself, as far as the Bank is concerned, depends on the creditworthiness of the government, not on the success of the project. In practice, debts to the World Bank are always repaid on schedule since the damage to a country's credit rating would otherwise be severe. The willingness of a country to borrow for a worthwhile development project should depend on its creditworthiness and ability to assume additional debt rather than on the degree of risk or innovation of the project.

3. A useful device is to encourage joint ventures between local and more experienced consulting firms, an arrangement that requires explicit division of responsibilities and explicit attention and resources devoted to training.

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