Policies For The Application of Science and Technology to Development

Four Papers Presented at:

"UNITED STATES BILATERAL AID STRATEGIES AND PROGRAMS IN SELECTED AREAS OF SCIENCE AND TECHNOLOGY,"

A Symposium Sponsored by the
Office of Science and Technology of the
United States Agency for International Development

MAY 7 - 10, 1973

Convened by

Program on Policies for Science and
Technology in Developing Nations
180 Uris Hall
Cornell University
Ithaca, New York 14850

October 1973

Copies may be obtained for $4.00 by writing to

Program on Policies for Science and Technology in Developing Nations
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The Program was established in September 1971 with a five-year institution building grant from the Agency for International Development, Washington DC. It is sponsored jointly by the Center for International Studies, the Program on Science, Technology and Society, and the College of Engineering of Cornell University.

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PREFACE

About the Papers

The four principal papers of this volume were commissioned for a symposium on "U.S. Bilateral Aid Strategies and Programs in Selected Areas of Science and Technology" which was held at Cornell University on May 7-8, 1973. The participants included U.S. students of development, similar students from developing nations, and AID officials. The symposium was funded by a contract from the AID Office of Science and Technology (OST), and was one of a series of symposia which OST has held in the last two years as part of an overall analysis of important areas for study and support. From the standpoint of AID, the Cornell symposium was actually a four day effort. The first day was devoted to a presentation and discussion of a group of commissioned papers. On the second day, there were progress reports on activities of the principal efforts of the several contractors for OST. On the third day, the participants split up in a series of working groups which developed recommendations for further program activities of OST. Finally, the OST group of AID officials met in executive session for a day to assess the implication of these earlier discussions to their program activities and budgetary needs.

Soon after the termination of this AID sponsored symposium, the Cornell hosts addressed the question of possible broader interest in the presentations and discussions of the introductory day of the symposium. The group quickly reached the conclusion that the general papers of this first day would be of wide interest, and that it would be useful to distribute them rapidly to the development community. The Cornell group also felt that it would be helpful to an outside audience to supply an introductory paper which put the other four papers in context, and which gave some flavor of the response of the participants to them. This volume is the direct consequence of these decisions.

About the Authors

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Dr. Efraim Otero is Director of the Colombian Fund for Scientific Research (COLCIENCIAS). [He has had a long record of study and activity in the field of medicine.] He received his M.D. degree from the Universidad Javeriana School of Medicine, with an honors thesis on the first clinical applications of radioisotopes in Colombia. After postgraduate work at the Oak Ridge Institute of Nuclear Studies, the Columbia-Presbyterian Medical Center at New York City, and the Donner Laboratory at the University of California at Berkeley, Dr. Otero returned to Colombia to work in the National Cancer Institute. He was later appointed as Head of the Research Department at that Institute, a position which he held until his appointment to his present position.

POLICIES FOR APPLICATION OF SCIENCE AND TECHNOLOGY TO DEVELOPMENT

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Introduction

The papers in this volume discuss policy problems for areas of science and technology which are important to national development and which offer the promise of fruitful cooperation between the United States and countries of the less developed world. The areas selected are ones that do not customarily fall within the traditional components of United States foreign technical assistance, (agriculture, population and health, and education, all of which rightly continue to command high attention). The areas discussed are, however, important in their own right. They are areas where policy development by the less developed countries appears of particular potential value. They involve fields of study for which an increasing number of developing countries have indicated an interest in collaborating with the United States. Finally, they are areas where the United States has long experience and outstanding capabilities for problem solving as well as for policy development.

In recent years, most of the less developed countries have invested substantial sums in strengthening their scientific and technological institutions and capabilities. A principal reason that this has been done has been the conviction, based especially on the experience of the "Green Revolution", that adaptive research is a form of investment which can lead to rich rewards. In the agricultural sector, major efforts have been made by a number of countries to develop the institutions and trained manpower to take advantage of the breakthrough in the development of the new high-yield and high-protein cereals. Although progress has been substantial, the application of these new seeds and farming techniques has not been accomplished without frequent, occasionally severe, difficulties and setbacks. The almost inescapable conclusion has been that the problem of adapting these new agricultural technologies to local conditions is a significant one requiring considerable local effort if it is to succeed. Recognition of this fact has stimulated the governments of the less developed countries concerned to increase their investments in local research institutions, which in turn are backed by an increasingly effective network of regional and international research organizations, all seeking solutions to the problems of adapting these technologies to local conditions.

The pitfalls that have been encountered in introducing new technologies in the area of food production are also prevalent in the introduction of new technologies to other fields of endeavor. Here too, there have been occasional serious setbacks with the attendant wastage of scarce resources. In other cases, the imported technologies have flourished but have been accompanied by side effects which have created new and difficult problems, problems which in some measure have offset the benefits realized from the primary investment. This is highlighted in the report of the President of the World Bank in his address to the Board of Directors in September 1971 where he noted that the rapid expansion of the industrial

sector among developing countries was all too often accompanied by a disappointingly modest increase in employment. Since in many less developed countries the level of unemployment and underemployment has been so large as to create severe social and political pressures, the need to find appropriate technologies which will ease the unemployment situation has become a major national goal. In other less developed countries a major goal has been to obtain a more equitable distribution of income, for example, by encouraging the development of labor intensive industries in rural areas. In response to these broadened goals, governments of most of the less developed countries have devised new agencies and efforts to analyze policies for the best application of science and technology to national needs, recognizing that these policies must be developed in close conjunction with economic and social policies, all oriented toward rapid attainment of agreed national goals. Many of these countries also invested heavily in research establishments and programs of higher education in the expectation that they will develop the tools to master and utilize modern science and technology to cope with their urgent problems. At the same time, they are pressing the United States, which many regard as a leader in scientific and and technological training and application, for assistance in guiding their efforts along fruitful lines.

The United States has impressive credentials for assisting the less developed countries in building their own capabilities in science and technology. It also has a record of interest and concern, as demonstrated by the many existing programs of bilateral assistance and collaboration. It is sometimes argued that a drawback to the United States is that it has advanced technologically to a point so distant from the experience and needs of most of the developing countries that it has little to offer which is appropriate and relevant. Increasingly, however, it is realized that the problem is not that of bodily transferring advanced U.S. technologies to the developing countries, but rather of assisting these countries in developing their own capabilities for policy analysis, applied research and technology adaptation so that they can work out their own destinies more effectively. It is to this area of effort that this volume is oriented.

The four papers which are presented here were prepared for and discussed in a symposium on "U.S. Bilateral Aid Strategies and Programs in Selected Areas of Science and Technology" which was held at Cornell University in May of 1973. The first paper deals with institutions and procedures for policy development for science and technology and hence can be thought of as concerned with process. The next three deal with the application of science and technology, and hence can be thought of as concerned with programs. As implied by this categorization, the symposium itself dealt in considerable measure with the interplay between process and program. The program areas to which the other three papers are addressed are: scientific and technical education and the role of the universities in development; natural resources and policies for their indentification, use, and conservation; reducing public investment costs in the construction industries. As all four of the papers make clear, there are no ready answers for the problems of any of these areas. In contrast to agriculture where there is a long record of international collaboration and a relative abundance of data, policy analysis and international collaboration in other fields have started relatively recently; data are scarce and difficult to obtain and there has

been little sustained systematic effort to identify and illuminate the complex issues involved.

On the other hand, progress in any one of the fields discussed offers opportunity for impressive savings on the part of the developing nations. For example, in most developing countries the construction industries absorb a large fraction of the gross national product and provide employment for from five to fifteen percent of the labor force. Technological improvements on even a modest scale, as discussed by Professor Moavenzadeh in his paper, could result in large savings of scarce resources and could create new employment opportunities in impressive numbers. The need for technological innovation and policy development for the construction sector and for effective implementation of these policies is a common problem for almost every developing nation.

A final introductory comment is that the Cornell Symposium and the discussion of these papers took place while the United States is rapidly expanding its scientific and technical relations with other countries. Since 1961, the U.S. has entered into nineteen bilateral agreements with other countries for general scientific and technological cooperation, and eight of these agreements were signed in 1972 alone. Evidently, the U.S. is giving added emphasis to increased collaboration on scientific and technical programs and policy development. It is equally significant that the developing nations increasingly seek to strengthen their application of science and technology and as part of this are interested in scientific and technical collaboration and policy analysis with the United States. The importance of the papers of this volume is that they address specifically both the opportunities and problems which will be involved in expanded collaboration between these countries.

Science Policy and Programs of Foreign Technical Assistance

Science policy is a short cut phrase for an activity which, broadly defined, is concerned with guiding efforts in science and technology toward the definition and achievement of national goals. In his paper, "Science Policy as an Organizing Principle for Government Action," John Montgomery presents an important analysis of the role of science policy in development and especially of the specific decision processes and procedures which are required to produce effective programs. As Professor Montgomery sees it, the successful application of science and technology to the production and service functions of society involves three different kinds of effort: social decision making on the use of science and technology; establishment of appropriate linkages to carry out the resulting programs; development of broadened perceptions of the opportunities which the new technologies offer. Three orders of decision making are involved. The first concerns the choice of appropriate technologies; the second order concerns the selection of implementing agencies for bringing the technology into being; the third involves the implementing decisions. For these three orders of decisions to be wisely made and effectively implemented requires a complex set of linkages (flows of information and resources) among the several groups concerned. There must be both horizontal linkages, as for example among different ministries of a central government, and vertical linkages, e.g.

ministries and from them to the final consumers. Finally, a variety of international linkages will usually be involved.

Professor Montgomery illustrates these different orders of decision and different kinds of linkages by a number of illuminating case studies in which particular problems of developing nations are analyzed.

An important aspect of the Montgomery analysis is to set reasonable bounds on what is actually to be included under the rubric, science policy. As he points out, if science policy is to be effective, it must be sufficiently focussed as not simply to be an "everything policy". The specificity which Montgomery builds into the topic of science policy, with its explicit orders of decision and linkages is, among other things, important in offering to developing nations a "checklist" with which they can analyze their individual procedures for development and implementation of policies for science and technology.

The Montgomery paper itself addresses these questions by presenting extensive analyses of the available data on science policy agencies in developing countries, and of the kinds of problems to which they have addressed themselves. Some of these analyses will inescapably be out of date since the literature from which they are made is for 1968 and science policy is an area in which recent developments have been very rapid. But in spite of this drawback, the Montgomery analysis will again lend specificity and substance to the efforts of individual countries to analyze their programs in a detailed way. The general aim is, in Professor Montgomery's words, "to perceive which problems and tradeoffs are appropriate concerns of science policy". This perception, however, is likely to differ considerably from one country to another, and the great virtue of Professor Montgomery's explicit categorization is that it permits the kind of detailed and local analysis which is clearly required if the policies and programs are to be effective.

Although there was general acceptance by the symposium group of the essential points of the Montgomery analysis, there were one or two interesting reservations. One of the participants from a developing nation commented that, useful as it is to have an explicit analytical procedure for the consideration of decision making and implementation, in the real world the more critical problem is often the establishment of national priorities indicating the areas where science and technology should first be applied. A second comment, which of course applies very generally to the development of new programs, was that the substantial program development which this sort of analysis implied offers danger of impacting upon deeply held social and intellectual values and traditions within a developing society. A final reservation, again from one of the participants of a developing nation, was that an important limitation on the rate of application of science and technology is the availability of trained manpower to develop policies and to implement them. This remark serves as a useful transition to the second paper of this volume which deals directly with the problems of manpower and training.

Scientific and Technological Manpower for Development

The paper by Efraim Otero, Director of Colombia's Fund for Scientific Research (COLCIENCIAS), provides illustrations of how one nation has developed policies for the enhancement of its scientific and technological manpower for development and of the problems as well as the successes which have been encountered in the implementation of these policies. Most of the activities on which Dr. Otero reports are recent, since in his words, "The concept of science and technology as a key to development is relatively new in Colombia."

Apparently, much of the impetus for new programs in Colombia came from a Colombia-U.S. workshop on science policy planning which occurred in 1968 and which led to the creation of both COLCIENCIAS and the National Council of Science and Technology. Program development for the institutions of higher learning in Colombia has been shared by COLCIENCIAS and another relatively new governmental agency, the Colombian Institute for the Development of Higher Education (ICFES). As a result of efforts of these two agencies and of the Ministry for Education, there has been very considerable change in the curriculum for science and engineering education in Colombia. Enrollment in these fields has increased steadily, until now, if registration at the national university of Colombia can be taken as typical, over 50% of university enrollment is in science, engineering and farm sciences.

These same agencies, with assistance from the U.S. National Academy of Sciences, have been making studies directed toward revitalizing the graduate education programs of the Colombian universities and it is interesting that the first conclusion of the joint review panel is that "graduate programs in Colombia must be closely correlated with the stated national priorities for social and economic development." A later and more general recommendation from these studies was "to improve cooperation among industries, the universities, and the Colombian Government."

After having described the considerable changes which have occurred in Colombian higher education, the Otero paper goes on to discuss specific programs in the universities which are oriented toward development. At the faculty and research level, there appear to have been established a number of special "institute" groups which are dedicated to the study of the technological, social, scientific and economic components of development. When one turns to formal academic programs directed toward the study of the development process or of the impact of science and technology, new programs are underway but progress has been somewhat slower. One significant new effort is a semester-long pair of seminars given to students of engineering and economics at the University of the Andes in Bogota on Problems of Technological Development.

COLCIENCIAS is persuaded that programs of this sort must be much more widely utilized in Colombian universities and is trying in several ways to promote them. One of the newest of these efforts, sponsored by COLCIENCIAS and ICFES, is a program called Government-University-Industry, which will try to bring into the universities representatives of the government along with members of the principal industrial and commercial associations

of Colombia. This is viewed as a particularly important effort, since it seems likely that, in the near future, Colombian industries will be given tax exemption if they can demonstrate that they are dedicating 10% or more of their gross earnings to scientific and technological research. Even apart from this aspect, a joint participation from government and industry in university-based programs would constitute a major innovative step for Colombian higher education.

In the development and promulgation of these new programs, Dr. Otero sees important benefits from collaborative efforts between U.S. universities and Colombian agencies. In some measure, this is a tribute to the activities of the U.S. National Academy of Sciences in aiding in the analysis of Colombian needs and opportunities in higher education. However, Otero sees possible collaborative activities going beyond the NAS including, for example, the development of fellowships for the training of Colombian university professors in various aspects of science, technology and development. A particularly interesting possibility is that this be done in an exchange mode which would permit a Colombian professor to go to the U.S. and a U.S. professor to visit Colombia and gain direct insight into problems of development. Otero also envisages a useful role for U.S. companies which have Colombian subsidiaries in which these might utilize the university groups for research programs of industrial interest.

Underlying most of the points which Dr. Otero makes about Colombian education is the strong implicit belief that it is not enough for universities in a developing nation simply to train scientists and engineers. They must, in addition, orient their programs toward a clearer recognition of national needs and toward the ways in which scientists and engineers can contribute to the solution of important national problems. In the informal discussion which followed the presentation of Dr. Otero's paper, it was evident that this view of the role of universities in developing nations was very widely shared.

Policy Development for Conservation and Use of Natural Resources

Much of the importance of the paper by Leonard Berry on "Natural Resources, Development and International Aid" stems from his emphasis on the necessity of taking a broad, systems view of the utilization and conservation of natural resources. The principal resources on which Professor Berry focuses are: mineral resources, forest resources, and water resources, i.e. he effectively excludes from consideration resources of tillable land and oceanic resources. In another and perhaps more important sense however, Professor Berry greatly broadens the discussion, as compared with more conventional approaches, by putting his main emphasis on how the development of natural resources may be used as a component or a lever in overall regional development. Thus, in analyzing the coming new projects in Indonesia for exploitation of metallic minerals, Berry points out that the agreements for exploration and exploitation which have already been signed call for expenditures of well over $1 billion. This is more than the total U.S. AID program to Indonesia for the fifteen year period 1946-1969. The problem then is, how to maximize the utilization of these large investments in assisting regional Indonesian development. Clearly, if significant progress is to be made in such an endeavor, virtually all of the orders of decision

and kinds of linkages discussed by Professor Montgomery will need to be invoked. There will need to be explicit policy consideration of what kind of technologies are to be utilized in minerals development. There will need to be consideration of what agencies are involved and what kinds of linkages required. Nor is this all. Professor Berry understandably gives considerable emphasis to the importance of utilizing the exploitation of these resources to assist in local development. For a dispersed island country like Indonesia, this means that regional policy development and regional linkage formation may, in the end, turn out to be even more important than that done at the level of the central government.

As Professor Berry sees it, the role of the developed nation in furthering this kind of progress is at least as much to be found in policy development as it is in the more conventional economic planning. He notes, in a second example, that for many of the developing nations in the tropics, the development of forest resources offers major potential. The need, however, is to go beyond simple exploitive development and attempt to integrate forest harvesting with the regional needs of the countries. In commenting on the role of the developed nations in this effort, Professor Berry comments, "The [forest resources] sector needs to be revitalized through thoughtful and long-range planning, backed up by a range of biological, operational and industrial research, which needs to take place in close coordination between developed and developing countries."

A somewhat curious interplay of sophisticated technical competence and local regional analysis is required for many of these natural resource projects, if they are to produce maximum returns to national development. In Professor Berry's words, "The use of ERTS (Earth Resources Technology Satellite) or other remote sensing techniques will allow a very few highly trained local personnel to play a leading part in controlling resource identification while at the same time the development of simpler techniques for field analysis of particular environments will again allow local people to play a fuller part." The conclusion is that what is likely to be required for these kinds of natural resources is a two tier approach, involving sophisticated central analyses in parallel with more "down to earth" local application efforts, not dissimilar to those that have been proposed and put into practice for various aspects of agricultural and industrial development.

Virtually all of the specific examples which Professor Berry uses to illustrate his theses relate to the importance of taking a systems approach to the exploitation and conservation of natural resources. He gives illustrations of failure, as for example a water resources program in the Sudan where a program consisting only of developing new water holes has led to serious overgrazing and resource degradation. He points in contrast to an integrated approach to development of a remote African valley in which new agriculture, marketing, and the public health of the region have simultaneously been greatly enhanced. He says, "A coherent approach to natural resource development seems important for ecological and environmental reasons. It also seems vital for sustained economic and social development."

Public and Technological Innovation for the Construction Industries

Historically, in developed countries as well as in less developed countries, the acquisition and use of appropriate technologies has been peculiarly difficult for that important segment of national life which is often categorized under the rubric Public Service Sector. This sector includes such vital components as construction, transportation, housing, postal service, communications and harbor development. Since in most countries these public sector activities operate with extensive government regulation and often with government management and control, one might expect that introduction of appropriate technologies and integration of efforts in these fields with regional development should be particularly easy. Historically, however, this has not usually been true.

The fourth paper of this volume by Fred Moavenzadeh, entitled "Transfer and Adaptation of Technology in the Construction Industry" discusses some of the problems and difficulties for one of the major components of public sector activities. As he notes, the construction industry plays not only a critical, but a highly visible role in the process of development. Its output utilizes a large fraction of the gross domestic product of the typical developing nation, and typically the construction industry employs in the order of 10% of the labor force. Finally, the government itself is often the largest client of the construction industry. When one further notes that the government also plays a central role in the regulation of the construction industry, it would seem particularly straightforward here to develop and implement policies for the appropriate use of science and technology.

Typically, a developing nation is characterized by a shortage of capital, an abundance of unskilled labor, and by severe restrictions on the market base. All of these will directly influence the construction industry. Part of the problem lies in the many-tiered character of this industry, which traditionally has three rather different sectors: the client sector, including investors, planners and developers; the design sector, including architects and engineers; and the contract sector, including suppliers, contractors, and labor organizations. Many of the problems result from independent, sequential actions taken by these various groups, each concerned with its own part of the total process.

Government leverage on the construction industry could be very great since it is usually not only a major client, but it is also a regulator, a supplier of material, and very frequently a direct participant. Add the fact that the construction industry is highly labor intensive, and is characteristically flexible in its use of technology, and one would expect considerable government attention to policy development for the industry and to the selection of appropriate technologies. In practice, the government's role in guiding industry appears often to be minimal. Part of the problem is the considerable fragmentation of the industry. Part of it is that, more often than not, construction is simply not recognized as an area of technological flexibility. (This lack of recognition of possible flexibility is not, of course, confined to the construction industry, but it is probably more pervasive here than in many other, more obviously technological industries.)

Implicit in Professor Moavenzadeh's analysis is the potential utility of a two-tier approach in this sector also. As he notes, computers and other sophisticated procedures offer great promise to increase the local design and planning capabilities. Equally, however, it is important to give great emphasis to the local conditions and to selection of labor intensive technologies when these are cost effective, as they very often will be.

From the standpoint of the symposium discussions, this important area seemed to be one where helpful analysis could be made in terms of Professor Montgomery's orders of decisions and types of linkage. Thus, Professor Moavenzadeh noted an important linkage which is often seriously weakened by explicit government policy. The example is that of public bidding on construction projects which had previously been designed by architect-engineering firms. By insisting on public bidding for the final construction (often for obvious and persuasive reasons) there is a serious weakening of the interplay which ought optimally to occur between designer and builder. Better coordination, utilizing the indicated linkages as advocated by Professor Montgomery, should make it possible to revise the public bidding procedures to provide the essential interplay between design, construction and maintenance.

Concluding Remarks

The papers of this volume were initially prepared as part of a program to assist United States Government agencies in evaluating current bilateral aid strategies and programs for development in selected areas of science and technology. From the discussions that took place at the Cornell Symposium it appears that the papers may have been genuinely helpful in this regard and may ultimately be reflected in future action programs of the United States Government in this area.

Continued and explicit interplay between the analytic approach as outlined by Professor Montgomery and the specifics of significant programs as illustrated by the other papers should have wide application. Furthermore, the contributions to the discussions by several experts from developing nations helped greatly in forming a conviction that the topics under consideration were not merely attractive to U.S. workers, but had great potential significance to the developing nations who, after all, are the clients of central interest. Finally, the program material presented was of sufficient diversity and detail as to point directly to a number of areas where further study was needed, or where new programs offered real promise.

Some of the needed further study will, of course, be done by groups within the developing nations, either alone or in collaboration with people from other nations and international agencies. They will, for example, work to apply the broad principles of decision-making and linkages, as elucidated by Professor Montgomery, to their particular institutions and problems. The analyses by Professors Berry and Moavenzadeh should be helpful, not only in addressing the problem areas of natural resources and construction treated directly in their papers, but to a broad spectrum of related areas.

The essential challenge is to apply science and technology to

development in the most effective way possible, with continuing consideration to the occasionally conflicting demands of short-range and long-range success. What is needed are thoughtful policies, consistent with national goals and well integrated into the ongoing economic and social planning efforts. The overall problem is a big one, and if the Cornell symposium and the papers of this volume contribute even modestly to an increased understanding of how best to use science and technology, the symposium participants can feel justified in their efforts.

SCIENCE POLICY AS AN ORGANIZING PRINCIPLE FOR GOVERNMENT ACTION

by

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Abstract

Analysis of decision-making in developing countries shows that science policy-making bodies participate significantly in choosing among alternative systems for producing goods and services, but much less frequently in comparing and choosing the channels of innovation, and only rarely in solving problems at the client or user level. Since all three choices may affect systems design, this functional limitation probably reduces the potential contribution of science and technology to development. Further analysis of the links between these policy-making bodies and the developers, users, and clients of science and technology shows that international ties seem to take precedence over domestic linkages; that these bodies are only weakly connected with inter-ministerial and inter-sectoral programing; that the private sector is not well represented in science policy-making functions; and that science policy bodies are on the whole more concerned with science itself than with its applications. These findings suggest that international assistance should investigate ways of linking existing scientific capacities to development goals, and of helping less developed countries identify gaps and assess priorities in their support to science and technology.

Science policy involves as much what governments do about "science" as how they use science to accomplish other goals. These goals are widely scattered. Legitimate science policy goals can be mutually incompatible: development, military security, national prestige, political appeasement of influential local scientists, and responses to international pressures, for example. Some science goals can be considered as ends in themselves, self-justifying in whatever amounts governments are willing to assign to them. Indeed, because of these incompatibilities, Science Policy is sometimes taken to mean Everything Policy -- and therefore no policy at all.

This paper assumes the major purpose to be development, that is, the introduction of science and technology (S & T) into the production and service functions of society in order to improve living standards. The fact that science policy also serves other objectives will presumably introduce changes in the structures, priorities, and relationships suggested in this model. It is only realistic to assume that in most countries science policies are pluralistic. It is also likely that some socialist or centrally planned economies have certain structural relationships that are so different from those appropriate to market-oriented and decentralized economies that they would call for significantly different approaches from those proposed here. The question this paper will address is what we have to know to help other governments organize their efforts to introduce science and technology at the points in their own societies where they can most effectively contribute to development and other major goals.

Science can become a major component of public action. There are no significant elements in the process of modernization that are not largely the product or by-product of science and technology. Sex and motherhood; health and the food we eat; what we must learn and how we learn it; our philosophy of truth and understanding of the universe: all are demonstrably different from their equivalents a few generations ago because of knowledge we have acquired and applied in the intervening years.

How then can "Everything Policy" be focused so that governments can introduce science and technology at the crucial points in the circle of development?

One approach to the problem is to examine the reasons why systematic knowledge is not being successfully applied to important human problems. Apart from the political problems of adverse interests and conflicting values, there appear to be three reasons for the shortfalls:

(1) Social decisions involving science and technology are not consciously made at all or are made incorrectly;
(2) The knowledge and resources necessary to carry out these decisions do not reach the institutions and individuals involved;
(3) The publics or potential clients of technological innovation do not respond favorably to the opportunity to change.

These three elements -- decision-making, linkage establishing, and opportunity generation -- constitute the essential components of a science policy addressed to problems like development.

I. Institutional Inventories

Governmental efforts to support, coordinate, and stimulate the generation and application of systematic knowledge in the service of developmental objectives involve an enormous range of functions: planning human resource (manpower) development to provide a nation with its needs for scientists and technicians; allocating public resources (especially funds, political attention and encouragement, and administrative and technical support) for research and education; establishing criteria for judging the actual and probable effects of technological change on national well-being; applying such criteria to technological systems by developing means for performance assessment, analysis of by-products, examination of distributive effects, and prediction; assessing, encouraging, and coordinating the efforts of scientists and technicians in the national government and throughout the public sector to improve their capacity to serve the nation's well-being; and developing incentives (and penalties) for the application of scientific knowledge in the private sector in accordance with national goals.

No country has a single agency responsible for such a wide range of policy. Indeed, some of these functions are not systematically performed at all, even in technologically advanced countries. But all of them are potential subjects for public consideration at some time. All become increasingly important issues of "science policy" as technology becomes more prominent as a source of change.

Thanks to the recent upsurge of interest in science and technology, there is no shortage of policy-making bodies concerned with science and technology, but their activities tend to cover only a small portion of the total range of science policies. UNESCO[1] lists 174 science policy agencies in Latin America and Asia, of which 59 deal with science and 27 with technology generally, and 88 work in specialized fields (See Appendix I). The budgetary and staff resources at the disposition of these bodies suggest different priorities among them that are difficult to explain except as accidents of history and politics. In Asia they have decided to devote much more effort to "technologies" than to the "sciences," while in Latin America the reverse is true. In Asia atomic technologies absorb many times more funds than agriculture, while in Latin America the proportion is reversed. This "distortion," if that is what it is, may be partly explained by the heavy expenditures in India, Pakistan, and Israel, all of which give military needs a high priority. But why are Cuban planners able to devote more resources to sugar cane than all of Asia together uses to improve its combined technologies of water and flood control, irrigation, drainage, and public works? How carefully are these needs and priorities assessed? How much S & T investment occurs without reference to these supposed policy-making bodies at all? How do decision makers gain access to the information necessary to determine where science and technology can make the greatest contributions to national purposes? Since we have no formula for defining the perfect allocation of resources to science and technology, we are forced to concentrate on the process by which these decisions are made.

Even this task is not easy. Few countries have thought it necessary to develop a coherent "policy about policies." Most governments have no easy way of knowing what policies now exist, where they are made, what major activities occur without reference to policy guidance at all and which areas of policymaking and activity are in greatest need of further development and guidance. There is not even a consensus on how to define an analytical structure in terms of which these functions can be assessed. That is why we shall begin by examining the kinds of decisions involving S & T which countries have to make about development.

II. The Three "Orders of Decision"

Three orders of decisions are involved when S & T are applied to developmental and other social purposes. The first order is the choice of appropriate technologies to serve immediate purposes with the least undesirable side effects. Among the science policy-making bodies listed by UNESCO, 84% participate in such decisions.[2] The second order is the choice of the implementing agency which is to be responsible for introducing science and technology in the production of goods, the rendering of basic services, and the performance of other social functions. These decisions are not often conceived as "science policies," but 64% of the bodies listed in the UNESCO survey participate in them. The third involves the implementing decisions: the assignment of specific administrative tasks, the fixing of adequate routines, and the stimulating and mobilizing of affirmative public responses to the opportunities for development. These issues are rarely mentioned in the literature on science policy, but 28% of the UNESCO-listed bodies accept some responsibility for them.[3]

Theoretically, each of these three orders of decision can be made rationally by comparing alternative systems for accomplishing desired goals. Thus a first-order decision might involve, in the educational sector, choosing between the introduction of instructional television, the expansion of organized schools, or the use of semi-professional community-dominated school systems as means of providing essential services. In the health sector, such choices may involve comparisons between hospital construction, expansion of public health services, large-scale disease control ventures, and updating of the practice of folk medicine as the means to achieve certain standards of public health. In industry, these choices usually involve analyzing the capital intensiveness of productive technologies, or the trade-offs resulting from the substitution among the factors of production, or some alternative sitings of an industrial development. In agriculture, the choices may involve the comparative advantages of introducing small-scale machinery versus using large, costly cultivating equipment, or using chemical weed control systems rather than intensive labor. Theoretically, these choices can be made by estimating the probable outcomes of each system and comparing them with assigned objectives.[4]

The second-order of decisions may well be as important as the first so far as obtaining results is concerned. Assigning new functions for implementing science policy involves making comparisons among public agencies which usually have unclear lines of jurisdiction and fierce jealousies in such matters (for example, a ministry of agriculture and a ministry of public works). It may also touch upon the comparative utility of private and public enterprises, or of introducing national entrepreneurial ventures as compared with multinational corporations. Choices between farmers' associations and private middlemen as suppliers of agricultural inputs are also second-order decisions. The "efficiency," "adequacy," "equity," and "stability" of programs of technological change depend heavily upon second-order decisions. Food enrichment programs often fail because they are assigned to the wrong agencies. If the first-order decisions are "systems" choices, those of the second order define the "channels" of innovation.

Third-order choices deal with "delivery" problems at the client or user level, and include the introduction of adoption incentives and risk coverage, the use of various forms of popular participation, and choices of organizational style. They are strongly affected by organizational behavior, including the division of responsibility among various levels and individual members of the civil service, the use of reporting and evaluation systems, incentive programs, and the training and motivating of agents of change. For the sake of convenience, these may be loosely described as "motivating" decisions.

It is fair to say that, difficult as first and second order decisions are, those of the third order are still more elusive. But for many developmental purposes, they are crucial. Because of its internal reward system, for example, Malaysia's Rubber Research Institute has contributed to enormous increases in productivity in that country. A contrary example is India's nutrition research establishment, whose efforts are said to have had only minor influence on that country's legendary malnutrition problems because the problem of motivation has been neglected.[5]

Many, though not all, technologies are ineffective until they become the basis of mass changes in behavior (factory discipline, improved agricultural practices, substitution of protein-enriched food for excess starches and carbohydrates, and the use of written instructions, for example). Governments' efforts to induce such behavior range from coercion and regulatory practices to various policies designed to produce incentives to change. Their freedom to choose among these options, and the inherent capacity of proposed innovations to elicit enthusiastic popular response, are both affected by scientific and technological considerations.

Part of the difficulty in making third-order choices rationally comes from failure to recognize the nature of the responsive behavior the public is expected to engage in if a program is to succeed. Once the public is seen as an active partner in the process of change, many of the intermediate relationships between plans and achievements are clarified. There is no generally accepted basis for classifying these responses, but I have found it helpful to identify three modes of modernizing behavior that can be influenced by S & T policy. The first kind of public response necessary to successful large-scale innovation is the acceptance of new standards (working hours or planting and fertilizing seasons, for example). Next follows the active investment of private resources (including labor) in new capital equipment, supplies, or consumer goods. And finally, since the benefits of innovation are rarely distributed equally, the public must also be willing to accept (and therefore be provided with) appropriate civic processes for mediating interest conflicts caused by technological change. If S & T policies can create favorable pre-conditions to these three modes of behavior (standard acceptance, investment, and conflict resolution), they will make a major contribution to the achievement of developmental goals. Failure to consider these issues will limit the effectiveness of new technologies regardless of the theoretical elegance of their design, delivery, and performance in the laboratory.

Most, though not all, of these pre-conditions are related to third-order decisions, though occasionally they cannot be satisfied without changing technological systems or channels of delivery. This conclusion should not be surprising. For generations industrial technologies have been shaped to a degree by consumer preference, and even high-technology companies have failed when they have ignored it. Production processes have been designed to accommodate the existing skills and attitudes of the labor force as well as of the engineering and marketing divisions. Such considerations may not often be decisive in the imperfect markets of the West, and they have rarely been introduced in non-industrial sectors at all. As societies become more policiticized and public services become increasingly central to the popular expectations of development, however, science policy makers will have to give more attention to these micro-level, third-order considerations.

Many decisions in all three categories are made as a matter of course without the rational comparisons suggested here. Ideology, tradition, and old-fashioned bureaucratic politics explain many developmental decisions, and indifference, neglect, and ignorance as many more. But relationalities are emerging in these decisions, especially in the field of industrial management; and development planners are discovering ways of making all three

choices systematically. Some countries with a firm commitment to development and with concentrated decision-making authority are beginning to make very effective use of such rational models.

These three orders of decision are not, of course, made by separate bodies designated to perform that role. Often such decisions emerge from bodies that have no official status; even more frequently they are ignored by policy-makers and made without access to scientific research at all. Only rarely is the scientific community prepared as a matter of routine to consider how to deal in advance with, say, the probable side effects of proposed large-scale irrigation dams or ground-water developments (first order decision); the effects on different linguistic and ethnic groups of new nation-wide systems for teaching by TV and satellite (first order); the applicability of steel processing techniques to small-scale producers (first order); the exchange of research findings between agricultural field stations and commercial manufacturers (second order); cooperation between university laboratories and industrial R and D sections (second order); licensing agreements permitting foreign enterprises to introduce new technologies (second order); the rural siting of village and artisan industries (second order); arranging incentives and subsidies for new designs and materials in low-cost housing developments (third order); encouraging individual entrepreneurs to invest in short-haul travel and transport facilities (third order); or packaging new pest and weed control technologies so small farmers can use them (third order). All of these decisions carry implications for the generation and use of science and technology for developmental purposes, but because they are made by operating units in the public or private sector, they are not often integrated with the larger context of science policy and therefore they proceed without reference to parallel decisions made in other sectors. In these cases there is often no organized way for the decision-makers to gain access to the existing knowledge, or to commission the needed research, to introduce modern technology into their operations.

The potential interrelationships among decisions like these is a matter of crucial importance in developmental planning. Often enough these decisions bring official involvement only after the interaction among them (the "careless technology") has produced a political crisis. One fundamental objective of science policy-makers, therefore, should be to organize their efforts so that technological planning, allocating, and monitoring facilities can anticipate such crises and optimize the interacting social consequences of the changes being promoted by government action.

III. Developmental Linkages Involving S & T

Organizationally, these decisions depend upon the relationships or "linkages" (flows of information and resources) among actors performing the various functions of developing and introducing science and technology. These linkages occur at six points of contact: (1) between public and private agencies; (2) horizontally between or among ministries at the same level of authority; (3) vertically within ministries, reaching from the centers of innovation to the final consumers; (4) among private parties using science and technology for their own developmental purposes; (5) between

the government and appropriate official regional or international centers; and (6) in international exchanges of technologies from commercial sources and bilateral aid agencies. Each of these sets of relationships occupies a distinct niche in the complex of science and technology activity, calling for a different government role and therefore conveying unique organizational implications for government action.

1. Public-private linkages (Sample problem: developing and exploiting a new satellite communications system). This relationship is especially important because of its integrating function between government and other initiatives. Governments can rarely provide all the capital and managerial-entrepreneurial resources required to achieve developmental goals. Moreover, they must be prepared to discourage socially harmful investments from the private sector (such as importing inappropriate capital-intensive technologies or equipment, siting production and service facilities unfavorably, and introducing ecologically harmful processes). The industrial and agricultural sectors are most affected by these relationships.

Science policies affecting these linkages are concerned mostly with first and second order decision-making, though sometimes it is necessary to change incentives (third-order decisions) in order to encourage or discourage specified activities. The devices available for organizing and coordinating these relationships require massive but infrequently recurring efforts. They include the practice of inviting industrial and agricultural associations, both private and voluntary, to participate in deliberative committees and advisory councils. They also involve procedures for coordinating the judgment of many different public agencies affected by the public-private linkages, notably the ministries of economic planning, finance, commerce and industry, and agriculture, as well as the national development banks.

There is usually no need for consistency among these different sectors in establishing public-to-private links, but there are some advantages to examining these extensive but casual relationships carefully in order to discover and coordinate elements of common concern. For this purpose, interministerial councils can be used on occasion. Where technical information is an important ingredient, a permanent staff needs to be supplied so as to permit continuity of contact and to provide a sufficient degree of professional competence. Often this staff is provided by the economic planning agency.

> Examples of public-private linkages: Argentina's National Council for Scientific and Technological Research, which operates under the President, is financed under the national budget augmented by grants and contracts from other sources. It has 9 advisory commissions and 9 regional commissions. It is supposed to coordinate both public and private efforts in the fields with which it is concerned.
>
> In India the Planning Commission has a Scientific Research Section in its Resources Division to advise on budgetary allocations for research, including some private sector activity.

India's National Research Development Corporation is an autonomous government-financed agency that tries to stimulate the development of patents where the national interest is involved, whether originally produced under public or private sponsorship. The Council of Medical Research, another autonomous agency, works with private industry on special problems of industrial waste disposal, pollution, and drug standards.

China (Taiwan) has an Industrial Research Commission in the Ministry of Economic Affairs whose function is wholly advisory, with representation from public and private enterprises and government ministries. Its Joint Commission on Rural Reconstruction works in both the public and private sectors through its grant-making and technical advisory functions.

Countries like these, with long histories of scientific study and substantial pools of technical manpower, can take very different positions regarding the possibility of relying on private initiatives in S & T from those appropriate to countries like Ethiopia and Nigeria, which have natural resources and a cheap labor supply but limited scientific and managerial capacity. Although the latter group of countries may have the greater need to assess priorities, they have less choice among potential innovators and fewer linkages to monitor. Korea's Institute of Science and Technology illustrates that country's determined, sharply-focussed effort to mobilize available public and private knowledge-based resources for development. Its trustees represent academic and business elements as well as the Economic Planning Board, the Ministry of Commerce and Industry, and the Ministry of Science and Technology, as well as the American aid mission and an American contract advising group. The Philippines have also organized an array of panels supported by a permanent staff in the National Science Development Board, which in turn is linked through its governing body to the National Economic Council (which itself has cabinet rank and includes representatives from the executive and legislative branches of the government and from the private sector).

2. Interministerial relationships (Sample problem: developing multi-purpose dams and water control systems). The importance of this set of relationships is that it permits the different elements engaged in related programs to shape and reinforce their fragmented efforts. The central government's purposes in promoting these horizontal linkages are (1) to enlarge the narrow sectoral view of development that is taken by most agencies; (2) to examine linkages to local levels of government in order to reduce duplication and jealous refusals to cooperate; (3) to improve "intergovernmental relationships" affecting technological systems, and (4) to work out means for integrating the efforts of different central agencies to implement programs in the "field." These relationships involve all sectors of development, but especially those dealing with public services such as education, labor, and health, which are often affected by large-scale expenditures involving capital construction. They affect all three orders of decision, and therefore they require continuous cooperative exchanges and

strong leadership by the chief executive.

The organizational requirements for promoting such relationships call for frequent or continuous communications, beginning at the level of permanent secretaries or top civil servants of the ministries and agencies involved and continuing to field offices charged with local coordination. Since the issues involved are often regional, some of the coordinating activities, such as conferences, can be best performed outside the capital city. Participation by field offices and cooperating local government instruments helps to dramatize their commonalities of interests and function. Since independent agencies seldom possess the incentive or capacity to coordinate their efforts with those of other units, and since central offices tend to prefer hierarchical structures of decision-making, the initiative and staff services necessary to monitor these linkages have to come from the office of the chief executive.

Interministerial cooperation has occurred more effectively in the industrial and, recently, the agricultural sector than in health and education. One reason for this unequal development in horizontal linkages is the higher priority governments have assigned to "production" than to "service" goals. Another is the higher degree of professionalism that dominates the latter sectors. Still a third factor is the greater amenability of industry and agriculture to improvement through "conventional" scientific research; new approaches in education and public health systems seem to require controlled social experimentation rather than "laboratory" research. These disparities suggest the need for a fresh look at possible linkages among different agencies engaged in applying science and technology to their problems.

Examples of horizontal linkages: One of the most interesting and purposeful efforts to improve inter-sectoral science and technology linkages is Korea's decision to create a combined Science Park, with a Consultative Committee to work out joint and common projects among the Advanced Institute of Science, the Korean Development Institute, the Agency for Defense Development, and the Scientific and Technological Information Center.

India's Council of Scientific and Industrial Research operates 52 different institutions with combined staffs of over 8,000 professionals; its Council of Agricultural Research coordinates science policy and administers 40 major agricultural research establishments. There is also a Council of Medical Research engaged in coordinating and financing research under a 5-Year Health Plan, which operates 5 permanent laboratory and 7 research units. Argentina also has a National Institute of Agricultural Technology and one of Industrial Technology.

The Philippines coordinates the work of 10 agencies engaged in related research by having them report to the Department of Agriculture and National Resources; while other research and technology-using bodies are coordinated by the Department of Science and Industry.

3. Intrasectoral Activities (Sample problem: nationwide disease control, like the recent malaria eradication programs). These relationships focus on the implementation of development programs involving science and technology, by a single ministry or agency. The functions necessary for strengthening these vertical linkages include reporting, impact assessmant and evaluation, and maintaining a balance among professional and bureaucratic ventures so that the defined goals are constantly reinforced. The central government's role in fostering these relationships is to keep all ministries and agencies aware of their links to their field offices and to their citizen-clients, to maintain developmental criteria for the evaluation of administrative operations, to reduce bureaucratic isolation and the "capital city" complex, and to get better feed-back from central performance to ministerial and national planning units. Since all governmental agencies presumably have some responsibility for "follow-through," the organizational implications of these linkages are potentially vast. Not all agencies, of course, have equal responsibilities for "implementation" of technological changes or for directly encouraging positive citizen responses.

The organizational structure to enhance these linkages differs among ministries, but in nearly all cases the central concerns of the chief executives are to assure an upward flow of communications equal to the traditional downward flow of directives. Policy makers also need reporting systems that will focus on program impacts and citizen response. Planners are also concerned with encouraging and monitoring administrative and social experimentation and promoting continuous receptivity to innovative practices.

Development administrators often point out that the process of planning is more important than the plan itself, and that implementation is more important than either. In science policy that dictum means that standards have to be maintained in the conduct of research. Developing countries cannot accept that familiar excuse for shoddy research: "It's close enough for government work."

Implementation of programs in science and technology has to mean the actual use of new equipment or knowledge, or the following of new procedures. Knowledge about nutrition-enriching processes has led to legislation in Latin America going back more than thirty years, but laws requiring salt iodization and cereal enrichment are not uniformly enforced -- to say the least -- in most countries.[6] In this sense, the task of implementation means more than improving services and other administrative outputs. It requires continuing observation of changing practices on the part of technicians and other users of technological systems. Such observation can lead to new designs where the systems themselves are at fault, and to new supporting policies and procedures when the incentives and other inducements are inadequate. The science and technology ingredient in efforts to improve implementation in this sense is not a constant factor, but it is a vital one. Qualified scientists are needed to establish the standards and criteria by which to determine whether or not a new technology is "working."

It is easier to monitor the use of innovations in industry and

agriculture than in health and education, where the incentives to modernization are less obvious. But innovation in these service functions can be fully as important to less developed countries as in industry or even agriculture. Because existing Western technologies are so often untransferrable to these situations, adequate science policy is probably even more essential to innovative behavior in the service than in the production sectors.

Examples of vertical linkages: The National Science Council of China (Taiwan), which is responsible for grants and subsidies, evaluates institutional policies and performance as part of its routine project reviews. Argentina's National Institutes (Geology and Mines, Agricultural Technology, and Industrial Technology) all observe operations in their respective fields in order to improve performance. Atomic energy commissions everywhere are responsible for monitoring even minor details in operating procedures because of the risks involved. India's Council for Scientific and Industrial Research uses its grant-making process as the occasion for reviewing performance. Its Council of Agricultural Research is also involved in monitoring cultivation practices as well as research performance. Its Council of Medical Research also establishes standards for evaluating performance in such matters as the use of pollution technologies and the application of pharmaceutical standards. The Scientific Research Section, in the Resources Division of India's Planning Commission, is specifically responsible for following up on the implementation of the research plan. Grant-making on the basis of competitive applications and peer group review are among the most effective devices for monitoring intrasectoral linkages.

4. Relationships within the private sector (Sample problem: encouraging the use of intermediate and labor-intensive industrial technologies). This set of linkages is especially important in mixed economies, where the range of investing activity in the private sector often exceeds the government's entire developmental budget. The central role is therefore to act so as to maximize private initiatives, especially in cases involving numerous small firms whose combined efforts affect and multiply the impact of large corporations. An example is the collective impact of small-scale transportation ventures by families owning one or two buses or trucks, where technological improvements can make important contributions to the farm-to-market network. Another is the relationships among isolated middle men who provide supplies, credit, and technical advice to farmers and consumers. In the field of public health, a parallel example is the system of paramedical entrepreneurs whose services are a substitute for modern hospitals. The organizational implications of this set of relationships affect commerce, industry, agriculture, and health.

Most of the decisions involving these links are made at the center. They are of the second order, since they require government intervention to protect small-scale operators against monopolistic or monopsonistic "squeezes." These interventions are especially important when large-scale entrepreneurs use their position to advance technologies that are labor-displacing or to eliminate their less powerful competitors. Probably this

government function should not be located in a central ministry of industry or agriculture because such agencies tend to favor large client groups and professional associations to the disadvantage of small-scale operators. Special efforts may be required to supply R & D services to small-scale operators and entrepreneurs.

Examples: The Madras Leather Technology Institute in India has developed intermediate labor-intensive technologies to protest the economic viability of small-scale entrepreneurs. Sometimes government efforts at developing small-scale technologies fall below expectations because private institutions are not sufficiently well coordinated to permit government-sponsored laboratories to identify the most pressing needs. Small machine shops in Ludiana, for example, are said to be turning out better varieties of agricultural implements than those being developed at the University of the Punjab.

Essentially private societies like the Argentine Scientific Society or the Philippines' National Research Society conduct seminars to provide some technological links within the private sector. Professional associations of lawyers and physicians also provide for a flow of technological information to improve the performance of their members. Industrial research can be performed by jointly sponsored private labs such as Philippines' Textile Research Commission, the Forest Products Research and Industries Development Council, or the National Water and Air Pollution Control Commission. Israel's Research Council aids private industry by setting up study groups to examine research needs in the existing industrial complex and to evaluate the economic significance of developments in science and technology.[7] Malaysia's famous Rubber Research Institute is financed by private producers.

5. Linkages with Specialized International Agencies (Sample problem: the development and introduction of improved cereal crops). The importance of this set of technological linkages is that it gives small countries access to R & D capacities adjusted to special needs (employment, soils, disease and pest control, small-scale markets, cooperative trading arrangements, large-scale river and harbor resource development, for example) that cannot be efficiently served by their own resources, yet are not available through commercial channels or other convenient sources of technology. A government's role in cultivating these linkages is a subtle one, since it must contribute its own talent and other resources for the support of regional and international centers, while insuring that these resources are used more effectively for developmental needs than they would be if invested locally.

Most of these relationships are in the agricultural sector, with some links developing in public health and education. There are still relatively few official international links serving industrial exchanges of technology.

Since these links are receiving increasing attention from the scientific community, it might be useful to describe some of the special

problems they pose to policy makers. One difficulty in these relationships is that they tend to deteriorate into "foreign office problems," that is, to subject the regional donors to protocol pressures or exercises in the assertion of national dignity. Regional centers are experiencing difficulty in getting their promised funds on time and in sufficiently flexible form; while not all donors can keep themselves adequately informed about the centers' operations without imposing undue burdens on their management. Most of these links involve second-order decisions; international centers are increasingly trying to improve their "outreach" capacity (third-order decisions), but this effort involves linking their activities with those of local "cooperating institutions."

Examples of "specialized" linkages: Most government links to international bodies occur among professional groups or agencies: India's Council of Medical Research with WHO and UNICEF, Argentina's National Academy of Sciences, with UNESCO, Philippines' National Economic Council's Office of Aid Coordination with the UN, a committee under the Undersecretary of Commerce with ECAFE, and a national committee under the NEC chairman, to deal with UNIDO. Many agriculture ministries maintain links with important regional centers like the International Rice Research Institute (Philippines), the International Corn and Wheat Center (Mexico), the International Center for Tropical Agriculture (Colombia), the International Institute for Tropical Agriculture (Nigeria), the International Potato Center (Peru), and the International Research Institute for the Semi-Arid Tropics (India). Some countries try to coordinate their relations with several international agencies by centering several functional linkages in one council (India's Council of Scientific and Industrial Research relates to UNESCO, WHO, ECAFE, and ICSU, for example).

All of these links offer potential support to locally activated R & D needs, but in the absence of strong representations of the national requirements, the international community of scientists tends to encourage an "internal brain-drain" of the energies and resources of scientists in the less developed countries away from local problems toward more "interesting" research. Pakistan, for example, spent ten times as much on nuclear energy research (1962-67) as on all other applied research, and it assuaged the medical preferences of its specialists by operating a highly sophisticated modern heart clinic. Venezuela devoted 75% of its research resources to fundamental research, as opposed to 22% on applied fields and 4% for development, during a year (1963) when developed countries were allocating 10-20% or less to fundamental research.[8]

This is no forum for an attack on basic research, but distorting national research programs in order to retain the services of talented scientists is a poor trade-off for underdeveloped countries. The links between national and international research agencies must reinforce national priorities, not displace them. This outcome will not prevail unless the national planning institutions are sufficiently strong to identify long-term needs

and reinforce the careers of scientists and technologists qualified to advance them.

6. International commercial and bilateral links (Sample problem: dealing with technological enclaves created by multinational industrial corporations). The impact of these linkages on developmental goals depends heavily upon the "terms of trade" by which existing technologies are introduced. Currency, import, and price policies sometimes distort the rational value of foreign technologies to a country's developmental goals. Many less developed countries are beginning to force multinational corporations to renegotiate the conditions under which they are permitted to exploit natural resources. They are also re-evaluating the utility of the capital-intensive technologies being exported to labor-surplus countries. International banks and bilateral donors have tended to reinforce the conventional preference for labor-saving, large-scale technologies. Their role in designing and financing irrigation systems, industrial developments, and public works construction, has not been significantly different in this respect from that of the private multinational investors. Most international transfers of technology originating from public or private sources in the industrial world are based on the domestic needs of the donor (including, for example, the protection of their own small-scale producers or non-competitive shippers, as well as the search for profits and the desire to reduce production costs of goods reimported to their own countries). These preferences often reduce the value of proffered assistance and call for a greatly enhanced resort to critical technology assessments in the receiving country.

The basic role for governments in these situations is to "look the gift-horse in the mouth" by setting priorities defining their immediate technological needs, and by maneuvering their options so that donors' offers, like private ventures, can be adjusted to national plans and other major social purposes.

These linkages involve all sectors of development, primarily at the point of first and second-order decision-making. But they are rarely subjected to the disciplines of science policy analysis. Even when the negotiations involve bilateral donors or international banks, there is little opportunity for rational choice except of the "take-it-or-leave-it" variety.

Examples of sixth-level linkages: Many of the difficulties about international drain-offs of talent, described as a problem in the 5th group of linkages, also apply to unofficial relationships. Economic and science policy agencies rarely deal directly with private multi-national corporations, and bilateral donors work through the foreign office because of representational problems. In either case, the relations require access to the sets of public-private links and the inter-ministerial links described above. In India, the National Research Development Corporation is charged with keeping track of international patents and licenses, and while it has no policy formulating role, it is expected to protect the national interest in private technological exchanges. Argentina's National Institute of Geology and Mines performs the planning functions for inter-

national unofficial as well as internal private and public activities engaged in research and surveys. There appear to be no agencies providing general coordinating links with private international purveyors of science and technology in any country as yet although the Andean Pact group were considering creating such linkages (as of March, 1973).

IV. Findings

Science policy is obviously not just an administrative issue. Organization is not a substitute for policy. But experience reasserts the obvious fact that policies do not emerge as coherent, guiding influences on activity unless some body of responsible persons is devoting serious attention to the major issues and monitoring the impact of decisions and other administrative steps already undertaken.

The summary matrix presented in Appendix VII reemphasizes the fact that in both Asia and Latin America, science policy-making bodies are concerned with first-order decisions more than those of second-order, and far more than those of the third. International linkages among these bodies are more important in Latin America than domestic linkages are, and this distortion is even greater there than it is in Asia. Finally, in neither area do science policy bodies in the private sector display much concern for the third-order decisions that are essential to modernization. The modernizing role of private industry is displayed, of course, through the market and third-order activities take place through the advertising system. In some cases this system is the most important influence on mass decisions, and it is perhaps ominous that science now pays so little attention to these influences through its participation in policy-making.

Actual Distribution of Units in Asia and Latin America by Decision Order and Linkage Functions

		Decision Orders		
		I	II	III
Linkages	1	51/46	47/46	15/19
	2	25/18	23/16	13/10
	3	12/20	9/7	4/6
	4	6/17	4/19	3/4
	5	40/59	39/53	12/24
	6	21/47	22/39	6/18

Asia/Latin America
Source: See Appendixes IV and V. Percentages appear in Appendix VII

The classification scheme proposed here, delineating orders of decision and linkage sets, can also be used to compare the major administrative aspects of science policy-making and implementation in individual large complex development programs like the Mekong regional enterprise. In it are all three orders of decision making (designing water control and irrigation systems, assigning of operating responsibilities among new and existing agencies, and establishing uniform systems so that farmers can be

assured of timely access). It also incorporates all six sets of linkages (public and private developers have to work out ways of integrating their activities, ministries have to cooperate both horizontally with other ministries and vertically with local authorities, wholly private farmers suppliers and biomedical personnel, and both official and commercial international connections have to be maintained). Finally, public response is an extremely important condition of success (acceptance of water discipline, relocation of homes and farms, and use of administrative and judicial procedures for reconciling conflicting land claims). And all of these problems have already been the subject of conscious deliberation, staff studies, and scholarly research by the secretariat of the Mekong Project, national planners, and internationally-supplied natural and social scientists. Many decisions are being made regarding S & T components with no systematic attention going to their interrelationships and potential integration.

In spite of the limited attention these dimensions have received at the country level, it is possible to develop situation profiles from the existing data so that we can identify major weaknesses and problem areas. The analysis, drawn from the data presented in the appendices, calls attention to some striking phenomena:

(1) International linkages of S & T bodies in all countries surveyed, in both Latin America and Asia, are far more numerous than any single set of domestic linkages. The implication is that at present, science policy makers' attention is oriented more toward international than domestic communications.

(2) Linkages coordinating S & T activities across sectoral and ministerial lines (linkage set 2) do not exist at all in 12 of the 21 Latin American countries included in the UNESCO survey, or in 3 of 17 Asian countries. The implication is that developmental S & T may be excessively fragmented.

(3) S & T policy-making bodies do not recognize any responsibility for the implementation of development or other action programs in 7 of the Latin American and 19 of the Asian countries in the survey (third level linkages). Query: Are these scientists just communicating with each other?

(4) Third order decisions, involving conscious efforts to gain public acceptance of S & T innovations, are not recognized as a function of science policy-making bodies in 10 of the Latin American and 8 of the Asian countries surveyed. It is quite possible that innovation rates may be unnecessarily slow.

(5) There is no effort on the part of the private sector to participate in science policy-making on the national level in 12 Asian and 10 Latin American countries, judging from the activities reported in the UNESCO survey. Some Third World industry is probably being born obsolescent.

(6) In the definition of functions provided by the science

policy-making bodies themselves, responsibility for making first-order decisions were described about three times more often than for third-order decisions. The frequencies are as follows (some bodies perform several functions):

Decisions	Asia (70 bodies)	Latin America (83 bodies)
First-order	58	71
Second-order	52	47
Third-order	17	26

Query: are scientists excessively preoccupied with a macrocosmic view?

(7) There were 20 science policy-making bodies concerned with agriculture (including rubber and sugar cane research). But 19 countries had no such bodies. In 19 countries where agriculture was served by such agencies, 9 allotted them the largest resources used by S & T bodies, and 3 gave them second priority, so far as the budget is concerned.[9] But 6 placed these functions last or next to the bottom in their total expenditures.[10] In 2 countries, these bodies provided the only formal opportunities to apply S & T to third-order decisions, and in 2 the only third level (that is, vertical or implementing) linkages. Some countries are apparently neglecting S & T in their major economic activity.

(8) 16 countries have policy-making bodies in the biomedical sciences (leaving 23 that do not). Only 1 was given the largest budget among these national agencies, and ranked second (6 were at or next to the bottom among priorities.[11] Query: are public health policies in some countries being left to practicing physicians?

(9) 17 countries had "technology" policy-making bodies, primarily serving industrial research needs (24 did not). They were well financed: their budgets in 7 ranked first or second among such bodies (where there were more than 1) and only 1 ranked last. In all but one case, countries that were served by policy-making bodies in industrial technology also had similar services in the pure sciences. Query: is Third World industry relying too heavily on government for S & T?

(10) No fewer than 27 countries have policy-making bodies concerned with the sciences themselves -- far more than available in either agriculture or medicine, and 10 countries have 2 or more such organizations. On the other hand, 6 countries have agricultural bodies but none for sciences, and 3 have medical policy-making bodies but none for the pure sciences. Policy-making bodies in the sciences are not necessarily a prerequisite to such efforts in applied fields, evidently. Very few (9 out of 44) of these bodies were concerned with third-order decisions, but their linkages were well developed in all cases. Their budgets placed them first or second in priority in 9 countries, and last or next to last in only 8. Can it be truly said that scientists are not neglecting science, whatever they may be doing for society?

These ten findings convey some implications for action, both nationally or internationally. Unfortunately, however, the evidence on

which they are based in often inconclusive, and possibly inaccurately reported (the UNESCO survey was not conducted with these uses in mind). The issues of what functions, linkages, and priorities are appropriate to science policy-making bodies remain elusive. Nor should any responsible advisor proceed from the assumption that science and technology requirements in all countries are the same, or that the process of applying knowledge to development will follow the same sequence in all countries. But these findings do suggest the basis for some consensus on how to approach priorities and on what points intervention may be appropriate.

V. Implications

The present approach suggests certain changes of emphasis in the present strategies for international assistance in science and technology. For one thing, it focuses more on the processes of science policy-making than on the policies themselves, which reverses earlier priorities. This strategy would support the institution-building efforts of the National Academy of Sciences and other science advisory bodies, but it would move the functions of the institutions they advise closer to national developmental objectives than they now are. It would reduce the reliance on international criteria for assigning priorities in scientific research, and it would substitute new standards of scientific output (essentially those relating to the achievement of national goals) for those so often suggested by the international community of scientists. It would not so much challenge the internationalism of science as reassert the national purposes of governmental science policy-making. It would devote more international scientific effort to identifying "problems" and less to proposing "solutions" that in the end so often turn out to be unacceptable or unworkable. It would abandon the present sectoral narrowness that treats science and technology as a separate, distinct element in the development process.

In practical terms, this analysis suggests that international donors should begin to help governments inventory their own science policy resources and capacities. For this purpose, existing classification systems are not fully adequate. UNESCO has compiled lists of manpower and institutional resources by field of science, but the resulting survey does not suggest the basis on which a country can determine its own distinct needs and priorities. The more recent UN World Plan of Action (N.Y.: 1971) has succeeded in crossing conventional disciplinary lines in classifying four "functions" under which science policy-making actions can be grouped, but the categories used in that report apply almost exclusively to research and thus ignore the problems of relevance to developmental goals, successes and failures of implementation, and social consequences of scientific innovation. The four categories they use are planning, decision, and control; coordination, promotion and financing; research execution; science and technology, public services like mapping, documentation, and extension. The Plan offers some useful advice in each category (pp. 64-67), and the follow-up Plan for Latin America[12] proposes that S & T be aligned with economic plans. It is time to proceed to the next stage of relating S & T to the implementation of developmental and other goals.

The international community can assist countries in examining

the linkages between plan and action; indeed, it would be difficult to offer sound advice on implementing science policy without adequate information structured along lines something like the ones suggested here. Advisors should know what kinds of decisions are now being made affecting the development and use of technology. They should ascertain in detail how such decisions are linked to the various groups and individuals actually devising and executing programs and responding to them. Finally, they ought to consider what demands S & T innovators plan to make on citizens and clients so that they can help define the parameters of technological systems they are asked to develop.

Task forces engaged in such inventory-making should be international in most cases (including at least some host nationals as principal members). They should be interdisciplinary in all (including research scientists, science administrators, and professionals or practitioners in the one or two major fields under immediate scrutiny).

How should international participation take place? In the Point Four prehistory of technical cooperation, the conventional wisdom called for a career service of advisors, working in semi-permanent country missions, serving long tours of duty, and possessing specialized "area knowledge" to avoid errors caused by indiscriminate transfer of existing technologies.[13] These errors are no longer epidemic in foreign aid; few technical assistants now expect to encounter situations in which they can offer solutions directly based on Western experience. Substitutes for the long-term resident advisor are proving more suitable in the present environment of international technical cooperation: the experimental approach and the reliance on joint action.[14] Short-term recurrent visits by several consultants working with a standing group are more effective in most situations than reliance on a smaller group of resident technical experts.[15]

International conferences are also important, not only for establishing and strengthening external linkages, but also for developing intersectoral and interagency relations in the participating countries themselves. But in order to achieve maximum benefit from these linkages, the conferees ought to be chosen from private as well as public spheres and among different agencies and levels of government. Conferences proposing action are more effective if they acquire some means of following up their recommendations either in the form of successive meetings to consider problems of implementation or through other exchanges of visits and information. Published reports can help focus the efforts of conferees, but they are usually unread by non-participants, especially if they are not directed to decision-makers. Most less developed countries' decisions involving S & T tend to be fragmented largely because the existing lines of communication do not permit scientists to learn how plans are constructed, or planners to participate in budgetary processes. International conferences can help provide these linkages. Obviously some functional specialization in inescapable if expertise is to prevail in each of these activities; but busy bureaucrats often find it easier to become acquainted with the requirements of other specialists in an international context than when working out of their own offices. The conference is an important vehicle for many more purposes than it has served in the past.

Beyond providing expertise and communications links, international agencies are helping countries develop research capabilities and build productive facilities that can serve regional as well as national needs. These ventures are not proceeding very rapidly outside the agriculture sector, though it is obvious that economies of scale (including assembly of "critical masses" of scientists) apply to research and development in industry, education, and health as well. International assistance can provide important initiatives in these fields.

Regional cooperation can permit countries to perform technology assessment studies for first-order decisions, once their importance has been recognized. Countries committed to regional cooperation can also use such resources to determine their own comparative advantage for developing specialized services and to work out approaches to common problems such as manufacturing and distributing high-technology goods requiring large markets and favorable export and import policies, all of which involve second-order decisions that can be improved through international initiatives. Eventually countries may even be able to develop common approaches to multinational corporations and at least in some cases rationalize the exploitation of their own natural resources in the context of intra-regional competition.

Some of these issues are too sensitive to approach directly, especially given the present state of our knowledge. For many years the international community of economists and administrators has been considering problems like trade-offs between efficiency and employment generation, growth and income distribution, export-intensivity and import-intensivity, sub-regional depression and national development, and productivity and pollution. They have not found definitive answers to any of them, but they are beginning to develop criteria by which to structure decision-making in most of them.

The international community of scientists and technologists is now beginning to perceive which problems and trade-offs are appropriate concerns of science policy. This perception will be greatly enriched by a closer examination of the experiences of countries whose governments are seriously concerned with improving their capacity to use science and technology for developmental objectives. Nearly all of the decisions and functions described here can become heavily politicized, but the fact that they are sensitive in one situation does not mean that they are "off-limits" for rational analysis everywhere. Scientists have learned to live with taboo when they have to, to ignore it when they can, and to translate it to mean "caution" during periods of transition. Science policy still has its taboos, but at least some small part of them are the result of ignorance.

And ignorance is a remediable condition.

Footnotes

[1]World Directory of National Science Policy-Making Bodies, Vol. 2, Asia and Oceania (Brussels: UNESCO, 1968) and Vol. 3, Latin America (Brussels, UNESCO, 1968).

[2]See Appendices IV and V. These judgments are based on functional descriptions supplied to UNESCO by the bodies themselves. The author is indebted to his research assistant, Dan Levin, for coding and tabulating the UNESCO survey in the Appendices.

[3]These gross findings are intended to be suggestive only. The original UNESCO survey was gathered for purposes quite different from the present analysis. The descriptions of science policy-making bodies, prepared by the bodies themselves, were in some cases doubtless self-serving and inaccurate. They were not standarized. Coding and classification were difficult and sometimes arbitrary. The author would be grateful for corrections and comments; the data are presented in full in the Appendices to facilitate such communications.

[4]Of course, life is not so simple. See Charles E. Lindbloom, "The Science of Muddling Through," Public Administration Review, 19 (Spring, 1959). Many readers of this paper will already be familiar with the technology assessments performed by the National Academy of Engineering and the National Academy of Sciences and published by them.

[5]Robert Muscat, "Some suggested guidelines for approaching science and technology development" (Washington, D. C.: processed, 1971).

[6]Pan American Health Organization, Guidelines for Food Fortification in Latin America and the Caribbean (Washington, 1972), Ch. IV.

[7]Eliezer Tal and Garon Ezrahi, Science Policy and Development, The Case of Israel (New York: Gordon & Breach, 1972).

[8]Graham Jones, Role of Science and Technology in Developing Countries (London: Oxford Univ. Press, 1971) pp. 42-49.

[9]Only countries served by more than one science policy-making body were counted in this comparison.

[10]Only countries with more than 2 such bodies were included.

[11]See the footnotes to paragraph 7.

[12]Not yet published.

[13]See Harlan Cleveland, The Overseas Americans (N.Y.: McGraw-Hill, 1960).

[14]Milton J. Esman and John D. Montgomery, "Systems Approaches to Technical Cooperation: The Role of Development Administration," Public Administration Review, Sept.-Oct., 1969.

[15]See Henry R. Glyde, Institutional Links in S & T (Ottawa: International Development Research Centre, n.d., 1970).

Table I

DISTRIBUTION OF DECISION ORDERS AND LINKAGES IN SCIENCE POLICY-MAKING BODIES

A. Asia

		Orders of Decision			
		I	II	III	Total
Linkages	1	14.4%	13.3	4.2	32.0%
	2	7.1	6.5	3.7	17.2
	3	3.4	2.6	1.4	7.3
	4	1.7	1.4	0.8	4.0
	5	11.3	11.0	3.4	25.7
	6	5.9	6.2	1.7	13.8
	Total	43.8%	41.0	15.2	n = 354

B. Latin America

		I	II	III	Total
Linkages	1	9.8%	9.8	4.1	23.7
	2	3.8	3.4	2.1	9.4
	3	4.3	1.5	1.3	7.0
	4	3.6	4.1	0.9	8.5
	5	12.6	11.3	5.1	29.1
	6	10.0	8.3	3.8	22.2
	Total	44.2%*	38.5	17.3	n = 468

Source: Data drawn from App. IV and V.

*Percentages of total number of decision orders and linkages coded.

C. Institutional Functions by Decision Orders and Linkages in Asia

		Orders of Decision		
		I	II	III
Linkages	1	73%*	67%	21%
	2	36	33	9
	3	17	13	7
	4	9	7	4
	5	57	56	17
	6	30	31	9

*Source as above. Percentages do not add to 100 because many bodies perform several functions.

D. Institutional Functions by Decision Orders and Linkages in Latin America

		Orders of Decision		
		I	II	III
Linkages	1	55%*	55%	23%
	2	22	19	12
	3	24	8	7
	4	20	23	5
	5	71	64	29
	6	57	47	22

*Source as above. Percentages do not add to 100 because many bodies perform several functions.

APPENDIX I

Number and Resources of Science Policy-Making Bodies in Asia and Latin America by Field

Field	Asia (18 countries)			Latin America (21 countries)			Total
	Number	Staff	Expend $million	Number	Staff	Expend $million	Number
1. General							
a. Sciences	30	6,387	36.073	26	7,540	12.980	56
b. Technology	19	9,075	53.809	8	814	3.000	27
c. Research Grants	3	49	12.751	0	--	--	3
d. Inter-University Activities	0	--	--	3	42	0	3
2. Specialized							
a. Agriculture	10	981	18.388	10	13,705	46.230	20
b. Atom	12	11,109	94.663	11	3,668	18.160	23
c. Geography, Geology Mining, Petroleum	0	--	--	13	2,564	10.140	13
d. Medicine, Public Health	9	2,304	5.826	12	1,269	3.156	21
e. Oceanography	1	20	.003	1	134	.614	2
f. Public Works, Irrigation, Drainage, Floods	2	26	.051	0	--	--	2
g. Rubber	1	1,021	.540	0	--	--	1
h. Space	1	90	.028	2	62	.763	3
i. Sugar Cane	0	--	--	1	775	1.380	1
TOTAL	88			87			175

Source: Compiled from UNESCO, World Directory of Science Policy-Making Bodies (Brussells), Vols. 2 and 3.

APPENDIX II

Budgets of Asian Science Policy-Making Bodies

LEGEND

I. The category code is as follows:

1. Agriculture
2. Atom
3. Medicine
4. Oceanography
5. Public Works
6. Research Grants
7. Rubber
8. Sciences
9. Space
10. Technology (Primarily Industrial)
11. Geography
12. Inter-University Activities
13. Sugar Cane

II. The letters under the NAME column are the initials of the institutions involved. (See App. VI)

III. The XPEND column is a listing of the budgets of the institutions in millions of US dollars. In the original data some of the institutions had fixed budgets and some had variable annual budgets. To normalize the data an average was taken for the variable budgets. The + after some of the figures indicates that the budgets were increasing and a - indicates that the budgets were decreasing. If a figure has no sign after it, this means that either the budget is a fixed annual appropriation or that, data for only one year was given.

APPENDIX II

Budgets of Asian Science Policy-Making Bodies

Country/ Name	Cate- gory	Staff	Xpend
BURMA			
ari	1	54	.208
bmri	3	136	.26
rpdb	8	35	0
ubari	10	256	.624
CEYLON			
cdaro	1	164	.613+
cmri	3	99	.49
cisir	10	84	.23 +
CHINA			
jcrr	1	183	.975-
aecey	2	15	.32
as	8	312	.30 +
nsd	8	91	1.43 +
irc/mea	10	15	
INDIA			
icar	1	32	15.85
aec/dae	2	8545	64.5 +
icmr	3	1333	3.10 +
ugc	6	15	12.6 +
nisi	8	45	.079+
csir	10	15485	13.55 +
INDONESIA			
naea	2	6	0
iis	8	249	0
IRAN			
ncar	1	336	0
tunc	2	140	.4 +
iphr	3	376	1.2
ISRAEL			
nuia	1	17	.287+
aec	2	917	13.6
iash	8	16	.202+
ncrd	10	86	2.156+
JAPAN			
jaec	2	202	.062+
cost	4	20	.003
cst	8,10	190	.017+
scj	8,10	287	.568+
sta	8,10	1905	48.99 +
nsac	9	30	.005

Country/ Name	Cate- gory	Staff	Xpend
KOREA			
mst	8,10	1060	0
nas	8	11	.015+
esc	8,10	9	.073+
niri	10	28	.196+
MALAYSIA			
imr	3	98	.8
mrfb	7	181	5.8
MONGOLIA			
asmpr	8	509	1.0 +
NEW ZEALAND			
nzaec	2	9	0
mcr	3	66	.30
ugc	6	34	.151+
nznrac	8	12	.008+
rsnz	8	116	.018+
dsir	8,10	1182	9.59 +
PAKISTAN			
arc	1	27	0
paec	2	862	15.05 +
pmrc	3	37	.055+
cwhr	5	4	.001
idfcrc	5	22	.05 +
nscp	8	15	.041+
pas	8	30	.01
pcsir	8,10	1207	4.01 +
strd	10	15	0
PHILIPPINES			
paec	2	165	.562-
mrfp	3	10	0
nrcp	8	604	.069-
nsdb	8	1269	.735-
SINGAPORE			
scs	8,10	21	.011
snas	8,10	15	0
THAILAND			
oaep	2	85	0
nrc	8	131	.546+
asrct	10	185	.425+
VIETNAM			
dar	1	167	.455+
aeo	2	163	.169
ncsr	8,10	8	0

APPENDIX III

Budgets of Latin American Science Policy-Making Bodies

LEGEND

I. The category code is as follows:

1. Agriculture
2. Atom
3. Medicine
4. Oceanography
5. Public Works
6. Research Grants
7. Rubber
8. Sciences
9. Space
10. Technology (Primarily industrial)
11. Geography
12. Inter-University Activities
13. Sugar Cane

II. The letters under the NAME column are the initials of the institutions involved. (See App. VI)

III. The XPEND column is a listing of the budgets of the institutions in millions of US dollars. In the original data some of the institutions had fixed budgets and some had variable annual budgets. To normalize the data an average was taken for the variable budgets. The + after some of the figures indicates that the budgets were increasing and a - indicates that the budgets were decreasing. If a figure has no sign after it, this means that either the budget is a fixed annual appropriation or that, data for only one year was given.

APPENDIX III

Budgets of Latin American Science Policy-Making Bodies

Country/ Name	Cate-gory	Staff	Xpend
ARGENTINA			
naavs	1	27	.009+
niat	1	4480	17.12 +
ncae	2	2396	8.29 +
nam	3	63	.212
mas	8	66	.019+
naepns	8	32	.034+
aaas	8	4	.028+
ncstr	8	93	1.72 +
ncsr	9	60	.023
ass	8	20	.079+
niit	10	464	1.078+
nigm	11	1140	2.45 +
BOLIVIA			
baec	2	35	0
gsb	11	5	.003-
nasb	8	34	0
BRAZIL			
dare	1	5550	0
bnec	2	498	5.54 +
nam	3	120	0
bas	8	286	.001
nrc	8	145	3.42 +
bsc	9	2	.74 +
nit	10	57	.576+
ndmp	11	500	3.58 +
CHILE			
ari	1	157	2.48 +
cnec	2	8	.066+
asic	8	18	.001+
ncstr	8,10	46	.193
gri	11	162	.89 +
cr	12	22	0
COLOMBIA			
nai	2	39	.157-
nam	3	40	.006
nih	3	99	.307
caepns	8	23	.004
tri	10	100	.573+
ngs	11	65	.123
COSTA RICA			
naec	2	14	0
dgmp	11	14	.094
CUBA			
scmp	3	114	.83 +
ncasrc	8	1635	4.08 +
nuc	12	11	0
cscpri	13	175	1.38 +
ECUADOR			
nialr	1	239	1.17 +
eaec	2	4	.013
nih	3	128	.865+
eins	8	30	.029+
ndgm	11	16	0
EL SALVADOR			
dar	1	131	.321+
cgsi	11	47	.115+
GUATEMALA			
nnec	2	28	.047+
ampnsg	3,8	61	.002
GUYANA			
admanr	1	147	1.75 -
HAITI			
ncsr	8	23	.003+
HONDURAS			
ngi	11	105	.207+
JAMAICA			
src	8	60	.17 +
MEXICO			
nari	1	320	2.4
nnea	2	594	3.94 +
namm	3	217	0
asr	8	180	.018
nisr	8	15	.306+
mitr	10	130	.677+
NICARAGUA			
ngsme	11	29	.122+
PANAMA			
nsc	8	15	0
PARAGUAY			
isnu	8	83	.084+
PERU			
dard	1	2368	9.78 +
aecb	2	29	.13
nam	3	100	0
nih	3	42	.475-
psi	4	134	.614+
naepnsl	8	40	0
pig	11	157	0
dgm	11	226	.596+
ic	12	9	0
URUGUAY			
nace	2	23	0
ncstr	8	11	.131+
nae	10	30	0

APPENDIX III (con't.)

Budgets of Latin American Science Policy-Making Bodies

Country/ Name	Cate-gory	Staff	Xpend
VENEZUELA			
ncar	1	286	11.2
nam	3	122	.01
nih	3	194	.81
apmns	8	80	.01
vaas	8	402	.016
ncstr	8,10	21	0
visr	8	218	2.73 +
dgmmh	11	98	1.96 +

APPENDIX IV

Functions and Linkages of S & T Decision-Making Bodies in Asia (Total 70)

LEGEND

1. Source: UNESCO, World Directory of National Science Policy Making Bodies in Asia (1968). Coded by Dan Levin

2. OD - Orders of Decision
   1 Choice of technology (n=58)
   2 Choice of implementing institutions (52)
   3 Mobilizing decisions (17)

3. LINKAGES (Flows of information and resources)
   1 Public and private (61)
   2 Between or among ministries (28)
   3 Within ministries or sectors (14)
   4 Among private parties using S & T for development (7)
   5 Between government and int/reg org. (49)
   6 International unofficial and bilateral exchange of technology (26)

4. See App. VI for key to abbreviations

APPENDIX IV

Functions and Linkages of S & T Decision-Making Bodies in Asia (Total 70)

Country/Name	OD	Linkages
BURMA		
ari	1	5
bmri	2	3
rpdb	132	12
ubari	1	12
CEYLON		
cdaro	1	15
cisir	12	1245
mri	1	3
CHINA		
as	12	15
aec	13	35
irc	21	2
jcrr	123	12356
nsd	2	1235
INDIA		
aec	123	235
csir	123	12345
icar	13	135
icmr	12	12356
nisi	2	15
nrdci	132	16
sacc	123	12456
srs	21	1235
ugc	2	156
INDONESIA		
iis	12	2356
naea	12	156
IRAN		
tunc	12	156
hcar	2	156
iphr	1	12356
ISRAEL		
aec	31	156
iash	12	15
ncrd	132	125
nuia	21	125
JAPAN		
cost	1	1
cst	31	12
jaec	231	1
nsac	1	1
scj	12	15
sta	321	12
KOREA		
esc	12	12
mst	12	1256
nas	312	15
niri	12	156
MALAYSIA		
mrfb	13	1456
imr	21	123456
MONGOLIA		
asmpr	12	15
NEW ZEALAND		
mrc	1	1256
mzaec	12	15
dsir	21	156
nrac	1	1
rsnz	1	15
ugc	2	1
PAKISTAN		
arc	21	15
cwhr	2	16
idfcrc	2	1256
nsc	12	126
pas	21	15
paec	12	125
pcsir	2	156
pmrc	12	126
strd	2	1
PHILIPPINES		
mrfp	2	4
nrcp	12	156
nsbd	12	156
paec	213	156
SINGAPORE		
scs	12	15
snas	1	4
THAILAND		
asrct	21	15
nrc	12	1256
oaep	23	152
VIETNAM		
ncsr	1	1
dar	1	135
oea	12	125

APPENDIX V

Functions & Linkages of S & T Policy-Making Bodies in Latin America (total 83)

OD1 = 71	L1 = 55
OD2 = 47	L2 = 20
OD3 = 26	L3 = 21
	L4 = 19
	L5 = 66
	L6 = 5

APPENDIX V

Functions & Linkages of S & T Policy-Making Bodies in Latin America (total 83)

Country/Name	OD	Linkages
ARGENTINA		
paavs	12	15
nam	12	125
nas	1	125
naepns	13	125
aaas	12	14
cnae	123	15
ncsr	12	156
ncstr	2	125
nigm	12	135
niat	32	12356
niit	21	12456
ass	12	46
BOLIVIA		
nasb	2	15
baec	12	1256
gsb	12	1356
BRAZIL		
bas	12	456
nam	12	1456
bsc	231	1256
bnec	123	125
nrc	21	1256
ndmp	1	356
dare	12	156
nit	12	1256
CHILE		
asic	132	15
cnec	123	125
ncstr	231	156
cr	21	1456
ari	12	1256
gri	21	1456
COLOMBIA		
caepns	1	156
nam	1	156
nai	123	1256
nih	123	356
tri	12	1456
ngs	1	36
COSTA RICA		
naec	1	12
dgmp	1	35
CUBA		
ccspri	1	36
ncasrc	12	156
nuc	2	15
scmph	2	356
EL SALVADOR		
cgsi	12	156
dar	1	356
ECUADOR		
eaec	123	15
eins	13	156
nih	123	356
nialr	13	16
ndgm	1	3
GUATEMALA		
ampnsg	2	46
nnec	2	156
GUYANA		
admanr	13	35
HAITI		
ncsr	12	156
HONDURAS		
ngi	1	356
JAMAICA		
src	123	156
MEXICO		
asr	123	456
mitr	12	456
namm	12	145
nari	132	15
nisr	2	156
nnec	12	35
NICARAGUA		
ngsme	1	356
PANAMA		
nsc	2	45
PARAGUAY		
isnu	21	145
PERU		
nam	1	145
naepnsl	12	146
aecb	123	1256
ic	1	4
pig	2	156
psi	231	12456
nih	32	1356
dgm	1	3
dard	312	256
URUGUAY		
nae	3	4
naec	123	1256
ncstr	2	1

APPENDIX V (con't.)

Functions & Linkages of S & T Policy-Making Bodies

in Latin America (total 83)

Country/Name	OD	Linkages
VENEZUELA		
nam	1	36
apmns	1	356
vaas	321	456
ncar	231	156
ncstr	12	1
dgmmh	1	356
nih	123	36
visr	1	1256

APPENDIX VI

Alphabetical list of organizations in Asia

Academia Sinica (China)
Academy of Sciences of the Mongolian People's Republic
Agricultural Research Council (Pakistan)
Agricultural Research Institute (Burma)
Applied Scientific Research Corporation of Thailand
Atomic Energy Commission (Israel)
Atomic Energy Commission/Department of Atomic Energy (India)
Atomic Energy Council (China)
Atomic Energy Office (Viet-Nam)
Australian Academy of Science
Australian Agricultural Council, Standing Committee on Agriculture
Australian Atomic Energy Commission
Australian Research Grants Committee
Burma Medical Research Institute
Ceylon Department of Agriculture/Research Organization
Ceylon Institute of Scientific and Industrial Research
Ceylon Medical Research Institute
Commonwealth Scientific and Industrial Research Organization (Australia)
Council for Ocean Science and Technology (Japan)
Council for Science and Technology (Japan)
Council of Scientific and Industrial Research (India)
Council for Works and Housing Research (Pakistan)
Directorate of Agricultural Research (Viet-Nam)
Economic and Scientific Council (Korea)
High Council for Agricultural Research (Iran)
Indian Council of Agricultural Research
Indian Council of Medical Research
Indonesian Institute of Sciences
Industrial Research Committee/Ministry of Economic Affairs (China)
Institute for Medical Research (Malaysia)
Institute of Public Health Research (Iran)
Irrigation, Drainage and Flood Control Research Council (Pakistan)
Israel Academy of Sciences and Humanities
Japan Atomic Energy Commission
Joint Commission on Rural Reconstruction (China)
Malayan Rubber Fund Board
Medical Research Council of New Zealand
Medical Research Foundation of the Philippines
Ministry of Science and Technology (Korea)
National Academy of Sciences (Korea)
National Atomic Energy Agency (Indonesia)
National Council for Research and Development (Israel)
National Council for Scientific Research (Viet-Nam)
National Health and Medical Research Council (Australia)
National Industrial Research Institute (Korea)
National Institute of Sciences of India
National Research Council of the Philippines
National Research Council of Thailand

APPENDIX VI (con't.)

Alphabetical list of organizations in Asia

National Research Development Corporation of India
National Science Council (China)
National Science Council of Pakistan
National Science Development Board (Philippines)
National Space Activities Council (Japan)
National and University Institute of Agriculture (Israel)
New Zealand Atomic Energy Committee
New Zealand Department of Scientific and Industrial Research
New Zealand National Research Advisory Council
Office of the Atomic Energy for Peace (Thailand)
Pakistan Academy of Sciences
Pakistan Atomic Energy Commission
Pakistan Council of Scientific and Industrial Research
Pakistan Medical Research Council
Philippine Atomic Energy Commission
Research Policy Direction Board (Burma)
Royal Society of New Zealand
Science Council of Japan
Science Council of Singapore
Science and Technology Agency (Japan)
Scientific Advisory Committee to the Cabinet (India)
Scientific Research Section (Resources Division Planning Commission) (India)
Scientific and Technological Research Division (Pakistan)
Singapore National Academy of Science
Tehran University Nuclear Centre (Iran)
Union of Burma Applied Research Institute
University Grants Commission (India)
University Grants Committee (New Zealand)

Alphabetical list of organizations in Latin America

Academy of Medical, Physical and Natural Sciences of Guatemala
Academy of Physical, Mathematical and Natural Sciences (Venezuela)
Academy of Sciences, Institute of Chile
Academy of Scientific Research (Mexico)
Agricultural Research Institute (Chile)
Agricultural Division, Ministry of Agriculture and Natural Resources (Guyana)
Argentine Association for the Advancement of Sciences
Argentine Scientific Society
Atomic Energy Control Board (Peru)
Bolivian Atomic Energy Commission
Brazilian Academy of Sciences
Brazilian Nuclear Energy Commission
Brazilian Space Commission
Centre for Geotechnical Studies and Investigations (El Salvador)
Chilean Nuclear Energy Commission
Colombian Academy of Exact, Physical and Natural Sciences
Council of Rectors (Chile)
Cuban Sugar Cane Products Research Institute
Department of Agricultural Research and Development (Peru)
Department of Agricultural Research and Experimentation (Brazil)
Department of Geology and Mines (Peru)
Directorate of Agricultural Research (El Salvador)
Directorate of Geology, Mines and Petroleum (Costa Rica)
Directorate of Geology, Ministry and Hydrocarbons (Venezuela)
Ecuadorian Atomic Energy Commission
Eduadorian Institute for Natural Sciences
Geological Research Institute (Chile)
Geological Survey of Bolivia
Institute of Sciences of the National University (Paraguay)
Inter-university Council (Peru)
Mexican Institute of Technological Research
National Academy of Agriculture and Veterinary Sciences (Argentina)
National Academy of Engineering (Uruguay)
National Academy of Exact, Physical and Natural Sciences (Argentina)
National Academy of Exact, Physical and Natural Sciences of Lima (Peru)
National Academy of Medicine (Argentina)
National Academy of Medicine (Brazil)
National Academy of Medicine (Colombia)
National Academy of Medicine (Peru)
National Academy of Medicine (Venezuela)
National Academy of Medicine of Mexico
National Academy of Sciences (Argentina)
National Academy of Sciences of Bolivia
National Agricultural Research Institute (Mexico)
National Atomic Energy Commission (Costa Rica)
National Atomic Energy Commission (Uruguay)
National Commission of the Academy of Sciences of the Republic of Cuba
National Commission for Atomic Energy (Argentina)
National Commission for Space Research (Argentina)
National Committee for Scientific and Technological Research (Chile)
National Council for Agricultural Research (Venezuela)

Alphabetical list of organizations in Latin America (con't)

National Council for Scientific Research (Haiti)
National Council for Scientific and Technical Research (Argentina)
National Council for Scientific and Technological Research (Uruguay)
National Council for Scientific and Technological Research (Venezuela)
National Department of Geology and Mining (Ecuador)
National Department of Mineral Production (Brazil)
National Geographic Institute (Honduras)
National Geological Survey (Colombia)
National Geological Survey, Ministry of Economy (Nicaragua)
National Institute for Agricultural and Livestock Research (Ecuador)
National Institute of Agricultural Technology (Argentina)
National Institute of Geology and Mines (Argentina)
National Institute of Health (Colombia)
National Institute of Health (Ecuador)
National Institute of Health (Peru)
National Institute of Health (Venezuela)
National Institute of Industrial Technology (Argentina)
National Institute for Scientific Research (Mexico)
National Institute of Technology (Brazil)
National Nuclear Energy Commission (Guatemala)
National Nuclear Energy Commission (Mexico)
National Research Council (Brazil)
National Scientific Council (Panama)
National University Council (Cuba)
Nuclear Affairs Institute (Colombia)
Peruvian Institute of Geophysics
Peruvian Sea Institute
Scientific Council of the Ministry of Public Health (Cuba)
Scientific Research Council (Jamaica)
Technological Research Institute (Colombia)
Venezuelan Association for the Advancement of Science
Venezuelan Institute for Scientific Research

NATURAL RESOURCES, DEVELOPMENT AND INTERNATIONAL AID

by
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A basic reason for the AID programme is of course a concern with development. However, concepts of the most effective ways of promoting international development have undergone a major evolution in the past decade. Reviews of progress, or lack of it, during the first development decade often voice disillusionment though substantial progress in terms of national economic growth was achieved in many countries.[1] The pessimism stems in part from the considerable difficulties encountered by the straightforward economic growth approach and a growing realization that a variety of objectives must be achieved to allow real developmental change.

The articulation of priorities has also changed. In the early part of the sixties the overwhelming concern was with national economic growth. The focus was increasingly on industry as a means of obtaining the most rapid expansion, and one means of financing the needed industrial plant was through international aid. Now a much greater range of approaches is considered necessary. While economic growth is still a prime objective, there is much tempering of this goal with the need to cut down rates of unemployment, to build viable rural structures, and to reduce the increasing inequality between rich and poor and town and country. The London Times recently commented "small is beautiful" in development today.

> As Robinson puts it:
> "In 1964, it was still possible to be reassured on these economic principles that the application of the most efficient technologies to industry and agriculture would automatically maximize employment and social well being ------- at the end of the decade the divergence of means of relieving unemployment with the means of maximizing economic growth became inescapable. In many cases, it now seemed wiser to accept a slower rate of advance in one direction in order to make progress in the other" (Robinson, 1971, p.4)[2].

The greater advance in GNP or the greater spread of regional development is not an abstract choice but one which needs frequently to be faced, though unfortunately is seldom presented with all the alternative facts and forcasts. When the siting of a project is being considered one site may offer better investment returns because of existing infrastructure, another better long-term benefits in regional spread of growth, reduction of unemployment, etc., but with a reduced short-term return on investment. The continued tendency to choose the former alternative contributes to the general polarization of development opportunity.

Now, well into the seventies, it is clear that these ideas have been well integrated into some aid programs; very little into others. There are real difficulties in changing direction both for programs and for people

within the developing countries and within the aid agencies. This puts extra responsibility on new programs and new emphases to compensate for this relative inertia.

Natural Resource Programs:

The AID agency has used the U.N. definition of natural resources as follows:

> "Natural resources included natural products (e.g. minerals, forests, fish, water) and amenities or situations (e.g. waterfalls, waterways, fertile soils, mountains) which are assigned value by man as a result of their potential economic or social benefits".[3]

Reviewing the pattern of development in these fields we find that the emphasis in natural resource development has been heavily on the side of the large scale projects and on goals of major national economic gain. These kinds of projects seemed in the sixties to meet the needs both of the aid program and of the counties concerned. They were transformation projects needing considerable foreign capital and high technical skill and with enough impact both to form visible signs of the program and to potentially play a significant role in transforming the economy. The pattern is clearer if we look at the major sectors involved.

Mineral Resource Development:

This sector more than any other has been dominated by the role of the foreign international companies who often have played a major part in mineral exploration and followed this with company financing and management of the development phase. A large part of the mineral resources so extracted have been taken into the world flow of minerals towards the developed parts of the world. In a period of increasing awareness of the finite nature of our world resource base and exponential climb in demand, there has been growing competition for exploitation rights. However, this comes at a time when many countries are concerned about the role that private companies can play in their economy, are concerned with the long-term best use of their resource base and feel they are not getting the best out of current arrangements.[4]

Mineral resource development does, however, play a major role in the economy of a number of countries. Zambia, for example, with large copper exports has a considerably higher GNP and, over the years, better foreign exchange position than many neighboring countries. The same country also illustrates the general problem of getting the financial resources obtained from mineral development into programs for generating a broader based and more internally oriented development. There has also been little evidence that extractive mineral development provides much trickle down effect perhaps where enormous wealth is generated by oil. There have been few examples that I know of where the necessary adjunct activities have been consciously attempted. Farly (1971) points out in his book on "Planning for Development in Libya" that even in an extremely wealthy oil economy under rigorous planning, overcoming the inertia in agriculture, industry, the problem of state and private industrial development issues, problems of manpower and administration make it extremely difficult to introduce

meaningful "trickle down" effects. It may even be more than usually difficult under these circumstances as the disparities of wealth grow so rapidly and become so obvious that evolutionary change becomes a more difficult task.

It seemed to me, from a recent visit to Indonesia, that the vast sums of private capital being invested in that country, should be seen to have greater impact on the regions in which the development was taking place. It is possible that the companies concerned or the national government could work towards an improvement of the situation but it is likely that external funds and expertise will be needed.[5]

The following table illustrates the sums involved for metallic minerals alone. In 1967 applications were invited for mining licenses for over 50 different areas and by 1972 14 agreements had been signed and many others were in final stages of negotiation. Although financial details are not available to me for all of these fourteen the table shows that over $1,200,000,000 will be involved. This compares with a total U.S. aid of around $1,000,000,000 for the period 1946-1969 40% of which was in the food for peace program. Other DAC loans and grants to Indonesia 1960-1968 totalled $766 million. We are thus in a situation in this country where investment in mining over the next few years is going to be well in excess of official aid flows.

International Company Investment in Metallic mining enterprises
Indonesia
1967-1972

Project	Survey Phase	Exploration	First phase Investment
1	$10 sq km	$100 sq km	
2	$10 sq km	$100 sq km	
3	$100,000	$1,000,000	
4			
5	$10 sq km	$100 sq km	
6			$140,000,000
7		$1,700,000	
8		$13,000,000	$130,000,000
9		$ 5,000,000	$240-400,000,000
10		$1,600,000	
11			$500,000,000
12	$121,000	Terminated	
13		$1,000,000	
14		$1,300,000	

The range of possibilities is considerable. In some cases the skills of private mining industry could be utilized to help in the spread of intermediate technology in an area, through training programs for low level engineering of the garage engineer type, through use of industrial workshops for repair of locally used machinery and even through a conscious effort to develop intermediate technology suitable to the area. In other cases the road and other transport infrastructure may provide an opportunity for the development of new crops or new agro-industries in an area. Such opportunities

frequently need additional financing, experimentation and training. In most cases the existence of a new enterprise forms a new market for food. If this new market is to be supplied from the local area in any significant way, some initial awareness on both sides of the possibilities is needed.

In this and in other cases which I will outline there is a need for a new kind of development assistance. One of the problems of development in my experience is the problem of (j-1) links. In so many cases there develop situations in which a number of innovations have been made but things don't work; no real change takes place. Because of a sectoral approach or because of some unforseen problem there is a missing link. The identification of that link or links is an important task needing personnel with a real understanding of the development process and an ability to tackle problems in the field. In natural resources we perhaps need an ecologically minded systems analyst. One of the issues related to the trickle down effect of mining projects is first an identification of the possibilities and opportunities and then the flexibility and funds to pursue them.

Thus, one important use of AID funds in this natural resource field could be in researching and developing ways in which the expenditures on the infrastructure and extraction aspects of mineral industries could be linked with the growth of other activities in the area. It is most likely that many of these activities would be related to general natural resource development in a regional context. Can a mineral extraction enterprise provide one focus for a program of comprehensive regional development? Can the income from these activities be more readily seen to promote national and regional economic growth and be employment generating? Can a thoughtful AID program help?

Forest Resource Development:

Fifty to sixty percent of the world's total biomass is found in the humid tropics and this area also shows the highest annual rates of growth. Yet most of the productive use of this resource occurs in the mid-latitudes. There are biological reasons which help to explain this fact but far more important are the great discrepancies in the levels of general economic development in the two areas.[6] At present, we are just not using a very large part of the world's renewable resources and even U.N. predictions for expansion in the next decade do not foresee a very different picture. A major problem is that much forest land is capable of use for other purposes and unless it can be shown to have economic value as forest, it may be lost to forest use. For a significant part, perhaps twenty percent, of the tropical rainforest area regeneration of cut forest may be impossible or at best a very long-term process.

Part of the problem lies in the diversity of species and the consequent difficulty of research and development of any but the most valuable timbers unless we develop means of managing purer stands and/or find ways of using a variety of timbers, say in wood pulp production. This latter trend is especially evident. To date, most of the exploitation of the tropical forests has been just that and in a similar way as with the mineral deposits the private companies have played a leading role in the utilization

of timber resources mostly in response to the needs of the market in the western world and Japan. Operations have thus tended to be large scale and contractural agreements with the host country which, in general, have not been long enough to encourage company interest in the long-term productivity of the land. In some cases, indeed, when the company has taken the initiative, the national government has not responded or not had the manpower to respond with the necessary follow-up work.[7]

Forest resources are thus an underdeveloped resource, but one which is in danger of being fast depreciated. The sector needs to be revitalized through thoughtful and long-range planning backed up by a range of biological, operational and industrial research which needs to take place in close co-ordination between developed and developing countries. However, in line with the growth of awareness of environmental concerns, there is a need for wide-ranging educational and training initiatives not only in the formal sense but also to more generally encourage greater awareness of the importance of the forest resource for national and global needs.

Water Resources:

Water impinges on so many aspects of development programs that the ramifications of the use of water as a natural resource must cover almost all aspects of economic development. Water resources are important at all scales from the small village pump and purification scheme to vast international impoundments. The harnessing of the great potential of the major rivers of the world has attracted much development attention and indeed Africa, for example, is very well endowed with water resources. However, the record of water management programs at this scale is mixed at best and in the less developed countries there have been many problems related to the generation of economic growth through water control.[8] These largely stem from the fact that projects have been attempted before there was time to accumulate much wisdom on the complex and wideranging effects of interference with biological, hydrological and socio-economic systems. It is not difficult to transfer dam building technology to any country in the world. It is much harder to judge the working mechanisms of the new large ecosystems so created and still more difficult to account for the side effects on fishing, agriculture, local communication and regional development. Thus, while some considerable engineering feats have resulted in major changes in the energy resources of some nations and this may be a focal point of new industrial and economic growth, the undesirable side effects have been subject of much critical comment and some rethinking of the merit of large schemes is taking place.[9]

Some general characteristics of all these resource approaches stand out. First, they have tended to be large scale; second, they have tended to be focused on exports of raw or little processed products; third, the benefits of such schemes have been at the level of national economic returns rather than regional or local development where some of the costs have been incurred; and fourth, private capital and technical skill have been heavily involved often to the benefit of economic and short-term commercial efficiency but resulting in a little emphasis on development of skills and appropriate managerial experience on the part of the nationals of the countries concerned.

It is clear that there is a need on both sides for some major resource development projects to continue. There is a world need for mineral and power resources of all kinds and that need can only increase. There is need on the part of the countries concerned to seize viable development opportunities and utilize private as well as official bilateral and multilateral capital. But it is also clear that there is a need to improve ways in which such resource development is carried out and to develop confidence on both sides on the relative equity of costs and benefits.

To these ends the emphases that AID proposes to develop make much good sense. Experience and ability in less developed countries' personnel is essential in all these fields and institutional and personnel development is the best kind of infrastructure. The national ability to assess the importance of natural resources and to control the search for and inventory of these resources is vital. Strangely this involves a two way polarization of the techniques used. On one hand, the use of ERTS or other remote sensing techniques will allow a very few highly trained local personnel to play a leading part in controlling resource identification while at the same time the development of simpler techniques for field analysis of particular environments will again allow local people to play a fuller part. While fast and cheap and more effective techniques are needed for appraising local resources, emphasis should be given to their adaptability to local conditions and use by local personnel.

The long-term effectiveness of these large scale approaches to natural resource utilization will in part depend on our success in encouraging:

(i) local and regional linkages and spread effects.
(ii) national and 'locally international' linkages in terms of industrialization and processing.
(iii) greater adaptation of technology to local needs and capabilities.
(iv) research to promote national products.

National resource programs can also be emphasized by adopting a two tier approach to natural resource development.

Approaches to the local development of Natural Resources:

The two tier approach to development originated, I think, with the concept of industry and agriculture as major sectors. Increasingly today a two tier approach to agricultural development is suggested in order to deal with the difficult problems of fitting together a need for rural transformation which can be achieved in particular favored localities with the obvious need to maintain and enhance the viability of the rural area as a whole. There is also room, I think, for two different kinds of approach to the problems of natural resource development. On one hand, it is likely that the large projects will continue and part of our strategy must be to find ways in which they can contribute to problems of employment, welfare and broader based development, while in addition there is a great need for a new and consciously experimental approach to alternative patterns of resource use, patterns which focus directly on the problems of employment and rural development rather than on national economic growth. There are many different possible approaches ranging from the invention and promotion

of particular kinds of intermediate technology to the most advanced research on uses for tropical products and research and experimentation in the most effective ways of producing well integrated and productive rural communities[10].

It is perhaps simplest to illustrate the kinds of approach I have in mind with one or two examples. One of my concerns over the past few years has been making the most effective use of investment which is being incurred in various sorts of water development programs. Water, of course, impinges on many aspects of rural life and provision of improved rural water supply may by itself be a catalytic factor in a few areas. But in most cases, any program which focuses on water must, in order to be effective, be prepared to deal with a number of ramifications of the change in the status of the water supply.

In the grazing areas of the Sudan, the provision of rural water points at various intervals across the semi-arid grasslands has, in fact, resulted in a major degradation of the environment, a selective eating out of palatable grasses in a zone around the water hole,[11] and consequent great problems of land restoration and economic recovery. The reason, of course, is that any prevision of this kind must necessarily be linked with policies for grazing use, marketing of livestock, range management capacities and some guidance for local people towards the need for these policies. This can only be done if we can predict the social and economic effects of the imposed interference with change. Change in a part of a system only is very likely to cause major imbalances within a formerly balanced situation. The more integrated approach is being supplied in some of the East African range management schemes at present.

The ultimate conclusion from an analysis of many such examples is that there should be very few water supply projects as such but rather an approach which would allow a much more integrated and problem solving approach. For most circumstances this is probably too idealistic and the best we can aim for is to allow the greatest possible flexibility to sectorally focussed programs. What are the likely benefits from water provision to be, how can they best be achieved, what are the most likely harmful effects of the supply, what else necessarily needs to be done to allow the water supply program to achieve its objectives? These are the kinds of questions that need to be asked before the decision to go ahead is reached.

Forests in developing countries have usually been viewed from the perspective of professionally oriented resource utilization program whether by a company or a government department. This has produced good results in some areas and problems in others. In any case, there are good reasons for attempting to begin parallel sort of programs which look at the possible uses of the forest areas as additional or, indeed, main elements in the economics of particular rural systems. As far as I know, there has been very little research or development attention given to this possibility, yet the mix of quick growing species and the variety of timbers which could be grown suggest that forestry might be a viable alternative to agriculture as a means of livelihood with employment in the forest maintenance and harvesting activities supplemented by small scale wood using industries for local and national markets. It is a major challenge to find ways of using

the inherent rapid growth qualities of the tropical environment to promote rural development.

One vital forest industry in Africa which is in danger of extinction in some areas because of the unplanned use of the environment in face of growing population and demand in urban centers, is the production of charcoal. While in a few areas, notably the Sudan, some replanting of woodland has had as one aim the production of material for charcoal manufacture, this is rare. Yet as a fuel it is likely to remain important in many areas of the world and can continue to be an important 'cash crop' if modest outlays on various aspects of the industry are made.

It seems totally irrational for many developing countries to have to switch to imported oil for cooking and heating when traditional and preferred sources can be maintained with quite small outlays. Quite recently I could find little data available on the charcoal needs of important African centers, on how much land was required in woodland to meet these needs and on the progressive problems of supplying larger centers in the face of rapid population growth. Yet equally it was relatively easy to gain an impression of the environmental degradation caused by cutting for charcoal around large cities and to show that over a relatively short time the situation had become much more difficult.[12]

I have a final example of a mountain area in the Usambara mountains of Tanzania where just three or four years ago a thorough researcher reported an almost classical case of extreme pressure on land resources due to population growth on a limited yet basically viable land base.[13] Stagnation had resulted at a low level of development with low nutrition levels, low per capita income and poor prospects for any rapid change. In this area, the political pressure for land had resulted in a gradual reduction of the forest reserve area, usually to no great economic benefit, as good forests were cut or burnt to be replaced with poor crops of maize on unsuitable soils. Fortunately a successful health research program in the area was expanded into an integrated district development effort, following up on basic needs revealed by health and nutrition studies. Obviously the program is still in its early stages and it is not time yet to cry success, but in three years it has been possible to introduce a successful vegetable production program to over 1500 farmers in the area and by assisting at a number of crucial points in the system insure the steady expansion of the enterprise. It was found that at first farmers needed help with seeds and cropping practices. Then some considerable efforts and short-term subsidies were necessary to insure good market prices and reliable transport of the produce to the major market some 200 miles away and finally as the project expanded in scope the bottle neck became storage, space and market handling in the major market center and once more financial and personnel assistance was necessary. At present, it seems that the major problem is the handling of scale problems associated with many other farmers and villages wanting to join the scheme. But in a very short period of time, a major change in use of land resources has been possible so that under the new production conditions there appears to be a real impetus for system change and an opportunity for rural development not only of the soils now being used intensively for vegetable production but also of the other parts of the land resource system as well.[14]

One common element of the three examples is the need to view the rural system in an integrated way whether the initial approach is through a sector such as water or if it is concerned right from the start with an integrated approach. In fact it is a common characteristic of successful development agents, whether they be AID officials, water resource engineers or university researchers, that they have the ability to see the problem they are dealing with in its broader setting and that while having the full technical ability to deal only with some aspects of the issue at hand, they are willing to go the extra step beyond their technical or academic boundaries when necessary. A coherent approach to natural resource development seems important for ecological and environmental reasons. It also seems vital for sustained economic and social development.

The following recommendation is part of the report of a recent workshop on natural resources held in Djakarta, Indonesia.

"Multiple Purpose Planning and Management"

"The planning and management of Indonesia's natural resources should be approached in a comprehensive way, emphasizing the inter-relations among resources and the effects development of one resource has on other resources.

Resources are part of the whole fabric of the earth and do not exist in isolation from one another. Poor management of a resource may well have adverse effects, not only on that resource but on others. The indiscriminate cutting of forests can lead to soil erosion, siltation of streams, destruction of wildlife, and change in air movements and temperatures. Analagous examples could be cited for other resources. It becomes essential then, to plan and manage resources in a comprehensive way, evaluating the costs and benefits of utilizing one resource in relation not only to economic factors, but also to possible impacts and costs to other resources. In many cases, comprehensive planning and management will require viewing resources in a regional context based on relevant ecosystems. Sound resource planning should also enable the establishment of priorities among competing uses for a particular resource. Such planning and management will require new types of multidisciplinary training, new organizational approaches, and new incentives."

If this is followed through it will, of course, also require new kinds of thinking on the role of external assistance in these programs.

These thoughts lead to two final comments on the educational aspects of international assistance in natural resource fields. If, quite rightly in my view, much AID emphasis is to go on training and institution building, what kinds of institutions and training should be emphasized? There is a strong tendency through the prejudices of our own experience and through the educational biases which are a factor in the training of many indigenous technical and administrative personnel to want to reproduce the kinds of specializations to which we have become accustomed. There is a clear need for many of these specialities in most parts of the world. But for a much wider body of people, there is a need to develop new philosophies of training and employment. At a social level, there is

a case for broader natural resource development training. Such training implies the establishment of compatible administrative and management structures. There is a real benefit if the bulk of the people working in natural resource development come from the area in which they are to live and work and have a long-term commitment to its progress.

Lastly in the light of much talk of experimental approaches and attempts to develop new patterns of resource use, there is a pressing need for more effective ways of evaluating the successes and the failures of such approaches and of incorporating this learned experience into ongoing programs in all parts of the world. The USA with its considerable university and other experience in natural resource planning, with its vast potential for large scale data analysis is in a good position to play a leading role in this field.

In summary, I find I have mainly asked questions; questions about how we integrate large natural resource projects into their regional and local setting and how we make them effective to all current development goals; questions about how we can use natural resources as focci of rural development and regional development programs; and questions about how we can learn from our accumulating experience and disseminate that knowledge. I think the content of an AID program in natural resources is important. I think the design of such a program is vital.

Footnotes

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ORIENTATION TO DEVELOPMENT OF SCIENCE AND ENGINEERING EDUCATION IN COLOMBIA

by
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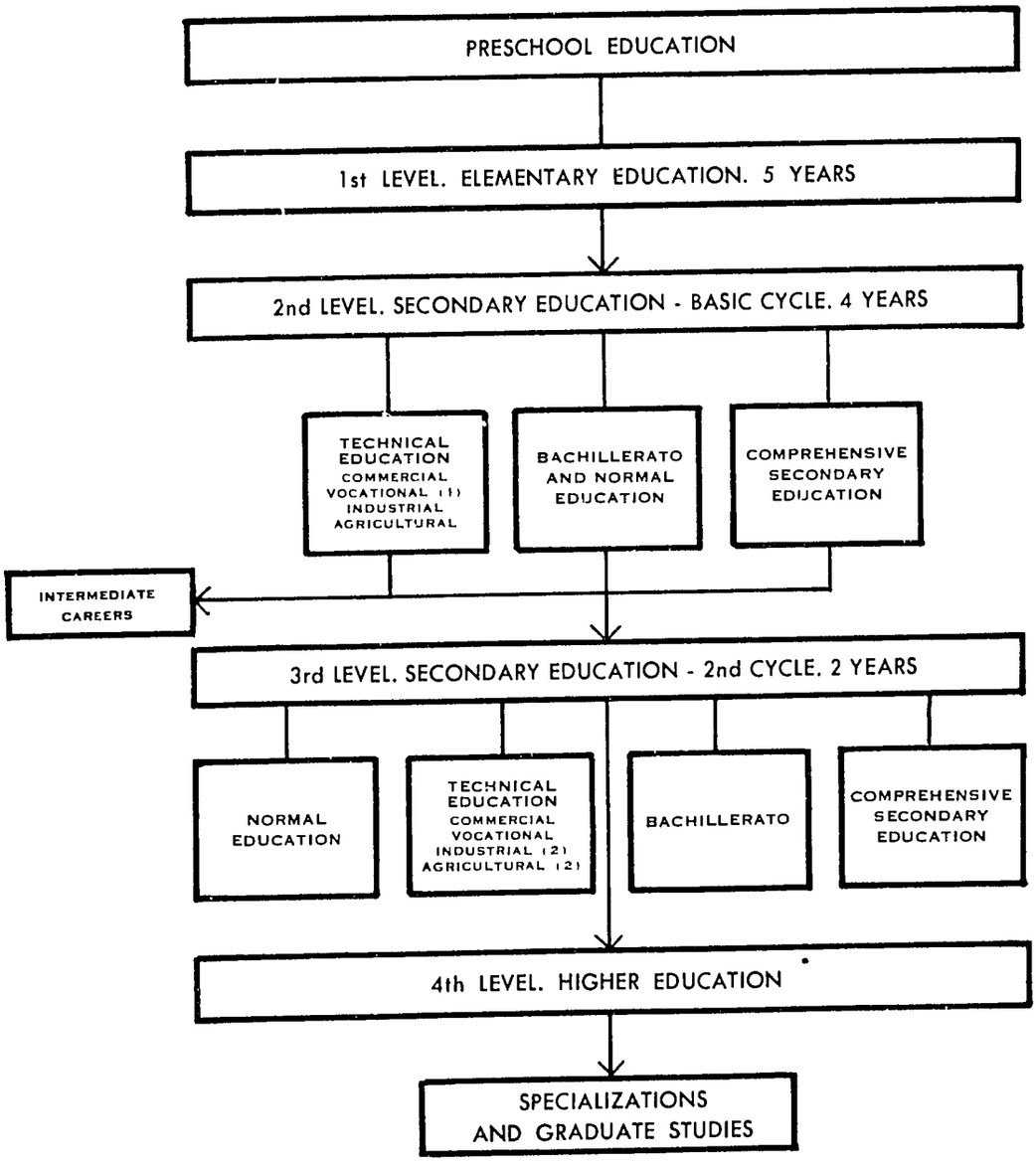
Introduction

It has been repeatedly emphasized that underdevelopment correlates all too well with the lack of adequately trained technicians and engineers who are able to convey the technological and scientific advances into the country's productivity. On the other hand, it has been found in some of the so-called "underdeveloped" countries that the mere training of technicians and engineers by the universities does not necessarily guarantee adequate solutions to the problems of growth and development; this seems due to the fact that those universities are, in general, remote from the true and specific needs of industry in matters such as technical development, research and innovation of technologies and even economically applicable research. The contacts between professors and industries, between the theoretical considerations of academic life and the practical problems of industrial corporations are generally either weak or nonexistent. It is also possible that the role expected from the engineer of technician is different from that in industrially developed countries. There may well be a need to either innovate or modify the technologies learned, in order to adapt them better to the particular technical, economic or social needs of the country, taking into consideration such variables as underemployment and/or local availability of labor, increasing costs, lower capital or credit facilities, local material resources, etc. Those needs cannot be learned from the outside but have to be determined by experience in each particular country, not only by government agencies or organizations but also by the universities. There should exist, then, adequate feedback mechanisms between industry on the one hand and government and universities on the other.

For these reasons COLCIENCIAS, since its creation in 1969 as a Government's granting and funding agency for the support of scientific and technological research, considered it essential to try to develop a "Government-University-Industry" program as one of its special areas of interest. For this purpose, an inventory of scientific and technical resources in industry is planned (part of it has been included in the general inventory of scientific resources carried out since 1971). Also, meetings with executives and directors of industries are scheduled in order to be able to devise a questionnaire that can give some real insight into their investigative and technological capabilities. In addition, support is being given to universities in Colombia to promote seminars and/or courses on technological development and to carry out short seminars on scientific methodology. The latter action will try to encourage a more energetic participation of industries in sponsoring special studies at graduate levels, such as thesis papers, dissertations, etc. A discussion

Fig. 1

ACADEMIC STRUCTURE OF COLOMBIAN EDUCATION



(1) 3 - YEAR BASIC CYCLE
(2) 3 - YEAR SECOND CYCLE

of Colombia's achievements and goals in this respect, together with a more general discussion on our educational systems and its trends in science and engineering is the subject of this paper, together with some considerations concerning possibilities for participation by U.S. universities and agencies in the near future.

1. Colombian Educational System

According to a recent study "one of the most outstanding features of higher education in Colombia is the very large number of public and private institutions, large and small, providing post-secondary education at different levels and of different academic quality. This condition is of particular interest considering that the ratio between the student enrollment at these institutions and the number of inhabitants in the age group eligible for higher education is substantially lower than in the more developed countries... Available openings at all these institutions are insufficient to meet the increasing demand resultant of population growth and the trend toward upward social mobility through education".

The general academic structure of Colombian education is shown in Figure 1. It is noteworthy that, due to the lack of available openings at private and public universities, two trends have been identified, (1) to diversify secondary education and to direct it more toward "technical" or vocational studies, the products of which can remain at the more or less qualified "technical" level and (2) to advance into the so-called "Intermediate" careers providing a more advanced technological education. A complete plan for the modification of this scheme taking into account the tendency to diversification and the creation of "institutes of intermediate education" (INEM) is currently in progress.

For the purpose of this paper, the term "sciences" includes the following: biological sciences, chemistry, geology, mathematics, pharmaceutical chemistry, physics and statistics. The term "engineering" includes civil, chemical, electrical, metallurgical, mechanical and mining engineering. And the term "farm sciences" includes animal husbandry. agronomy and veterinary medicine. The duration of all these careers ranges from 8 to 11 semesters, with an average of 10: most lead to a "doctoral" degree, more or less equivalent to the "M.S." degree in the United States, but some of them terminate at the B.S. or "Licenciado" level.

If we take the enrollment at the National University as representative of the country as a whole and divide it by schools (Fig.2) during the decade from 1961 to 1970, it can be seen that, of a total of 91,222 students enrolled, - 10,420 (11.4%) were enrolled in Sciences; 21,707 (23.8%) in Engineering; 16,754 (18.4%) in Farm Sciences. This suggests that slightly over 50 percent of the total students enrolled aspire to careers in science and engineering.

Regarding graduate education and research, this paper will draw heavily from a study jointly undertaken and sponsored by COLCIENCIAS, the Colombian Institute for the Development of Higher Education (ICFES) and the National Academy of Sciences (NAS), from February 1971 to October 1972, the summary of which was recently published by NAS. Four joint panels were

Fig. 2

ENROLLMENT BY SCHOOLS. UNIVERSIDAD NACIONAL DE COMOMBIA
1961-1970

Years	Total Enrolled	Arts	Sciences	Engin-eering	Farm Sciences	Law	Health Sciences	Human Sciences
1961	6,186	483	951	1,159	1,043	498	1,355	698
1962	6,856	464	1,015	1,555	1,211	517	1,301	793
1963	7,455	650	998	1,741	1,359	444	1,270	993
1964	7,377	666	939	1,872	1,370	277	1,227	1,026
1965	8,010	789	982	1,975	1,401	293	1,314	1,256
1966	9,682	1,117	906	2,583	1,415	316	1,654	1,691
1967	10,803	1,176	1,010	2,840	1,841	322	1,653	1,961
1968	10,050	888	949	2,240	1,981	357	1,799	1,836
1969	11,594	1,111	1,186	2,617	2,491	382	1,896	2,011
1970	13,209	1,199	1,484	3,125	2,642	400	1,971	2,388
Total	91,222		10,420	21,707	16,754			
Percent			11.4	23.8	18.4			

(From Low-Maus, R: Compendium of the Colombian Education System, Ed. Andes Bogota, 1971).

dedicated at separate intervals to study programs in chemistry, mathematics, engineering and applied sciences and biological sciences, and a multi-disciplinary review panel (of which the author of this paper was member and co-chairman) met in Bogota on October 30-31, 1972, to examine each of the four studies and to discuss summary conclusions.

At the undergraduate level, it can be said that the science education has steadily improved through the years, and scientific research within universities has been given a greater impulse since the creation of COLCIENCIAS. In the so-called "farm sciences" a very favorable factor during the past few years has been the close cooperation established between the Instituto Colombiano Agropecuario (ICA) - which carries out a substantial amount of research and has insured financial support from several U. S. and international foundations - and the universities at which those disciplines are taught.

Undergraduate teaching in engineering has varied little during the past two decades, except for the creation (at some universities) of new branches of engineering such as electrical, electronics, industrial and systems. Mining engineering has a long and respectable tradition at the University of Antioquia, located in the center of the mining district of Colombia. Electronics engineering has been taught during the past decade at three or four schools, two of which are private. A number of research projects have also been financed by COLCIENCIAS at several engineering schools during the past three years.

Teaching of engineering has been criticized as being too "classical", with a great number of subjects being taught at the same time, some of them considered "nonessential"; however, some of these are offered as electives. It has also been said that education is too theoretical, with the students having little or no opportunity to put into practice what is taught in the classrooms, or to orient their careers toward a certain specialization according to their personal preferences. All too frequently full time professors have had no experience with industry whatsoever, and thus their students are deprived of learning what is really happening in relation to the industrial development in the country. Some universities still require the preparation of a thesis paper prior to conferring their degree, and in general those theses are remote from the real problems or needs of Colombia. NAS panel members unanimously recognized the need for strong physics programs as one element in engineering education.

At the post-graduate level, it is pertinent to quote the conclusions of the NAS-COLCIENCIAS-ICFES joint review panel:

1. Graduate programs in Colombia must be closely correlated with stated national priorities for social and economic development. (It may be added here that those priorities have been extensively described in "The Four Strategies" published by the National Planning Department in 1972).

2. Before new graduate programs may be started at the universities, the need for highly trained persons in various specialities should be ascertained to try to insure that job opportunities will exist for them in Colombia.

3. Because of the importance of the National Information System and the Documentation Centers, especially in relation to graduate education and research, planning for graduate programs should include the use of these facilities.

4. In general, a strong relation between undergraduate and graduate programs is recommended.

5. Coordination of university graduate programs and manpower needs of industry are important to both the university and the industrial sector. Wherever possible graduate theses should be related to industrial projects.

6. Exchange programs and better use of existing human resources can be accomplished through cooperative programs and transfer of students among the Colombian universities.

7. Graduate programs should prepare new professors and also raise the level of in-service professors in the university system.

8. Along with graduate programs, there is need for an integrated system of maintenance and construction of instruments and equipment.

9. The minimum elements and criteria that distinguish a graduate program from other courses of advanced (non degree) training need to be identified.

10. Students in graduate programs should work as teaching assistants in undergraduate courses, to the benefit of both graduate students and the undergraduate programs of the universities.

In some of the individual areas, the subpanels were more explicit in their recommendations. For instance, regarding geology and metallurgical engineering they stated "Commercial exploitation of mineral resources in Colombia has not proceeded as far as the development in the agricultural and manufacturing sectors. The subpanel.... recommended that the Colombian government give more attention to mineral resources in its development planning; that the extractive industries be given appropriate incentives; and the universities strengthen programs in geology, metallurgical engineering, and mining engineering. The subpanel.... cited geology for first priority. They particularly emphasized economic geology based on modern geochemical and geophysical exploration".

The civil engineering subpanel "urged that greater resources be made available for graduate programs in sanitation, public health and transportation", and went as far as to consider the establishment of a multidisciplinary program in public systems engineering.

In regard to mechanical engineering, the subpanel was unable to determine the effective demand for advanced-level preparation in mechanical engineering. Consequently, they urged that undergraduate courses be strengthened, links with industry be created, and professional societies be strengthened so that the mechanical engineer's talents are better used and

kept up to date.

The "uncertain industrial demand" for graduates in chemical engineering was also noted by the respective subpanel.

It would be worthwhile to end this chapter by quoting from the highlights and comments of the above mentioned report: "In the opinion of U.S. panelists, the lack of participation by Colombian industrial leaders (in the subpanels) was a weakness of the studies, particularly in chemistry and some areas of engineering. However, formal links between Colombian industries and universities are not strong. Indeed, one general recommendation arising from the studies concerns the need to improve cooperation among industries, the universities and the Colombian government."

2. Existing Programs Oriented to Development in Colombian Universities

The concept of science and technology as a key to development is relatively new in Colombia. At least, it was not made sufficiently explicit until 1968 when a Colombia-U.S. workshop on science policy planning led to the creation both of COLCIENCIAS and the National Council of Science and Technology. The latter, at the presidential and ministerial levels, is in charge of determining priorities and accordingly establishing programs in science and technology for the nation as a whole. COLCIENCIAS acts as the executive organ of the Council.

This transformation has led to the formation of a conscience among the planners and the government of the need for planning in science and technology as a means for development. To quote from the introduction to The Four Strategies: "....That silent, semi-automatic process, self-generating of economic growth, which is so characteristic of those (free-enterprise) economies and which originates fundamentally in continued scientific and technological discoveries.... is rather uncertain in our developing economies." And later on, to bring about a new concept of development,".... to have objectives such as the utilization of modern technologies in order to increase productivity, to use efficiently the national resources of the country, to orient demographic factors and to produce adequate economic stimuli in order to reduce social inequalities".

Since its creation, COLCIENCIAS has tried to concern itself with many of those aspects, particularly with the interaction of scientific and technological factors with economic development, and the identification of problem areas. For this purpose, an inventory of scientific - manpower and facilities - resources at 110 institutions in Colombia has been completed and will be published in the next few months. COLCIENCIAS also has an "office of technological development", the main purpose of which is to discover ways of creating, transferring or innovating technologies, as well as to detect research efforts within the country's industries.

At the university level, there have occurred two distinct kinds of phenomena. Several special "institutes" or groups have been created at some universities, mostly within the frame of economic or social sciences, dedicated to the study of the technological, social, scientific and economic components of development. Such is the case of the Center for Investigations

on Development (CID) at the National University, or the Center for Economic Investigations (CEDE) at the University of the Andes. Several other small groups have been formed at universities in Bogota and in other cities, but their existence has been rather ephemeral. A private group of researchers, most of them former government officials or ex-members of the National Planning Department and almost all of whom are still active in academic positions at the universities, has been formed as a non-profit institution. This entity, the Foundation for Studies on Development, (FEDESARROLLO) is dedicated exclusively to studies on development, and several of its research projects have been financed by COLCIENCIAS.

However, it must be admitted that in the academic structure of the universities as such, very little effort has been made to orient studies in science or engineering toward development or to incorporate courses on the impact of science and technology into the curricula. The only effort worthy of mention is that of the University of the Andes in Bogota, which in 1968 began offering a program on Technological Development for students of engineering and economy, which was later divided into a seminar at the undergraduate level and a more formal course for graduate students. The seminar was divided into two parts: (1) Ideas and concepts on scientific and technological development; (2) Identification of specific projects regarding technologies adequate for the country. The course, which is included in the program for a Master's degree in Industrial Engineering, has expanded on the contents of the seminar and is intended also to attract students of economy. The following is a list of the subjects covered:

1. Concept of scientific and technological development as a social function.
2. Scientific policies and strategies to achieve scientific and technological development.
3. Consistency and coherence of scientific policies according to the country's social and economic development goals.
4. Interaction between technology and society: opportunities and problems arising in technological development.
5. Objectives of technological development in Colombia: the prospective point of view and the technological predictions.
6. Elements of technological development: isntruments and means of achievement. Traditional institutions and their attitude toward technical change. Legislation and politics as agents of change.
7. Channels for technological transfer: the decision for technological dependence or independence.
8. The transactions in the technology market and their incidence in the balance of payments.
9. Technical innovation as a dynamic factor in development. Planning versus free enterprise.
10. Strategies for technological innovation in Colombia.
11. Studies on "appropriate" or adequate technologies according to the type of society in which they are employed.
12. Identification of specific projects regarding appropriate or adequate technologies.

The duration of the course is one semester. It consists of lectures, group discussions, bibliographical research and term papers on

specific projects. An effort is being made to bring executives or prominent members of local corporations and industries as lecturers. It is conducted by a group of five professionals, led by the former director of COLCIENCIAS.

There are a few isolated efforts, mostly in schools of economics, to give courses on "development", but they are concerned generally with the social and economic aspects of development and have not taken into account science and technology or have mentioned them only in passing, without concerning themselves with the efforts being made by the country in those areas.

3. Orientation of Science and Engineering Studies to Development: Present Needs and Future Developments.

From the considerations in the previous chapter, it can be gathered that there is a great need for orienting studies in science and engineering schools to development. This point is also implicit in the recommendations of the NAS-COLCIENCIAS-ICFES review panel, mentioned in Chapter 1, and will be brought to the attention of a national meeting of Colombian university rectors to discuss orientation and planning of graduate studies, to be held at the end of May, 1973.

COLCIENCIAS is also aware of this acute need, and is trying in several ways to promote these studies at different levels within the universities. For this purpose COLCIENCIAS is currently:

a. Financing and sponsoring the formation of research committees, bringing together specialists and investigators in the several branches of science and engineering, as well as the social sciences, and encouraging them to promote discussions on the impact of science and technology in their respective communities.

b. Organizing seminars on the scientific method. These seminars also include discussions on industry participation, technological impact and orientation to development. In universities that are mainly technological, participation of leaders from business or industry is encouraged.

c. Developing as a joint effort with ICFES a program called "Government-University-Industry" which, in the beginning, will try to bring together representatives of the government[1] with directors and/or members of the main industrial and commercial associations.[2] The first meeting, scheduled for the second half of 1973, will be directed toward a discussion of the recommendations for effectuating a detailed inventory of scientific and technological research in industry. This has a great urgency in view of the forthcoming approval by the Colombian congress of Law No. 24 of 1972, which gives tax exemption to industries which can demonstrate that they are dedicating ten percent or more of their gross earnings to scientific or technological research. Further points in the agenda will be discussions of sources and availability of scientific and technical information in industries (aimed at the establishment of a National Service of Technical Information for Industry) and also the ways of achieving a more active participation by local industries in promoting or financing

scientific and technological research at undergraduate and graduate levels in Colombian universities.

d. Encouraging the formation of groups on "Science, Technology and Society" at those universities that are mainly technological, namely those in Bogota, Bucaramanga, Cali, Pereira and Medellin. From a superficial estimation of facts, it can be said that Medellin, which is the center of the mining and textile industries in the west of Colombia, has achieved more contacts between industries and universities. This has been accomplished on a purely empirical basis and without pre-established programs; however, the School for Administration and Finances, EAFIT, is beginning to concern itself with those contacts and, through its graduates in Business Administration and Finance is trying to establish closer relationships between the industries in that region and the universities which provide them with their main source of manpower.

Finally, it is imporatnt to note that the head of the Colombian Institute for the Development of Higher Education (ICFES) is a former rector of the Technological University at Pereira, and he is trying to help COLCIENCIAS implement those programs at the universities, whose structure, curricula and sometimes financing depend upon his direct supervision.

4. Possible Participation of U. S. Universities and Agencies in Helping to Orient Science and Engineering Studies to Development in Colombia

As was repeatedly emphasized at the meeting of the joint review panel with members of NAS and IDFES, once the rectors of Colombian universities have decided on the priorities for the implementation of graduate studies, the main role of the U. S. National Academy of Sciences would be in trying to help COLCIENCIAS and ICFES to develop their "Government-University Industry" program. For this purpose, of course, the experience of several major U. S. universities and the financial support of AID would be required. We are indebted to the U. S. National Academy of Sciences for having helped in evaluating these studies and preparing the final documents which will constitute an invaluable reference at the meetings.

The strategy could follow a path similar to that of the evaluation of graduate studies. Groups of professors from U. S. universities where similar types of studies are conducted (such as Cornell, MIT, University of Wisconsin, etc.) could be coordinated by the Foreign Secretary of the National Academy of Sciences to make visits to Colombian universities where studies related to their programs are in progress, to participate in seminars or group discussions concerning ways in which industry can be brought to cooperate with universities, to determine to what extent some of the teaching programs in science and engineering could be oriented to development.

On the other hand, a number of fellowships for training of Colombian university professors in the various aspects of scientific and technological development should be offered. This would help to arouse interest in the seminars and group discussions. An interesting possibility (once a program in a particular university has been advanced) would be to encourage exchange of professors and/or researchers in certain fields for limited

periods of time. The Colombian professor would gain the experience of a more advanced program, whereas the visiting U. S. professor would gain some insight into the problems related to underdevelopment.

U. S. companies or enterprises with Colombian subsidiaries should encourage more contacts between their personnel and Colombian universities (regarding common areas of interest) so as to explore how much of their present or future manpower could be provided by this or that university and accordingly also in coordination with the program, to find ways to support research projects of immediate industrial interest. This, of course, would be greatly facilitated if the local "centers" could be clearly defined during the first phase of the program.

There is also the need for channelling the assistance offered by U. S. granting or funding agencies to support the following areas: (1) Academic programs, specifically dedicated to orientation of science and engineering studies to development; (2) Research projects of national interest in these areas; (The qualification of "national interest" could be given by COLCIENCIAS acting as linking agency in the coordination of the program.) (3) Research programs leading to the recuperation of local experiences in adapting or innovating technologies, or related to the estimation of the impact of new technologies upon different groups (or social strata of the Colombian population.

Perhaps an initial meeting in Washington, bringing together members of U. S. AID, National Academy of Sciences, National Science Foundation, representatives of U. S. industry, as well as professors from U. S. universities interested in the program, with Colombian members of COLCIENCIAS, ICFES, National Planning Department, members of the industrial associations, and representatives from the above-mentioned technological universities would be advisable in order to further expand the ideas presented at this seminar.

Footnotes

[1]National Planning Department and Ministry of Development as well as the Bank of the Republic and the Fund for the Promotion of Exports (PROEXPO).

[2]National Association of Industries (ANDI), Colombian Association for Small Industry (ACOPI), National Federation of Businessmen (FENALCO). Chamber of Commerce, etc.

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TRANSFER AND ADAPTATION OF TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

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Summary

The construction industry is responsible for the generation of constructed physical facilities which play a critical and highly visible role in the process of development in many regions of the world. Its output constitutes a major fraction of GDP, and it employs between 5 and 15% of the labor force in most developing nations.

In most developing countries, the government is the largest client of the industry, in addition to being its regulator and material supplier. The labor intensive nature of the construction industry coupled with the fact that most developing countries have some indigenous industry in this area makes the construction industry an attractive area for creation of jobs, conservation of foreign currency, and a training medium for transformation from agricultural based employment to that of manufacturing.

The possibility of introducing a various mix of labor and capital technologies and the use of staging strategies in major public work construction offer an excellent opportunity for transfer and adaptation of technology.

I. Introduction

A major problem facing the world in the remainder of the twentieth century is to narrow the gap between the developed and the developing nations. Unfortunately the developed countries, already far ahead, are drawing still further away from the less developed countries and thus worsening a rather explosive situation.

Although economic and social change in the developing countries depends primarily on the actions of their people and their governments, the cooperation of the developed countries, especially through financial and technical assistance and multi-lateral cooperative arrangements, is vital. In recent years, the nature of this cooperation, its objectives and goals, and its modes of operation have been carefully reexamined by many institutions concerned with international assistance programs. It has become clear that financial assistance in support of, for example, a single spectacular project (a steel mill or a major hydroelectric power project) will not contribute significantly to the development program of a country and in many instances the project may only drain the limited and scarce resources of the local government for its operation and maintenance It is generally agreed that the role of international assistance programs should be shifted more toward institutional building in developing countries than toward single, short term spectaculars. This shift in emphasis, however, requires a thorough

understanding of the economic and social structures of developing nations and an awareness of the extensive changes required in human values and attitudes including education, communications, acceptability of new ideas, administrative effectiveness, business enterprise, and political leadership. Without this understanding the transfer of knowhow will remain an imitative process and foreign to the cultural, social, and political processes of the developing countries.

Transfer, adaptation, or development of new technology suitable for improving certain economic and social aspects of life in the developing countries has been considered as a most promising avenue of cooperation and collaboration between the developed and the developing nations. The transfer of technology, when properly administered, integrates a number of complementary activities: it provides for change in social systems and attitudes; it generates new knowledge and human skills; and it requires a new physical environment for its successful operation. Methodologies for establishing the technologic needs of a developing region, for selecting an appropriate level of technology to meet the established needs, and for assessing the impact of the transferred technology on the developing countries are, however, not fully developed and depend upon a complex set of social, economic, and technologic measures. For this reason, most technology transfers have been discussed within the framework of one sector of the economy and normally for a particular level of development.

This paper focuses on transfer and adaptation of technology in the construction industry and identifies the role that this industry has played and continues to play in the development process. The paper initially reviews the economic and technological conditions of underdevelopment which might impact the construction industry. It then defines the industry and its role in the development process and finally makes some recommendations on the nature of technological changes necessary in this industry in the developing countries.

II. Conditions of Underdevelopment

The economic and technological conditions most affecting the construction industry can be divided into three categories: capital scarcity, labor supply, and market basis restriction.

Capital Scarcity: All developing countries face a severe shortage of the capital necessary to begin and accelerate their development. Few of them even have sufficient capital resources to maintain a satisfactory rate of growth, say 5% or greater, let alone begin to accelerate it (1).

Brazil, Mexico, Taiwan, and a few other developing countries can be said to have significant internal capital resources. Most developing countries, however, rely heavily on external loans and grants-in-aid for their capital formation. In 1965 external sources furnished approximately $9.7 billion in capital to developing countries (2). This amounts to less than $10 available capital per capita in developing countries as a whole and compares with the $100 and more per capita invested annually in the U.S. Moreover, this scarce supply of externally obtained capital is unequally distributed throughout the world. Among those countries with populations

between 1 and 2 million, for example, the external capital available from international assistance in 1965 ranged from $69 million for Jordan to $4 million for Singapore.

A possible source of capital for the developing countries has been the encouragement of multi-national companies to invest in the local economy by setting up local plants. This mode of investment in the developing countries is reported to have been about 2 to 2.5 billion dollars per year in the past 20 years (7). Most of these investments have been in the areas of natural resources (petroleum and mineral recovery) or in the manufacturing processes. Foreign investment in constructed facilities has been limited only to the manufacturing of certain building materials. The author is not aware of any major foreign private investments in constructed facilities in the developing countries. There are, however, several instances of large scale investments by a private enterprise in housing and non-residential buildings in the developed countries; Levittown in France is a typical example.

Labor Supply: In general, developing countries have an abundance of very cheap but unskilled labor and a virtual absence of technically skilled labor (Egypt and India are exceptions to this latter condition). Most developing countries are agrarian, and the growing urban areas of developing regions consequently are populated principally by former farmers acquainted only with the most primitive agricultural methods. Most available workers have had little, or at best indirect, experience with machinery, and truly skilled technical workers are almost nonexistent. The low per capita income of developing countries indicates, in addition, that the prevailing wage for such unskilled workers is very low, amounting to only a few cents per hour in some areas.

In many countries large fractions of the labor forces have annual outputs per worker that are dismayingly low even when measured by their own average productivity standards. In a productivity sense, these people have a large measure of functional idleness, and this, too, is partly responsible for the lowness of their per capita incomes (3).

The large numbers of unskilled and unemployed workers are, in a sense, one of the most readily available natural resources of developing countries. At the same time, these workers are a great social problem, for mass unemployment causes widespread poverty and political unrest. The creation of employment, therefore, is considered by the governments of many developing nations to be an urgent, primary goal of economic development.

The scarcity of capital and the surplus of cheap labor might seem to indicate the general desirability of labor-intensive economic activity. Labor-intensive methods of production, however, may be inefficient for many processes and consequently may result in economic waste (4). Moreover, many products made by labor-intensive methods may be of inferior or variable quality. In addition when a market for goods produced by capital-intensive methods is created, backward and forward linkage mechanisms begin to operate (5). And because owners of capital tend to have high marginal propensities to save, this will lead to the creation of domestic capital sources and further growth (6).

Capital-intensive industries, on the other hand, require certain conditions which developing countries may find difficult and costly to meet. For example, they require certain minimum numbers of highly skilled workers. In many developing countries, it may be necessary to pay the added cost of importing skilled workers and other technical personnel from industrialized countries. Capital-intensive operations further require that available workers be accustomed to industrial surroundings, operations, routines, etc., and that these workers be stable in their work habits and located near their place of employment. Finally, extensive capital-intensive operations require a considerable infrastructure (roads, power supplies, housing and schools for workers, etc.), the cost of which must often be borne by the developing country (6).

Industries which are adaptable to varying mixtures of capital and labor intensity are said to be "technologically flexible". Woodworking and brickmaking, for example, are among the traditional technogically flexible industries. Many modern industries whose current technology is exclusively capital-intensive are, as a result, beyond the means of many developing countries in which these industries could play a useful role. The United Nations and others, therefore, have suggested that a high priority be given to the development of efficient capital-saving techniques in the core operations of these currently technologically inflexible industries (6).

The determination of the optimal mixture of capital and labor intensity for any manufacturing or construction must be made on the basis of the factors involved in each specific situation. For any given product, a range of product qualities, production efficiencies, capital/output ratios, possible profits, etc., are possible. Specific consideration of some of these factors in the construction industry is found in the next part of this paper.

Market Base Restrictions: Markets for various products in developing countries tend to be restricted in magnitude and geographic extent by low per capita income and inadequate infrastructure. Per capita income of $300 per year or less is the rule in developing countries. Per capita consumption of many goods is directly related to per capita income. As a result, low income countries have only moderate to low capacities for the immediate consumption of many goods, including construction materials. The market bases in these developing countries are limited accordingly.

Developing countries also have low levels of infrastructure for the support of general economic growth. The infrastructure of an economy includes public works (roads, airports, dams, power stations, etc.) which are necessary for any substantial economic growth and also public services (housing, schools, hospitals, etc.) which raise the standard of living but do not contribute directly to the economic growth of the country. The development of adequate infrastructure in developing regions requires large amounts of capital input, with little or no direct economic output in return.

The existing infrastructure of any developing region has great influence on the costs of production of many goods. For example, the transport facilities included in the infrastructure are very critical to the economic feasibility of most manufacturing operations. Most construction

materials manufacturing operations, in particular, require sizeable quantities of raw materials and produce bulky and/or heavy goods. The costs -- or even the feasibility -- of supplying raw materials and delivering finished goods must be within reasonable limits to allow such operations to be economically viable. Hence, the existing infrastructure figures directly in the costs of goods produced in developing regions.

The geographic extent of the market base for any given product is also dependent on the ease of transportability of the product. It may prove economically and technologically possible to deliver large precast concrete panels anywhere within a 5-mile radius of an urban area, for example, while deliveries to towns 50 miles away might be almost impossible at any cost. The geography of the market base therefore depends on the size, weight, and usual required quantity of any given construction material and on the ability of the transport infrastructure to move these goods at low cost.

In summary, the conditions of developing countries which influence the choice of technology in construction include scarcity of capital, abundance of unskilled labor, scarcity of skilled and management manpower, and limitedness of infrastructure and market base.

III. Construction Industry

The construction industry plays a vital and highly visible role in the life of every nation and its people. Through planning, design, construction, and operating activities, it transforms resources of capital, labor, materials, equipment, and technology into the constructed facilities required to meet society's needs for shelter, transportation, power, communication, water supply, waste disposal, and industrial production capabilities.

Construction is one of the oldest industries in the world and most developing countries invest a substantial portion of their capital on creation of physical facilities necessary for the enhancement of life in their society. The industry is responsible for creation of infrastructure which is vital to the initial phase of the development. In addition it plays a key role in satisfying a wide range of physical, economic, and social needs of developing nations. It makes critical and significant contributions to the fulfillment of major national goals. In most developing countries the government is the major client of the industry, and thus its policies and decisions have direct impact upon the future of the construction industry.

Each country, regardless of its level of development, has certain capabilities in the construction field. In addition certain local know-how and local building materials industries do exist in all developing regions of the world. Its size, the nature of its operation, and its presence in every developmental activity have made the construction industry the prime target for much experimentation with regard to enhancing the effectiveness of international assistance and cooperative works.

The following sections will discuss the importance of construction

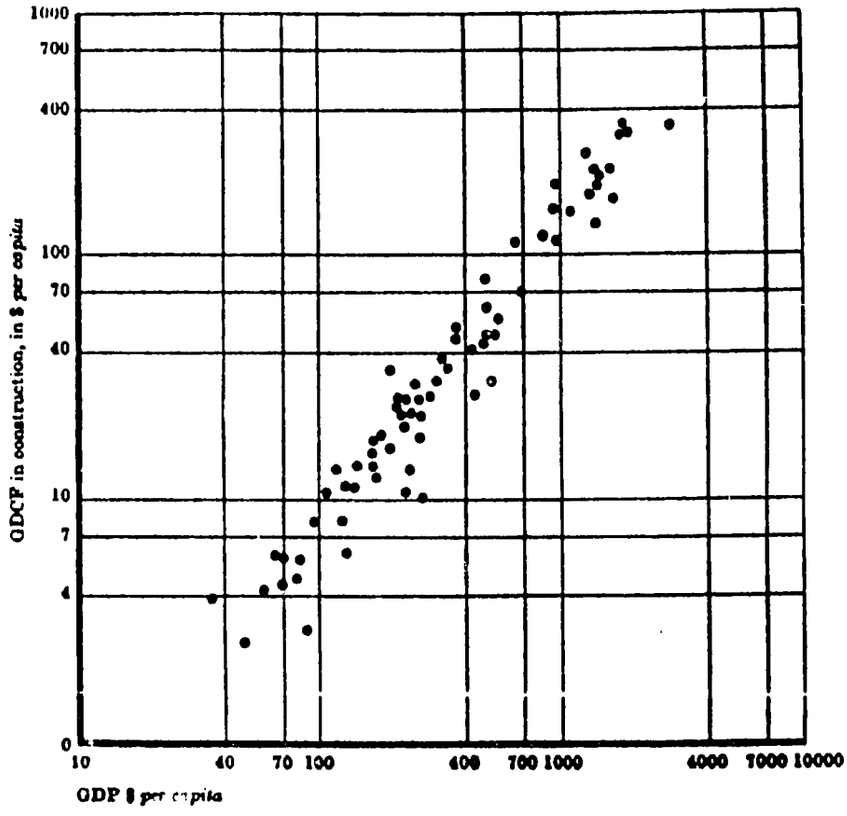

Figure 1: Per capita GDCF in Construction and GDF

Source: See Reference 8.

in the national economy of developed and developing countries, the process of construction and its inputs, and the issues facing the industry.

Construction Industry and National Economy: One of the major difficulties confronting those interested in a quantitative study of the construction industry is the unavailability of accurate and detailed data on the many different facets of the industry. This difficulty arises from several peculiar features of the industry: it is large but highly fragmented and somewhat specialized; it is highly dispersed geographically; its manpower, equipment, and materials are widely used by other industries; and associated with it is a large group of ancillary industries ranging from materials manufacturers to banking and insurance industries. Nevertheless, enough statistics are available to demonstrate the significance of the industry and to establish its role in the national economy of both developed and developing countries.

A recent study by the United Nations (8) shows that the world resources for construction are very unevenly distributed among countries at different economic levels. Table 1 gives the world estimate of gross domestic capital formation (GDCF) in construction for various income groups and different regions of the world in 1965. The data shows that of $230 billion invested in construction, 88 percent was in countries in the top two income groups. North America alone accounted for over 40 percent of the world GDCF in construction. Furthermore, these data show a strong correlation between GDCF in construction and per capita gross domestic product (GDP) (Figure 1).

Since 1947 contract construction in the United States has increased at a rate of 5% per year and the GNP at 3.7% (9). Similar figures for the developing countries cannot reasonably be obtained because of the fluctuations which exist in the demand, the sensitivity of the industry to political and economic uncertainty, and the fact that the developing countries have occasionally carried out single but very large projects which distorts the construction market picture.

The manpower requirements of the industry span a broad spectrum of personnel, ranging from highly educated to completely unskilled. The role that this manpower demand-supply plays in the national economy is of utmost interest to those concerned with the planning of the national economy. In the U. S. and many other developed nations, the industry provides from 6 to 10 percent of total employment, while in the developing countries it accounts for only 2 to 6 percent. The ancillary operations associated with the industry currently provide an additional 2 to 4 percent of employment in the developing countries and 4 to 6 percent in the developed nations.

Comparison of construction's share of the manpower market with its share of the output per year shows that its average productivity is significantly lower than that in the economy as a whole. Furthermore, the change in labor productivity over time is much less in construction than in other industries. For example in the U. S. in 1959, 2.7 million construction workers produced an output of about $25,000 per worker. In 1968. 3.4 million workers produced an output of about $26,000 per worker. This

Table 1

Gross Domestic Capital Formation in Construction (1965)

Billions of Dollars

Income Group GNP/Capita	North America	Oceania	Western Europe	Eastern Europe	Latin America	Middle East	Asia	Africa	%of World Total
$ 2000+	90.7		5.1			.2			41.8
700-2000		3.2	48.8	41.8	2.7	.6	8.9		46.1
400-700			3.1	2.4	2.1	.1	.2	1.2	4.0
120-400			1.1		2.5	.3	1.6	1.3	3.0
120							10.9	1.0	5.2
% of World Total	39.5	1.4	25.3	19.2	3.2	0.5	9.4	1.5	100

represents a productivity increase of only 0.4% a year per worker, compared with an annual productivity improvement rate of 2.5% for the economy as a whole. (10) This lack of improvement in the productivity is attributed, by many, to the unsuitability of most construction processes to automation and mechanization.

Many construction activities require a large number of skilled laborers and craftsmen. The labor in the building construction segment of the industry is composed of more than twenty crafts and many specialties (11). The dependency of construction on climatic conditions and the fact that manpower is generally hired for a particular job and layed off after the job is finished have resulted in a very high incidence of unemployment and job insecurity for the laborer. The incidence of unemployment in the industry is two to three times higher than the national average. In the developed countries, the labor organizations have attempted to limit the impact of this factor on their members by influencing the training and hiring practices. In the developing countries, the existence and the influence of trade unions are growing, but the construction worker is still faced with a very uncertain and fluctuating market. This lack of protection in the developing countries has resulted in a wage structure for construction workers which is substantially lower than that in the manufacturing industry. History has shown, however, that as the development process advances, the gap between manufacturing and construction wages narrows.

The level of development has also been shown to influence the nature of construction firms and the types of construction. In the least developed countries, construction is primarily focused on the basic infrastructure in agriculture, mining, and transportation. It is done mostly by a few foreign firms, and the projects are sponsored by the national government. In this situation, most projects require direct imports of not only materials and equipment but also of skilled manpower and managerial staff. Table 2 compares the profile of construction inputs of a typical developed country with a per capita GNP of $1200 with a less developed country with a per capita GNP of about $100. The data for the developing country shows that more than 60% of the material input is imported. The high cost of its transportation causes 55 percent of the total output to be due to materials and their handling. The dependency on imports of as much as one third of the total value of construction in the less developed countries has generated substantial interest in the development of local building materials industries and/or development of construction technologies which could utilize the existing local materials.

Construction Process: The industry in most developed and developing countries consists of three traditional sectors: investors, planners, and developers combine with the owner (often the government) to form the client sector; architects, engineers, and consultants form the design sector; while suppliers, general contractors, specialty subcontractors, and labor organizations form the contractor sector. The delivery process has been, and for the most part continues to be, executed by sequential activities in which each sector attempts to act independently to satisfy its own objectives. Decisions are made within a labyrinth of constraints often arising from partial or faulty information.

The client sector may consist of private individuals, or it may

Table 2

Profile of Construction Inputs

(Gross Value of Production Equal to 100 Units)

	Developed			Developing		
	Domestic	Import	Total	Domestic	Import	Total
Materials	26	8	34	17	25	42
Transportation and Handling	7	1	8	8	5	13
Sub Total	33	9	42	25	30	55
Salaries and Wages	43	-	43	28	3	31
Others; Including Taxes, Amortization, and Income	14	1	15	10	4	14
Total Value of Production	90	10	100	63	37	100

be public agency. In the latter case, the public agency is only representing the ultimate user of the facility, the collective client. In many cases the agency may not know the users; nevertheless, it must attempt to assess their needs. This separation of the users from the government agencies representing them has been considered a main reason for the failure of many public projects, such as public housing, hospitals, etc. In addition, failure to recognize the need for subsequent maintenance and upkeep of most public works has resulted in the rapid deterioration of these systems and a significant reduction in their useful lives. The concept of the total cost of the facility, which includes not only the initial construction cost but also the maintenance and operating costs over the design life of the facility, is gradually being introduced in most public works activities in both developed and developing nations.

The government, in addition to representing the collective clients in public works construction or acting as the client for publicly owned facilities, also acts as the legislative authority imposing external constraints on construction. The building codes and regulations which have been developed over the years in the developed countries, and which in many instances are transferred to or adopted intact by the developing nations, have stifled the development of new materials and techniques and have added to construction costs. This is especially serious in the developing nations where the adopted regulations do not even conform with the climatic, technical, and economic conditions of the region. For example, in the Caribbean, where the Canadian Building Codes were being used, most housing manufacturers had to meet the snow load requirements for the design of the roof system.

In addition to the numerous other responsibilities in construction, the government in most developing countries participates in various phases of construction. For example, transportation, national utility, and health and education departments of many developing countries often not only have their own design teams, but also have their own construction crews (generally in the form of maintenance crews who may undertake certain reconstruction activities). Furthermore, by owning and operating major construction materials manufacturing plants (cement, steel, glass, etc.), the government can influence the price of materials and consequently the preference for the type of construction. By providing preferential treatment to a particular sector of the industry, the government can substantially affect the distribution of the available manpower in the industry. For example, availability of low interest rates for housing will encourage substantial activities in that area. At the same time, it will increase the tendency for the introduction of labor-saving and capital-intensive construction techniques but only in housing.

In the construction industry, as in most other industries, there are many alternative combinations of processes and products. In terms of products, three broad categories can be recognized: residential buildings, non-residential buildings, and public works construction. Residential buildings, which include single and multiple dwellings, can be considered as consumers' durable goods. Non-residential buildings, consisting of industrial, commercial, educational, and hospitals, are similar to producers' durable goods. Public works construction, which represents government outlays for public facilities, consists of transportation infrastructures,

water supply and sewer systems, public utilities, etc.

The products of the construction industry, unlike those of most manufacturing industries, are primarily custom-built and thus are highly sensitive to the design phase of the process. Contrary to practice in the manufacturing industry, the product design stage in construction is normally separated from the production management. Therefore, collaboration of the designers and manufacturing experts, which is necessary to minimize the production costs, is seldom realized in the construction industry. The general contractor's participation starts only after the design is finalized. This separation of design from production has significantly limited the choice of the input factors of production. The designers have consistently overlooked the type of labor, equipment, and construction methods available to the contractors and have indirectly forced them to choose the technology which is dictated by the design rather than that which is most suitable to the local conditions.

While architects and consulting engineering firms who have the design responsibility refrain from competitive bidding for their services, the general contractor who has the production responsibility generally enters the process through a negotiated arrangement or competitive bidding. The main objective of selecting a contractor by competitive bidding and of having him offer a firm price in response to a set of predetermined drawings and specifications is held to be for the good of the public interest and the prevention of corruption, in addition to giving the client the best value for his money. It is, however, completely ignored that the competitive bidding approach encourages the freezing of technological change and forces the contractors to use the conventional procedures and techniques. Although numerous variations of competitive bidding and negotiated price contracts have been tried in various instances, none has received a widespread acceptance in both developed and developing nations.

The contractor sector is primarily responsible for the assembly operation, which until recently has been done exclusively on the construction site. Generally subcontractors are heavily relied upon to perform the required specialized processes, and in many projects the general contractor may only provide coordination and supervision. The mix of labor, equipment, and material in each process is rather unique and requires a separate production function. For example in the building segment of the industry, the foundation and grading process can vary from a highly mechanized and capital-intensive technique to a fully manual and labor-intensive activity where unskilled labor can be utilized with a minimum of training. On the other hand, electrical and mechanical works, although highly labor-intensive, require highly trained and skilled labor.

The fraction of cost allocated to each specialized process in the assembly phase varies from project to project. For example, in the building segment of the industry, the following breakdown of total construction cost is common: Foundation and grading 5-15%, erection and framing of structure 25-55%, electrical and mechanical work 20-35%, finishing 15-35%. The entire assembly process consumes up to 90% of the total initial investment required for a typical project, and it is the lengthiest phase of the construction process. The major components of cost in the assembly phase are the labor

and material costs.

The building materials industry is very diffuse and hard to define because most of the materials are used by many other manufacturing industries. A few materials are manufactured solely for use in construction, and among these cement is by far the largest and most widely manufactured building material throughout the world. Due to their low value to weight ratio, building materials are not usually transported over great distances, and their production, therefore, tends to be dispersed. In most developing countries, there is rarely sufficient continuous demand to permit the producers to stock the materials and overcome the oscillation in demand. This has resulted in the creation of the building materials merchant who acts as an intermediary between the manufacturing industry and the contractor sector of construction. In many developing countries, importation of basic building materials constitutes a significant drain on their balance of payments, and the development of a local building materials industry has normally received primary consideration.

Despite the high wages prevalent in the industry, construction is still a labor-intensive activity in both developed and developing countries. Table 3 shows the percent distribution of labor inputs by type of construction in the U. S.

In the developed countries, increases in the price of labor relative to other inputs has led contractors to find substitutes for labor. This substitution is achieved through the use of more productive equipment or by the use of a more capital-intensive method of construction which reduces the onsite labor requirements. Trends toward industrialized housing or prefabricated systems, whereby components of the building are fabricated off-site (occasionally are also partly assembled) and transported to the site for erection, serve to reduce the labor requirements as well as the dependency on the climatic conditions. Substitution of very high land fills for bridges in road construction is another example of labor substitution, which has become economically feasible with the development of very heavy and efficient road construction machinery.

The labor productivity and consequently the labor input to construction are also highly dependent upon the labor unions' rules and regulations as well as the type of construction project and its method of construction. Table 4, for example, compares the labor productivity in England with that of the Continent for the same type and method of construction. It can be seen that average man-hours for industrialized building on the Continent is 170 percent below the British average. Furthermore, it takes more labor to build an industrialized building in England than it takes to build a conventional building in the U. S. It is also interesting to note that labor in England is paid the same rate in the factory and on-site, while in the U. S. the factory rates are 25 to 40% lower than the on-site rates.

IV. Issues in the Transfer of Technology in the Construction Industry

The foregoing discussion has established that the construction industry is one of the largest sectors of economic activity in both developed

Table 3

Distribution of Total Construction Cost by Type of Construction in the United States

Percent of Total Construction Cost

Type of Product	Labor	Materials	Equipment & Overhead
Residential			
i) residential	30%	51%	19%
ii) prefabricated	18%	50%	32%
Non-Residential	26-29%	51-54%	20%
Public Works	27%	34%	39%

Table 4

Labor Productivity in Three Industrialized Regions of the World

Average Man-Hours per 1000 Square Feet of Multi Family Residential Buildings

	Industrialized		Conventional
	England	Continent	United States
on-site	1687	462	1165
off-site	375	300	149
TOTAL	2062	762	1314

Source: Engineering News-Record, October 22, 1970

and developing nations. Its products are essential for the industrialization process currently going on in most developing nations. The government in the developing countries plays an important role in the operation of the industry by being its regulator, its major client, its supplier, and a participant in its various activities. The industry is highly labor-intensive and is also technologically flexible.

The industry's products are heavy users of public funds. In most developing countries a large number of projects with high social returns still remain to be built, and the construction industry continues to contribute to their development. Although it is believed by many that construction as an industry should be given adequate consideration in planning economic strategy, unfortunately this is not currently the case in most national plans. The extent of investment in physical infrastructure is so vast that the construction industry has tremendous potential to contribute to the development process of the emerging nations in many more ways than just the building and construction works. For example, because construction embraces a wide variety of skills and activities and thus enables people to obtain training and experience, it provides an excellent medium for training a large number of people and assisting them in making the necessary transition from agriculture to industrial work. In this way it can act as a transitory job market between agriculture and manufacturing for a very large fraction of a country's manpower. In addition construction activities frequently initiate opportunities for other trade and commercial activities of very long durations.

It is therefore safe to assume that the construction sector of the economy deserves serious attention in the reevaluation of the current international assistance and cooperation programs.

The basic issues involved in the transfer of technology in this sector of the economy may be discussed in four broad categories of management and control, capital, technology, and manpower and labor. In the following sections each category is briefly discussed within the context of the developing countries, and certain suggestions are made as possible avenues for future works. The concept of labor substitution is stressed in each case, in light of its importance to the problem of unemployment or underemployment.

Management and Control: One of the most difficult problems in construction is that of its fragmentation. The industry is extensively fragmented both in terms of the nature of activities involved and the size of each firm. The industry consists of a large number of small firms, produces diverse product types, and lacks vertical integration or even just continuous working relationships among participants involved in the different production processes from one project to the next. The production units are small with each firm holding only a small share of the local market. The industry is noted for its "easy entry/easy exit" nature. It is generally accepted that economies of scale do not exist in the industry in most parts of the world, and in fact some diseconomies of scale seem to exist in some parts.

The fragmentation has prevented formation of industry wide

cooperation and organization which is so important in focusing the attention of the industry on the local needs and on the development of an understanding of unique local conditions requiring special consideration. In addition, as a result of this fragmentation the indigenous construction industry consists of small firms limited to one or two basic skills and lacks expertise to coordinate all the complexities of major projects.

The "easy entry/easy exit" nature of the industry is also reflected in the operation of major international construction firms working in the developing countries. In construction the true multi-national organizations with well established, permanent, operating subsidiaries in several countries have not developed, despite the fact that the international construction firms have been operating in the developing countries for many years.

The role of government, particularly as a regulator, is very important in providing an atmosphere conducive to the development and growth of the indigenous construction industry. Programs with significant components for training and educating the local personnel should receive priority over those which are selected solely on the basis of minimum cost and competitive bidding. In this regard the possibilities of establishing a central institution responsible for collection, evaluation, and dissemination of construction related information and statistics would be extremely helpful. It would provide a focal point for exchange of information and knowledge, for establishing standards, and possibly for initiating research on local problems. Using projects supervised and managed by international firms as field training centers, the governments could rapidly and with a very small expenditure increase their scarce pool of skilled labor and middle management.

Capital: The scarcity of jobs and resources in developing countries has a pronounced effect on the construction industry whose products require high capital investment and a large number of laborers. This scarcity makes itself felt both in the composition of resources and in the timing of investment.

The composition refers to the balance between labor and capital which is required to implement a project. Capital is scarce in most developing countries and labor relatively plentiful. The labor aspect of the problem is discussed in more detail in the following section.

The timing aspects of scarcity stem from the fact that resource availability, especially with respect to capital funds, is generally tied to political bodies at the national or international level. There is a great deal of uncertainty associated with future funding for projects, which leads to a strategy of requesting the maximum amount possible for present funding and spending it immediately. This effect is typically demonstrated by the neglect of maintenance and the emphasis on overdesign in construction.

At issue then are the inefficiencies, in terms of total use of resources, which may arise from heavy emphasis on one aspect of composition or timing. When this emphasis results in neglect of other aspects of resource usage, substantial losses in overall development benefits may result. Therefore, the developing countries should be provided with knowledge and methodologies which will display the broader picture in more specific and

quantifiable terms.

Related to the problems of resource availability are the varieties of costs through which resource needs are evaluated. Costs of constructed facilities are distributed among construction, operation, and maintenance, between local currency and foreign exchange, among the users, government, and international donor and lender. These costs are by no means equivalent in their importance and impact on a particular developing nation. For instance most developing nations face severe shortage of foreign exchange. This condition places a special premium on construction technologies which minimize foreign exchange requirements. This premium in turn may imply a preference for labor intensive technologies because of the need to import capital equipment. There is a need then to be able to predict how various technologies will affect these numerous aspects of cost.

Staged construction, which results in deferral of costs, offers an excellent opportunity for the developing countries. It is a procedure whereby a facility is built initially to meet the immediate demands of the user; that is, for example, demand over only a five year period. The facility is then upgraded through reconstruction to meet increased demands. The opportunity for deferral of expenses which staging presents may result in reduced cost and in more effective use of resources by allowing their use in other sectors. Furthermore, in several construction activities, especially road transportation, the staging provides a measure of adaptability which is not present otherwise. For example, should traffic growth predictions for the road project, built by staging, prove to be only optimistic, the initially lower standards of the road will entail less of a loss in the form of sunk costs than would the higher quality project. It is thus important that the construction technologies suitable for stage construction be identified and brought to the attention of the developing nations.

Technology: Introduction of new technology in the construction industry has been the prime factor in the gains in productivity which have been achieved in the industrial nations. In addition utilization of modern technological concepts and tools has given the industry capabilities necessary for conception, design, and construction of such major projects as nuclear power plants and the Aswan dam.

Although the degree of technological sophistication varies from one sector of the industry to another, one can divide the contribution of technology into two broad categories: 1) software, including planning and analysis techniques, design methods, management information and control, and construction methods and 2) hardware, including materials and equipment.

Concerning the first category, the introduction of the computer has dramatically increased the capability for planning and designing large scale facilities and for economically evaluating a wide range of available alternatives. More exact methods of analysis and design have resulted in the construction of more efficient, complex, and elaborate structures. New techniques of information processing have allowed the industry to apply the principles of systems engineering in the evaluation of several different strategies for large scale projects, such as regional water distribution systems and transportation network systems.

Most of these advances have been put into practice through the existing structure and organization of the international firms. No substantial efforts have, however, been made to study the effect of computers on organization and operation of this industry in the developing countries and on increasing the efficiency and effectiveness of the limited existing design and planning capabilities in these countries. The design and analysis phase of the construction process is a highly technical field requiring a well educated and experienced cadre of engineers which is currently of limited availability in the developing regions. Novel application of computers could very substantially increase the capability and the productivity of this scarce talent and also provide incentive for innovation and adaptation in design consistent with the local environment and requirements.

As far as the material is concerned, the establishment of basic building materials manufacture in developing countries depends on both economic and technical considerations.

The capital expenditures necessary to establish various building materials manufactures vary from a very small amount for bricks to several million dollars for aluminum and steel, as shown in Table 5. On the basis of the minimum capital cost necessary for beginning the economically justifiable production of building materials, strong advantages are held by cement, wood, lime, and brick products. The commencement of steel and aluminum manufacture requires large amounts of capital investment even at the smallest justifiable level of production. This diversity of capital requirements suggests, for example, that a developing nation might well establish a moderate to large capacity cement plant, while relying entirely on the importation of steel to supply the necessary reinforcing rods and mesh. Alternatively, because bricks and wood products are most readily adaptable to small scale and primitive modes of production with virtually no capital investment required, a developing nation might decide to rely on its production of these for building materials.

The adaptability of building materials manufacture to labor-intensive methods, while preserving overall efficiency, is of special concern to developing nations. The degree of labor intensity required will depend on many factors, including available capital, dependence of efficiency on mechanization, local labor costs, and the required proportion of skilled and unskilled workers. These factors will depend not only on the building material but also on the local conditions under which manufacture is to take place. However, some figures for labor costs and requirements for production of certain building materials can be given. Table 6 gives wage levels and proportion of skilled workers to total employment in certain building materials industries in India. Wage levels and percentage of skilled workers required are low for brickmaking and sawmilling, moderate for cement production, and high for production of steel and nonferrous metal primary products. If these figures are typical for developing countries, it would appear that operating costs of production are directly related to capital costs necessary to establish production. Thus the total cost of manufacture (capital costs plus operating costs) of the various building materials parallels the disparity of capital costs shown in Table 5.

Table 5

Building Material (by type of plant	Capital Cost per tpy Capacity	Minimum Economic Plant Size	Capital Cost for Minimum Economic Plant
Bricks	variable	variable	variable*
Wood:			
Sawnwood	$30	variable	variable*
Plywood	$96	5000	$500,000
Softboard	$123	5000	$600,000
Hardboard	$96	5000	$500,000
Particle Board	$55	5000	$275,000
Lime:			
Small Unmechanized Vertical Kiln	$13.6	30,000	$410,000
Large Mechanized Vertical Kiln	$14.6 to $18.7	30,000	$440,000 to $560,000
Rotary Kiln	$22.8 to $28.4	30,000	$680,000 to $850,000
Cement:			
Vertical Kiln	$28	30,000	$880,000
Rotary Kiln	$40-$50	100,000	$4,000,000 to $5,000,000
Aluminum	$800 to $900	10,000	$8,000,000 to $9,000,000
Steel	$250	100,000	$25,000,000

Table 5: Minimum Capital Costs and Economic Scales of Production for Building Materials Manufacture

Building Material	Average Daily Wage		Ratio Skilled Workers to Total Employment (R_s)	Weighted Labor Cost $W_sR_s + W_u)1-R_s)$
	Skilled (W_s)	Unskilled (W_u)		
Bricks, Tiles, Lime	$.51	$.26	0.284	$.330
Plywood	$.71	$.16	0.384	$.372
Asbestos Products	$.56	$.325	0.444	$.429
Sawmilling	$.56	$.345	0.412	$.432
Cement Pipes	$.86	$.33	0.262	$.469
Secondary Nonferrous Metal Products	$.58	$.35	0.570	$.481
Secondary Steel Products	$.65	$.36	0.480	$.499
Cement	$.76	$.325	0.433	$.514
Primary Nonferrous Metal Products	$.78	$.375	0.499	$.578
Primary Steel Products	$.82	$.39	0.529	$.618

Table 6: Labor Costs and Proportions in Building Materials Manufacture in India

The diversity of uses for various building materials leads to possible secondary economic effects which must also be considered. For example, the manufacture of wood products can lead to secondary economic benefits, especially on the local level. Furniture and match making are industries which are frequently encouraged by the establishment of a sawmill producing good quality sawwood. The low capital and labor costs of wood products production, coupled with the possible secondary manufacturing operations, make this a natural area of growth for developing nations with under-utilized forest resources. Cement, on the other hand, has virtually no uses outside the field of construction, and its secondary manufacturing effects are limited to encouraging the production of concrete and cement blocks, pipes, prefabricated panels, etc. Concrete is the universal construction material, however, and is used in all types and magnitudes of construction projects. Consequently, the secondary effects of cement manufacture within the field of construction are likely to be considerable.

As far as materials technology is concerned, more efforts are being made to develop cheap, serviceable, and easily assembled building materials. The qualities sought in these building materials are:

1. The building material should, if possible, be made of locally available raw materials;
2. The building materials must be cheap to produce;
3. The materials must be easy and economical to use in actual construction, whether used by professional builders or by an individual building his own house;
4. The materials should be serviceable in all types of small buildings and should be as adaptable as possible to use in all parts of the building (floors, walls, roofs);
5. The materials must meet minimum structural and health requirements and also any special climatic conditions.

The development of such building materials is currently grouped around two approaches to the problem. The first approach aims at the improvement of traditional building materials and methods. The second approach aims at the development of new building materials or components which will be integral parts of modern building systems. Each of these approaches deserves some elaboration.

In evaluating any building material, the minimum economic scale of manufacture and the potential utilization of the material are prime considerations. Most traditional building materials, like wood and bricks, can be produced locally on a small scale. The use of these traditional materials, however, is largely dependent on the existing local building trades and contractors. For example, a brick industry was started in the Territory of Papua and New Guinea, largely as a result of the abundant clay deposits there. The industry has not been able to grow, however, because there are not enough bricklayers in the Territory to lay the bricks already being produced (13). In other words, the existing building skills in developing regions must be assessed before the suitability of introducing a traditional building material can be judged. The regional customs or practices relating to building can also be important in judging the

suitability of a building material. In East Africa, for example, building contractors commonly manufacture their own building materials (cement blocks, for example) for each job (14). Hence, the introduction of a building material which must be produced on a large scale is not impossible, but a building material economically produceable on a small scale would be much more likely to win quick acceptance.

Where construction activity or needs are of sufficiently large scale, preplanned building systems can offer significant economies of both time and money. Developing regions not only have great need for buildings, but there is also similarity in the types of buildings needed. Table 7 shows the types of dwellings proposed by various countries for their low-cost mass housing developments. One and two storey dwellings are the most common type of construction planned. Two storey construction is, in fact, very often the cheapest type of building (per ft^2 of habitable space) when the cost of land is not excessive. The prevalence of one and two storey construction around the world has led to widespread interest in the use of light-weight structural panels for use in this type of construction. Among the most promising of these lightweight panels are those made of wood and ferrocements.

Attempts at transfer of technology in the building materials industry should therefore be concerned with not only technical feasibility but also the macroeconomics of the developing region as well as the micro-economics of manufacturing the material, such as capital costs, operating costs, and efficiencies of various scales and modes of production.

Labor: The issue of the labor force and its utilization in the construction industry has received substantial attention in the literature. This interest stems from three basic characteristics of the construction industry: a) construction is labor-intensive and technologically flexible, and there exists a continuous spectrum of labor-capital exchanges; b) many facets of the industry can absorb a large number of unskilled laborers, and a significant fraction of the needed labor force can be trained on-site and taught the skills required; c) the construction industry is a major component of the national economy, and its products are essential to the development of other economic sectors. This last point has also been used in the context of expanded public works construction programs so that the left-over and unemployed labor force could be at least temporarily absorbed in an artificially created job market.

On the other hand some have argued (3) that the major client of this industry is the government and thus that utilization of construction as a potential job market is mixed by bureaucracies typical of civil work departments of many governments. Lewis (3) has also argued that because of this difficulty, policy makers in the developing countries "are likely to be skeptical of the proposition that the public-works approach has much untapped potential for attacking the new levels of urgency that the poverty and underemployment problems seem to have reached". He, however, points out that the use of public work sectors as a means to control unemployment and poverty becomes very attractive when compared with alternative policies, especially in the near and medium term.

Table 7

Types of Construction Recommended by Various Governments for Low Cost Housing Programs.

Country	Type of Housing Proposed	Suggested Building Materials	Total Floor Area (ft^2)	Living Space per Person (ft^2)
Pakistan	1-storey with central courtyard	permanent	275	125
India	1-storey semi-detatched	brick	250-480	135-190
India	Village house	mud, thatch	500	250
Hong Kong	5-6 storey tenement	concrete	120	36
Hong Kong	11-storey flats	concrete	413	58
Singapore	Semi-urban small dwelling	timber, thatch	530	400
Kenya	2-storey	permanent	960	132
Tanganyika	1-storey	semi-permanent	1000	200-400
Uganda	1-storey detached	semi-permanent	1000	280-560
Zanzibar	1-storey house	semi-permanent	660	190-380
South Africa	Detached house	permanent	650	530
West Indies	1-storey detached house	timber	500	150-300
Latin America	1-storey rural detached house	-	684	388-465

Source: Inter-African Conf. on Housing & Urbanization, Housing and Urbanization, pp. 151-153.

Construction being a technologically flexible industry, offers many cost-effective modes of construction which are labor-intensive. However, to consider construction as a residual employer or to expect it to serve as the "manpower sponge" does not appear to be consistent with long term planning goals for economic development. Such a policy in many cases may conflict with the national choice of technology on a long term basis and may impede the capability of the country to compete in export markets or to advance the development of its more progressive sectors.

Selection of labor-intensive techniques in construction for the purpose of job formation should not rely upon "technological retrogression". The argument that "the only way to absorb surplus labor ... is to lower the technological level of production" (31) is not normally consistent with the economic efficiency of construction. In fact, in the construction industry one can, in many situations, find or devise techniques which utilize the fixed available capital and all the available labor without the marginal productivity of labor falling to zero. In construction one should realize that labor-intensive techniques do not imply that each laborer must be equipped with the same amount of capital equipment or that a certain task be carried out by the same technique.

In many situations in the construction industry one is faced with the problem of lack of certain skills rather than absence of capital or oversupply of laborers. For example, the use of a large number of unskilled laborers, on several occasions, has not been feasible because the skilled supervisory and organizational personnel were not available. On other occasions, immobility of labor forces has caused scarcity of labor in one region while severe unemployment existed in other regions. The cross Amazon highway program in Brazil is an excellent example of this latter point. Excessive labor forces in the northeastern part of Brazil can not be convinced to move to the central region where highly capital-intensive techniques are being utilized due to lack of manpower.

As far as capital-intensive construction techniques are concerned, the absence of infrastructure for repairs and maintenance as well as organizational personnel and supervisors familiar with the advanced technology may in fact cause diminishing returns to scale from capital-intensive means. Engineers should allow for alternative techniques so that their chosen design does not dictate factor proportions. The design should be such that techniques can be devised to utilize as fully and effectively as possible the factors available in a developmental unit.

V. Summary and Recommendations

The need for constructed facilities in developing countries is substantial and the capital required for their construction constitutes a major portion of resources available to the developing nations. This need is anticipated to grow at a very rapid rate in the foreseeable future, because the constructed infrastructures provide the backbone of developmental programs in other sectors of the economy.

The industry is highly labor intensive, is technologically flexible, and offers numerous opportunities for absorbing a major fraction

of the labor force and providing the unskilled laborers with on-the-job-training which will increase their productivity and consequently their earning power.

The issues involved in the construction industry can be grouped in areas of management, capital, technology, and labor. Government, with its numerous construction related concerns, plays an extremely sensitive role in developing a viable indigenous construction industry which is responsive to the social needs and aspirations of the people.

The severity of the scarcity of capital necessary for the construction of the needed physical facilities can be lessened by appropriate choices of technology, labor substitution and staging of the construction activity itself. Technology offers assistance in numerous manners. The use of computers and its associated software capabilities should be viewed as a very promising means to increase the planning and design capabilities of local expertise. Development of computer technology consistent with the needs of developing countries should be encouraged by both local governments and the international institutions. Building materials technology is an area that, although certain headways have been made in it by several of the more advanced developing nations, still offers a major opportunity area for developing countries to invest some of their resources. This segment of construction industry offers not only job opportunities for unskilled and semi skilled labor, but it also reduces the import needs and generates significant backward and foreward linkages.

The abundance of unskilled labor in developing countries and the labor intensive nature of construction have for many years been considered an excellent match for alleviating the problem of unemployment. However, lack of careful planning on the part of local government and the assumption that the construction industry can absorb all the unemployed (especially through creation of public work programs whose needs could not otherwise be justified) have made the match rather unattractive to the policy makers in the developing nation. It is suggested that this attitude should change because the alternatives to job formation are much less promising.

The following specific recommendations are made. The list is, by no means, exhaustive, but it contains a few areas worth further study and discussion.

1. The role of multi-national construction as a vehicle for transfer and adaptation of technology should be examined. This examination should focus on their past performance, their current concerns, their relations with the indigenous firms, and their positions viz-a-viz, regulatory activities of local government.

2. The staging of construction and the impact of various monetary policies, especially with respect to cost of money and availability of foreign exchange for importation of capital equipment on the construction industry's choice of technology warrant careful review and analysis.

3. The impact of computer technology in planning, design, construction, operation, and maintenance aspects of constructed physical facilities in the developing nations requires basic and fundamental research.

4. The building materials industry and its role in the national economy offer numerous attractive possibliities for adaptation of technology.

5. Considering construction as a part of national economic planning and thus providing continuity in its operation both spatially and temporally should receive the attention of policy makers in the developing nations.

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