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ADAPTATION OF INDUSTRIAL AND PUBLIC WORKS TECHNOLOGY
TO THE CONDITIONS OF DEVELOPING COUNTRIES

Report of Activities

December 1, 1971 to July 1, 1972
under
Five Year 211D Grant, AID/CSD 3360
December 1, 1971 to December 1, 1976

PRINCIPAL OBJECTIVES

Under this grant M. I. T. proposed to develop a cohesive program concerned with the exploitation of technology for public works and industrial development in developing countries. The Institute planned, in the initial phase of the program, to improve understanding of the processes that enable technology to contribute to industrialization in the less developed countries, with emphasis on the following:

- (1) Understanding the nature of technologies that are appropriate to countries or regions in various early stages of industrial development, particularly those countries in which the factors of production have relative values different from those of developed nations.
- (2) On a case basis, finding effective technical solutions to be adopted or further developed by developing countries, including adapting existing technology for local conditions and needs or devising appropriate new technical solutions.
- (3) Identifying the skills required to select and adapt technologies appropriate to the developing countries. Examining the techniques for strengthening these skills, including technical education and appropriate design of products, processes and plants suited to the conditions.
- (4) Understanding the processes by which technological and managerial knowledge and skills can be effectively introduced, disseminated, and used in developing countries, including an understanding of cultural impediments and the obstacles to technological development that have been encountered in the past, and developing methods of improving transfer and diffusion rates.
- (5) Examining, at the national and enterprise levels, the long-term and short-term economic and social advantages and disadvantages of importing rather than establishing indigenous manufacturing technology.

Management of the Grant

M. I. T. management of the Grant resides with a Steering Committee that reports to the Provost, consisting of Peter Eagleson, Head of the Department of Civil Engineering; Everett Hagen, Professor of Economics and former Director of the Center for International Studies; William Pounds, Dean of the Sloan School of Management; Lloyd Rodwin, Head of the Department of Urban Studies and Planning; George Rathjens, Professor of Political Science; and J. P. Ruina, Professor of Electrical Engineering and Chairman of the Committee.

The Committee decided to begin activities under the grant by increasing faculty understanding of M. I. T. 's past experience in work related to technology adaptation and by establishing goals and priorities for the program based on the direction of faculty interest. Funding of new research projects was delayed until June, 1972. This period also provided an opportunity to learn about the relevant experience of neighboring institutions.

Faculty Workshops

To achieve these objectives a series of faculty workshops were held, attended on an average, by 19 faculty and some select graduate students as well. Notes on each meeting were prepared and circulated to the Steering Committee. The speakers and topics were as follows:

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| February 14 | Presentations by Professor F. McGarry, M. I. T. Department of Civil Engineering; Professor Charles Savage, Harvard Business School; and Dr. Rao, Ford Foundation on the M. I. T. Inter-American Program in Civil Engineering (all three speakers had been associated with the program). |
| February 22 | Presentation by Professor Everett Hagen on the early stages of industrial development and potential methods of investigation of the later stages. |
| February 29 | Presentations by Professor R. L. de Neufville, Department of Civil Engineering on approaches to transportation systems in ldc's and Professor J. Schaake on integrating the development of the Rio Grande, Argentina (an IAP Project). |
| March 6 | Presentation by Professor Rodwin, Head of the Department of Urban Studies and Planning and members of the SPURS (Special Program for Urban and Regional Studies of Developing Areas) faculty on the SPURS program and other on-going and planned department work in developing countries. |
| March 14 | A workshop on M. I. T. 's institution building programs overseas with discussion by a number of faculty members who have been, or are involved in these programs. |
| March 28 | Presentation by Dr. Jack Baranson of the World Bank and the NAS on defining appropriate technologies for developing countries. |

- April 3 Presentation by Dr. Nevin Scrimshaw, Head of the Department of Nutrition and Food Science on world-wide problems and potential solutions to protein deficiency with particular attention to the production of single cell protein.
- April 11 Presentation by Professor Horatio Caminos of the Department of Architecture and graduate students from the department on urban settlement design in developing countries.
- April 18 Presentation by Professor Carroll Wilson, Sloan School of Management and Constantine Simonides, Vice President of the Institute, on the M.I.T. Fellows in Africa Program (1960-1967) and the M.I.T. Fellows in Colombia Program (1965-1968).
- May 2 Presentation by Dr. Walter Falcon of the Harvard Development Advisory Service on the operations and experience of the DAS in developing countries.
- May 8 Presentation by Dr. Bruce Old, C. Bliss, J. Mitchell and D. Feeley of Arthur D. Little Co. on the operations and experience of ADL in developing countries.

From the workshops and proposed projects the departments with the greatest immediate interest in program participation appear to be the Departments of Aeronautics and Astronautics, Architecture, Civil Engineering, Mechanical Engineering, Sloan School of Management, and Urban Studies and Planning. Potential interest has been shown by members of the Departments of Nutrition and Food Science, Chemical Engineering, Ocean Engineering, Political Science and Economics.

Educational Programs

Discussions are underway with several departments on the possibility of developing workshops and seminars on specialized subjects within the area of technology adaptation either at M. I. T. or overseas, and of modifying existing graduate programs to serve better the needs of students interested in problems of technology that are faced by developing countries. The main problem that is encountered here is that such programs must not only address pertinent technical problems and provide a useful experience for the individuals involved, but they must also meet the academic requirements and standards of M.I.T. Some departments are better suited to this kind of program than others. Particularly unsuited are those departments which concentrate

in areas of highly sophisticated technology or technology useful only to nations in a very advanced stage of development.

Linkages to LDC Institutions

Understandably linkages will be established with different institutions for some of the projects listed below. In addition we plan to explore the establishment of an informal relationship with KIST, The Korean Institute of Science and Technology. A new research institute in Korea, KIST is part of a complex which includes The Korean Advanced Institute of Science, with which Cornell has a working relationship.

Library

A preliminary search of materials in the M. I. T. library system has indicated that M. I. T. has a strong collection of the "classical" literature in the area of technology adaptation and transfer. It has become apparent that grant funds are not adequate to develop a complete library on the subject as well as support research projects. However, grant funds will be used to augment existing collections, particularly with documents which would be unlikely to reach the library through other channels.

Overseas Travel

Two overseas trips were made under the grant by faculty members during this period at the invitation of AID. (Professor Thomas Allen visited Guatemala December 8-10, 1971, Professor Richard de Neufville visited Colombia April 4-8, 1972). Professor Ruina traveled on an AID mission to Nigeria and Ethiopia using other funds.

Research Projects

Ten projects have been approved and are now underway. The majority of these will be supported for one year only and are expected to generate funds from other sources for continuing work.

In selecting projects the Steering Committee has emphasized the extent to which each might contribute to M. I. T.'s long term research capabilities and/or strengthen course work in the area of technology adaptation, as well as the extent to which each project meets the objectives of the grant.

1.

Title: Application of Highway Cost Model to
Venezuelan Road Transportation
Principal Investigator: Fred Moavenzadeh, Civil Engineering

The objectives of the research (in collaboration with Central University in Venezuela) are to validate, calibrate, and implement a Highway Cost Model which has been developed at M.I.T. during the past three years. Major stress will be placed on testing and validating the staged construction capabilities of the model. Staged construction attempts to reduce the total expenditures in any period through periodic upgrading and investments. Through cooperative work with the faculty of the engineering school at the Central University and the personnel of the Venezuelan Department of Transportation, field data will be collected for the calibration of the model. The capabilities of the model as a tool in the planning of highway links and in the scheduling of maintenance and reconstruction will be tested and evaluated.

The Highway Cost Model to be used was originally developed in 1969-70 under contract to the World Bank. The original model consisted of a series of submodels that could estimate the costs of construction, maintenance and vehicle operation, given a description of the road and its traffic. The submodels were deterministic simulators of the processes that occurred during the life of a road.

Under sponsorship by the Department of Transportation the capabilities of the HCM were expanded in 1970-71. Research objectives were to make it a more comprehensive framework for decision making in low traffic volume road construction, to examine the effects of staging of construction, and labor intensive maintenance on the costs of various roads.

The present research will apply the model in five stages:

1. Selection of case studies in Venezuela. Three recently completed projects will be selected primarily on the basis of availability of data suitable for the model and the willingness of Venezuelan co-workers to monitor the process.
2. Tuning of the model to simulate the selected cases. After the model has been modified to account for the special features of each case, sensitivity and trade-off analyses will be made to demonstrate its capability in predicting future needs in terms of maintenance and reconstruction.
3. Examination of Alternative Strategies: By varying the input

variables the consequences of such things as different construction standards, maintenance standards and practices, availability of foreign exchange, labor vs. capital intensive alternatives, and variation and distribution of capital costs, will be explored.

4. Development of Guidelines for Construction Management of Low Volume Road Systems in Venezuela. Based on the results of certain guidelines with regard to the staged construction, strategies and future maintenance policies will be established to assist the planner in his approach to new and existing road projects.
5. Preparation of Report and Proposals for Outside Funding. It is expected that by demonstrating the usefulness of such models in evaluating alternative strategies, outside funding can be obtained for extension of the model to inter-model studies, where the available alternatives would be extended to other transportation modes.

2.

Title: Water Resource Development

Principal Investigators: Professor Frank E. Perkins and
Professor David C. Major, Department
of Civil Engineering

The objective of the project is to develop a detailed plan to apply modern water resource planning technology to a river in a substantially underdeveloped nation.

In developing this project the principal investigators will draw upon their experiences and assessment of the M.I.T. Argentina project in water resource planning that will end on August 30, 1972.

In the M.I.T.-Argentina water resource planning project, modern investment criteria, mathematical programming and hydrologic simulation techniques have been used in a context of continued interaction between the M.I.T. team and Argentine decision makers to (1) develop alternative management and investment programs for the Rio Colorado, Argentina and (2) show how modern systems techniques can be used for water resource planning in Argentina, a country at a middle level of economic development where planning has been relatively crude and unsystematic.

The planned outputs of the current Argentina program include the models and recommendations developed for the Rio Colorado, general recommendations on planning techniques for other rivers, and a number of trained professionals to utilize the Rio Colorado models and apply the same techniques to other rivers. Included in this group are six Argentines who have had formal training at M.I.T., a group of professionals who attended a short course given in Argentina, as well as a relatively large number of professionals who have had close contact with the M.I.T. group in Argentina.

Based in part upon the assessment of the Argentine project, a detailed proposal for the adaptation of modern water resource systems techniques to river basin development in a nation at a low level of per capita income will be developed.

A possible choice of country for the current project is Nigeria, which meets the income level and language criteria.

The work to be accomplished in this phase of the project includes the assessment of candidate rivers in terms of data availability; suitability with respect to national development plans; availability of counterpart personnel who might participate in the project; and the interest of the ldc government in the work.

3.

Title: Urban Transportation Systems

Principal Investigators: Professor Daniel Roos and Professor Nigel Wilson (Civil Engineering)

The project objective is to adapt and implement techniques resulting from several research efforts already underway concerning urban transportation systems analysis in developing countries. Latin America would be the focus of the work, though the techniques would be applicable to other developing areas.

The transportation systems division of the Department of Civil Engineering has been working on the optimal design of transportation facilities in developing countries, modelling transit requirements in Bogota, Colombia, inter-city transport requirements in Venezuela, the optimal location of airports in several Latin American countries, tradeoffs in air, road and water transport, and time staging strategies for investment decisions in transportation networks.

The project would build upon and apply recent work of the Division of special relevance to urban passenger transport in developing countries. In most developing countries the drift of population to the few major cities has resulted in severe transport problems within these cities. Because of the very low auto ownership rates, public transport plays a vital role.

Traditionally, the existing transportation modes are fixed route bus, colectivos and taxis. Generally bus systems operate with decrepit equipment run by many small, private operators with resultant intense competition and inefficient use of resources. Many of these cities are now planning subway systems and reviewing operation of other modes.

The work proposed on modelling these transport systems would seek to determine the correct mix of these systems and optimal operating policies (fares, routes, schedules) for each system. Efforts would be made to apply these models to specific cities to demonstrate their utility.

It is anticipated that during the first year of this project the groundwork will be done for preparing a fully detailed proposal to be submitted to the appropriate funding agencies in 1973.

Finally, a significant part of the project will be the collection of material and information to be incorporated into several courses in the Civil Engineering curriculum.

4.

Title: Air Transportation in Developing Countries

Principal Investigators: Professor Robert Simpson (Department of Aeronautics and Astronautics) and Professor Richard de Neufville (Civil Engineering)

The purpose of this project is to help authorities responsible for civil aviation in developing countries to deal with the problems of the growth of aviation, including those of an environmental nature. The program will attempt to find the patterns of air transportation system development (the airlines, the aircraft, the airways and the airports) that will promote system growth to the advantage of the nation's overall economic development. In developing countries air transport can be more than an expensive, high speed, transportation system. It can assist greatly in the development process by providing a flexible transportation mode. This mode can be designed to utilize in an optimum fashion the developing nation's scarce resources allocated to its transportation system.

The proposed project will consist of two overlapping phases--first, the education of M.I.T. personnel about the nature of the problems faced by developing countries in the air transportation area, and, second, initiation of appropriate research programs in the host countries and educational programs at M.I.T.

Phase I: In order to identify those areas (and countries) which appear to have the most immediate use for the type of knowledge in the field of air transportation that M.I.T. possesses and can readily transfer, research will proceed as follows:

1. Intensive literature search
2. Discussions with appropriate U.S. government agencies, international air carriers, and non-governmental organizations working on technology adaptation and air transportation programs in developing countries.

Graduate research assistants will be engaged during the entire project to help distill and assemble the information obtained.

Phase II: As the logical and responsive points of contact in developing countries appear, visits will be undertaken to these countries to exchange personally information and discuss the most efficient or useful procedure to be followed in each individual case.

The furthering of the education of middle level government officials responsible for aviation matters, in conjunction with the M. I. T. Center for Advanced Engineering Studies, may be one option offered. Research in the host country or at M. I. T., on problems of air transportation in developing countries, with an aim of furthering the educational capability of M. I. T. is another possibility.

5.

Title: Systems Analysis as an Aid in the Development Process

Principal Investigator: Professor Robert E. Stickney, Department of Mechanical Engineering

The objectives of the project are first, to provide a detailed test of the usefulness and limitations of systems analysis as an aid to developing countries in their planning and evaluation of alternative development programs, and second, to prepare several case studies illustrating the application of systems analysis to the problems of ldc's for inclusion in a new course in the Mechanical Engineering curriculum.

1. Systems Analysis as a Development Aid

The initial test selected for the project is the development of a systematic method for evaluating alternative nutrition programs for a developing country. The particular country for the study has not yet been determined. The project will draw upon two earlier graduate research studies: one which formulated an analytical approach to the evaluation of alternative strategies for improving infant nutrition in developing countries; and another which developed an approximate method for determining agricultural production patterns (product mixes) that would provide adequate nutrition for a given population while minimizing cost, land, water and fertilizer.

The country selected for the study will be visited to obtain needed information and to discuss the project with interested persons. It is anticipated that the present study will generate funds from other sources for ongoing work.

2. Case Study Preparation

Support is being given to develop case studies illustrating the application of systems analysis to the problems of developing courses. They will be included in a new subject to be offered in the spring of 1973, titled "Modelling and Analysis of Systems Pertaining to National Development". The objective of the course is to introduce students to the systems techniques that may be used in studies of development problems in both developing and developed countries.

6.

Title: Materials Adaptation for Developing Nations

Principal Investigators: Professors N. Cook, P. Griffith and D. Wilson, Department of Mechanical Engineering

A recurrent technological problem facing ldc's is the lack of engineering materials--steel, cast iron, polymers, etc.--and the resulting import burden on the economy. The objective of the project is to explore the possibility of discovering material substitutes, which are in the main available locally, and which will satisfy the necessary functional criteria. Can approaches, systems and methodologies be developed which can help an ldc identify, develop and promote such a materials substitution?

Initial work will focus on the feasibility of using a cement based substitute for conventional metals--possibly using the "ferro-cement" technology that has been developed during the past decade for boat hull manufacture.

During the first year a two part program will be established:

- (1) work with ldc's to establish material needs, and to form the cooperative groups required for the development and exploitation of substitute materials.
- (2) work with students (here, and possibly in the ldc's) to begin evaluation of the metal/cement substitution.

The initial country choices are Nigeria and Colombia.

The program goal is the establishment of a separately funded project to continue work in materials adaptation.

7.

Title: Transfer and Adaptation of Housing Technologies
Principal Investigators: John Turner and Don Turner, Department of Urban Studies and Planning

A study will be undertaken that will

- (1) analyze the simple, locally-inspired ways in which developing nations might use indigenous materials and capabilities, supported by new technology, to improve the safety, speed, and ease of self-help building methods;
- (2) create several documented case studies and other teaching materials that could be packaged for short-term training institutes to be held at M. I. T. or at various locations throughout the world. Such training institutes would help to promulgate various strategies designed to enhance the transfer and adaptation of housing technology and standards to the needs of developing countries; and
- (3) document the failures of industrialized housing technology transfers from developed to less developed nations and help to formulate policy guidelines to prevent the repetition of such failures in the future.

The project will include the presentation of at least one new course offering at M. I. T. as well as the accumulation of additional data, field experience, and research of special interest to students and faculty working on technological adaptation in housing, especially as it relates to the needs of developing countries.

It is anticipated that the current study will generate other funds to extend the project beyond the initial phase.

8.

Title: Development of Basic Performance Standard for Urbanization and Housing Technologies through Testing of Models in Nairobi, Kenya

Principal Investigators: Professor Horatio Caminos, Reinhard Goethert, Department of Architecture

The objective of the project is to develop basic performance standards for urbanization and housing technologies, including environmental conditions, physical characteristics, utility networks, service facilities, regulations, circulation systems, housing systems and land development opportunities.

Housing standards in developing countries are generally more appropriate to the conditions of advanced nations. Revision of these standards, to allow a transfer of housing technology compatible with local materials, techniques and cultures, is badly needed.

During the summer of 1972 a group of M.I.T. faculty and graduate students will go to Nairobi, Kenya where they will evaluate local housing systems, future housing needs and performance requirements. The medium of their work will be field studies, workshops and seminars in collaboration with the University of Nairobi and the Nairobi City Council. Tentative performance standards will be formulated and compared with United States and Latin American references. Finally models will be prepared during the 1972-73 academic year for testing of the standards.

The project aims at expanding current Latin American expertise in the Department of Architecture into the African context. The Nairobi project will provide a case study to be included in a course on housing standards which is now being developed by members of the Department, as well as the basis for a conference on Urbanization and Housing Technologies to be held in the spring semester of 1972. A complementary project on the Transfer and Adaptation of Housing Technologies is being undertaken by members of the Department of Urban Studies and Planning.

Funding of future phases of this project, including the implementation of the performance standards formulated, is anticipated from other sources.

9.

Title: Organizational Studies and Development

Principal Investigators: Professor George Farris and Anthony Butterfield (Sloan School of Management)

The project objective is the preparation of a fully elaborated proposal on "Organizations and Economic Development: Research and Action in Brazil" for submission to the appropriate funding agencies by the end of August.

The proposal being developed aims at designing a long range program leading to the institutionalization of organizational research and development capabilities within Brazil. Brazil has been selected as a key developing country with an unusually rich learning potential. An earlier project has shown the relevance and acceptability within Brazil of the general approach to organizational research and development, and could serve as a base upon which to build a more lasting program.

Little is known about organizations and how they relate to their environment in developing countries, or how they cause and are influenced by processes of economic development. A program leading to the creation of a center or other type of institution for the study of the problems can be composed of inter-related phases and activities.

By means of early heavy use of overseas advanced training for Brazilians, simultaneously with visiting professors in Brazil, a center could be established which at the end of approximately eight years would:

- a) have significantly advanced knowledge about operations in their environments
- b) have assisted many Brazilian organizations to become more effective
- c) have trained many Brazilian executives and administrators
- d) have educated and trained many Brazilians in organizational r & d
- e) be producing advanced graduates with a Brazilian faculty and staff
- f) be to a considerable extent self-supporting through studies in client organizations, both public and private

10.

Title: The nature of R & D by Industrial Firms in India
(Research for a Doctoral Thesis)

Principal Investigator: Bruce Kutnick (Graduate Student,
Sloan School of Management, under
supervision of Professor J. Bhagwati)

A twelve-month study will be undertaken on the nature of R & D by industrial firms in India, with particular emphasis on the chemical and pharmaceutical industries. Indian R & D has been selected because it seems to be oriented towards adapting imported processes toward the use of domestically available inputs. The Indian approach seems strikingly different from that of other countries where R & D is aimed at product changes and "improvements" and towards cost reductions through capital savings processes, etc. R & D in India reflects instead the whole strategy of import-substituting development.

The study will broadly review and analyze R & D efforts, expenditures and accomplishments in the Indian economy but will focus on the chemical and pharmaceutical industries as they account for a substantial portion of industrial R & D. The R & D investment behavior of multinational corporations in these industries will also be investigated.

Six to eight months of field work will be conducted in India using the medium of questionnaires and interviews within the firms in question. The remainder of the twelve month period will be spent interviewing in U.S. firms associated with the industries studied in India and compiling the results.