TRANSFER AND ADAPTATION OF TECHNOLOGY IN THE CONSTRUCTION INDUSTRY*

Prepared By

Fred Moavenzadeh

Professor of Civil Engineering
Massachusetts Institute of Technology
Cambridge, Massachusetts

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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 re-examined 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 nonexistant. 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 technologically 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 are 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 are 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 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.

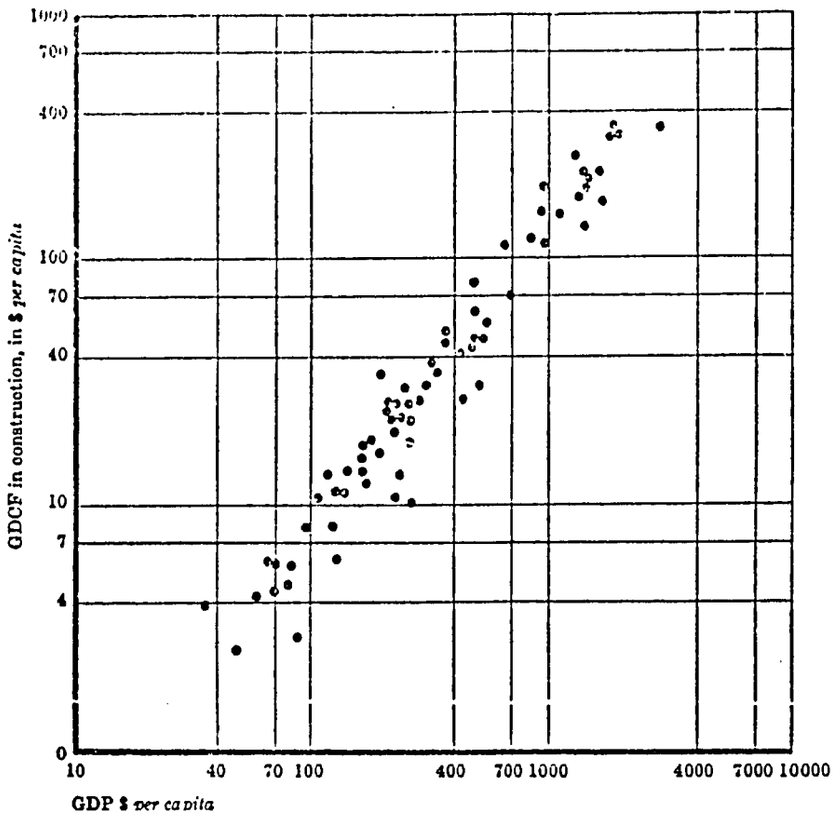

Figure 1: Per capita GDCF in Construction and GDF

Source: See Reference 8.

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

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 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

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

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 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 a set of predetermined drawings and specificati to be for the good of the public interest and t of corruption, in addition to giving the client value for his money. It is, however, completel that the competitive bidding approach encourage of technological change and forces the contract the conventional procedures and techniques. Al variations of competitive bidding and negotiate have been tried in various instances, none has widespread acceptance in both developed and dev

The contractor sector is primarily respons assembly operation, which until recently has be 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 se
breakdown of total construc
and grading 5-15%, erectio
electrical and mechanical
entire assembly process co
investment required for a
lengthiest phase of the co
components of cost in the assembly phase are the labor and
materials costs.

The building materials industry is very diffuse and hard to define because most of the materials are used by many other manufacturing industries. For example, steel is used not only in construction but also in automobile, machinery, and many other 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 on-site 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.

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.

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 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 re-evaluation 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.

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

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 $W_s R_s + W_u(1-R_s)$
	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

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

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-detached	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 houses	timber	500	150-300
Latin America	1-storey rural detached houses	-	684	388-465

Table 7: Types of Construction Recommended by Various Governments for Low Cost Housing Programs.

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

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 macro economics of the developing region as well as the micro economics of manfacturing 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 labor, 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.

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 "tech-

nological retrogression". The argument that "the only way to absorb surplus labor ... is to lower the technological level of production" (31) is not normally consistant 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 over supply of laborers. For example the use of a large number of unskilled labor, in several occasions, has not been feasible because the skilled supervisory and organizational personnel were not available. In 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 techniques. In most construction work, the role of engineers, primarily those in the design process, should be to provide for a joint use of efficient labor-intensive techniques and 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 labor 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 it's 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 softward capabilities should be viewed as a very promising means to increase the planning and design capabilities of local expertise. Development of computer technology

consistant 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 require basic and fundamental research.

4. The building materials industry and its role in the national economy offer numerous attractive possibilities 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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