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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna

Monographs on Appropriate Industrial Technology
No. 13

APPROPRIATE INDUSTRIAL TECHNOLOGY FOR BASIC INDUSTRIES

UNITED NATIONS
New York, 1981

EXPLANATORY NOTES

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions.

A slash (/) is used to indicate "per", for example t/a = tonnes per annum

A slash between dates (for example, 1979/80) indicates an academic, crop or fiscal year.

A dash between dates (for example, 1970–1979) indicates the full period, including the beginning and end years.

References to dollars ($) are to United States dollars unless otherwise stated.

References to rupees (Rs) are to Indian rupees. In October 1978 the value of the rupee in relation to the dollar was $1 = Rs 7.90.

The word billion means 1,000 million.

The word lakh means 100,000.

The following notes apply to tables:

Three dots (. . .) indicate that data are not available or are not separately reported.

A dash (–) indicates that the amount is nil or negligible.

A blank indicates that the item is not applicable.

Totals may not add precisely because of rounding.

In addition to the common abbreviations, symbols and terms and those accepted by the International System of Units (SI), the following have been used:

Economic and commercial terms

CMEA	Council for Mutual Economic Assistance
GNP	gross national product
R and D	research and development

Organizations

PEMEX	Petroleos Mexicanos
SAIL	Steel Authority of India Limited

EXPLANATORY NOTES *(continued)*

Technical abbreviations and symbols

bbl/d	billion barrels per day
BBOP	bottom blown oxygen process
BF	blast furnace
BOF	basic oxygen furnace
CC	continuous casting
CNC	computer control
DCs	developing countries
DNC	direct computer control
DR	direct reduction
EF	electric furnace
LD	Linz-Donawitz
NC	numerical control
NPK	nitrogen-phosphorus-potassium
OH	open-hearth
PVC	polyvinyl chloride
RCC	reinforced cement concrete
UHP	ultra-high power

The concept of appropriate technology was viewed as being the technology mix contributing most to economic, social and environmental objectives, in relation to resource endowments and conditions of application in each country. Appropriate technology was stressed as being a dynamic and flexible concept, which must be responsive to varying conditions and changing situations in different countries.

It was considered that, with widely divergent conditions in developing countries, no single pattern of technology or technologies could be considered as being appropriate, and that a broad spectrum of technologies should be examined and applied. An important overall objective of appropriate technological choice would be the achievement of greater technological self-reliance an increased domestic technological capability, together with fulfilment of other developmental goals. It was noted that, in most developing countries, a major development objective was to provide adequate employment opportunities and fulfilment of basic socio-economic needs of the poorer communities, mostly resident in rural areas. At the same time, some developing countries were faced with considerable shortage of manpower resources; in some other cases, greater emphasis was essential in areas of urban concentration. The appropriate pattern of technological choice and application would need to be determined in the context of socio-economic objectives and a given set of circumstances. The selection and application of appropriate technology would, therefore, imply the use of both large-scale technologies and low-cost small-scale technologies dependent on objectives in a given set of circumstances.

Report of the Ministerial-level Meeting,
International Forum on Appropriate Industrial Technology

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Foreword

As part of its effort to foster the rapid industrialization of developing countries, the United Nations Industrial Development Organization (UNIDO), since its inception in 1967, has been concerned with the general problem of developing and transferring industrial technology. The Second General Conference of UNIDO, held at Lima, Peru, March 1975, gave UNIDO the specific mandate to deal in depth with the subject of appropriate industrial technology. Accordingly, UNIDO has initiated a concerted effort to develop a set of measures to promote the choice and application of appropriate technology in developing countries.

Appropriate industrial technology should not be isolated from the general development objective of rapid and broad-based industrial growth. It is necessary to focus attention on basic industrial development strategies and derive from them the appropriate technology path that has to be taken.

The Lima target which, expressed in quantitative terms, is a 25 per cent share of world industrial production for the developing countries by the year 2000, has qualitative implications as well. These comprise three essential elements: fulfilling basic socio-economic needs, ensuring maximum development of human resources, and achieving greater social justice through more equitable income distribution. Rapid industrialization does not conflict with these aspirations; on the contrary, it is a prerequisite to realizing them. But, in questioning the basic aims of development, we also question the basic structure of industrial growth and the technology patterns it implies.

Furthermore, it is easy to see that the structure of industrial growth that should be envisaged and the corresponding structure of technology flows should be different from what they are today; a fresh approach is called for. This does not mean that the flow of technology to the modern sector and the application of advanced technologies are unnecessary. On the contrary, it is essential to upgrade the technology base in general, and it is obvious that to provide basic goods and services, there are sectors of industry where advanced or improved technology is clearly necessary. It would be difficult to envisage a situation where the dynamic influence of modern technology is no longer available for industrial growth and development in general. However, an examination of the basic aims of industrial development leads to the conclusion that there must be greater decentralization of industry and reorientation of the design and structure of production.

Such decentralized industry in the developing countries calls for technologies and policy measures that often have to be different from those designed for the production of items for a different environment, that of the developed countries. As a result, there is a two-fold, or dualistic, approach to an industrial strategy. Moreover, the two elements in such an industrial strategy need to be not only interrelated but also integrated.

In approaching the question of appropriate industrial technology from an examination of basic development needs, a mechanism is necessary to link and integrate appropriate industrial technology to the overall development process. Through such a process the concept of appropriate industrial technology could be placed in the mainstream of the industrial development effort.

It is hoped that these mongraphs will provide a basis for a better understanding of the concept and use of appropriate industrial technology and thereby contribute to increased co-operation between developing and developed countries and among the developing countries themselves.

It is also hoped that the various programmes of action contained in the monographs will be considered not only by the forthcoming meetings of the United Nations Conference of Science and Technology for Development and UNIDO III but also by interested persons working at the interface over the coming years.

Abd-El Rahman Khane
Executive Director

Preface

To focus attention on issues involved in choosing and applying appropriate technology, UNIDO organized the International Forum on Appropriate Industrial Technology. The Forum was held in two parts: a technical/official-level meeting from 20 to 24 November 1978 at New Delhi and a ministerial-level meeting from 28 to 30 November 1978 at Anand, India.

In response to a recommendation of the ministerial-level meeting, UNIDO, with the help of a generous contribution by the Swedish International Development Authority, is publishing this series of monographs based mainly on documents prepared for the technical/official-level meeting. There is a monograph for each of the thirteen Working Groups into which the meeting was divided: one on the conceptual and policy framework for appropriate industrial technology and twelve on the following industrial sectors:

Low-cost transport for rural areas
Paper products and small pulp mills
Agricultural machinery and implements
Energy for rural requirements
Textiles
Food storage und processing
Sugar
Oils and fats
Drugs and pharmaceuticals
Light industries and rural workshops
Construction and building materials
Basic industries

The monograph on the conceptual and policy framework for appropriate industrial technology also includes the basic part of the report of the ministerial-level meeting and some papers which were prepared for the Second Consultative Group on Appropriate Industrial Technology, which met at Vienna, 26–29 June 1978.

PART ONE

Issues and considerations

Note by the secretariat of UNIDO*

INTRODUCTION

Certain basic industrial materials and products are essential to industrialization and constitute the material basis for industrial growth. In addition to infrastructure such as energy supply and transport, developing countries must assess their needs for such basic materials and products and plan for their assured supply through domestic production or through imports. Both the quantitative and qualitative structure of domestic demand for such products changes significantly with successive levels of industrialization.

Since an important objective of industrialization in developing countries is best use of domestic natural resources, the planned growth of industries based on those resources is necessary. Exploitation of minerals and production of basic metals, particularly iron and steel, where these resources are available, must be given high priority, taking of course other techno-economic considerations into account. Similarly, the production of certain chemicals, petrochemicals and fertilizers needs to be planned in relation to domestic resources and domestic demand because such production provides the material base for a large number of industrial and agricultural enterprises. The metal processing sector, particularly capital goods production, needs to expand rapidly because it provides the basis both for the development of technological skills and for meeting the growing needs for machinery and equipment in all production sectors. Attention must also be given to industrial sectors which produce processed basic materials for other industrial sectors. An analysis of the technological needs of the basic industries can illustrate the issues and implications of technological choice.

Industrial sectors which exploit mineral resources or produce chemicals, petrochemicals, fertilizers and capital goods are often called heavy industries because of the large capital outlays they entail and the large scale of their operations.

In this note some of the principal technological implications of the production of iron and steel, basic chemicals, petrochemicals, fertilizers, and engineering goods are discussed in relation to the fulfilment of broader socio-economic objectives, particularly industrial dispersal.

The issues of technological choice and application differ from industry to industry. However, in all sectors the principal elements and implications of

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*This note was prepared by Rana K. D. N. Singh, now Director, Information Analysis Division, United Nations Centre on Transnational Corporations (UNCTC), when he was Special Adviser to the secretariat of UNIDO.

alternative technologies and certain broad criteria for determining appropriate strategies for investment and technology choice can be identified. Appropriate strategies, however, require consideration of alternative technologies at all stages of manufacture and possible co-operation and co-ordination between production enterprises in a given sector. The investment pattern and the range of technological choice must be determined for each stage of processing and production. At certain stages of processing choice may be limited to certain technologies and scales of production; at other stages, greater flexibility can be exercised in choosing technology and production scale. Suitable combinations of investment and technology need to be identified in relation to available resources, demand and other techno-economic considerations.

The traditional pattern of investment and technology choice for heavy and basic industries presupposes large-scale production using sophisticated and capital-intensive technologies from developed countries. The massive capital outlays required by such projects are often not available in developing countries. With growing control of some production sectors by relatively few transnational corporations, the implications of private foreign investment become particularly significant. Such investments are inevitably related to the global policies and production programmes of transnational corporations. At the same time, more developing countries are becoming aware of the need to employ national resources in the national interest. Several developing countries possessing scarce natural resources such as petroleum, natural gas and certain minerals have succeeded in doing this thanks to their strong international bargaining position. However, in developing countries where significant resource advantages do not exist or cannot be effectively exploited, investment and technological choice may be limited.

In addition to the availability of natural resources the flow of investment capital to basic production sectors is also determined by both domestic and foreign market conditions. Global production of steel, copper and certain petrochemicals, for example, has achieved levels where production costs and prices have become increasingly competitive and significantly affect investment in and technological choice for new enterprises or for expansion of existing enterprises. In the engineering goods sector international competition has also been increasing significantly. Nevertheless, developing countries have significant resource advantages which they can effectively use to establish and develop basic industries in ways consistent with achieving their socio-economic objectives.

OBJECTIVES

The principal objective of establishing basic industries in developing countries is to provide essential processed goods and to ensure better use of natural and human resources within the framework of broad socio-economic goals. The provision of basic industrial goods such as iron and steel and certain chemicals and fertilizers is essential to balanced industrial growth and agricultural development while the development of the capacity to produce engineering goods is necessary both for the growth of technological skills and to meet the growing demand for machinery and equipment. Natural resources, particularly minerals, must be so exploited as to produce maximum advantage to the economy.

TECHNOLOGICAL ALTERNATIVES

Basic metals

The range of investment and technological alternatives in the metallurgical sector must be considered at all stages from mining and ore extraction to metal production. In mining the technological trend in developed countries is towards highly mechanized operations. The extent of mechanization appropriate in developing countries must be related to the need to create employment opportunities. While technological improvments which provide greater safety and efficienc in mining operations should be adopted, mechanization which displaces labour may not be suitable. The use of sophisticated mining equipment may often not be necessary, except in handling operations at pit-heads or ports. At various stages of mineral processing, however, modern and sophisticated production techniques may be needed to improve product quality and reduce production costs. Appropriate techniques and processes must be identified at each stage of conversion and processing. While traditional, labour-intensive techniques may be suitable at certain operational levels in given situations, sophisticated and capital-intensive processing technologies may be needed at other levels.

Alternative scales of production and related technology should be considered for the production of basic metals. In steel, aluminium, copper, zinc and other metal production, scale and choice of technology must be related to patterns of ownership, demand and availability of resources in a given country. While sophisticated technology may be needed at various stages of processing, alternative production scales may be considered for most such operations. To illustrate this point the range of choice in iron and steel production is briefly described below.

Adequate production or assured availability of iron and steel is essential to developing countries because these metals constitute the essential material basis for industrial growth.

Production alternatives range from integrated steel plants producing 10 million t/a or more to plants producing steel by electric smelting with capacities of 20,000 t/a or more. It is estimated that a steel plant with a capacity of 1 million t/a and employing about 6,000 persons would require an investment of $800 million. A plant of this or greater capacity would necessitate not only a major capital outlay but would presuppose a detailed techno-economic analysis of raw material availability, demand, location, choice of process and technology, choice of end-products, sources of financing and sources of machinery and equipment. The establishment of large integrated steel plants with blast-furnaces and Linz-Donawitz (LD) oxygen converters must be based on long-term techno-economic considerations and the use of suitable technologies at each stage of production.

At the other end of the technological spectrum scrap-iron melted in electric furnaces can provide the raw materials for rolled steel rods and bars. This process may be appropriate, particularly in smaller countries with limited internal demand, although the availability of scrap may constitute a major limitation. Between these two scales of production there are many alternatives. High-grade ore can be converted into sponge-iron by the direct reduction process; in turn, the sponge-iron can be converted into steel in electric-arc furnaces. An integrated plant of this kind with a capacity of 500,000 t/a would require an investment of about $250 million. Up to certain levels of capacity it would also be possible to use charcoal for the production of high-grade steel.

Broadly considered these technological alternatives are available for steel production:

(a) Blast-furnaces based on coking coal with oxygen converters supplying molten steel to the rolling mill complex. Minimum capacity is about 500,000 t/a; capacity could range up to six times that;

(b) Charcoal blast-furnaces with oxygen converters to supply molten steel;

(c) Electric reduction with oxygen converters to supply molten steel; minimum economic capacity would be about 50,000 t/a;

(d) Direct reduction with electric-arc furnaces to supply molten steel; capacity could range from 200,000 t/a upwards;

(e) Electric furnaces fed with scrap-iron to provide the raw material for steel bar mills; capacity would be about 25,000 t/a;

(f) Bar mills (re-rolling mills) fed with local or imported supplies of steel billets; minimum economic capacity would be about 10,000 t/a.

The selection of an appropriate technological alternative or alternatives depends on various techno-economic factors. In large developing countries, where the demand for steel is increasing rapidly, integrated mills using advanced technologies may be needed to produce steel at competitive prices. Where forest resources are abundant, charcoal blast-furnaces with oxygen converters may be more appropriate. The electric reduction process is more appropriate where low-cost electrical power is available and access to good coking coal is limited. Direct reduction processes fuelled by gas are more appropriate where oil and natural gas resources are available. Developing countries at earlier stages of industrial growth might use electrical furnaces to melt scrap-iron where scrap is available or can be supplemented by imported sponge-iron. Developing countries with abundant iron ore might also export ore and possibly participate in foreign mills processing such ore until techno-economic conditions justify domestic production of processed iron and steel.

The range of technological alternatives for the production of iron and steel is thus fairly wide. Comparable alternatives exist in other metal industries. Choice between alternatives must be exercised in the context of given situations. Choice should also be exercised within the framework of a particular technology at each stage of production.

Basic chemicals and petrochemicals

Domestic availability or domestic production of certain basic chemicals constitute the material basis for a wide range of chemical end-products. While end-products can be manufactured at various scales of production, technological trends increasingly reflect large scales of production and the use of highly capital-intensive technologies. Plants are being made for petrochemical refineries with throughputs of up to 10 million t/a of crude oil while ethylene crackers are being designed for capacities of 500,000 t/a and more. Large-scale petrochemical production has been increasingly undertaken in developing countries with substantial oil or natural gas resources or in large developing countries with growing internal demand.

Technological alternatives in chemicals and petrochemicals take various forms and can be related to operational technology or to process technology. At one end of the production spectrum, a number of end-products can be manufactured with particular types of equipment; thus, several plastic products can be manufactured with the same type of machinery. The production of certain basic petrochemicals, however, requires heavy capital outlays and capital-intensive processes although, for most products, alternative technologies are available.

The production of chemicals and petrochemicals in developing countries must be carefully planned in relation to demand and availability of raw materials. While the degree of domestic demand would determine the production of certain goods, the production of basic petrochemicals for export can be undertaken in developing countries rich in oil and natural gas resources. The initial objectives of domestic production should be substitution of local goods for imports and provision of processed materials for domestic manufacture of end-products.

It may be necessary to produce certain basic chemicals and petrochemicals in large-scale units using advanced, capital-intensive technologies. Production can, however, be developed in stages appropriate to local situations. It is important, however, to ensure close co-ordination between production in large plants and production in possibly dispersed satellite units. Dispersed manufacture of intermediate and end-products from imported raw materials could also be undertaken in countries where manufacture of basic chemicals and petrochemicals may not be practicable for techno-economic reasons or because of limited resources.

A wide range of chemicals can also be produced from alternative raw materials. Various sodium products and derivates as well as several chlorine-based chemicals can be produced from salt, for example. Alternative raw materials entail the use of alternative technologies which may be suitable for use in developing countries.

The pattern of technology application for chemical and petrochemical production can be based both on alternative raw materials and on various scales of production. Generally the raw-material base will determine the kind of technology used. Choice of appropriate technology must be related to the availability of raw materials and other techno-economic considerations. In its overall impact on society and the economy, however, the relationship between the production of basic chemicals and their use in the manufacture of a large variety of end-products may be more significant.

Fertilizers

While ensuring that basic and intermediate processed materials are produced on optimum scales using sophisticated and capital-intensive technologies, it may also be appropriate to decentralize the production of fertilizer end-products to the extent technologically feasible. Ammonia, for example, is being increasingly produced in large-scale units with capacities of 1,000 t d or more not only in developed countries but in several developing countries as well. Large-scale capital-intensive ammonia plants of increasingly large capacity could be established either in countries with significant natural resources or where internal demand for fertilizers would sustain such production.

It should be possible, however, to decentralize production of fertilizer end-products, both in the interest of industrial dispersal and to allow production closer to end-users. Intermediate or end-products could be transported in bulk and blended at decentralized locations to produce appropriate mixtures for local agriculture. Decentralized production of liquid fertilizers might require advanced technology to transport intermediate products to decentralized, satellite units. Plant and equipment required in such decentralized units would include bulk storage facilities and machinery facilities and machinery for blending different fertilizer end-products.

Capital goods

Capital goods can be broadly classified as all goods, including infrastructure, which are used to produce other goods. The manufacture of plant and equipment in developing countries must be seen from another perspective than the production of basic metals or chemicals. The latter usually needs to be based on natural resources unless internal demand is sufficient to justify the heavy capital outlays necessary. Capital goods, on the other hand, must be produced both to meet the growing internal demand for machinery and equipment and to provide the opportunity for accelerated growth of domestic technological skills and capability.

The production of machinery and equipment should be seen as essential to the growth of technological infrastructure and technological capability. While imported machinery provides the opportunity to learn how to operate machines, it is necessary to transform and develop such skills into machine-building capability within a reasonable period of time so that technological dependence is not perpetuated and technological progress can keep pace with the desired level of industrial expansion.

The engineering skills needed to design and build machines are essential to the growth of indigenous technological capability. The relatively high labour-intensity, which is characteristic of capital goods industries when compared with continuous-process technologies in other sectors, can also provide many employment opportunities where employment is a socio-economic goal. In addition to providing a strong and diversified base for a wide range of metalworking industries, capital goods industries provide considerable impetus to the growth of domestic design, production engineering and production planning capability.

Capital goods production in individual developing countries will follow different patterns but it will always be necessary to identify sectoral production and technological gaps and, where relevant and possible, to select *(a)* labour-intensive technologies; *(b)* technologies which can operate efficiently on relatively small scales of production; *(c)* products whose intermediate components are already or can be manufactured domestically on an economic scale.

Different resource endowments and varying levels of technological capability make it impossible to prescribe a uniform pattern of product selection or sectoral growth for all developing economies. Programmed growth of the capital goods sectors must be considered in stages, depending on factor availability and technological capability. Initial efforts are often concentrated on setting up repair facilities and producing spare parts. This level has been reached in most developing countries.

Simple mechanical equipment and parts, such as structurals, simple lathes, small pumps, compressors and fractional motors, can be manufactured on a relatively small scale and often in conjunction with various consumer durables. Thereafter, machine-building capacity can be expanded to include more complex items requiring sophisticated production processes. The production of heavy mechanical equipment for the steel, fertilizer and petrochemical sectors constitutes a third stage of development. The manufacture of electric equipment can also be undertaken in stages. Initially transformers, insulators, conductors, switches, insulated wires, small and medium-sized motors and starters can be produced. Thereafter, equipment for generating and distributing electric energy locally can be produced as well as durable electrical consumer goods. The third stage would include the manufacture of heavy equipment, such as power boilers, turbines, generators, transformers, and circuit breakers for large central power stations and high voltage transmission systems. However, the transition to manufacturing sophisticated machinery is very difficult and the comparatively higher capital outlays required, the longer gestation periods and the unfavourable investment-output ratio in the early years of production, which often characterize machine-building enterprises, necessitate a specific programme to ensure allocation of adequate resources for development.

Programming the development of capital goods industries requires a radical modification of present industrial development patterns. Governments must encourage producers, consumers, research institutes and training centres to develop new industrial policy instruments.

Programming should not only identify specific products to be manufactured, it should also evaluate technological alternatives in terms of socio-economic costs and benefits, so that manufacturing priorities can be clearly defined for each stage of development. The investment priorities thus defined must be incorporated in the overall plan for investment and resource mobilization.

The objective of sectoral programming is to establish broad priorities for development planning and to close production and technological gaps in the economy to the extent possible. It may desirable to develop export capability for some sophisticated machinery products to achieve economies of scale. Export capability can, however, generally follow domestic acceptance of a product. Import substitution cannot be pursued beyond a limited point unless internal demand is high and sustained or unless adequate export capability is developed over a period of time. The presence of other factors such as economies of scale, access to technological developments and production efficiency will also have to be guaranteed before machine-building projects can be oriented for export to competitive international markets.

Use of appropriate technology in capital goods production is directly related to the extent to which the manufacture of parts and components can be subcontracted to medium and small-scale enterprises. It is through such subcontracting and decentralization of manufacture that greater technological skills can be diffused throughout the economy. Such decentralization would not only reduce investment in individual plants but it would also be more cost-efficient over the long term. Close technological and financial co-ordination is necessary between enterprises producing parts and components and enterprises assembling final products. As large machine-building enterprises expand their production, the degree of subcontracting should be increased to ensure continuing diffusion of technological capability and continuing dispersal of industrial activity.

Capital goods production necessitates acquiring and developing technological information. Such information can be obtained from external sources both in developed and developing countries. Technology from developed countries is becoming increasingly capital-intensive as the result of greater automation, more complex equipment and ever greater production capacities. Such technology is often not suitable for developing countries at other levels of industrial and economic development. Domestic demand in developing countries is generally for relatively simple but strong machines and structurals which can be operated and maintained effectively in prevailing conditions. The demand for machinery and equipment in the dispersed sector also necessitates capital goods of types and capacities often not available in advanced industrial economies. Hence there are both a pronounced potential and a pronounced need for greater technological co-operation between developing countries in the capital goods sector. Countries at intermediate levels of industrialization, with a growing demand for machinery and equipment of types and capacities generally different from those of developed economies, could collaborate in joint production programmes to meet their respective needs. The flow of technology to developing countries in the capital goods sector should also be increasingly geared to greater domestic production of parts and components by small-scale enterprises.

PROGRAMME OF ACTION

Developing countries need to identify specific production programmes in basic and heavy industries. These programmes must be based on domestic resources and technological capability. Such programmes should be directed at production of essential industrial materials, including basic metals and chemicals which can be processed into end-products by domestic enterprises, particularly in the medium and small-scale manufacturing sectors. The production of capital goods also needs to be undertaken in most developing countries. The extent to which heavy industries can be established will depend on resource availability, technological capability and internal and external demand. Since domestic markets in developing countries are usually limited, heavy industrial production should be related as much as possible to regional demand and joint production programmes with other developing countries should be considered.

While certain stages of industrial production may require sophisticated large-scale capital-intensive technologies to produce goods at internationally-competitive prices, other stages of manufacture should use technologies appropriate to the general level of domestic technological capability. Broad policy guidelines should be drawn up to promote the maximum dispersal of industry, both geographically and to medium and small-scale enterprises. Because conditions in many developing countries are similar, technological alternatives available in other developing countries, and greater technological co-operation between developing countries, should be given particular consideration.

Report of the Working Group

INTRODUCTION

The crucial importance to developing countries of those industries which provide the material base for industrialization cannot be stressed enough. Such industries include iron and steel, chemicals and petrochemicals, fertilizers and engineering and capital goods and can be called basic industries. These industries are essential for broad-based, self-sustaining industrial growth because they provide processed materials for other productive sectors of the economy. They also ensure optimum utilization of natural resources, an important objective of industrialization in developing countries. The Lima Declaration and Plan of Action has also emphasized the importance of such basic industries and the Industrial Development Board of UNIDO has considered them as priority areas for international consultations.

Since plans for the development of such industries should be an essential component of the industrial growth strategy of developing countries, it follows that the selection of appropriate technology in these industries is of critical importance. The basic industries are essentially capital-intensive and selection of inappropriate technology would result in a substantial misallocation of resources which the developing countries can ill afford. The inadequate growth of such industries could also impede the development of other sectors of the economy.

It is necessary to recognize that technological options are available in the basic industries. It also possible to disaggregate technologies and to identify alternative technologies for specific subprocesses. It should, however, be noted that technology is constantly changing and that what constitutes appropriate technology must be viewed in a dynamic context. The conditions and resources of developing countries vary so that the importance of selecting technology with reference to specific country situations should be emphasized.

The developing countries should have access to technologies for the basic industries ranging from traditional technologies to modern, capital-intensive technologies. The choice of a particular technology should be governed by the requirements of a specific situation. The overall international economy is also relevant. The highly inflated prices of capital goods and the growing debts of the developing countries must be taken into account. In view of the increasingly competitive market for products such as steel, copper and certain petrochemicals, the technology selected for the basic industries should be cost-effective and of the requisite quality. It is also relevant to note that most technologies developed in recent decades have been oil-based and that there is accordingly a need to identify technologies particularly suited to oil-scarce developing countries.

Appropriate industrial technology is a function of policy objectives, resource endowments and conditions of application as well as of economic and social milieux and market size. Other important factors include utilization of natural resources, semi-processed materials and intermediate products, creation of employment opportunities and diffusion of benefits to the masses. Factors such as lack of infrastructure or lack of investable resources could limit the selection of technology. Selection of technology involves its careful characterization in terms of mission (i.e., production for export or local consumption), and type (i.e., whether based on equipment, product, process or a combination of the three).

The role of adaptation in the successful application of appropriate industrial technology should be recognized and these questions should be raised when considering the choice of a new technology: Does the technology need to be adapted? Is the adaptation likely to be successful? Is the technological capability available to carry out the adaptation?

IRON AND STEEL

Technology options

Broad technology options have to be considered from the stage of mining and ore extraction to that of finished products. In the mining sector technological trends in developed countries are towards highly mechanized operations and handling. The extent of mechanization appropriate in developing countries should be related to employment needs. While technological improvements which provide greater safety and efficiency should be adapted to local conditions, mechanization resulting in displacement of labour may have to be carefully evaluated. The use of sophisticated mining equipment may often not be necessary except in bulk handling operations at pit-heads or at ports. At various stages of mineral processing, however, modern and sophisticated production techniques may be needed to improve product quality and reduce production costs.

Available alternatives for the production of iron and steel include:

(a) Blast-furnaces based on coking coal with oxygen converters supplying molten steel to the rolling mill complex; minimum capacity would be about 500,000 t/a and capacity could range up to six times that;

(b) Charcoal-fuelled blast-furnaces with oxygen converters to supply molten steel;

(c) Electric reduction furnaces with oxygen converters to supply molten steel; minimum economic capacity would be about 50,000 t/a;

(d) A direct reduction process with an electric-arc furnace to supply molten steel. Capacities range from 200,000 t/a upwards;

(e) Scrap-based electric furnaces to supply molten steel to bar mills; capacity would be about 25,000 t/a;

(f) Bar mills (re-rolling mills) based on local or imported supplies of steel billets; minimum economic size would be about 10,000 t/a.

A country could adopt more than one of these technologies, depending on resources and prevailing conditions, since they are not mutually exclusive and may be used in combination. In large developing countries, where the demand for steel is increasing rapidly, it may be necessary to set up integrated steel mills using advanced technologies to permit production at competitive costs. In countries with abundant forest resources charcoal-fuelled blast-furnaces with oxygen converters may be appropriate. An electric reduction process may be suitable for countries with low-cost electric power and limited access to good coking coal. Gas-based direct reduction processes are suitable for countries with oil and natural gas resources. Developing countries in early stages of industrial growth may utilize electrical furnaces fed with scrap, if the supply of scrap can be ensured or supplemented by imported sponge-iron. Developing countries with abundant iron ore can export ore and could participate in foreign steel mills using such ore until techno-economic considerations would justify domestic iron and steel production.

The natural resource endowments, in particular iron ore and the reductant (e.g., coal), are the starting points for selecting appropriate technology. Available resources will determine which processes and equipment are appropriate. Required quality standards will also influence the choice of process and equipment.

The adaptation of available technologies to natural resources is central to the application of appropriate technologies. Indian experience, which showed that the high ash-content of domestic coal and the low quality of refractories necessitated considerable adaptation of imported technology, underlines the need for such adaptation. Thus it is important that at an early stage in the selection of technology the need for adaptation should be investigated. Similarly, long-range planning should co-ordinate technological choices with resource endowments.

Policy aspects

The location of natural resources and the additional investment required by decentralizing industry contribute to the centralization of industry. Decentralization could lead to an otherwise avoidable increase in production cost and in cost to end-users. At the same time there are specific situations in which intermediate products could be finished in factories dispersed throughout the country. The re-rolling of steel products, for example, could be undertaken in decentralized plants. In this case centralized industry would confine itself to production of intermediate products. The specifications of the required iron and steel products are relevant to determining the extent of desirable decentralization. Judicious consideration of the relevant factors is therefore necessary before deciding whether or how much to decentralize the iron and steel industry.

International co-operation

The experience of developing countries such as India in adapting technology is relevant to other developing countries with similar problems, and efforts should be made to share this experience.

Some countries have iron ore but not the energy required to convert it. By exporting iron ore to countries where energy is available, iron and steel production in the developing world could be increased. UNIDO should study the possibility of matching such resource endowments.

Developing countries urgently need to exchange their experience of all aspects of iron and steel technology. The exchange of experience could be promoted by personnel exchanges and by conferences. Training programmes could also be undertaken as part of co-operation among developing countries.

Institutions in developed countries are undertaking R and D on iron and steel technology which could produce findings useful to developing countries. International co-operation to utilize the results of such research for the benefit of developing countries should be encouraged.

BASIC CHEMICALS AND PETROCHEMICALS

The production of basic chemicals and petrochemicals in developing countries needs to be undertaken after careful assessment of demand and of the availability of raw materials. While domestic demand will determine the extent to which certain products will be produced, the production of certain basic or primary petrochemicals can be undertaken for export by developing countries with abundant oil and gas resources. The objectives of domestic production should be import substitution and supplying processed materials which can be utilized by domestic enterprises to manufacture end-products.

Technology options

While end-products can be manufactured at various scales of production, technological trends favour increasingly large scales of production and use of highly capital-intensive technologies. In view of the significant economies of scale arising from large-scale production and in the absence of viable alternative technologies, the economic benefits arising from large-scale production outweigh the benefits of additional employment generated by small-scale production. In developing countries it would, however, be possible to introduce less capital-intensive technologies to handle materials, for example. Relatively capital-intensive technologies which are being rendered obsolete in developed countries by technological progress may also deserve the attention of developing countries with limited markets and scarce investable resources. The use of multi-purpose equipment would also contribute to the more effective utilization of capacities.

Policy aspects

In spite of the large-scale production required by petrochemicals, for example, end-products can sometimes be manufactured on a relatively smaller scale. Basic petrochemicals, for example, can be produced in large plants while end-products are processed in satellite production units dispersed throughout semi-urban and rural areas. Such dispersed production of end-products can also be undertaken in countries where the manufacture of basic chemicals and petrochemicals may not be practicable for techno-economic reasons or because natural resources are lacking. The manufacture of products such as polyvinyl chloride, polyethylene, and polyester fibres can be undertaken in medium-sized plants. Product use can be significantly extended both to meet demand for consumer goods and to provide alternative materials for agricultural use.

To promote the dispersal of industry wherever possible developing countries could earmark part of basic chemical and petrochemical production for processing to end-products on a dispersed basis. To do so effectively would require long-range planning taking both the availability of natural resources and technological options into consideration. Such planning would not only ensure the selection of appropriate technology but would also reduce the cost of acquiring such technology and promote the development of indigenous technological capability.

The ecological implications of given technologies should be carefully evaluated as an integral part of the process of choosing a technology. Ecological implications derive both from the process employed and from the use of the end-products. Pollution control technologies developed to date are usually sophisticated and expensive, and further research is needed to develop appropriate technology in this field.

FERTILIZERS

In view of the critical importance of fertilizer production for the growth of agriculture, developing countries should establish policies requiring local production of about 80 per cent of their needs.

Technology options

Large-scale technologies are necessary to achieve economies of scale. The production of ammonia has been increasingly undertaken in large-scale production units with capacities of more than 1,000 t/d not only in industrialized countries but also in several developing countries. Large-scale ammonia plants could be established in developing countries with significant natural resources or where domestic demand for fertilizers would sustain large-scale production.

It should be possible, however, to decentralize production of fertilizer end-products, both to promote industrial dispersal and to enable production facilities to be located closer to end-users. Intermediate or semi-finished products can be shipped in bulk and blended at decentralized locations to produce mixtures appropriate for local soils and local crops.

Policy aspects

Long-range planning is required to assure selection of appropriate technologies. Countries like Mexico have been able to select one technology which can be used in a number of plants and have thereby effected significant savings. A similar step has been taken in Indonesia. In the context of long-term needs developing countries should, therefore, investigate the possibility of acquiring one technology for several plants.

Developing countries should consider adopting a policy to ensure that a specific proportion of fertilizer production (say 25 per cent) is undertaken by dispersed industry. This would also ensure that production facilities were located as close to local markets as possible.

ENGINEERING AND CAPITAL GOODS INDUSTRIES

Engineering and capital goods industries are of critical importance to the overall industrial development strategy of developing countries. Such industries provide not only a wide variety of equipment for production of a wide range of consumer goods and durables but also a basis on which technological capability can be developed. By providing equipment and machinery to other industries they also influence technological choice in those industries. The long-term requirements of a given developing economy must be assessed to identify the types of capital goods industries required.

Technology options

A wide choice of technology is available. For example, machine tools for cutting and forging metal range from simple, labour-intensive models to sophisticated, automatic, numerically or computer controlled models. In many structural and capital goods industries the production of such items as castings and forgings can be farmed out to minimize the amount of capital investment needed in any particular unit. The capital goods industries require, for example, facilities for welding, machining, and heat treatment but these facilities need not be concentrated under one roof. Similarly sub-assembling or the production of components can be undertaken in a large number of satellite plants while the parent unit confines itself to final assembling. Investment in the capital goods industries can be optimized if facilities are carefully planned and co-ordinated.

The extent to which facilities for production of capital goods should be concentrated or dispersed depends on the situation in a given country. For example, a country with ample financial resources but scarce labour might choose relatively sophisticated, labour-saving equipment for use in a central location.

Adequate attention should be given to a number of related and important considerations. A close relationship exists between process and equipment. Knowledge of design, of design capability, and of the properties and use of materials are important. There should be facilities for production of the spare and replacement parts needed to maintain capital goods since without such facilities, dependence on the suppliers of the original equipment could be considerable.

Policy aspects

Establishment of engineering and capital goods industries is a prerequisite of self-sustaining industrial development. These industries can, however be established in phases corresponding to the stage of development and requirements of the country in question.

Inasmuch as the engineering and capital goods industries are basic industries essential to overall industrial development, it is important that these industries be established as part of an overall development plan. The plan should include a detailed analysis of the technological inputs needed to ensure the development of these industries.

There is also a need for development of adequate training facilities. However, in many countries the establishment of capital goods industries cannot wait until trained personnel are available and efforts will have to be made to provide on-the-job training. Such training should include not only instruction in operating machinery and in such skills as welding, forging and cutting metal but it should also aim to develop the technological capability needed to evaluate alternative technologies.

Policy should clearly define what capital goods are to be produced and whether production would be centralized or decentralized. Policy decisions are also needed to specify whether equipment and materials are to be standardized, since in the absence of such standardization, the choice and application of technology would be more complex.

International co-operation

The importance of regional and subregional co-operation in the production of engineering and capital goods is obvious. Collaboration between developing countries could be an effective means of developing appropriate technologies.

The need and the potential for greater technological co-operation between developing countries are particularly pronounced in the capital goods sector. Countries at intermediate levels of industrialization, which have a growing demand for equipment of ranges and capacities generally different from those of developed economies, should collaborate in joint production programmes. This is particularly true because the demand for equipment in the dispersed sectors of developing economies will also necessitate manufacture of types and capacities of capital goods often not available in advanced industrial economies.

POLICY OBJECTIVES

In view of the crucial role of basic industries in promoting the growth of other industries, developing countries should take the necessary decisions to establish them. The establishment of such production capabilities should be brought within the framework of overall development strategy and of an industrial development plan which take the long-term needs of the economy and the availability of natural resources into account.

The kind, quantity and quality of natural resources available should determine the selection of technology. Technologies selected should be adaptable for use in as many production units as possible. Environmental aspects of the use of technology should be given due attention.

To secure economies of scale the technology selected for some basic industries may have to be capital-intensive and suited for use in centralized locations but significant scope should be allowed for dispersal of production of intermediate and end-products. Developing countries should systematically explore such possibilities, especially in iron and steel, petrochemical and fertilizer production.

Each developing country should be enabled to select appropriate technology in the light of its own needs and conditions. The responsibility for the selection of technology rests with each country. Developing countries should take measures to strengthen their technological capabilities and to promote co-operation among themselves not only in production and maintenance technology but also in such related technological areas as R and D, consultancy, design and engineering, standardization, technology evaluation and negotiation for acquisition.

PLAN OF ACTION

Development of technological services is of paramount importance for the selection and application of appropriate technologies as well as for the generation of new technologies. Special regard should be paid to adaptive and applied research including production-oriented and problem-solving technological services such as consultancy and design engineering. Access to existing knowledge and the ability to use it should be promoted and the innovative capabilities of the technical personnel of developing countries should be actively encouraged.

National level

Developing countries should take steps to:

(a) Make systematic surveys of their natural resources;

(b) Formulate technology plans and policies for the basic industries;

(c) Institutionalize the evaluation, acquisition and monitoring of technology;

(d) Upgrade their capabilities in the fields of consultancy, design engineering, standardization, and technology evaluation;

(e) Promote R and D on practical problems and encourage commercialization of the results of such research.

Co-operation among developing countries

Developing countries should be encouraged to exchange experience and expertise systematically through visits, seminars and training programmes. Such co-operation should include evaluating, acquiring and monitoring technology and surveying natural resources. Developing countries should also identify their complementarities and promote activities to exploit them.

Action by UNIDO

UNIDO should provide consultancy services and technical assistance to developing countries to enable them to carry out the national programme of action. Specifically, UNIDO should:

(a) Promote and assist the establishment of centres of excellence for specific basic industries to identify problems, to conduct R and D, to disseminate information and to train personnel. Such centres could be established on an international, regional or subregional basis;

(b) Promote systematic co-operation between existing technological institutions in developed and developing countries;

(c) Facilitate the flow of technological information in the basic industries through its Industrial and Technological Information Bank;

(d) Undertake or promote training activities to upgrade the technological capabilities of labour in developing countries;

(e) Formulate guidelines for the evaluation of technologies and technological capability in specific sectors;

(f) Sponsor research on critical technological problems of common concern to developing countries by helping to identify the problems and locating sources of finance for the required R and D.

The existing institutional base of UNIDO should be expanded and strengthened to secure the effective implementation of the above activities.

PART TWO

Selected background papers

Basic materials industries: aspects of technology choice and industrial location

*K. H. Yap**

Key factors

The choice of process technology is a key factor in the development of basic materials industries. Location, too is vital, bearing in mind sources of raw materials and eventual users. Another major factor is technological development itself. New materials are developed and new processes render older materials and processes obsolete. In developing countries the establishment of basic materials industries is closely linked with general development.

Interrelated technology patterns are common in industries whose processes cause fundamental changes in the physical substance of materials. In the chemical industry, for example, the desalinization of sea water by electrodialysis also results in the production of salt and of a number of chlorine-based chemicals which can be used in the production of plastics, synthetic fibres, pulp and paper, soap and detergents, insecticides and glass.

In a developed industrial structure the demand for end-products can to a large degree be predicted and economic plant size can be estimated on the basis of such predictions. In countries with a developing industrial structure a different approach is often desirable. What is needed is a diversification strategy which includes an inventory of available resources, a description of related technological processes and a projection of end-product requirements. In the example cited this would mean estimating human salt consumption on the one hand and the requirements of industry for chlorine-based chemicals on the other. Patterns of rapid growth might suggest decisions favouring larger units among the range of economically viable production options; on the other hand they might also indicate weaknesses and the danger of technological obsolescence. In such a case it would be better to choose among alternative smaller units.

As industrialization progresses the interactions between diversification based on natural resources and demand based on the needs of industry become more complex. The technology development strategy will have to evolve correspondingly.

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* Director, Centre for Management and Industrial Development (CBO), Rotterdam, the Netherlands.

Linking industrial processing sites with the sites of natural resources and points of entry for imported materials, on the one hand, and with location of domestic and foreign end-users, on the other, is a key element in industrialization strategy.

Industries not located at the source of raw materials require an assured supply of raw materials. Stock formation, recycling and use of alternative materials are ways to ease dependence on distant sources of raw materials. Raw materials should be supplied to standard technical specifications. Pricing is also important. Overpricing would have an unfavourable effect on subsequent processing. Production costs must not exceed selling prices. The capital intensity of basic materials industries would, in such instances, cause an indirect irrational burden on the sector and the entire economy. Such a burden would also occur in case of oversized but underused production facilities.

Various stages can be distinguished in the development of diversification patterns. To develop an effective pattern of supplying raw materials to end-users a distribution system must be evolved. Such a pattern may be based on the location of sources of raw materials or on the settlement pattern of end-users.

Fertilizers provide an example of a product which is distributed to a diversified group of end-users. The basic production of raw materials is largely determined by the location of deposits or of petrochemical complexes or, if imported raw materials are used, of their entry points. End-use patterns vary with soil conditions, crop types and planting practices. Mixing and blending the basic ingredients near the end-users would have advantages. Transportation and storage facilities will influence the distribution system.

Overlapping sectors

Various types of intrasectoral systems will evolve as higher levels of development are reached and will produce new patterns of specialization or require new scales of operation. New scales of operation do not always mean larger scales of operation. The breakthroughs in electronic miniaturization in the last decade are a striking example of a trend towards smaller units. Mandatory incorporation of quality standards will also influence the structure of systems. The interdependence of distribution and transportation has been referred to above. It is particularly important, for instance, in the construction and building materials sector in which various types of materials from dispersed sources are often used at the same location. These resources will increasingly acquire the character of industrial products as development attains higher levels. A subsector in which this tendency is particularly pronounced is the cement industry. In the last two decades the vertical kiln process has made it possible to set up economically viable dispersed small-scale production units which have the additional advantage of utilizing scattered limestone deposits to supply cement for local construction activities. The action radius of these smaller plants will depend on topographic conditions, the volume and rate of construction activity and the demand for cement.

Technology choice at plant level

After beneficiation, further processing of ores and minerals results in a variety of semi-finished products which serve as basic materials to other industries. Because of the geographically uneven distribution of ores and minerals, material substitution has long been recognized as a major area in which applied technological research can contribute to redressing structural balance-of-trade problems.

Iron ore, for example, is usually reduced in a blast-furnace using coke. The molten iron is converted into steel in oxygen converters, a process which, in the last twenty years or so, has become the main one for steelmaking. The steel is then rolled in a rolling mill. Integrated iron and steel plants of this type may range in capacity from a few hundred thousand to more than 10 million tonnes a year (t/a). Ordinarily, a steel plant of 1 million t/a capacity would require an investment of from $800 million to $1 billion and would provide employment for 8,000–10,000 persons. It is evident that for any economy such an investment requires careful choice of location, technology and end-products.

The availability of iron ore and good coking coal, the incorporation of technological innovations and the utilization of by-products must also be considered, as well as the special problems of commencing operations and of day-to-day operations. Based on reverse integration, operations could begin with a rolling mill; steelmaking and iron production could follow at later stages Steel can also be produced by electric smelting from pig-iron, sponge-iron or scrap. The capacities of electric furnaces range from 20,000 t/a upwards. Capital investment for a 100,000 t/a plant would require a capital investment of about $25 million and would employ 800 persons.

Other technological possibilities have been explored in the last two decades, such as the use of charcoal in blast-furnaces in areas where forest wood is abundant.

There are the direct reduction processes in which gas or coal can be used to reduce the iron ores.

These processes require relatively high grade ores, that is, ores with an iron content of 65-67 per cent. Direct reduction results in the production of sponge-iron, with a metallization approaching 91–94 per cent Fe. Sponge-iron is subsequently processed in electric-arc furnaces into steel. From 1950 to 1975 many different processes for steel production by direct reduction of iron ore in conjunction with electric-arc furnaces were investigated. Some have been put into commercial operation in the last 10 years. Capacities range from 150,000 t/a to 1.5 million t/a. A 500,000 t/a integrated plant utilizing the direct reduction process would require an investment of about $250 million and would employ 3,000 persons.

A clear trend is discernible towards lower ranges of optimal plant capacities. This provides a higher degree of flexibility and improved possibilities for situating first-stage processing operations near ore deposits. The choice and application by Indonesia of a direct reduction process developed in Mexico exemplifies technology transfer between developing countries. In Brazil abundant forest resources and a limited coal supply have led to the development of charcoal blast-furnaces.

General considerations

Reference has been made to salt, hydrocarbons, metal ores and various non-metallic minerals as some of the natural resources on which basic materials industries can be established. Primary aims in developing these industries are to increase domestic value added and to strengthen the materials supply to light industries and other processing activities. The availability of basic materials will provide the basis for new development opportunities. Availability of suitable process technologies are of course a prerequisite to these developments. Technology should be chosen in a dynamic long-term context. Some main factors in choosing technology are the patterns of international trade, production specialization and resource availability.

Resources

Most ore mined in developing countries is still being exported in run-of-mine condition to industrialized countries. In the coming decades technological developments will probably permit developing countries to produce a greater share of processed iron products than is now the case and local production in developing countries will be increasingly able to meet iron and steel requirements. Local processing of bauxite and aluminium is still limited to a few locations. Although production statistics indicate that developing countries are consuming more fertilizers domestically, a more intricate distribution pattern of production facilities will have to be considered. Potash and phosphate deposits are concentrated in relatively few locations; natural gas and other sources of nitrogenous fertilizers are, however, widespread.

Setting up a given plant requires consideration not only of availability of raw materials, of potential markets and of appropriate technology but also of infrastructure, especially of energy and water supply and of transportation. In urban and developed areas these facilities are largely available through existing public utilities. In rural, remote and underdeveloped areas it is usually necessary to develop these facilities. Often the best locations for basic materials industries are found in relatively undeveloped regions.

The establishment of a plant will affect the area in which it is located and, from a general development point of view, it may be desirable to distinguish direct process requirements, plant organization requirements and general area requirements. Process requirements are directly related to technology choice and are an integral part of the plant's techno-economic structure. Plant organization requirements are often of a broader nature: they might include housing for plant personnel, educational and medical-care facilities for dependants, development of roads and transportation facilities and are distinct from primarily community-oriented infrastructure. In remote areas, the development of such facilities often requires considerable investment. These facilities could, however, be extended to serve a larger group of the local population. Such benefits could also be derived from basic materials industries situated in urban or more developed areas, but they are most important in rural, remote or relatively undeveloped areas. While economic viability is the basis of direct process operations, it would be desirable to approach the project as a whole, not as a single-purpose industrial undertaking, but as a primary nucleus for area as well as sector development. In other words, it is advisable to consider basic materials industries as new central places in a much wider framework.

Choice and adaptation of alternative technology for the iron and steel industry

B. R. Nijhawan[*]

There are many technological alternatives for iron and steel production. The selection of alternative technology is complex and many non-technological factors must be taken into consideration.

A few cases will illustrate the complex issues involved. Afghanistan, for example, has abundant resources of high-grade iron ores and ample reserves of high-grade natural gas. These major resources can be used to produce high-grade sponge-iron which, in turn, can be easily processed into steel. But Afghanistan has no rail or road transport system in the mountainous areas where the ore deposits lie, the domestic iron and steel market is very small and the export market is nil. These non-technological factors, namely, the lack of infrastructure and a very limited market will determine the choice of technology for initial iron and steel production to meet Afghanistan's domestic requirements of 25,000 to 50,000 t/a in the form of light sections and angles for the building industry. As trained manpower becomes increasingly available and infrastructure and markets develop, the country can plan for alternative technologies to meet growing needs.

Bolivia also has high-grade iron ore deposits and abundant natural gas resources. While the domestic steel market in Bolivia is small, Bolivia can export the high-grade ore to Argentina which needs this raw material for its expanding iron and steel industry. Reciprocal trade projects between Argentina and Bolivia are now in the active planning stage.

In addition to high-grade iron ore and natural gas, Malaysia also has large rubber forests. The limited domestic steel market makes a small charcoal blast-furnace and conventional Linz-Donawitz (LD) oxygen steelmaking integrated into a small to medium-sized plant the optimum technological alternative. This alternative was selected by Malaysia and the Malayawata steel plant is using this technology to produce a profitable mix of iron and steel products.

In Brazil side by side with large integrated iron and steel plants with capacities of 1 million t/a and more, the charcoal-based iron and steel industry in the private sector is producing high-grade foundry iron and basic iron for steelmaking at the rate of well over 3.5 million t/a. The relatively purer high-grade foundry iron is exported at a premium price, earning rich dividends in foreign exchange which are being used to finance expansion of the charcoal-based iron and steel industry to a planned capacity of 9 to 10 million t/a by 1985.

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[*] Senior Interregional Adviser, UNIDO.

Other forest-rich countries like the United Republic of Cameroon, Nepal and Paraguay are also considering the technological alternative offered by charcoal-based processes for establishing their own iron and steel industries on optimum scales.

The choice of alternative technology must therefore be based on various considerations ranging from availability of raw materials and other natural resources to infrastructure and market potential.

The goal of indigenous steel production is to provide the light and heavy engineering industries with their basic raw materials and thereby promote the economic development and industrial growth of the country. This goal is important for all developing countries.

Alternative technologies

The table summarizes the many technologies available for iron and steel production.

The table is self-explanatory but the following points should be noted:

(a) The choice of processes, equipment and scale of operations is wide;

(b) Small, semi-integrated (steelmaking plus rolling) plants can be operated with scrap at scales as low as 20,000 t/a;

(c) Pig-iron can be produced at scales as low as 5,000 t/a;

(d) Small, integrated plants based on the charcoal blast-furnace can be operated at scales as low as 100,000 t/a. Sponge production for export is an interesting option for some developing countries;

(e) In some cases only semi-products (slabs, blooms, billets) are produced which are then processed elsewhere in the country or exported. This is an option for some developing countries.

It should also be noted that some developing countries are in a better position to advise and assist other developing countries in the choice of certain optional processes (charcoal-based iron and steel production, for example) than are most developed countries.

The selection of process and equipment best suited to local conditions is important to the success of a new plant. The table indicates alternative technologies in actual use today; it also indicates the normal ranges of production capacity, required staff, required construction time and cost. These figures vary widely depending on local conditions and should be considered rough estimates.

The present unused steel production capacity in the industrialized world–many plants are operating at 60 per cent of rated capacity–largely precludes new or expanded production for export in the developing countries. The economies of scale and quality standards needed to compete in export markets combined with the existing excess capacity of the heavily industrialized countries necessitate the most costly modern technology. This consideration as well as the practice by developed countries of dumping excess steel production on the world market make it extremely risky to plan to operate a plant at 100 per cent of capacity on the basis of export sales. Severe competition and the difficulties of meeting principal and interest payments on new plant and

TABLE · TECHNOLOGICAL ALTERNATI

Type		Material —— Process —— Product
I.	a¹	Billet —— Bar Section mill —— Bare, light sections
	a²	Cold coil/sheet —— Coating line —— Galvanized sheets, tin plates
	a³	Hot coil —— Tube pipe machine —— Tubes, pipes
	b¹	Hot coil —— Cold rolling mill —— Coating line —— Flats
	b²	Bloom —— Billet Bar Section mill —— Non-flats
	b³	Slab —— Hot rolling mill —— Cold rolling mill —— Coating line —— Flats
II.		Scrap Sponge iron Cold pig —— EF —— Ingot / CC —— Rolling mill —— Mainly non-flats
III.	a	Charcoal Ore —— Charcoal BF —— Foundry pig iron
	b	Charcoal Ore —— Charcoal BF —— LD —— Ingot / CC —— Rolling mill —— Mainly non-flats
	c	Non-coking coal Ore —— Electric reduction pig iron smelting furnace —— LD —— Ingot / CC —— Rolling mill —— Non-flats and flats
IV.	a¹	Coke Ore —— BF —— LD —— Ingot / CC —— Rolling mill —— Non-flats and flats
	a²	Gas (or coal) High-grade ore —— DR —— EF —— Ingot / CC —— Rolling mill —— Non-flats and flats
	b¹	Coke Ore —— BF —— LD —— CC —— Slabs, Blooms, Billets
	b²	Gas (or coal) High-grade ore —— DR —— DR pellets
	b³	Gas (or coal) High-grade ore —— DR —— EF —— CC —— Slabs, Blooms, Billets

Note: EF electric furnace; CC continuous casting; BF blast furnace; LD Linz-Donawitz; DR direct reduction.

[a] Figures in parentheses give range of capacities of works employing the technology.

OR IRON AND STEEL PRODUCTION

Countries to which most applicable	*Capacity[a] of works (1 000 t/a)*	*Number of employees (persons)*	*Period of construction (years)*	*Capital investment (million $)*
Countries with very low steel consumption and without any significant raw materials. Material-supplying countries often supply finance and technology	30 (10-100)	200	2	5
Very few countries use these types; but types may become very important for regional and subregional co-operation in connection with types IV, b^1 and b^3	500 (100-1 000)	1 200	2-3	75
Developing countries. Availability of scrap at reasonable prices is most important. World-wide spread of DR pellets may greatly contribute to the development of this type	100 (20-400)	800	2	25
Highly recommended for those countries which have forest resources and are going to initiate steel industries	10 (5-40)	50	2	1
Countries with forest resources may become self-sufficient in steel utilizing this type with relatively low investment	200 (150-400)	2 000	2-3	100
Countries with abundant electricity with low-cost but good coking coal may advantageously employ this type	200 (150-1 000)	2 000	2-3	100
Applicable for countries with large market and relatively high level of industrialization	1 000 (300-10 000)	6 000	5-6	800
Gas-rich countries. Flexibility in scale of works is also advantageous for developing countries	500 (150-1 500)	3 000	3-4	250
Ore-rich countries may have this type with long-range export agreements of semis	2 000 (2 000-10 000)	4 000	5-6	1 200
Gas-rich countries may contribute to the development of type II in many developing countries by stable supply of pellets	1 000 (1 000-5 000)	1 500	3-4	150
Gas-rich countries may have this type with long-range export agreements of semis	1 000 (1 000-3 000)	2 500	4-5	400

equipment make it prudent to limit excess capacity to what is actually needed to meet expected demand during the first years of operation. It should also be noted that projections of demand and prices can easily fluctuate by 10 to 20 per cent and that careful consideration should be paid to the consequences of lower demand or lower prices.

International co-operation

International co-operation in iron and steel production might include: *(a)* technical assistance and co-operation between developing countries; *(b)* technical assistance and co-operation between developed and developing countries; *(c)* technical assistance promoted by United Nations agencies and other international organizations.

Appropriate technology for the iron and steel industry

R. K. Iyengar and *S. Ramachandran**

INTRODUCTION

This paper surveys India's efforts to find an appropriate technology for the production of iron and steel.

Choice of appropriate technology should be guided by these considerations:

(a) Minimal consumption of non-renewable natural resources;

(b) Direction of economic growth towards satisfying needs rather than wants;

(c) Concentration on technologies requiring a low capital to output ratio.

Appropriate technology should contribute to a production system which mobilizes human resources and supports them with first-class tools. It should also contribute to creating a closer relationship between the organized and unorganized sectors of the economy so that they may grow together. To achieve this the resources of the modern industrial sector must be used to raise the productivity of the rural sector.

Before 1950 the steel industry fulfilled most of the criteria for appropriate technology. It was not highly capital-intensive, it employed many people, the plants were near sources of coal or iron ore and most of the steel was produced for domestic consumption. The subsequent development of steel technology away from these criteria of appropriate technology followed technological developments in other industries. The economics of the new technologies demanded increased throughput. With bigness came speed, and speed at high temperatures required more automation and increasingly skilled labour. As production capability grew, demand for raw materials increased. Since local resources were either insufficient or unsuited to the higher production rate, it became necessary to import raw materials. At the same time increased output flooded domestic markets and it became necessary to find export markets to keep production units operating economically. The net result of all this was a decreased need for unskilled labour, increased dependence on imported raw materials and on foreign markets and such an increase in the size of plants that the capital investment requirement per tonne of steel produced increased geometrically.

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* Research and Development Division, Steel Authority of India Ltd., Ranchi, Bihar, India.

If Inidia attempted to implement post-1950 steel technology in the context of a feudal social system, it was because no one realized that socio-economic factors influence industrial growth. It was sincerely believed that sophisticated technology could be used economically in a society in which most people had not even seen a simple machine. Traditional Indian steel technology did use local iron ore and coal. It did produce iron and steel for domestic consumption and it did employ a larger number of workers per unit of capital invested than did the technology used in developed countries. However, capital investment required per worker and per unit of output has increased disproportionately. This trend will continue if India continues to use present ironmaking technology. Finally, India's inability to increase output through indigenous technological innovations and its reliance on foreign experts underlines a chronic problem which is due to social attitudes, administrative policies and lack of training, education, organization and discipline in technological fields.

DEMAND

Per capita consumption of steel is one indicator of economic prosperity. Long-term trends in steel consumption are principally determined by the level of economic development and by the structure of the economy. Although short-term variations in steel consumption and overall economic activity will occur periodically, both steel consumption and gross domestic product continue to increase when the economy has reached industrial maturity.

Certain features of the Indian economy have directly influenced the pattern and level of steel consumption. Of the 7.5 million tonnes of finished steel produced during 1977–1978, about 4.5 million tonnes, or about 60 per cent, were nonflat products mostly for the construction industry; the remaining 3 million tonnes were flat products supplied to manufacturers of industrial goods. As the industrial economy develops, the percentage of nonflat products should fall.

In India the major steel buyer is the organized urban sector. Nearly 80 per cent of total domestic sales by the Steel Authority of India Limited (SAIL) plants during 1977–1978 was to ten urban centres; indeed the four metropolitan centres, Bombay, Calcutta, Delhi and Madras, accounted for 40 per cent of total consumption.

One way to increase *per capita* consumption of steel is to increase consumption in rural areas where 80 per cent of the population live. Increasing the purchasing power of the rural population will require development of both rural infrastructure and rural industry.

To date the iron and steel industry has taken the domestic market for granted and made no special effort to strengthen the rural market for steel. Technical guidance publications should be produced in local languages to inform and educate the rural population in the uses of steel and exhibitions and films could illustrate the agricultural and rural uses of steel for houses, farm buildings, tools and machinery.

To promote the use of steel in the rural sector SAIL has now appointed a production group and a marketing and distribution group. The production group has suggested setting up workshops on a pilot basis in four geographical areas to promote rural use of steel. The marketing effort will be based on local entrepreneurs guided by SAIL personnel. If the scheme is successful, it is estimated that it would increase the demand for steel products by 500,000 to 1 million tonnes.

CAPITAL COSTS

The steel industry is capital-intensive. The capital investment in plant required per tonne of steel produced has risen over the past two decades more than threefold; the capital investment required per employee has also increased. At the same time the ratio of turnover to invested capital has decreased. These facts suggest that present steel technology as a whole cannot be considered appropriate for developing nations.

In general, in an integrated steel plant ironmaking requires 20 per cent of capital invested; steelmaking, 15 per cent; rolling mills, 30 per cent; supporting services, 35 per cent. Supporting services include provision of emergency power; oxygen production; water treatment; machine, structural, foundry and forge shops; production of refractory materials; internal transportation. Clearly, one major cause of the high capital investment requirement is the investment required for supporting services. It might be possible to spread this amount by establishing satellite and ancillary plants near the main integrated steel plant. In the future it may be possible to exclude some of these services from the steel plant by introducing less capital-intensive technologies which also employ more labour.

RAW MATERIALS

The blast-furnace (BF) process is currently the predominant ironmaking process; it accounts for over 97 per cent of world production. However, it enjoyed its greatest popularity and success when cheap coking coals were abundant and energy costs were low. In India, however, as in most developing countries, the required quality of coking coal is not available and it has been difficult to introduce optimal ore treatment processes.

In India the coke rate is 700–800 kg per tonne of pig iron and productivity is about 1.3 t/m^3 per day as compared to 450 kg per tonne of pig iron and 2.3–2.5 t/m^3 per day in Japan. Hence in view of the techno-economics of furnace operation, the high investment for the BF complex and the depletion of coking coal deposits in India, there is a need to develop and adopt an appropriate technology.

FUELS

Fuels constitute another major problem. Reserves of coking coal, a non-renewable resource and a key raw material in the production of steel, are found in only a few places in the world and are being consumed at a rate that poses a severe threat to developing countries like India. To meet this challenge a number of technologies have been developed to reduce or totally eliminate the use of coking coal. One technology substitutes the injection of coal slurry, natural gas and tar or pitch. This is an attractive process since the equipment needed is simple and relatively inexpensive. Eighty per cent of world pig-iron output is now produced by some fuel injection process. However this technology does not entirely meet India's appropriate technology requirements because oil and natural gas are also non-renewable resources. Tar and pitch on the other hand, which are produced in the steel plant, meet Indian criteria of appropriate technology. The technology of pulverized-coal-slurry injection which is successfully used in China, the United States of America and on an experimental basis in the Union of Soviet Socialist Republics, also meets Indian criteria of appropriate technology. However the coal-slurry injection process requires expensive and complex equipment and must employ coal of low ash content, which is scarce in India.

Charcoal-based BF ironmaking is well established in a number of countries including Argentina, Australia, Brazil and Malaysia. In Brazil, current production is over 5 million tonnes a year. Where forest resources are available or can be developed this technology may be appropriate. Brazil is setting up a major steel producing complex based on charcoal in conjunction with a large forest development scheme.

Small and low shaft furnaces require low capital investment and appear to be suited to small markets but not very much information is available for techno-economic analysis of these furnaces.

Other alternatives for reducing consumption of coking coal include blending charges, grain size adjustment of coal fines, oiling, and the use of non-coking coal. However, to prevent environmental pollution with these technologies, sophisticated and expensive equipment is required which is difficult to install in existing coke ovens.

The briquette-blending coking process, in which a mixture of coal fines and briquettes is coked in conventional coke ovens, allows a reduction in coking coal of up to 30 per cent less. Additional capital investment is required only for the briquetting equipment. This is another appropriate technology which could find wide application in existing coke producing plants.

A formed-coke process might solve both the problems of scarce, unevenly distributed coking coals and environmental pollution. Despite many successful trials, adoption of this process on a wide scale would require further development of carbonization furnaces and large-scale hot-forming machines with a long life, the availability or development of binding additions and the development of a BF technology suited for use with formed coke. Major impediments to the rapid adoption of this technology are the capital investment in existing coke ovens which have a long life (20–30 years) and the need to maintain the energy balance of steel plants which now depend largely on coke-oven gas.

CONVERSION

The technology of converting pig-iron to steel has been continually changing for the past 100 years. The present technology of pneumatic oxygen steelmaking, the Linz-Donawitz (LD) process and, more recently, the bottom blown oxygen process (BBOP) have displaced the open-hearth (OH) process which required an external fuel supply and which posed severe environmental pollution problems. The pneumatic process, on the other hand, is more automated and therefore employs fewer people per unit of capital invested.

Choice of process affects to some extent choice of raw materials and fuel consumption. BBOP permits more flexible operation in terms of product quality, permits easier recovery of the rich off gas and consumes less fuel. For integrated steel plants BBOP technology represents a greater advance towards appropriate technology than does the LD process. BBOP requires 10 per cent less capital, can increase output per unit of capital invested, is a simpler technology, requires less raw material such as burnt lime, facilitates environmental control and reduces the strain on fuel and other resources at the BF. Further improvements in this process might also reduce the capital to output ratio.

Processing liquid steel into semi-finished products raises the question of the appropriateness of continuous casting. With respect to the capital to output ratio, it is cheaper to produce small tonnages of flat and nonflat products by continuous casting than by conventional ingot casting, blooming and billet mills, but as plant size increases and approaches 2.5 million t/a, this advantage is reduced, especially for nonflat products. For heavy structural and forging quality steel, continuous casting is not favourable.

The continuous casting process has made possible small-scale steel plants producing 40,000 t/a or more and in this sense it meets the criteria of appropriate technology better than do conventional ingot casting, blooming and billet mills.

Recent developments in horizontal continuous casting in the Union of Soviet Socialist Republics, the United Kingdom and the United States permit casting a greater range of billets and blooms (from 70 mm to 200 mm) on the same machine. This reduces required capital investment by obviating separate billet and bloom casters and certain auxiliary handling facilities.

FINISHING METHODS

The technology of producing finished steel goods varies with the specifications of the desired product. Forging is appropriate for alloy steel tools and implements because it can be dispersed over a wide area and can employ many people. Wire rods to reinforce concrete can be produced by simple re-rolling mills; but it is appropriate, in terms of low capital investment and the large number of workers employed, to produce the sheets required for simple applications such as spades by hand rolling.

Alternatives to the modern hot-strip mill for producing sheets and plates are the semi-continuous mill and the Steckel mill. The Steckel mill requires a smaller capital investment than the continuous hot-strip mill but the quality of the steel sheet rolled cannot compete with that from the continuous hot and cold steel mill.

Nonflat products can be produced by mills of various sizes and varying degrees of sophistication but the use of all of these mills entails a compromise between low capital investment and high labour-intensity on the one hand and high energy consumption on the other.

SCRAP

At present most of the steel used for making simple tools and fixtures in rural areas comes from scrap. Forming and fabrication is done mainly by blacksmiths who must pay as much as five times more for scrap than is paid in urban centres. This robs the rural entrepreneur of the margin required to make cheap steel products. To remedy this, the feasibility of dispersing the re-rolling and metal forming industry to rural areas should be studied in detail because this would generate scrap and reduce the number of middle-men in steel trading. The dispersal of the metal forming industry to rural areas could be done by upgrading the smithy to a small-scale forging operation. The Ministry of Steel and Mines and SAIL have endorsed this concept in principle and drawn up a programme for setting up rural workshops.

A STRATEGY FOR STEEL PRODUCTION

The first UNIDO consultation meeting on the iron and steel industry in 1977 predicted an increase in world steel production to 1,750 million t/a by the year 2000. It also expressed the hope that 30 per cent of this amount would be met by the developing countries. Accordingly, steel demand in India should rise to 20 million t/a by 1985 and 43 million t/a by 2000 as compared to present production capacity of less than 14 million t/a.

One way to meet the increased demand for steel is to increase the output of existing plants. An examination of the cost of producing finished steel in new plants shows that raw materials constitute 40 per cent of the cost; processing, 10 per cent; depreciation and interest on capital, 50 per cent. Hence technology introduced to increase the output of existing plants will be most appropriate if it contributes to reducing the capital to output ratio.

The bulk tonnage of steel products is generally shaped in the rolling mills of integrated steel plants. Current practice aims at large-scale economies through high capacity rolling mills for both flat and nonflat products. However, lower capacity mills have recently been installed in other countries to supply limited local demand for rolled products; these mills can fill small orders efficiently and effect savings in transport and finishing costs. In India such mills were first set up outside integrated steel plants to convert railway scrap into steel bars and rods. With the gradual development of other industries scrap also became available from steel plants, shipyards, and engineering works. The major expansion in the re-rolling industry took place during the 1960s with the introduction of dispersed mini steel plants when continuously cast billets and pencil ingots became available. This development was the result of policies encouraging dispersed industrial development of backward areas, the need to meet increased regional demand for steel and to use local scrap and the need to reduce capital investment and to shorten construction and gestation periods.

In steelmaking scrap is a major raw material. In developed countries it contributes nearly 30 per cent to steel production. In India some scrap is used to make alloy steel but most scrap is used in small plants equipped with electric-arc furnaces of 5–20 t capacity mostly producing pencil ingots. Some of these plants employ continuous casting; a few have re-rolling facilities.

The electric-arc furnace has almost replaced the OH furnace in the production of steel from scrap since the latter's output per unit of capacity installed is much higher. With the introduction of ultra-high power (UHP) technology and secondary steel refining, electric-arc furnace technology has become attractive in comparison with conventional BF-BOF integrated steel plants. A scrap-based UHP electric-arc furnace with secondary steel refining has the lowest capital investment requirement per tonne of steel produced of any available technology.

It may be of interest to note that a steel plant based on direct reduction, electric furnace and continuous casting with a captive electric power plant has the highest capital investment requirement per tonne of steel produced and in this respect represents an inappropriate technology for steel production in India.

A comparison of actual production costs shows that conventional BF technology is the cheapest producer followed by the scrap-based electric-arc furnace method. The direct reduction sponge iron-based electric arc furnace is highly competitive with conventional BF-BOF technology especially when the elimination of capital costs for coke ovens is considered. Lack of scrap is the major restraint on the growth of plants based on electric-arc furnace technology.

ROLLING ECONOMICS

There are about 200 mini steel plants including re-rolling mills of all types in India with a total capacity of 3.6 million t/a of rolled products (RCC bars and rods). Actual production has been just below 1 million t/a.

To assess the economic impact of decentralized rolling, the table below compares the capital and conversion costs of low capacity re-rolling mills with high capacity mills in integrated steel plants.

TABLE. CAPITAL AND CONVERSION COSTS

Mill capacity (t/a)	*Capital cost (million Rs)*	*Specific capital investment (Rs/t)*	*Operating cost including overhead (Rs/t)*	*Depreciation and interest (Rs/t)*	*Total conversion cost (Rs/t)*
18 000	18	1 000	270	105	375
36 000	30	833	240	85	325
500 000	580	1 160	95	140	235

Notes: 1. The above costs do not include interest on working capital.

2. Financing has been assumed in the debt-equity ratio of 1.1; interest has been assumed at 10.5 per cent per annum.

3. The 500,000 t/a mill is assumed to work three shifts; the other mills, two shifts.

4. Depreciation and interest charges pertain to the unit proper.

While decentralized rolling mills may be desirable from the viewpoint of dispersed industrial development, use of local raw materials and meeting regional demand, the table suggests that:

(a) The specific capital investment for low capacity mills is lower by about 15 to 30 per cent;

(b) The conversion cost of low capacity mills is, however, appreciably higher and the quality of the product is inferior to the product of high capacity rolling mills.

R and D efforts are needed to make these low capacity rolling mills more appropriate to the Indian context without increasing the capital investment requirement per tonne of steel produced. Such mills could stimulate the rural metal-forming industries to increase production of farm and household implements and to supply consumable steel products to the organized industrial sector.

CHOOSING AN APPROPRIATE TECHNOLOGY

The following main points characterize the present state of steel production technology in India:

(a) The integrated steel industry as a whole is highly capital intensive with a major portion of investment going to build up infrastructure and necessary supporting services;

(b) Integrated steel plants are living precariously on a non-renewable resource, i.e. coking coal. Fortunately technological options are available both to reduce dependence on and consumption of coking coal;

(c) Ninety-seven per cent of the iron made in India is produced by BF technology which requires large quantities of raw materials such as coal, iron ore, limestone, and refractories;

(d) Newer processes for converting iron to steel such as BBOP use technology more appropriate to India in terms of lower capital and lower quality raw materials requirements, higher output per unit of capital invested, fewer environmental problems, and better recovery of waste products;

(e) The technologies of continuous casting and horizontal continuous casting are developments in the right direction for India and other developing countries. They are less capital intensive, less severe on the environment, provide higher yields and produce less waste and are efficient at both small and large scales of operation. Horizontal continuous casting promises to reduce capital investment further and may allow more intensive use of labour; it also appears to be suitable for an even smaller scale of operations than conventional continuous casting;

(f) The technology of forming steel is flexible. It is less capital intensive as the scale of operation becomes smaller because of the possibility of introducing manual handling methods. The cost of such production is high but it may be reduced by further technological developments. If small dispersed re-rolling mills were located in regions where rural industrial growth is desired, the lower transportation costs would be a further advantage.

The Chinese experience

The rural industrial system in China is based on production of energy, cement, chemical fertilizers, iron, steel and agricultural equipment. The extractive industries, coal and iron ore, form the second important component of the Chinese system. There are also engineering workshops. The outstanding accomplishment of the system is the link it has made between agricultural development, small production units and modern industries. Chinese rural industries are based on local resources.

Powder injection

With Government financial support the Swedish steel industry has started to seek alternatives to traditional BF technology. The decision to develop new processes was based on:

(a) Lack of coking coals; most BFs in Sweden are fuelled with imported coking coals, mostly from Poland and the Soviet Union;

(b) Absence of sufficiently large markets to justify installation of large BFs;

(c) Recently introduced strict anti-pollution laws.

Existing alternatives to BF technology were reviewed but none seemed to fit Swedish requirements. In 1974 researchers listed these desiderata:

(a) The process must produce a liquid product suitable for subsequent oxygen conversion to steel;

(b) The process must operate on non-premium raw materials, i.e., iron ore concentrates available in Sweden and relatively low-grade non-coking coal;

(c) The process must operate economically at relatively low capacities;

(d) Environmental pollution should be kept as low as possible.

The research led to a choice between flash smelting of concentrates coupled with smelting reduction in an induction furnace (INRED process) and bottom (side) injection of powders into a converter reactor with a channel induction heater for supplying endothermal heat requirements (UDDACON process).

The INRED process was developed just after the Second World War for smelting copper concentrates, the technology for which is commercially well established and is characterized by very high throughputs. As adapted for ironmaking, the process involves burning a powdered mixture of iron ore fines or concentrates, coal and flux with oxygen. This results in slag with a high ferrous oxide content and metal which trickles into an induction furnace containing high carbon iron. The endothermic heat for the reaction is supplied by induction heating. The INRED process is now being used in Sweden in a 30,000 t/a pilot plant. The plant operates on iron ore concentrates and non-coking coal containing 20 per cent ash (steam coal quality). The process does not require sintering or coke production and the entire power requirement is met by steam generation from off gas. The INRED process is important to India because:

(a) It can directly use high-grade ore fines including the blue dust abundantly available in India;

(b) Non-coking coals with an ash content of about 20 per cent are abundantly available and widely distributed in India,

(c) Independent power generation is a built-in feature of the process

The UDDACON converter developed in Sweden is designed for injection of powdered material below the bath surface to achieve fast and complete reactions. Heat is provided by a mains frequency channel inductor. A 10 t pilot plant was commissioned in October 1973. The converter uses air or argon as carrier gas and has been found suitable for a wide range of applications including desulphurization, dephosphorization, decarburizing and reduction of easily reducible metal oxides.

The dust from electric-arc furnaces processing steel scrap sometimes contains zinc and lead. Injecting the dust in an UDDACON converter fully reduces the iron while vaporizing and burning the zinc and lead to form a secondary dust which is collected in a bag filter. After treatment to remove alkali, the resultant material can be used for zinc production.

Low carbon ferromanganese is a premium raw material for steelmaking which is produced in conventional electric furnaces from manganese ore and silicomanganese. It is difficult to control this process and the yield of manganese is low. The UDDACON converter can produce low carbon ferromanganese from silicomanganese melt. Manganese oxide mixed with lime is injected into the bath using, for example, argon as carrier gas.

SUMMARY AND CONCLUSIONS

Steel production is useful to developing nations because it has a catalytic effect on economic growth. Cost analysis of steel production shows that the value of the finished product is many times the value of the raw materials. Part of this value added is distributed as wages and profits; part, to pay for services and goods. This pumps money into the economy. Part of the value added is recovered as taxes which can be reinvested in further economic growth.

Steelmaking technologies must be developed which will be less capital intensive, consume fewer non-renewable resources, make better use of available skills, make better use of local raw materials and which will provide more jobs. One way to reduce the high capital cost of steel production is to disperse supporting services throughout the regions surrounding the steel plants. Rolling and forming steel also offer opportunities to decentralize the steel industry and strengthen links with rural industries. The steel industry has a central role to play in the total industrialization of India. Reducing capital costs is important, but conservation of non-renewable resources may be more important.

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Appropriate technology for the capital goods industry (machine tools) in developing countries

*S.M. Patil**

Introduction

Developing countries have usually adopted the pattern of industrial development of the industrially advanced countries which have supplied them with technology. But in spite of impressive industrial performance many developing countries still suffer from unemployment and mass poverty. In addition to explosive population growth one reason for the employment problem appears to be the adoption of inappropriate industrial technologies. In the search for appropriate technologies which would ease the problem of unemployment the capital goods industries, particularly engineering and metalworking, have demonstrated the best possibilities for creating jobs. This paper attempts to recommend guidelines for the development of these industries.

Many advanced, labour-saving technologies have been used in developing countries without modification because it was assumed that there was no scope for introducing labour-intensive methods without sacrificing the quality and cost of the end-products. Closer investigation, however, might have revealed that this was not the case.

Import substitution should be the guiding principle for the development of capital goods industries. Initially, Governments can encourage import substituting industries by offering suitable incentives and protection from competitive imports; later, when self-reliance has been achieved, the goal should be changed from import substitution to export. Greater technological co-operation among developing nations would probably further the development of appropriate technologies and allow them to avoid many of the mistakes and problems which face the industrialized world today.

Machine tools

The machine tools industry plays a central role in the production of capital goods.

The introduction of carbon-steel cutting tools in the early eighteenth century and the subsequent introduction of high-speed tools has speeded up

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* Consultant, Bangalore, India.

production of components and improved their quality and finish. Today the industry has moved into the era of sintered-carbide tools, ceramic tools and lasers. Ever higher productivity and greater automation have been the result.

Advanced production technology may not be directly relevant to the production of metalworking machines and other electrical and mechanical engineering requisites in many developing countries, but industrial planners concerned with the development of these industries in developing countries should be aware of them. Planners need insight into recent work on machine tool design and engineering if they are to determine which components of a given technology should be imported and which be modified or developed locally.

Some recent developments in machine tool production technology include:

(a) High power cutting and grinding aids which cut metal faster and produce better finishes and closer tolerances;

(b) Metal-forming machinery which operates more quickly and more efficiently than ever before;

(c) Automatic machine tool control systems which require less time for planning and inspection and allow more time for production;

(d) Increasingly versatile machine tools which can be used for a variety of operations in one set-up.

The most significant developments in metalworking during the past decade have been the introduction of numerical control (NC), or control of machine tools by punched tape, and of computer control (CNC). Adaptive control and direct computer control (DNC) have also been introduced. All these techniques have been effectively combined in one type of machine tool called the machining centre which is controlled by punched tape, CNC and DNC machining programmes. Machining centres are equipped with automatic tool changers having 60 or even more cutting tools, each capable of performing a special type of operation. Machining centres are mostly used to cut metal at a faster rate than can be done by machines of conventional design. Computer monitoring, or control of plant operation by computer, will probably be the most important growth area in the metalworking industry during the next decade.

Choice of technology

The purchase of advanced technology from industrialized countries should not be an exercise in blind faith in technology. Developing countries should keep in mind their means and their development objectives. Indeed developing countries must evolve an approach to industrialization that combines the use of advanced technologies with the use of inexpensive alternative technologies which would encourage employment and production in rural areas and in small-scale industries. Alternative technology should not be confused with primitive technology; alternative technology can be quite advanced in terms of scientific and engineering thought.

Argentina, Brazil, India, Mexico, the Republic of Korea, Singapore and Venezuela, for example, already have sufficiently adequate infrastructures to use appropriate technologies and to begin production of capital goods more easily and more rapidly than many other developing countries. Hence the ways and means of initiating capital goods production will vary widely from one developing country to another.

Production technology

In the production of machine tools or any metalworking machinery there are normally two main operations: the manufacture of various components and assembly, including testing and finishing. In both operations production engineering has recently undergone spectacular changes which have revolutionized the designs of machines and machine tools.

In least developed countries, where there is little or no capital goods or machine tool industry, there appears to be no alternative but to buy designs and production know-how from abroad. What is needed are general purpose machine tools of simple design like centre lathes, drilling machines, shaping machines and knee-type milling machines. The technology needed to produce the components of these machines should be simple and make extensive use of general purpose machine tools. Because skilled labour is scarce, these countries need more production aids like jigs, fixtures, and similar assembly aids. Strict quality control, including individual inspection of each component, is necessary to avoid faulty workmanship which would cause problems in the assembly and testing stages of production.

Assembly operators such as scrapers and fitters must be highly trained so that they can correct machining inaccuracies. Inspection at part manufacturing, unit assembly and final assembly stages must be carried out with skill and care. Although developing countries often make great efforts to plan the production of high quality goods, they do not take sufficient care to see that the products are finished properly.

Small-scale and ancillary industries

Most industries in developing countries have been established as large-scale units in collaboration with developed countries. Little attention has been given to the development of small-scale, and supporting industries and many of the large-scale, capital-intensive process industries, as planned, provide little scope for decentralization or for sub-contracting work to small-scale and medium-scale units.

In contrast, the production of metalworking machinery, including mechanical and electrical machine tools and engineering goods, provides ideal possibilities for decentralization. Large-scale units should in fact be planned to include the development of a number of ancillary units. Ancillary units should be near the main factory and should produce accessories or carry out such operations as machining simple, small components, assembly, heat treatment, casting, fettling, sand-blasting, forging, and welding. This pattern of ancillary units provides additional employment opportunities and maximum dispersal of industrial activities. The experience of developing countries which have adopted this pattern has shown that it can cut production costs considerably.

Technology transfer

Developing countries may have to begin acquiring technology through collaboration with foreign partners. Joint ventures, turnkey projects and licensing are three common ways of transferring technology.

Joint ventures

The first type of collaboration usually adopted by developing countries is a joint venture in the form of financial participation. While this has proved to be a successful arrangement in many cases, it is not without potential disadvantages. In spite of minority participation, for example, the management of many joint ventures has slipped into the hands of foreign partners. Domestic production can lag behind targets while imports remain substantial, resulting in continued dependence on imports and limited growth of local capabilities. Long-term considerations such as local research and development, training and development of local personnel and social objectives have often received scant attention from foreign partners.

Turnkey projects

Turnkey projects are usually expensive and entrepreneurs must know what they want and how to negotiate with foreign collaborators. International agencies such as UNIDO or specialized government bodies in other developing countries can help determine what is really needed and how to negotiate for it.

Licensing

Experienced developing countries can make licensing arrangements. Success with licensing arrangements, however, presupposes the existence of a well-developed industrial base, experience in the disaggregation of technology packages and experience in negotiating with foreign partners. Normal practice is to make a down payment to compensate the licensor for development costs and to pay royalties only on the indigenously manufactured components of the product. Sometimes part compensation is made to the licensor by placing a large order for components; sometimes, by importing ready-for-sale machines from the licensor for use in gauging product acceptance in local markets.

Royalty arrangements are advantageous because they sustain the licensor's interest in the project throughout the term of the contract; at the same time they usually give the licensee access to improved designs and production methods for the product under licence.

Collaboration among developing countries

It is sometimes to the advantage of developing countries to seek technological aid from other developing countries. Developing countries which have successfully modified production technology would probably be less expensive sources of appropriate technology than developed countries would be.

The dangers of inappropriate technology

The search for appropriate technology has stemmed from the realization that indiscriminate use of sophisticated technologies from highly industrialized countries is partly responsible for the persistence of critical socio-economic problems in developing countries. Today even the highly industrialized countries recognize that advanced technology alone will not pave the way to a better future. Many of the technological developments on which the economic prosperity of the highly industrialized countries is based presuppose the availability of cheap oil; but petroleum is no longer cheap, and many modern technologies dependent on oil have become economically questionable. Furthermore, the ecological problems resulting from the use of some advanced technologies have cast grave doubt on their long-term utility.

The promotion of technologies that are appropriate to the needs and resources of the poor will require close co-operation among the developing countries themselves. Technological transfer between the nations of Africa, Asia and Latin America will help them solve their own problems and will enable them to avoid many of the problems resulting from the use of inappropriate technology which now face the industrialized world.

The role of the engineering industry

The National Industrial Development
Corporation Ltd., India

Introduction

In India, national policy has aimed at intensive development of the engineering industry with emphasis on the production of capital goods. The goal of this strategy is self-sufficiency in the production of basic industrial machinery and machine tools. The location of these industries was made after careful consideration of the level of existing development; the availability of transport and communications; and the supplies of water, power and skilled manpower. India has also launched schemes to promote small-scale industrial estates for the production of components for use by larger industrial units and for the production of consumer goods. In fact, such small-scale industries now account for nearly 30 per cent of India's engineering activities.

When the engineering industry in India began to develop, it was largely dependent on collaboration with industrialized countries and the choice of technology was limited to what was available from them. It was not possible to examine in detail the techno-economic implications of the technologies acquired. However, as the engineering industry has grown, opportunities have arisen to introduce more appropriate technologies including technologies for mass production and for the production of sophisticated machine tools.

The engineering industry plays an important role as a basic consumer of industrial products. In turn the products of the engineering industry are used by the consumer goods industries where they contribute not only to generating employment but also to raising the standard of living in areas where these industries are located. The engineering industry directly improves the skills of the work-force, providing a pool of skilled manpower for the development of other industries.

India's experience may not be repeated in other developing countries but it can serve as a useful guide to possible developments.

Existing technology

Except perhaps for textiles, there was hardly any organized industry in India before independence. After independence, industrial development was rapid, diversified and widely dispersed but almost entirely based on imported technology. However, particularly in the consumer and consumer durables sector, local innovations have now been made and, in several areas, foreign technology is no longer dominant.

A unique feature of industrial development in India has been the rapid growth of the consumer durables industry. This has led to the development of a variety of low-priced special-purpose machines.

Some of the larger industries like the railways and automobile engineering were necessarily set up with foreign technical help. Invariably little attention was paid to future local needs. Consequently, almost all manufacturing units for trucks and cars employ techniques or produce goods already obsolete in the developed countries.

To improve technology, the Indian Government has set up R and D centres like the National Institute of Foundry and Forge Technology, the Central Machine Tool Institute, the National Metallurgical Laboratory and the Central Mechanical Engineering and Research Institute to make detailed studies of the most appropriate long-term technologies.

While India is producing a large variety of industrial goods today, complete technological self-reliance has not yet been achieved in all spheres. India has shown marked self-reliance in the production of some goods, such as general-purpose and special-purpose machine tools, cutting tools and metal forming machines, and some of these products are now being exported to developed countries. Another example of self-reliance was the local development of tractors and power tillers. Unfortunately this development took place at a time when industry had already begun producing tractors in collaboration with foreign firms and the local products found no outlet. Small-scale and medium-scale industry has also been successfully making stationary diesel engines for irrigation and emergency power generation.

Small-scale industry has shown that it can produce consumer goods acceptable to Indian buyers including radios, television sets and other domestic appliances.

Indian industry has also developed machinery for moulding plastic and rubber which is simple, strong and easy to use; because many of the operations are manual, the cost of buying and maintaining the equipment is low.

India today can offer metalworking technologies to meet many requirements, particularly those of other developing countries. The technologies are simple and the equipment is simple and sturdy.

Many entrepreneurs have marked their success by exporting a variety of products like fasteners, builder's hardware, electrical appliances and switches; some have even given technical help in establishing similar ventures in other developing countries.

Technology training courses have been started and several universities have carried out research on technology in practice. Some R and D institutes have been set up with help from United Nations organizations. Finally, industry itself has set up professional bodies which are concerned with technology design and development.

The Indian Government has also directly helped small-scale industries by developing an infrastructure, setting up raw materials banks at consumer points, and providing various kinds of financial incentives.

SIX CASE STUDIES

Choice of technology for any industrial activity is dependent upon various factors such as infrastructure, availability of skills, financial resources, market potential, collaboration and social needs. In a changing economic and social situation, such as India has experienced in the past three decades, no decision can be proved conclusively right or wrong. An important requirement of any industrial activity is, therefore, flexibility and adaptability.

The following case studies describe the development of various engineering industries in India.

Structural engineering

The earliest engineering industries in India were the railways, small public works department workshops, textile mills and port workshops. While rolling-stock was imported, mostly from Europe and the United Kingdom, some factories were set up in India, mostly as subsidiaries of United Kingdom organizations, to fabricate structural works from imported heavy beams and girders for making bridges and similar structures. These girders were also used in road building. Many of these factories flourished in the eastern part of India, the only area before independence with some engineering base. However, most of the materials required for this work, such as steel plates, angles and sections, continued to be imported from the United Kingdom. Soon after independence, management of these companies became totally Indian. Throughout their existence these factories had almost never been modernized and even after independence there was virtually no new investment. The result was that these companies continued to use obsolete technologies; many quickly deteriorated. Some factories came under partial government control; others were fully nationalized. Only then were technological innovations introduced so that the factories could begin to contribute to the requirements of modern industry. They soon acquired expertise and today these public sector companies are effective partners for such basic industries as cement, fertilizers, petrochemicals, iron and steel, sugar and chemical processing.

An important development in structural engineering has been the design and construction of steel transmission towers; several firms have specialized in this work and are now among the world's leading manufacturers of such towers.

Another major development has been the production of electric overhead travelling cranes. Before independence such cranes were imported; India now builds its own cranes with capacities up to 100 t.

Industrial expansion during the first three plans created a large capacity for structural production. Total capacity is now approximately 450,000 t/a Recent annual production, however, has been less than 125,000 t/a. This is because all industrial activity has slowed down since the fourth plan. Nevertheless the Indian structural engineering industry has progressed to a point at which Indian companies are capable of taking on turnkey assignments for design, manufacture and installation. Some Indian manufacturers have become leading contractors to other third world countries

The automobile industry

Shortly after the Second World War, a private firm was permitted to begin assembling and then manufacturing passenger cars. In the early 1950s two more companies began manufacturing passenger cars. A few years later the production of commercial vehicles was initiated. As motor cycles and later motor scooters became popular, Italian technogical co-operation was sought. Automobile production has, however, always been on a small scale when compared with automobile production in the developed countries. This has meant the use of small-scale production techniques with general purpose machining involving a larger number of operations and long cycle times, and has limited the quality of the vehicles produced. During the automobile industry's period of growth there was a scarcity of structural carbon, alloy and sheet steels, so that the early development of the industry in India was marked by heavy dependence on imported materials. At the same time, industrial production was dominated by general purpose machinery. A turning-point was marked by the introduction of mass production techniques to the truck sector. This led to the use of more automatic machine tools, transfer lines, and multi-spindle lathes. At the same time developments in the capital goods industry lessened the dependence of the automotbile industry on imported materials.

Today few materials are imported. In some areas, exports have begun. Indian trucks, buses and scooters are widely sold abroad. Even previously imported products such as radiators, wheel-rims, dashboard instruments, fuel injection and electrical equipment are now being made to international standards and exported to developing and developed countries.

Railways

Railway engineering work includes the building and maintenance of locomotives, rolling-stock, track, bridges and other structures. India's vast network of British-built railways was nationalized in the early 1950s. In the early 1960s India decided to change from steam to diesel and electric locomotives. A factory for the production of diesel locomotives was set up with American collaboration and some locomotives are now being exported. To reduce dependence on imported diesel oil, the use of electric traction is now being emphasized. The remaining steam locomotives are being replaced by diesel and electric locomotives produced within the country.

This has helped to set up a technological base in the country for welding and for making steel and alloy castings and heavy forgings.

Metalworking machines

Beginning in the early 1950s industrial development created a huge demand for metalworking machine tools and the Indian Government declared that every large industrial unit should promote subsidiary industrial estates for small-scale entrepreneurs. In turn this led to a demand for simple general purpose machine tools at prices that small entrepreneurs could afford.

With the growth of industrial activity more types of machine tools have been produced, both with and without foreign collaboration. These include special purpose machines used in the railway, automobile, tractor and electrical industries and numerically controlled machines used in batch production industries. In 1977–1978 more than Rs 100 million worth of these tools were exported. While the performance of the industry is impressive, its standards are often lower than those of developed countries. In sum, the industry has adequate manufacturing competence but its design competence has yet to be fully developed.

Consumer durables

Consumer durables are such items as bicycles, sewing-machines, electric fans, electric irons, air-conditioners and refrigerators. Until independence almost no consumer durables were produced in India. Most of them were imported from the United Kingdom.

Bicycles

Bicycles are very popular in India. In rural areas they are used to transport both persons and goods. Bicycle production has always been on a large scale and many firms have collaborated with foreign manufacturers. In other cases foreign technicians were hired to initiate local production As the demand for bicycles rose, firms often expanded their factories by duplicating their plants. Because bicycle production rose in India at a time when it was declining elsewhere, export opportunities became available to the Indian industry.

Recent developments have included fitting bicycles with small petrol engines. These are becoming increasingly popular. Some manufacturers have gone further and are now making mopeds. Another recent innovation has been the setting up of establishments in several other developing countries to export information, equipment and engineering services. Today the bicycle industry is one of the most self-reliant industries in India.

Sewing-machines

The development of the sewing-machine industry has been on a different scale. The technology for domestic production was either imported or copied. Large companies grew up and soon captured almost the whole Indian market. However, local firms in the small-scale sector began manufacturing components and because their overhead costs were low, their prices were competitive.

As demand grew, mass production techniques were introduced to the manufacture of sewing-machines. Many firms developed their own special purpose machines which quickly brought down costs and increased productivity. Indian sewing-machines are now among the most competitively priced in the world. In fact some developed countries, including Japan, have begun to import components from India.

The industry has, however, done little experimentation up to now. The demand for industrial sewing-machines to stitch canvas and leather, for example, has been neglected. These machines are still mostly imported.

Electric fans

India, a largely tropical country, has always had a ready market for table and ceiling fans. With the spread of electricity, the market has expanded. Most electric fans are made by large firms but they often subcontract work to small-scale enterprises. India enjoys a regular export trade in electric fans.

Refrigerators and air-conditioners

Refrigerator production began in the late 1950s in the form of technical collaboration with developed countries. Until then refrigerators had been considered luxury goods and few persons could afford them. The technical collaboration involved the supply of part drawings, know-how, testing instructions, precision tooling and, in some cases, machinery.

Power

At the time of independence virtually no power generation equipment was made in India. Even small items such as electric motors used in industrial machinery were imported.

The five-year plans stressed the importance of power generation as an instrument of technological progress. Foreign help was employed to make steam and water turbines, alternators and transformers with capacities up to about 110 MW. Absorbing the technologies for making these goods proved difficult and India continued for some years to import some raw materials and components. Turbine blades, rotors, heavy castings, lamination sheets, and some special types of contactors, for example, had to be imported for so long and foreign exchange was so restricted that the growth of the industry was limited.

However, the industry today is producing captive power units of 50, 110 and 250 MW capacity which meet international standards. Plans are also in hand for building 500 MW equipment, including the necessary boilers, pumps, valves, turbines, transmission equipment and control gear. Other positive developments include high voltage switch gear, transformers and solid-state control equipment.

So far India has no technology for making the power generating gas turbines which are becoming increasingly popular elsewhere in the world.

IMPORTING TECHNOLOGY

After independence India emphasized production of capital goods starting with machine tools made by conventional methods. These were not intended for use by large-scale production facilities and demand ultimately compelled the industry to turn its attention to the more sophisticated technologies of transfer and special purpose machines, for example.

The use of sophisticated, imported technologies, however, requires careful consideration. Since India has a large population with a low *per capita* income, the use of modern capital-intensive technology to produce essential items could result in the production of of highly priced goods for which there are no buyers.

In the last 30 years India has made considerable industrial progress. Nevertheless the industrial activity generated today is still not enough to satisfy the economic needs of large sections of the population. Because of this the Government has launched various schemes to spread industrial activity as widely as possible. It has set up state aided industrial estates throughout the country and several agencies to encourage small industries. These industries have raised the level of skills and created jobs in the regions in which they are established. In addition to supplying industrial products to other industries they have begun to make consumer items such as buttons, electrical switches, and agricultural products, thus spreading the industrial revolution to the countryside.

PROBLEMS OF UNEVEN DEVELOPMENT

The population of India is fairly evenly distributed but development has been uneven. Some areas have good transport, communication and service facilities; others are poorly developed. The reasons are partly historical, partly political. While the Indian Government has not prevented growth in existing centres of industrial activity, it has promoted many schemes for industrializing less developed areas. Roads and railways have been extended, raw materials provided and financial incentives offered. Whenever possible the Government has set up large industrial ventures in less developed areas. For example, heavy electrical factories were built at Bhopal and Tiruchirappalli and heavy engineering factories at Ranchi rather than in existing industrial centres like Bombay, Calcutta and Madras.

Further dispersal of industry has taken place by setting up metalworking plants and tool-rooms in the regions around large factories; in turn, these have become centres of attraction for small and medium-scale industries. Greater dispersal of such metalworking industries would call for simultaneous development of other facilities like transport, roads, communication networks, and power and water supplies.

CONCLUSION

India's industrialization plans after independence recognized the importance of trade as an instrument of political influence in the world. The Government therefore decided to allow foreign capital participation in selected areas only; no foreign capital participation, for example, was allowed in mining, steel production, power generation and defence.

Indian planners felt that as long as capital goods continued to be imported, the skills of the country would not be adequately developed; they believed that development of the capital goods industry would mean simultaneous development in related areas. For example, an industry manufacturing locomotives would lead to the development of the grey iron, steel, precision casting, non-ferrous metals and electrical industries. It can thus be seen that the development of a capital goods industry would spur the development of almost every branch of engineering. Unfortunately in India this engineering boom coincided with substantial developments in other sectors of the economy, particularly in agriculture, putting great pressure on resources. Because development of the capital goods industry is necessarily slow, large investments had to be made without the possibility of immediate returns and this produced an inflationary trend in the Indian economy. Once inflation set in, the cost of every input including development activity increased so much that development itself became difficult, sometimes impossible

In the mid-1960s earnings from exports failed to match the country's demand for imports. This, coupled with poor agricultural production and heavy defence spending put a tremendous strain on the country's economy. In the severe recession which followed, the metalworking industry was the first to suffer and the last to recover. Government development funds were reduced, causing a further decline in orders for industrial machinery and machine tools. After nearly three years of recession the economy began to improve but it was again put under pressure by more military spending and then by the major oil price increases of 1973–1974. However, this time Indian industry had developed enough resilience and flexibility to permit industrial activity to continue without major interruptions.

In conclusion it may be said that the simplest and most productive activity for any developing country is the development of engineering industries. Depending on the levels of literacy and skill, the availability of funds and national priorities, this might include capital goods, industrial machinery and consumer goods. These activities would generate employment and create wealth. Simultaneously they would help the country to become an importer of processed raw materials rather than an importer of finished capital goods. The demand for skilled workers would lead to an improvement of local skills and this in turn would attract even more industries. The wealth created in this chain reaction would mean that there would be money available for the development of primary industries like iron and steel.

Indian experience suggests that consumer goods industries should be developed with caution. Consumer goods industries can create employment, but they can also hinder the prosperity of the country as a whole if the capital goods industry is not yet adequately developed. However, the development of the capital goods industry should also be carried out carefully. India, for example, is making jute and textile machinery in such a way as to keep the equipment fairly modern but yet not so automated as to displace labour already employed. Similarly in the production of metalworking machine tools and industrial machinery, equal emphasis has been placed on general purpose machine tools and special purpose machine tools. In both cases greater importance has been attached to reliance on human skill rather than to sophisticated, automated machines and instruments.

Appropriate technology for the chemical industry

J. Giral B.*

INTRODUCTION

Since 1968 the Group for Development of Technology, National Autonomous University of Mexico, has been studying appropriate chemical technology and has developed a methodology for applying the results of research to macro- and micro-economic planning for the Mexican chemical industry. The results of this research support three key assumptions:

1. Technology is not an amorphous concept. It can be methodically characterized, classified and analysed.

2. Industrial development must be planned from the point of view of technology as well as economics. Traditional macro-economic planning is concerned with the economic implications of industrial development, but it is also necessary to incorporate such additional planning criteria as social impact, environmental impact, competitive strength and technological implications.

3. Technological planning information can be started with very limited information and still produce valuable insights for policy making.

The methodology is described in the first section of this paper, and the application of it to produce quantitative models of technological, financial and labour requirements for the Mexican chemical industry over the period 1977–1982 is the subject of the second section.

I. CONCEPTS, DIMENSIONS AND ELEMENTS OF APPROPRIATE TECHNOLOGY: A FRAME OF REFERENCE

It is assumed that the appropriateness of a given technology is a function of the time, the place and the specific sector in which it is to be used and that unless these parameters are well defined, no analysis will produce useful results.

The research incorporated in this section represents the experience of some dozen technologists over the past 10 years. The frame of reference employed has been tested for several years in industry and is now being tested by the industrial development and technology agencies of the Mexican Government.

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* Director, Group for Development of Technology, Graduate School of Chemical Engineering, National Autonomous University of Mexico, Mexico.

Basic differences

If it is assumed that the appropriateness of a technology is a function of a given place, a given time and a given sector, then it is necessary to define the characteristics of that place, that time and that sector before planning industrialization. Experience has demonstrated that the effort required to define such characteristics is rewarded by the increased sensitization of engineers, technologists and other specialists to the individual features of a project that they must be aware of, if they are to work productively. This is specially important in technology transfers involving nationals of several countries.

It is recommended that Governments define the general features of their countries and include these definitions in their industrialization plans and in their industrial promotion activities. Governments should also support the efforts of professional societies and of sectoral and regional industrial organizations to define the specific features of their areas of interest or responsibility. It should, however, be stated clearly that such definitions are illustrative rather than absolute and that a project engineer must carefully evaluate the specific features of a given project.

For example, some of the general features of the Mexican economy in 1977/78, expressed as comparisons with the economy of the United States of America, were:

Markets 4 to 12 per cent as large

Labour costs 15 to 30 per cent as high

Capital costs (interest rates) of 18 to 22 per cent for pesos compared to 8 to 9 per cent for dollars

Locally produced equipment and raw materials costs 15 to 50 per cent higher

Electricity costs 20 per cent less

Other sources of energy costs 15 to 40 per cent less

Adequate transportation is available in Mexico at competitive rates.

The climate of central Mexico is desert-like. No frost occurs, except in the north so that there is no need to lay piping beneath the frost line and there is no need to calculate roofs and foundations for snow loads. The low average humidity is ideal for natural convection or forced-draft tray drying without additional heat.

The central plateau is 1,500–2,100 m high; boiling temperatures there are reduced 6° to 10°C, almost doubling chemical reaction times, and air intake rates for compressors, dryers etc. are reduced from 25 to 40 per cent.

Planning base

The essential task of national planning is to define national priorities clearly. An effective approach to doing so is first to define no more than half a dozen economic goals and then to assign them relative priority. Typical economic goals are employment, balance of payments, use of local raw materials, ownership and control of industry by nationals, productivity, income distribution, competitiveness (local versus international prices), decentralization (promotion of less developed areas of the country).

National planners must then select the sectors of the economy through which they expect to realize the goals chosen. Whether a sector is expected to maximize all the economic goals or only certain of them should be clearly indicated.

National planners must also indicate the instruments (i.e., controls and incentives) they expect to use to promote development in the sectors selected.

Criteria of plausibility

The definition of the basic features of the country and an explicit statement of its economic goals, priority industrial sectors and the instruments to be used to encourage and control industrial development provide government agencies and industry with common reference and guidelines on how and where to plan growth.

Another useful common reference is a set of criteria of plausibility. In this context plausibility means the socio-economic impact of a project as distinguished from its economic feasibility.

A good example of plausibility in this sense is Spain's slogan, referring to an effort to reduce excessive consumption of gasoline "Maybe you can afford it, but your country cannot."

Criteria of plausibility can be used, for example, to identify potentially beneficial projects regardless of their economic feasibility. Controls and incentives can then be used to make such projects economically feasible.

The Mexican industrial development agency (Secretaria de Patrimonio y Fomento Industrial) is currently using the following set of plausibility criteria in the chemical and related sectors:

Criterion	*Weight (%)*	*Basis for quantification*
Employment	25	Investment per job created
Balance of payments	20	From a deficit to a surplus
Competitiveness	20	Mexican vs. United States prices
Local integration	15	Percentage of local value added
Decentralization	10	Location of industry in one of five selected regional areas
Local control and ownership	10	Percentage of local equity and local participation in management

Industry submits a project proposal to the Government, which then evaluates its plausibility and suggests ways to improve the project by relocation of the plant to a higher priority area, for example, or by increasing the share of local equity. Industry's response to the Government's suggestions provides the basis for the Government's decision to protect or subsidize the project.

Although the system has been in operation only a short time, the reaction of industry has been very positive. The system also allows seven interacting government agencies to share a common system for project evaluation.

The identification of basic features, the establishment of a planning base and the application of criteria of plausibility constitute the macro-economic aspects of development planning. Proper use of these tools should help Government and industry do a better job in selecting projects appropriate to the development needs of a country.

Characterization of technology

Characterization of technology means identifying and describing the dimensions of a given technology. Such characterization is the basis for selecting, acquiring, transferring and adapting the technology.

It is assumed that three principal dimensions characterize a technology: commercial mission, difficulty of assimilation and type of technology.

Commercial mission

The commercial mission of a technology may be classified as:

(a) Export oriented. Typically a project is export oriented when, because of some local production advantage (raw materials or labour, for example), it is believed that the product can compete successfully in international markets and accordingly 30 to 70 per cent of product capacity is justified on the basis of potential exports. However, this limits the flexibility of technological choice because product specifications must match those of international competitors, which in turn usually implies that plant size must be comparable to the world's largest;

(b) Local-market oriented. When a project is justified on the basis of import substitution or satisfying the needs of a growing local market, then there is increased flexibility in choosing the technology: plants can be smaller and products can be modified to suit local conditions and to simplify the manufacturing process;

(c) Oriented to satisfy a latent need. Most developing economies have large population groups with limited resources whose needs are not being satisfied by the product mix available to them. This leads for example, to such purchasing aberrations as colour television sets or expensive appliances in adobe shacks: a few hundred dollars of income was available but there was no appropriate product to buy.

This problem needs much more attention; its solution would provide many opportunities to improve the quality of life of the population. Ultimately, most efforts in technology development should be concentrated in this area.

Since fulfilling latent consumer needs requires both product and manufacturing process design, it also permits great flexibility in product specifications and plant size.

Difficulty of assimilation

This dimension characterizes the degree of sophistication of a technology from the standpoint of local assimilation. Experience has shown that unless the capacity to assimilate a technology is adequate there is no possibility of attaining technological self-reliance or the capacity to adapt a technology to local conditions. Difficulty of assimilation is assessed as:

*(a) **High**.* Highly sophisticated technologies usually requiring an internal technical staff of more than 10 specialists;

*(b) **Intermediate**.* Technologies requiring the participation of fewer than 10 technicians or persons with some technical knowledge;

*(c) **Elementary**.* Technologies which can compensate for lack of technical staff by careful management.

Although practical experience has shown that recognition of the level of difficulty of assimilation is essential for effective planning it has not yet been possible to generate sufficient information to describe these levels more precisely.

Type of technology

All technologies can be typified as follows:

*(a) **Equipment-based technology**.* The technology required to operate the plant is implicit in the equipment and acquired with it; raw material suppliers provide whatever additional technical information is required;

*(b) **Product-based technology**.* The key aspect of the technology is in the chemical composition or physical structure of the final product and not in the manufacturing process; typically, a technician with experience in the industry in question and access to product technology and patent can design an adequate manufacturing process;

*(c) **Process-based technology**.* The final product and the equipment are well known and the proprietary value lies in the details of the process, such as materials balance, energy balance or a flow-sheet. These technologies are typically continuous process technologies related to the chemical industry;

*(d) **Operations-based technology**.* Typically these are the oldest and most developed technologies and represent a mixture of the other types of technology. As equipment-based technologies become more developed and generate a larger volume they merge into operations-based technology.

As can be seen from table 1, in every one of these four types the original technology was developed differently, and there is a different mechanism of protection of the technology, a different mechanism for transfer and licensing, and a different type of adaptation potential.

Technology acquisition

The five most important ways to acquire technology are:

*(a) **Purchase**.* Processed information with minor modifications to fit local needs is acquired from a single supplier;

*(b) **Integration**.* Technology is acquired in two or more easily integrated modular packages requiring minimum local adaptation;

TABLE 1. CHARACTERISTICS OF THE FOUR TYPES OF INDUSTRIAL TECHNOLOGIES

Type	*Examples*	*Development of the original technology*	*Protection and availability of the technology*	*Mechanisms of technology transfer*	*Adaptability*
Equipment-based	Food packaging Plastics conversion Textile Rubber Pharmaceutical forms	By the equipment manufacturer and the raw material supplier	Available with the purchase of the equipment or the raw material, usually with an implicit payment in the overall purchase price	Instructions for equipment use	Direct use of the equipment Control simplification Replacement of automatic operation by manual Minimum adequate specifications Design of new products
Product-based	Food processing Metal mechanic (bicycles, farm machinery, typewriters) Pharmaceutical Cosmetics Organic chemical (dyes, pigments, agrochemicals) Soft drinks	By the product manufacturer	Patents Registered trade marks Some licensing and franchising	Use specifications of raw materials Physico-chemical parameters Reaction kinetics Process handbook	Batch processes Moderate pressures and temperatures Adaptation of reaction conditions Rationalization of patented alternative processes to synthesize analogous products
Process-based	Petrochemical Steel Petroleum refining Detergents Fertilizers	By engineering firms (and by the manufacturers)	Much licensing Flexibility in the level Important to know what to negotiate	Process handbook Plant handbook Equipment design Operation handbook	Continuous processes High pressures and temperatures High level of optimization Separation represents 80% of total investment and operating cost (exclusive of raw materials)
Operations-based	Mining and metallurgy Electrochemical Automotive Metalworking	Evolution over a long period Mix	Know-how	Plant handbook Equipment design Operation handbook Operating tricks (experts)	Processes and equipment Relatively easier to adapt than process-based technology Availability of raw materials

(c) *Adaptation.* Technology is acquired and adapted to local conditions: detail engineering is developed locally according to need,

(d) *Development.* The need for a technology is recognized and a technology is developed to meet this need;

(e) *Contract-development.* As an alternative to local development a needed technology is commissioned abroad and developed under contract.

Innovation is not singled out as a source of new technology because it is an important element in all technological development.

Table 2 shows how the characterization of technology relates to the mode of acquiring it.

As can be seen, the commercial mission of the proposed technology and the degree of sophistication required to assimilate it determine how best to acquire the technology.

The type of technology has more influence on the packages themselves and the mechanisms for transfer and local development, rather than on the way the technology should be acquired.

TABLE 2. WAYS OF ACQUIRING TECHNOLOGY BY DEGREE OF SOPHISTICATION REQUIRED AND COMMERCIAL MISSION

	Degree of sophistication required to assimilate the technology		
Commercial mission	*High*	*Medium*	*Low*
Export oriented	Purchase, integration	Integration, adaptation	Solving the administrative and logistic problems involved
Local-market oriented	Adaptation	Adaptation development	Adaptation, development
Oriented to satisfy a latent need	Contract-development	Development	Development, education and training

The development strategy also may affect the way in which technology is acquired. Thus, if the strategy is one of self-sufficiency, obviously the preferred way will be by local development and innovation with the corresponding expenditure of funds to develop an adequate infrastructure for R and D. On the other hand, if the strategy is defined as one of self-determination, under some circumstances direct purchase or contract-development may be preferred.

Selecting and negotiating technology packages

Technology packages are the usual medium of technology transfer. Table 3 gives the most common packages and payment formulas used in Mexico between 1970-1978; they are not exhaustive.

TABLE 3. CONDITIONS FOR THE ACQUISITION OF TYPICAL TECHNOLOGY PACKAGES

Package	*Protection and payment formula*	*Supplier and typical restrictions*
EQUIPMENT BASED TECHNOLOGY		
Basic installation package:		
Civil, mechanical and electric specifications Maintenance requirements Proposed layouts Operating suggestions	Implicit in the acquisition of the equipment. Supplier may send expert during installation and charge fee plus expenses	Equipment manufacturer Very few restrictions, usually Some restrictions in export competition
Operating package:		
(a) Instructions: Operation and maintenance Equipment check-up and adjustment Failure detection and correction	*(a)* Implicit in the acquisition of the equipment. Supplier may, at buyer's request, provide a more comprehensive operating manual or send operating consultant, for a fee	*(a)* Equipment manufacturer Very few restrictions
(b) Specifications: Raw materials Final product	*(b)* Implicit in cost of raw material. Service by experts is never charged	*(b)* Raw material supplier No restrictions
Technical assistance:		
Operation Quality control Productivity analysis Product design and improvement	Payment usually reckoned as a percentage of sales or as cost-plus fee. Only product design and key methods for productivity improvement protected by patent	Equipment manufacturer, usually; co-manufacturer from other, non-competitive areas; occasionally consultant engineer
PRODUCT-BASED TECHNOLOGY		
Product franchising or licence:		
Use of trade name Use of logos and basic design regulations Advertising pattern	Franchising. Product patent (not in all countries). Licence of registered trade name and of patent. Payment 1% to 5% of sales. Lump sum	Product producer Export and diversification limitations Requirement for free feedback of technological improvements
Product design package:		
Blueprints, sketches, design details, fabrication specifications (or, if a chemical, chemical structure and basic physical chemistry) Considerations on flexibility of product design, tolerances, quality control	Royalty (1%–6% of sales) or payment per unit produced or sold. Patent rights and manufacturing rights are usually licensed, not sold	Same as above
Operating package:		
Manufacturing process or fabrication technique. Safety and environmental considerations. Productivity indicators Quality control	Usually included in the payment for product design package. May cost 1%–2% more, especially if technical support included	Same as above

TABLE 3 *(continued)*

Package	*Protection and payment formula*	*Supplier and typical restrictions*
PRODUCT-BASED TECHNOLOGY *(continued)*		
Basic installation package: Equipment description Civil, mechanical and electrical specifications Maintenance requirements Proposed layouts Operating suggestions	May be negotiated separately as a lump sum or as part of the engineering detail package May amount to 10% of investment	Product producer seldom, engineering firm more often Few restrictions
Technical assistance: Operation Quality control Productivity analysis Product design and improvement	Payment is usually 0.5% of sales or per man-day used plus basic lump-sum fee	Either product producer or engineering firm. Restrictions on diversification, requirements of free feedback on innovations
PROCESS-BASED TECHNOLOGY		
Process know-how: Basic process data Flow sheets Materials of construction	Patents. Licensing on a 10-year basis. Payment as lump sum (about 10% of investment) or royalties (1% to 2% of sales)	Producer or engineering firm No sublicensing. Exports and total amount limitations
Basic engineering: Basic process data Flow-sheets Materials of construction Equipment description Plant layout	Same as above	Same as above
Detail engineering: Same as basic, plus: Equipment specifications Piping, electrical, instrumentation diagrams Civil and mechanical blueprints Material take-offs Piping, insulation, painting specifications	Same as above, plus payment for engineering on man-hour or lump-sum basis	Few restrictions, if any, from firm doing engineering work. All restrictions come from licensor
Operating package: Step-by-step operating procedures on all key equipment. Safety and environment protection. Quality control	Not patentable. May be negotiated together with above packages or separately. Usually costs 0.5% to 1% on sales	Few explicit restrictions, except those associated with above packages
Technical assistance: Operation Quality control Productivity analysis New materials of construction New auxiliary equipment	Payment is usually 0.5% of sales or per man-day used, plus basic lump-sum fee	Requirements on free feedback of innovations. Secrecy agreements. No sublicensing

Package	*Protection and payment formula*	*Supplier and typical restrictions*
OPERATIONS-BASED TECHNOLOGY		
Know-how package:		
Basic operational data Flow-sheets and plant diagrams Key steps in the operation	Patents cover some. The rest is protected by secrecy agreements. Lump sum or around 1% on sales	Producer or engineering firm Limitations vary with value of proprietary information to competitors
Plant-construction package:		
Key equipment specifications Procurement assistance Detail engineering co-ordination Supervision and expediting	Very limited, if any, protection. Payment as lump sum or cost-plus fee	Engineering firm Few restrictions beyond secrecy agreements
Operation and technical assistance:		
Step-by-step operating procedures Quality control Safety and environment protection Productivity	Limited protection beyond secrecy agreement. Lump sum or fee as percentage of sales	Producer or engineering firm, usually through experts in the field Few restrictions

When selecting and negotiating a technology package, the buyer must ascertain what capacity to assimilate the technology exists.

Whenever possible the licensee's technical specialists should collaborate with the licensor's technical specialists in preparing the technology package. This usually reduces the ultimate cost of the package, and makes it easier to assimilate and increases its potential for adaptation. Generally licensees can also benefit from visiting other licensees to learn firsthand about operating problems.

A methodology for adapting technology

The experience of adapting over two dozen technologies to Mexican conditions has produced a methodology that will probably be helpful for adapting equipment and product-based technologies and may be helpful for adopting any type of technology, although it is likely to be less useful for operations-based technology and still less useful for process-based technology.

The Mexican methodology is based on the realization that successful adaptation of a technology requires knowledge of:

Market
Product
Process
Raw material availability
Basic features of the country and their effect on industrial infrastructure
Labour markets

With this knowledge it is possible to assess to what degree two conditions are satisfied in the case of a given technology:

(a) That there is indeed the need to adapt the technology;

(b) That the personnel and materials required for successful adaptation are available.

The following conditions for adaptation of a technology exist:

Need, as determined by:
  Industry mission
  Availability of an appropriate technology
  Direct and indirect costs of acquisition of the technology
  Ecological considerations and social impact

Adaptation potential, as indicated by:
  Sensitivity of cost to scale
  Level of sophistication
  Degree of development
  Availability of information
  Flexibility of the licensee to make morphological changes

Capacity to adapt, as limited by:
  Human resources
  Economic resources
  Time

If these conditions are met, technological packages can be selected and adapted to local needs. The fulfillment of these conditions provides a frame of reference for all the variables relevant to the problem.

These variables can be grouped in five categories:

Category	*Variable*	*Treated as a function of*
Product	Demand	Specifications
	Market and competitive dynamics	Price and time
Raw materials	Cost and availability	Specifications
Transformation	Chemical reaction rates and equilibrium	Physico-chemical variables
	Methodology for physical changes	Local conditions
Separation and finishing	Cost	Specifications
Auxiliary systems (energy, control, pollution, safety)	Methodology	Basic differences

When the trade-offs of these interrelationships become apparent to the adaptation team, they can plan a more effective job of adaptation. The purpose of adaptation is to obtain the minimum adequate specifications both in plant and product. Anything more represents an unnecessary expense; anything less ceases to be adequate. The true measure of appropriate technology, then, is the fulfillment of minimum adequate specifications.

Reference has also been made to the importance of competitive dynamics. As Governments become increasingly aware of the importance of reaching satisfactory levels of productivity and efficiency, it becomes increasingly important for industrialists to ensure that projects will meet minimum standards of competitiveness.

The Group for Development of Technology analyses competitiveness on the basis of a model that classifies competitiveness in three categories:

(a) Exogenous competitiveness: The excess cost of competitiveness is due to overpriced but necessary inputs such as raw materials, shadow prices and taxes;

(b) Endogenous competitiveness: The excess cost of competitiveness is due to poor planning as evidenced by wrong scale and wrong technology;

(c) Projected competitiveness: The project is competitive in today's market but projections indicate that it will soon lose its competitiveness due to obsolescence and world market trends.

Creativity, innovation and entrepreneurship

Lack of creativity and lack of innovation are complex socio-cultural problems. In many developing countries religious and economic, social and faulty structures reinforce authoritarian attitudes and behaviours which are not conducive to creativity and innovative thinking and which discourage the development of the ability to take risks necessary to successful entrepreneurship.

Mechanisms and organizations for applying appropriate technology

Much of the work done up to now on appropriate technology has tended to neglect consideration of who or what organizations will apply the technology and has assumed that these organizations will emerge spontaneously. In fact, practical experience has shown that even the existence of adequate policies and the availability of trained human resources, while necessary conditions for the application of appropriate technology, do not suffice to guarantee successful application of appropriate technology. In addition to the Government and universities, the co-operation of research, development, engineering, equipment manufacturing and production organizations are needed to ensure the effective application of appropriate technology.

Research

Research institutions can concentrate on one piece of a more general problem without the need to justify the study on the basis of short-term profitability. Developing countries do indeed need research, not necessarily oriented to invention or discovery but rather to the design of a product mix which would contribute to improving the quality of life of the local population.

How is the quality of life to be measured? The experience of the past 30 years has shown that GNP and degree of literacy are not ideal indicators. It is, for example, more important that fishermen be aware of the need to respect the biological cycles of fish and that farmers learn more about adequate seed selection, adequate fertilization, and crop rotation than it is for them to read.

Local research institutions must concentrate then on designing products to satisfy the real needs of the country and on the manufacturing techniques required to produce them.

Development

If development is defined as the first integrated effort to put a given technology to practical use with a commercial or business objective, then it is evident that in developing countries there are generally organizations which can make this effort. Existing organizations are not fully integrated or cannot do an efficient job. Or, the final objective of producing an adequate product in realistic quantities at an acceptable price is not clearly perceived and, as a result, is not attained.

While recent discussions have helped to clarify and define the skills needed to promote technological capability, up to now a mechanism for integrating those skills has been generally lacking.

Engineering

Mexican experience suggests that this area has been well served both quantitatively and qualitatively by local organizations. It should, however, be noted that the ability to transfer a technology from one engineering group in one country to another engineering group in another country appears to be better developed than the ability to engineer a local development.

Equipment manufacturing

The greatest limitation of innovative research is the necessity of adapting all ideas to the capabilities of available manufacturing equipment. Local manufacture of equipment is important not because of foreign exchange savings (hidden costs often make this questionable) but because of the need to coordinate local equipment manufacture with the application of appropriate technology.

Analysis of policies to promote local manufacture of equipment should begin with characterization of the technology, as described above, but including this information:

Use of labour
Productivity
Product quality
Safety
Environmental effects

Production

Production is the result of all the efforts described above but can also serve as a testing ground if properly used.

For every innovation born in the research laboratory, several innovations have been born in the plant. The reason is simple: more people are involved in the production process and there is more incentive to innovate, in terms of short-term benefits, and less risk, because testing the innovation is a highly reversible process. If the result is below expectation, it is relatively easy and inexpensive to return to prior conditions. Technological innovation in production can be classified as:

Solution of an explicit problem
Identification and solution of an implicit problem
Systematic optimization
Adaptation
Basic technological development

II. TECHNOLOGICAL PLANNING OF INDUSTRIAL DEVELOPMENT. THE CASE OF THE CHEMICAL INDUSTRY IN MEXICO

Here is a brief summary of the information developed for technological planning of the Mexican chemical industry for 1977–1982.

Macro-economic projections of the chemical industry within the overall economic context of Mexico, both from econometric models (Wharton Diemex) and from the estimates of various government and industrial agencies, lead to an overall estimate of new investment for the Mexican chemical industry in this six-year period of approximately 90 billion constant pesos ($Mex) or $3.9 billion at December 1976 parity rates ($1 = $Mex 23). This compares with an estimated $124 billion for total investment in Mexico in the same period. Accordingly, investment in the chemical industry represents slightly more than 3 per cent of total investment. The breakdown of this projected investment into sectoral components is as follows:

Sector	*Value* (billion pesos)	*Fraction of total* (%)
Petrochemicals	50	55
Basic chemicals	24	27
Agrochemicals	7	8
Others	9	10
	90	100

Information was then collected on individual projects planned for the period under study. The main sources of this information were the published plans of Petróleos Mexicanos (PEMEX) (the official government industry) on basic petrochemistry and the announced plans of public and private industries regarding secondary petrochemical projects. This information was supplemented by a survey of the key members of the chemical industrial association and the major engineering firms. This information was collated and analysed by a research team of the Group for Development of Technology.

From this information lists of key investment projects were prepared. The projects were classified as large (more than $10 million), medium ($1 million to $10 million) and small (less than $1 million). Projected investment totalled $3.3 billion for large projects, $72 million for medium projects and $12 million for small projects. These projects represent 80 per cent of total planned investment; the remaining 20 per cent is to be invested in related projects or in expansion of existing projects.

This data was then run through the steps described in section I.

The criteria of plausibility of 85 projects were rated on a scale of 0 to 10 for each of four classes of criteria, namely, market, economic, finance and technological. The overall rating was the sum of the individual ratings and ranged from 0 to 40. The results are shown in table 4.

TABLE 4. PLAUSIBILITY RATINGS OF 85 PROJECTS

Rating range	*Number of projects*	*Percentage of total*	*Investment (million dollars)*	*Percentage of total*
40–36	7	8	139	15
35–31	8	9	106	12
30–26	26	31	360	39
25–21	30	36	173	19
20–16	13	15	95	10
15– 0	1	1	47	5
Total	85	100	920	100

Table 5 summarizes the data characterizing the technologies. These results reflect the importance of the large-scale, export-oriented process technologies required for the petrochemical expansion programme which must be purchased and transferred directly.

TABLE 5. CHARACTERIZATION OF TECHNOLOGY

Characteristic	*Investment (millions of dollars)*	*Percentage of total*	*Number of projects*	*Percentage of total*
Type				
Equipment based	33	1	10	6
Product-based	128	4	31	20
Process-based	3 024	88	100	66
Operations-based	236	7	13	8
Total	3 421	100	154	100
Degree of sophistication				
High	3 073	90	100	65
Medium	283	8	42	27
Low	65	2	12	8
Total	3 421	100	154	100
Way of acquisition				
Purchase	2 299	67	103	65
Adaptation	542	16	30	20
Integration	54	2	2	3
Development	526	15	19	12
Total	3 421	100	154	100

The study did not consider selection and negotiation of individual technology packages or adaptation of specific technologies because Mexican policy supports the view that these steps should be taken by the people who will ultimately be responsible for the commercial implementation of a project. However, the available data were used to assess the human resources and capital goods required for such an investment programme. Table 6 shows how human resources would be distributed over the various stages of a project as a function of the scale of the project; table 7 summarizes the results of applying the data of table 6 to the chemical industry. Table 8 shows the technological coefficients for equipment required by different investments; table 9 shows the results of applying these coefficients to the data described above.

These coefficients are based on the experience of private chemical and engineering firms in designing, estimating and constructing more than a billion dollars worth of chemical projects in Mexico.

TABLE 6: DISTRIBUTION OF HUMAN RESOURCES OVER THE STAGES OF A PROJECT AS A FUNCTION OF THE SCALE OF THE PROJECT

	Scale			
Stage	*Large (over $10 million)*	*Medium ($1 million to $10 million)*	*Small (less than $1 million)*	*Average cost (dollars per man-hour)*
	Percentage			
Selection, negotiation and transfer[a]	2	2	1.5	25
Adaptation	1[b]	5	6	18
Development	5	10	10	18
Basic engineering[c]	5	5	5	18
Detail engineering[d]	75	58	52.5	10
Construction and start-up[e]	12	20	25	15
Total	100	100	100	

[a] Including only technical labour, excluding time involved in legal and bureaucratic procedures.

[b] This figure is small because in Mexico adaptation in large chemical processes is minimal.

[c] Most of this basic engineering is not performed in Mexico but abroad, usually in the countries of the licensor.

[d] Including all engineering specialities (about 28 per cent of this total is chemical engineering).

[e] Including only engineers' time (about 10 per cent is that of chemical engineers). As the size of the project decreases there is a shift from time spent in detail engineering to time spent in field supervision at construction and start-up.

TABLE 7. HUMAN RESOURCES REQUIRED IN THE CHEMICAL INDUSTRY AS A FUNCTION OF CONDITIONS ASSUMED[a] (NUMBER OF PERSONS)

Stage	*Case 1*	*Case 2*	*Case 3*	*Case 4*
Selection, transfer and negotiation	18	23	43	55
Adaptation	23	27	46	48
Development	27	64	60	144
Basic engineering	58	56	142	138
Detail engineering	1 160	1 222	2 948	2 730
Construction and start-up	206	200	470	456
Total	1 492	1 592	3 709	3 571

[a] Case 1: excluding PEMEX; no change in technological factor. Case 2: excluding PEMEX; higher local development of technology. Case 3: including PEMEX; no change in technological factor. Case 4: including PEMEX; higher local development of technology.

TABLE 8. TYPICAL BREAKDOWN OF THE INVESTMENT IN A MEXICAN CHEMICAL PROJECT FOR DIFFERENT TYPES OF TECHNOLOGY (PERCENTAGE)

	Type of technology											
	Process-based			*Product-based*			*Operations-based*			*Equipment-based*		
Item	*L*	*M*	*T*	*L*	*M*	*T*	*L*	*M*	*T*	*L*	*M*	*T*
Equipment	*5*	*40*	*45*	*5*	*50*	*55*	*5*	*55*	*60*	*4*	*56*	*60*
Process equipment	3	17	20	4	26	30	2	8	10	2	8	10
Process machinery	–	10	10	–	15	15	–	25	25	–	30	30
Pumps and compressors	–	5	5	–	5	5	–	10	10	–	10	10
Auxiliary equipment	2	8	10	1	4	5	3	12	15	2	8	10
Installation costs	*11*	*18*	*29*	*11*	*9*	*20*	*11*	*6*	*17*	*10*	*7*	*17*
Civil and mechanical installation	2	–	2	3	–	3	5	–	5	3	–	3
Piping, valves and fittings	4	6	10	4	3	7	2	1	3	1	1	2
Insulation and painting	1	1	2	1	1	2	1	–	1	1	–	1
Instrumentation and control	2	8	10	1	3	4	–	1	1	1	2	3
Electrical installation	2	3	5	2	2	4	3	4	7	4	4	8
Building and structures	*8*	*3*	*11*	*10*	*3*	*13*	*6*	*2*	*8*	*10*	*5*	*15*
Design	*8*	–	*8*	*6*	–	*6*	*7*	–	*7*	*4*	–	*4*
Field administration	*7*	–	*7*	*6*	–	*6*	*8*	–	*8*	*4*	–	*4*
Total	*39*	*61*	*100*	*38*	*62*	*100*	*37*	*63*	*100*	*32*	*68*	*100*

Note: L = labour; M = materials; T = total.

TABLE 9. SUMMARY OF EXPECTED EXPENDITURES BY THE MEXICAN CHEMICAL INDUSTRY FOR EQUIPMENT, 1977–1982

	Type of technology									
Type of equipment	*Process-based (million $) (%)*		*Product-based (million $) (%)*		*Operations-based (million $) (%)*		*Equipment-based (million $) (%)*		*Total (million $) (%)*	
Process equipment[a]										
Large	607.6	88.7	20.8	3.0	19.6	2.9	1.2	0.2	649.2	94.8
Medium	8.8	1.3	16.9	2.5	2.9	0.4	1.8	0.2	30.4	4.4
Small	0.8	0.1	4.5	0.7	0.2	0.02	0.4	0.1	5.9	0.9
Total	617.2	90.1	42.2	6.2	22.7	3.32	3.4	0.5	685.5	100.1
Process machinery[b]										
Large	357.4	75.8	11.9	2.5	61.2	12.9	4.3	0.9	434.8	92.1
Medium	5.2	1.1	9.7	2.0	9.2	2.0	6.8	1.4	30.9	6.6
Small	0.5	0.1	2.6	0.6	0.6	0.1	1.6	0.3	5.3	1.1
Total	363.1	77.0	24.2	5.1	71.0	15.0	12.7	2.6	471.0	99.8
Pumps and compressors										
Large	178.7	80.4	3.9	1.7	24.5	11.0	1.4	0.6	208.5	93.8
Medium	2.6	1.2	3.2	1.4	3.7	1.6	2.2	1.0	11.7	5.3
Small	0.2	0.1	0.8	0.4	0.3	0.1	0.5	0.2	1.9	0.8
Total	181.5	81.7	7.9	3.5	28.5	12.7	4.1	1.8	222.1	99.9
Auxiliary equipment										
Large	285.9	85.5	3.2	1.0	29.4	8.8	1.2	0.4	319.7	95.6
Medium	4.2	1.3	2.6	0.7	4.4	1.3	1.8	0.5	13.0	3.9
Small	0.4	0.1	0.7	0.2	0.3	0.1	0.4	0.1	1.8	0.5
Total	290.5	86.9	6.5	1.9	34.1	10.2	3.4	1.0	334.5	100.0

[a] Typical process equipment: decanters, heat exchangers, columns and towers, atmospheric tanks, pressure vessels, reactors, condensers, evaporators, driers, furnaces, crystallizers, conveyors.

[b] Typical process machinery: filters, agitators and mixers, fans and blowers, centrifuges, extruders and expellers, mills, breakers, crushers

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Technology for oil and gas based industries: the case of Kuwait

*M. J. Ma'Rafi**

The Kuwaiti economy

The economy of Kuwait is based almost entirely on oil. Oil exports constitute 96 per cent of government income, 86 per cent of foreign exchange earnings and 81 per cent of gross national income.

The first oil-well was discovered in 1938; exports began in 1945. Production, refining and marketing were in the hands of foreign companies until 1964 when a partnership agreement gave the Government 60 per cent equity in the Kuwait Oil Company, the major oil company operating in the country.

The first refinery was built in 1949 with a capacity of 25,000 bbl/d. There are now three refineries in operation with a total capacity of approximately 63 million bbl/d.

Associated gas is Kuwait's second major resource. Until 1960 the gas was flared; since then liquid gas has been extracted. Production increased from about 200 bbl/d in the 1960s to 90,000 bbl/d in 1971. Some of this gas was utilized as fuel for industry; since 1966 some of it has been used as raw material for the chemical fertilizer industry. The chemical industry now produces about 750,000 t/a of urea for export to world markets.

A major liquid petroleum gas plant producing almost 200,000 bbl/d of propane, butane and gasoline was expected to go into operation in 1979.

Technology and industrial development

The facts and figures outlined above help to define the characteristics and role of the technology required for the industrial development of Kuwait. Kuwait possesses huge oil reserves of average quality. Hence Kuwait should give first priority to technology that will improve the quality of its oil and permit it to remain an active competitor among world energy suppliers. Kuwait also needs technologies that will help it to establish a petrochemical industry. A fertilizer industry has been established and liquid petroleum gas and melamine industries will soon commence operations but Kuwait must be prepared to produce olefins, aromatics, plastics, rubbers and other oil and gas based products. The type of technology needed for these developments will also be determined by these factors:

(a) The social structure of Kuwait. The population of Kuwait is now about one million, half of whom are Kuwaiti nationals engaged in government service,

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*General Manager, Kuwait Melamine Industries Co., Safat, Kuwait.

trade or commerce. Industrial and technical jobs are largely filled by non-Kuwaitis. In 1975 oil industry statistics showed that only about 25 per cent of persons employed in the industry were Kuwaitis; by 1980 this figure is expected to rise to about 33 per cent as a result of extensive local and foreign oil industry training programmes. Even so, it is clear that unless labour is imported, the most appropriate technology for Kuwait will be technology of the fully automated type;

(b) Natural resources. Kuwait does not have extensive natural resources except oil and gas. To obtain optimum returns they should be processed into intermediate and finished petrochemical products. Accordingly Kuwait primarily needs technologies directly related to the petrochemical industry. Other technological needs are secondary;

(c) Need to diversify income. Because the Kuwaiti economy is based on one major resource, it is liable to severe dislocations in times of crisis. Hence sources of income should be diversified by creating new bases for the economy. The search for petrochemical technology should be co-ordinated with the worldwide search for new sources of energy so that every barrel of oil that is not needed as a source of energy can be turned into a finished petrochemical product;

(d) More self-sufficiency. Another need is to create and advance industries that can lessen Kuwait's dependence on imports. Local enterprise should be encouraged to satisfy local needs;

(e) Investment. The oil-producing countries have developed considerable monetary reserves. These reserves have been largely invested abroad because few opportunities were available locally. Technology should be used to create new local industrial ventures attractive to investment. This would mean safer investments and create more employment opportunities for local graduates.

Education

Because Kuwait is dependent on oil, its educational programmes should be oriented accordingly. Vocational, technical and industrial training, using the most up-to-date teaching methods such as closed circuit television, on-the-job training and model workshops, should be emphasized. The target should be a generation of technicians who can translate technological information into industrial production units.

Research and development

Experience in oil refining has shown that the flow of scientfic and technological information within the industry has never been adequate or easy. There has been a lack of direct and efficient communication between R and D institutions and industry. There are, however, encouraging signs that present obstacles to communication will be overcome. Another optimistic aspect of the situation is the fact that Kuwait is building up a reserve of manpower capable of absorbing and using new technologies. For example, the number of students at all levels of education increased from 125,000 in 1971 to 235,000 in 1976; during the same period the number of schools increased from 210 to 355.

Conclusion

Encouraging scientific and technological research, facilitating the transfer of scientific and technological information to industry and increasing the number of technical and vocational schools will help Kuwait to find and use the technology it requires for balanced and productive development.

The fertilizer industry in India

Fertilizer (Planning and Development)
India Ltd., India

The role of fertilizers in the national economy

Consumption and production of fertilizers in India has changed considerably since 1951. Consumption rose from 66,000 t/a in 1951 to over 4.3 million t/a in 1977/78 and was expected to reach 4.7 million t/a in 1978/79. If recent trends continue, consumption will increase to nearly 7 million t/a by 1981 and 10 million t/a by 1985. Production increased from 39,000 t/a in 1951 to over 2.6 million t/a in 1977. Installed production capacity is expected to reach 6.8 million t/a by 1980 and 9.1 million t/a by 1983 while actual production is likely to be 4.5 million t/a and 6.6 million t/a respectively.

Despite increasing consumption the level of fertilizer use in India is still low. In 1975/76 the level of consumption was only 16.5 kg/ha in India as compared to 48 kg/ha in China, 319 kg/ha in Japan and 358 kg/ha in the Republic of Korea. The fertilizers themselves are unbalanced in composition: they contain too little phosphorous and potassium compared with the nitrogen in them.

The role of industrial fertilizers in agricultural development

Industrial production of fertilizers in India started with a small single superphosphate unit at Ranipet in Tamil Nadu in 1906. The production of nitrogenous fertilizers started as a by-product in the Tata Iron and Steel Company at Jamshedpur (Bihar) in 1933. Medium-scale production of ammonium sulphate started at Fertilizers and Chemicals Travancore, Alwaye, in 1947. An acute shortage of food grains after the Second World War emphasized the need to increase agricultural production and an additional fertilizer plant was established at Sindri in 1951 to produce ammonium sulphate, ammonium sulphate nitrate and urea. Eight fertilizer units were commissioned in the 1960s. Subsequently, India expanded its production capacity for primary nutrients, namely nitrogen and phosphorous pentoxide. The present production capacity for primary nitrogenous fertilizers is about 3,280,000 t/a; for phosphorous pentoxide, about 1,270,000 t/a.

About 70 per cent of nitrogenous fertilizer production units now in operation use naphtha as a raw material. Natural gas is used as the raw material for another 17 per cent. Naphtha is likely to lose its dominance as a source of nitrogenous fertilizers because of its relative scarcity. In India this has led to the use of alternative raw materials such as fuel oil and coal.

Indian production facilities for nitrogen and phosphorous pentoxide have been operating below rated capacity largely because of inadequate and uncertain supplies of electrical energy. Inadequate raw materials, lack of spare parts for processing machinery, labour problems and pollution have also contributed to low productivity. Efforts made to overcome these difficulties include installation of power plants in factories and plant modernization through systematic repair and replacement of aging equipment.

Since the discovery of oil deposits near Bombay and off shore from Kutch, the problem of a source of suitable raw materials does not appear to be as acute as it seemed in the recent past. Some new units expect to obtain natural gas or naphtha from these reserves.

Distribution and marketing

Subject to some governmental control, fertilizers are distributed and sold by the manufacturers. Controls are necessary because of the need to import certain fertilizers and the need to encourage wide distribution. The aim of import controls and distribution plans is to prevent the industry becoming totally dependent on imports or on a single manufacturer.

According to the agricultural census 1970/71 there were more than 17.4 million agricultural holdings in India but only 96,000 sales points, or one outlet for every 733 holdings, to service them. Efforts are being made to increase the number of sales points.

The prices of nitrogenous fertilizers are set by the Government of India. The prices of phosphatic fertilizers are controlled indirectly. If the Government and the manufacturer can agree on a selling price, the Government will subsidize the cost of the phosphorous pentoxide component in such fertilizers.

In India both surface and water transportation are used to distribute fertilizers. About 76 per cent of the shipments are made by rail. Water transportation is largely confined to coastal areas. Rail transportation can be as much as 50 per cent cheaper than road transportation. However, high transportation costs remain an obstacle to the development of the fertilizer trade in India.

Annex I

SELECTED DOCUMENTATION PUBLISHED OR COMPILED BY UNIDO RELATING TO THE SUBJECT

Capital goods

Capital goods industry (preliminary study). 1978. 145 p. tables. (UNIDO ICIS.70)

Report. Conclusions and recommendations. Preparatory Expert Panel Meeting for Consultations on the Capital Goods Industry, Vienna, Austria, 1977. 1978. 21 p. (UNIDO/EX.32)

Thoughts concerning co-operation between Islamic countries for the development of the capital goods industry. Prepared by Y. Le Moal. 1979. 19 p. (UNIDO ICIS.94)
Also published in Arabic and French.

Transfer of technology with special reference to manufacture of mechanical and electrical equipment in developing countries. Paper prepared by R.K.D.N. Singh for the National Consultation on Licensing, Patents and Transfer of Technology, Montevideo, Uruguay, 1976. 1976. 24 p. (ID/WG.228/11)
Also published in Spanish.

World-wide study on capital goods industry. Progress report. 1979. 30 p. (UNIDO ICIS.108)

Papers issued for the Global Preparatory Meeting for the First Consultation on the Capital Goods Industry, Warsaw, Poland, 24-28 November 1980

ID/WG.324/1	Concepts and proposals concerning new contractual agreements for setting up a capital goods industry. 58 p. A. Benbouali Also published in French.
ID/WG.324/2	Study of the development and growth of the capital goods industry in Spain summary and conclusions. 95 p. M. Seis Also published in French and Spanish.
ID/WG.324/3 and Abstract	Capital goods in the developing countries. 17 p. Also published in French and Spanish.
ID/WG.324/4 and Summary	Technology in the service of development. 98 p. Also published in French and Spanish.
ID/WG.324/4 Add.1	Some aspects of technology and engineering in the capital goods industry. 43 p. Also published in French and Spanish.
ID/WG.324/4 Add.2	Technical Annex. 96 p. Also published in French.
ID/WG.324/5	Long-term contractual arrangements for the setting up of capital goods. 11 p. Also published in Chinese, French, Russian and Spanish.

ID/WG.324/6	Long-term contractual arrangements for the setting up of capital goods in the iron and steel industry. 57 p. A. Benbouali Also published in French.
ID/WG.324/7	The production of capital goods in developing countries at an intermediate state of development: the cases of Guatemala and Peru. 100 p. C. Gillen Also published in French and Spanish.
ID/WG.324/8	Development of the capital goods industry in Bulgaria. Summary and conclusions. 121 p. Institute of Economics, Bulgarian Academy of Sciences Also published in French and Spanish.
ID/WG.324/9	Industrialization and the international market of capital goods. 93 p. F. Fajnzylber Also published in French and Spanish.
ID/WG.324/10	Types of technologies in the service of the capital goods industry's development. 30 p. L. Wasilewski Also published in French and Spanish.
ID/WG.324/12	Development of the capital goods industry in Poland. 80 p. PROMASZ (Bureau of Studies and Projects, Development of Engineering Industry)
ID/WG.324/14/ Rev.1	Report. 17 p.

Papers issued for the Seminar on Strategies and Instruments to Promote the Development of Capital Goods Industries in Developing Countries, Algiers, Algeria, 7-11 December 1979

ID/WG.314/1	Capital goods programme in Mexico. Conception, content and achievement. 62 p. F. Fajnzylber
ID/WG.314/2	A case study on the strategy for the promotion of heavy industry in developing countries. 71 p. G. D. Robinson
ID/WG.314/4	Study on demand forecasting for capital goods–Mexico. 31 p. A. Bozzolo and R. Trufello
ID/WG.314/5	Study on productive capacity in the mechanical industries. Mexico. 69 p. J. Ayza
ID/WG.314/6	Study on specific aspects related to the preparation and promotion of capital goods projects in developing countries. 56 p. S. Musa
ID/WG.314/8	Report. 28 p. Also published in French and Spanish.

Chemicals

Information sources on the pesticides industry. Guides to information sources no. 10. 1974. 102 p. (ID/120)

Information sources on the soap and detergent industry. Guides to information sources no. 24. 1977. 69 p. (ID/181)

In-plant pollution control work in an organic and inorganic chemical plant. 1974. 21 p. (UNIDO/IOD.259)

Pesticide formulation. 1978. 61 p. diagrams. (UNIDO/IOD.148)

Technologies from developing countries. Development and transfer of technology series no. 7. 1978. 35 p. (ID/208)

Desalination of saline water by reverse osmosis, p. 24.

Potassium schoenite from marine mixed salt, p. 24.

Technologies from developing countries. Development and transfer of technology series no. 7 (II). 1980. 65 p. (ID/246)

Carboxy methyl cellulose, p. 6.

Ethyl ether, p. 6.

Pentaerythritol, p. 7.

The production of pesticides in developing countries including natural products. 1979. 27 p. (UNIDO/EX.87)

Engineering

Background paper. Association of Indian Engineering Industry. Meeting of Engineering Industry Associations from Selected Asian Countries on Co-operation between them and UNIDO, New Delhi, India, 1979. 1979. 28 p. tables, diagrams. (UNIDO/EX.69)

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Copies of these compilations are available to requestors from developing countries only. The reference number must be quoted.

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Aluminium coating. (IIS file no. 5473)
Aluminium extrusion. (IIS file no. 6514)
Aluminium foil. (IIS file no. 6609)
Aluminium sulphate-alum. (IIS file no. 5754)
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Iron-powder production. (IIS file no. 4048)
Mosquito-repelling pyrethrum coils. (IIS file no. 5731)
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Natural rubber products. (IIS file no. 6361)
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Steel strips. (IIS file no. 8206)
Steel washers. (IIS file no. 6697)
Storage tanks. (IIS file no. 5737)
Wire netting. (IIS file no. 5980–82)

Annex II

WORKING GROUP PARTICIPANTS AND OBSERVERS

Participants

A. B. Chatterjea, Metallurgical Adviser, M. N. Dastur Co. (P) Ltd., Consulting Engineers, Calcutta, India.

S. Elekoev, Senior Research Officer, Institute of World Economy and International Relations, Academy of Science of the Union of Soviet Socialist Republics, Moscow, Union of Soviet Socialist Republics.

H. Hadjiat, Chief Metallurgist, Société Nationale de Siderurgie, Algiers, Algeria.

P. Kane, Director, Formation Permanente, Ministère de l'Enseignement Supérieur, Dakar, Senegal.

Y. Le Moal, Director, Groupe de Recherches des Etudes Sociales et Economiques, Montpellier, France.

M. J. Ma'Rafi, General Manager, Melamine Industries Co. KSC, Safat, Kuwait.

R. D. Moeller, Administrator, United States Agency for Industrial Development, State Department, Washington D.C., United States of America.

S. M. Patil, Consultant, Bangalore, India.

S. Ramachandran, Adviser (Technical), Steel Authority of India Ltd., New Delhi India.

M. Turpin, Consultant, Ministry of Industry, Paris, France.

K. Venkataraman, Consultant, Madras, India.

M. C. Verghese, Consultant, Madras, India.

M. E. Visveswaran, Director, Central Machine Tool Institute, Bangalore, India.

Observers

Y. Abdullah Bin Mohamed, Controller Standard and Industrial Research Institute of Malaysia, Shah Alam, Malaysia.

B. K. Agarwala, Deputy Director, National Physical Laboratory, New Delhi, India.

R. J. Green, Director of Operations, National Science Foundation, Washington D.C., United States of America.

D. R. Guha, Assistant General Manager, Bhartia Electric Steel Company Ltd., New Delhi, India.

M. M. Luther, Chairman, The Projects and Equipment Corporation of India, New Delhi, India.

P. Madan-Almándoz, Scientific Secretary (Chemical Sector), Comité Estatal Ciencia y Técnica, Havana, Cuba.

A. Magid, Projects Director, Ministry of Industry and Minerals, Baghdad, Iraq.

K. V. Prabhakar, Research Metallurgist, Department of Metallurgy, Delft University of Technology, Delft, the Netherlands.

W. Prihadi, Agency of Development and Application of Technology, Djakarta, Indonesia.

M. Schneider, Consultant, Ministry of Foreign Trade, Berlin, German Democratic Republic.

D. Yassi, Chief Engineer Ministry of Planning, Baghdad, Iraq.

Printed in Austria
V.81-23510–August 1981–10,000