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SUMMARY OF THE DRAFT WORLD-WIDE STUDY OF THE IRON AND STEEL INDUSTRY: 1975-2000[1/]. (197

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INTRODUCTION

At the Second General Conference of UNIDO, held in Peru, March 1975, the Lima Declaration and Plan of Action on Industrial Development and Co-operation was adopted in which the role of industry was re-asserted as a dynamic instrument of growth essential to the rapid economic and social development of the developing countries, and in which a target was set whereby the developing countries' share of world industrial production should be increased from its present level of 7 per cent to at least 25 per cent by the year 2000. The Declaration and Plan of Action was subsequently endorsed by the General Assembly of the United Nations at its seventh special session.

Among the mandates entrusted to UNIDO at Lima was one which stipulated that: "in order to give concrete content to the process of industrialization in the developing countries, studies must be undertaken and specific measures formulated in different sectors of industry, special attention being given to priority sectors". The Lima Conference identified the steel industry as one such priority sector.

Potential for growth exists in the iron and steel sectors of both industrialized and developing countries, as does potential for co-operation in this area between developed and developing countries, for whereas the former dispose of the necessary capital, know-how and technology, the latter have raw material in abundance, the labour to mine it, processing sites relatively free of environmental problems, and vast markets for the final products. It is a situation that underscores the fact that the modern world has become an interdependent entity in which countries and groups of countries must consult and co-operate with one another for the common good.

Before meaningful consultations can take place on any industrial sector, however, precise knowledge is needed of its economic, technological, financial and human aspects, its relative position, actual and potential production trends, its managerial requirements, and its potential impact on the environment.

The present document contains a summary of a draft report prepared by the newly established International Centre for Industrial Studies in UNIDO with the purpose of providing the above information, including projections of supply and consumption to the year 2000, as a contribution to the process of consultation. The second in a series of such sectoral studies featuring long-term projections, the draft will be distributed for comment to governments and other decision-making bodies and individuals throughout the world in December 1976. Naturally, the study, and its projections, will be revised periodically in the light of changing circumstances.

WORLD STEEL CONSUMPTION TO THE YEAR 2000

In this study, global estimates of steel production in 1985 and alternative growth scenarios to the year 2000 are presented. The 1985 estimate was obtained by elaborating upon projections made by the International Iron and Steel Institute at Brussels. 1/ In the course of this elaboration, past trends in production and consumption were analysed, as were subjective judgements with regard to future rates of substitution for steel and competitive products, the severity of the 1975-1976 recession, and country plans for future development of the industry.

Estimates for 1985, together with high and low growth scenarios for the year 2000 are given in Figure 1. World steel production is expected to reach almost 1.1 billion tons by 1985. The share of the developing countries in this production should rise from the 1974 figure of 5.1 per cent to 11.7 per cent (125 million tons).

The growth scenarios developed for the year 2000 were based on postulated annual growth rates for world steel production of 3 and 4 per cent respectively. These scenarios should be interpreted strictly as indications of possible future growth. According to alternative A (3 per cent) some 1.7 billion tons of steel would be produced in 2000, whereas according to alternative B (4 per cent) this figure would be some 1.9 billion. The estimated share of the developing countries could range from 20 to 25 per cent of world production.

A supplementary investigation of historical changes in the pattern of industrial growth and its implications for steel production and consumption was also carried out. The methodologies applied were quantitative, based on the approaches adopted by other international organizations.

Undoubtedly, these estimates will have to be revised as world economic conditions change. In anticipation thereof, more formal means of forecasting steel production are being developed in UNIDO. Owing to the strict time schedule that had to be maintained during the conduct of this study, the preliminary results of the more formal forecast could not be explicitly

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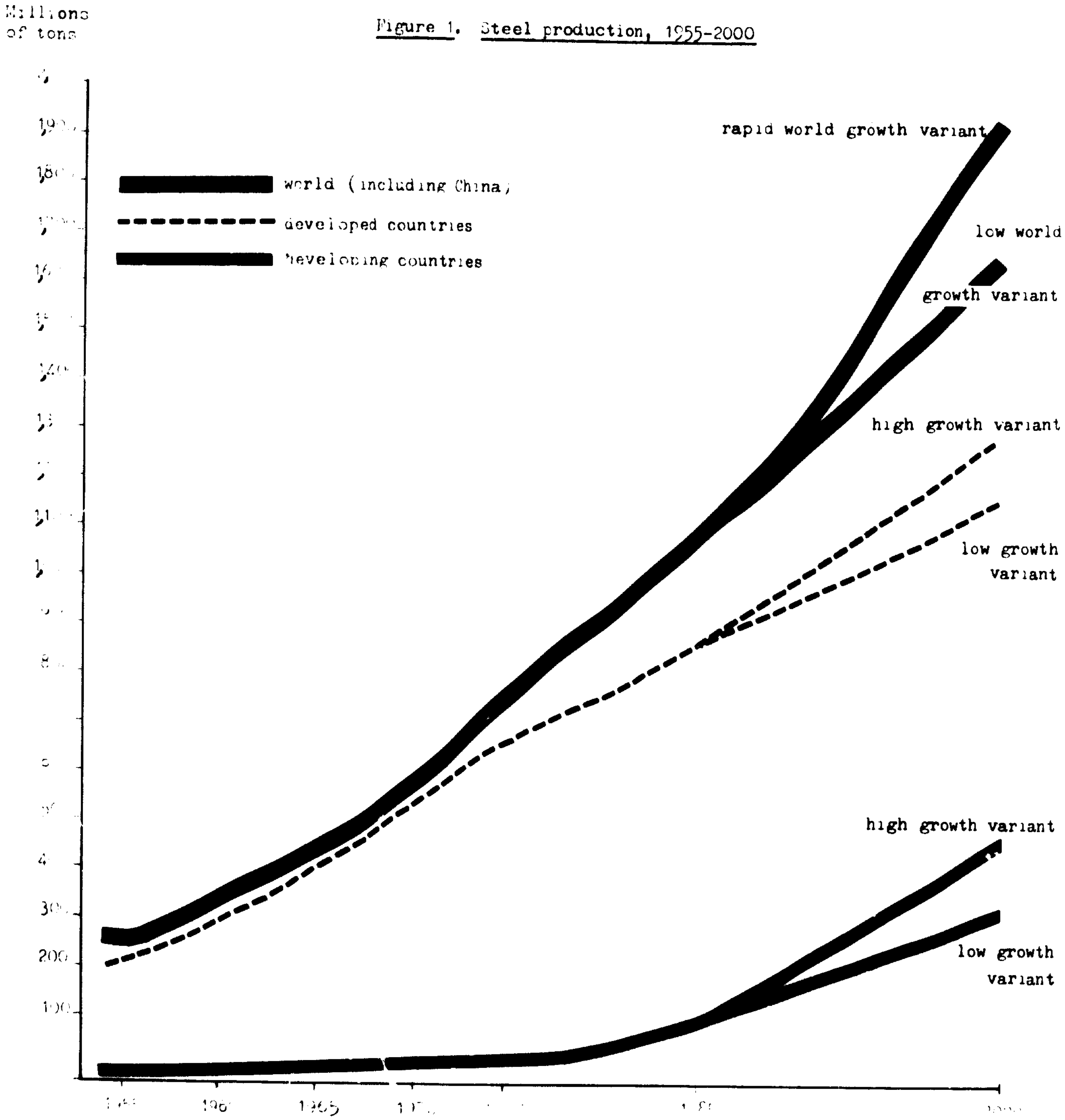
1/ See International Iron and Steel Institute, Projection 85, Brussels, March 1972.

Figure 1. Steel production, 1955-2000



Note: Figures for China are included in the world totals, but are not shown as part of the two economic groupings.

Source: UNIDO estimates.

incorporated in the estimates presented. Nevertheless, it is considered useful to present the results of the quantitative investigations carried out since they complement some of the assumptions employed in developing the estimates in this report, and the techniques constitute one element in a more sophisticated forecasting framework.

Production patterns in iron and steel

The work draws heavily on the structuralist approach to sectoral development and adopts traditional structural models to estimate sectoral growth.[2] Multiple regression techniques were applied to the following equational forms:

$$\ln x = a + b \ln y + c \ln N$$

and

$$\ln x = a + b \ln y + c \ln N + d (\ln y)^2$$

where x = per capita value added by iron and steel;[3] y = Gross Domestic Product per capita; and N = population in millions.

Per capita income is traditionally considered the most important determinant since demand for iron and steel is known to increase substantially as income rises. The distribution of total demand among investment, government consumption and private consumption varies with the level of per capita income and thus has a significant impact on demand for iron and steel. With regard to supply, the level of per capita income tends to be closely related to the relative costs of labour and capital; it is thus indicative of the probable extension of industrial production into capital-intensive and complex industrial sub-sectors such as iron and steel.

The second structural variable incorporated in such an approach is population. Production of iron and steel is dependent, to some extent, upon economies of scale. Together with per capita income, population provides a means of measuring the influence of market size, and thus the importance of

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[2] This is a method frequently employed to approximate the growth paths of manufacturing and/or industrial sub-sectors, such as iron and steel. See, for example, H.B. Chenery and M. Syrquin, Patterns of Development, 1950-1970, a World Bank research publication (London: Oxford Univ.Press, 1975), and UNCTAD, "The Dimensions of the Required Restructuring of World Manufacturing Output and Trade in order to Reach the Lima Target" (TD/185/Supp.1), presented to UNCTAD IV, Nairobi, May 1976.

[3] Value added is at factor cost. The definition of the iron and steel sector is taken from the UN International Standard Industrial Classification.

economies of scale in iron and steel production.

The percentage change of iron and steel production for a given percentage change in GDP per capita or population can be derived from the regression analysis. The derivations, which conform to the traditional concept of elasticity, are known as growth and size elasticities, respectively. For example, a coefficient of 2.15 (see Table 1 below), implies that iron and steel production increased by about 2 per cent for a 1 per cent increase in GDP per capita. A similar interpretation applies to the population elasticities.

A summary of the growth elasticities for selected levels of per capita income is shown in Table 1. Comparison of elasticities for large countries (populations of more than 15 million) with those for small countries (populations of less than 15 million) reveals important differences in growth patterns.

Growth elasticities in small countries are decidedly higher than those in large countries. This serves to demonstrate the rapid response of iron and steel production once the constraining factor of small market size is alleviated.

Table 1. Growth elasticities for iron and steel production, by level of income, selected years a/

(GDP per capita)

	$ 225		$ 500		$ 3,000	
	Large countries	Small countries	Large countries	Small countries	Large countries	Small countries
1963	2.15	3.28	1.84	2.73	1.26	1.72
1966	2.21	4.68	1.86	3.69	1.24	1.86
1970	2.25	3.96	1.90	3.18	1.26	1.76
1973	2.15	3.91	1.85	3.18	1.28	1.84

Source: UNIDO, based on data supplied by the UN Statistical Office.

a/ The elasticities are derived from the regressions for the second equation quoted on page 5.

As indicated in Table 1, the growth elasticities tend to decline at higher levels of per capita income. However, they exceed unity throughout the income range shown. This fact suggests that iron and steel is an important growth sector, regardless of the level of development. Over the period 1960-1973, each set of elasticities can be seen to have exhibited a similar pattern of behaviour, reaching a maximum in the latter half of the 1960s and declining in more recent years. For large countries, the relationship between iron and steel production and per capita income was remarkably stable over the period investigated. However, annual fluctuations in the figures for small countries were somewhat high. These facts are particularly important when regression results are intended to serve as a guide to the approximation of future growth patterns in iron and steel production.

Size elasticities are not a significant determinate of iron and steel production. Unlike per capita income, small increases in population do not have a substantial impact on production. This characteristic distinguishes the iron and steel industry from consumer goods industries, such as food, textiles or clothing, where minor population increases stimulate production through final demand. In investment goods industries, production is responsive to factors other than consumer demand.

Consumption patterns in iron and steel

As with the production analysis, a cross-section approach to the study of steel consumption was adopted. Unlike a time-series approach, this method enables the researcher to assess the impact of common factors affecting consumption patterns in all countries for given years or groups of years. When the identified relationships between steel consumption and its determining factors remain stable over a period of time, the statistical results provide a guide to future conditions.

The basic hypothesis is that the per capita steel consumption observed at a given time in various countries is subject to the same broad set of factors, such as access to the same types of production technology, similar price ratios between steel and other goods, and comparable patterns of steel utilization.

According to a line of reasoning analogous to that described for the production patterns (page 5), GDP per capita is frequently used as the measure best reflecting these factors.

The methodology used in this report to determine consumption patterns was a standard bivariate and multivariate regression analysis applied to data given for 45 countries. The following expressions were selected as an initial attempt to provide a plausible explanation of the relationship between per capita steel consumption (c) and GDP per capita (y):

$$\ln c = a + b \ln y$$

$$c = a + b \ln y$$

$$\ln c = a - {}^{b}/x$$

$$\ln c = a - {}^{b}/x - c \ln x$$

$$\ln c = a + b \ln y + d (\ln y)^2$$

where a, b and d are constants. [4]

These equations were tested for several time periods and sample stratifications. The results confirmed the analytical validity of the approach and revealed a slight superiority in the performance of the multivariate models when applied to the total sample, and a clear superiority in that of the bivariate model where the samples were stratified according to the level of economic development. Hence, the hypothesis of a common pattern of steel consumption among different countries can be accepted. As confirmed by detailed analysis, the level of economic development is an important factor in specifying the relationship between steel consumption and per capita income.

Further investigation served to reveal how consumption patterns change over time. In the case of the developed countries, the pattern exhibits a tendency to rotate clockwise in successive two-year periods from 1950 to 1970. Time instability was also found in the case of developing countries, but no clear trend could be detected.

Income elasticities of steel consumption were derived from the regression equations. Depending upon the functional form considered, these elasticities are constant, or they decrease with either higher levels of per capita steel consumption or higher levels of per capita income.

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[4] **These forms have been applied in several instances. See, for example, FAO, Agricultural Commodities - Projections for 1975 and 1985, Vol.II, Rome, 1967.**

Table 2. Income elasticities for steel consumption, by country grouping, selected years

	All countries	Developed countries	Developing countries
1950-52	1.329	1.083	1.234
1959-61	1.384	1.062	1.321
1968-70	1.261	0.977	1.068

Source: UNIDO, based on data supplied by the UN statistical office.

Table 2 shows examples of elasticities obtained from regressions of the equation $\ln c = a + b \ln y$ in selected years.
As might be expected, income elasticities for developing countries are generally higher than those for developed countries, i.e. marginal increases in income induce larger increases of steel consumption in developing countries than in developed countries. In the case of developed countries, the time trend was found to reduce income elasticities, a phenomenon that may be interpreted as reflecting a trend towards saving steel.

Methods and results of the 1985 estimate

The Brussels forecast, upon which the present projections were partly based, was carried out in 1971/72 as a medium-range forecast for 1985. Subsequent to the forecasting exercise, unusual cyclical fluctuations occurred. Although the original forecast had been based on a trend line and due account had been taken of past cyclical fluctuations, the extent of the 1973-76 fluctuations necessitated an adjustment.

In effecting this adjustment, future plans for expansion and investment in the iron and steel industry were given serious consideration. This information was compiled on a country-by-country basis, often at the project level. Where demand projections at the national level were available in respect of projects planned, these data were also taken into account as well as any intentions to produce either for export or domestic markets. Major and potential steel producers in all developing countries were included. Owing to divergent assumptions regarding such factors as planned rates of capacity utilization and possible project delays, some degree of judgement was required in determining the weight to be given to each plan when making the projections. On the basis of such exogenous information, the original Brussels forecast of 1,144 million tons of steel to be produced in 1985 was revised to 1,069 million tons.

Estimates for the year 2000

The alternative growth rates for world steel consumption in the period 1986-2000 cited in this study reflect the fact that, since world production will equal world consumption in the long term, the same growth rates apply to production. Levels of world production and consumption thus calculated for the year 2000 are 1,665 million tons (Alternative A) and 1,925 million tons (Alternative B).

Sub-regional growth rates for steel production and consumption: 1986-2000

Regional and sub-regional totals for production and consumption have been estimated on the basis of the UNIDO forecast for 1985. Growth rates at regional, sub-regional and country levels have been assumed for the period 1974-1985 in order to estimate the pattern of distribution.

Comparable estimates have been made up to the year 2000. Consumption rates of 2 to 2.5 per cent are assumed for the developed countries while those in the developing countries are assumed to be 3-4 times higher.

Whereas production in the developed countries is assumed to grow at approximately 2 to 2.5 per cent up to the year 2000, production rates in the developing countries are expected to increase by 6.7 to 9.4 per cent over the same period.

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International trade in iron and steel [5]

Implications for developing countries

Global trade patterns in the iron and steel industry are determined by steel consumption trends which in turn are commensurate with the pace of industrialization. As developing countries enter the early phases of industrial

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[5] Extracted from a preliminary report prepared by the secretariat of UNCTAD on the trade implications of a restructuring of the world iron and steel industry, in compliance with resolutions adopted at the Second General Conference of UNIDO in March 1975 and at UNCTAD IV in May 1976.

development, their imports of steel and steel-intensive products tend to increase rapidly. Over the period 1964-1973 the developing countries' imports of crude steel rose in value from $1.6 billion to $5.1 billion: if the Lima target is to be attained, it has been estimated that the steel imports of these countries must increase to a value of $26.2 billion by the year 2000. Developing country imports of semi-finished steel products from developed countries grew from 986,000 tons in 1964 to over 5 million tons in 1973, and the value of indirect steel imports through capital equipment rose from $9 billion to $30 billion from 1967 to 197[illegible].

Steel exported from the developing to the developed countries between 1964 and 197[illegible] increased in value from $10[illegible] million to $668 million: three-quarters of these exports were in the form of semi-finished products. Primary and intermediate processing of steel is being located to an increasing degree in the developing countries, and it would appear that this trend will continue since it enjoys wide support among decision-makers in both industrialized and developing countries.

The total trade in raw materials, semi-finished, and finished steel products of the 50 developing countries (from six regions) that supplied statistical information for this study was largely with developed market economies which in 1973 provided some 80 per cent of these developing countries' steel imports and absorbed 60 per cent of their exports. Approximately 10 per cent of the steel trade flow of these countries was with the developed countries with centrally planned economies. Whereas their imports from other developing countries were less than 10 per cent of their total, their exports to other developing countries approached 30 per cent.

The intraregional patterns of steel trade at all levels of processing seem to suggest that while the dependence of the developing countries on steel imports from the developed countries will certainly continue and even increase, certain of the more advanced developing countries are emerging as prominent intraregional suppliers, for geographical and pricing reasons.

A significant aspect of trade in the iron and steel industry is that contrary to the pricing behaviour of most commodities, where price stability increases with every stage of processing, costs in the iron and steel industry fluctuate most at the top rather than at the bottom of the processing ladder. Whereas the cost per ton of heavy steel plate increased from $88 in 1966 to $402 in 1974, or some 457 per cent, the prices of iron ore in, for example, India and Brazil, rose by only 13 and 60 per cent respectively over the same period (India: $6.85 to $7.85 per ton; Brazil: $9.30 to $14.90 per ton). The main explanation for this is that iron ore export prices are set in long-term contracts while those of intermediate and finished steel products are subject to the cyclical variations of the world steel market with "on-the spot" purchases and open bargaining. On the other hand, the f.o.b. price of coal, a resource that is concentrated largely in the developed countries, effectively doubled, from $11.15 to $22.12 per ton, in the period 1964-1973.

Barriers to trade in iron and steel

Among the chief obstacles to international trade in iron and steel are tariffs, non-tariff barriers and high transport costs.

Most developed countries currently levy tariffs of 6-10 per cent on intermediate and finished iron and steel products, the tariffs escalating with the level of processing involved. However, for most developing countries these tariffs are offset by the Generalized System of Preferences, which provides duty-free access for their iron and steel products, but is subject to arbitrary and complex quota restrictions.

In accordance with the Lomé Convention, the European Economic Community grants duty-free privileges to 46 developing countries on all their industrial and primary exports to its member states.

Non-tariff barriers include such ad hoc restrictions as import licences, exchange controls, customs duties, as well as patents and trademarks. Their impact varies from case to case, but they must be taken into account by developing countries considering the export of steel to developed markets.

Transportation costs present a major obstacle to prospective steel exporters in developing countries since they can reduce or eliminate whatever advantage their exports may enjoy in the markets of the developed world. Escalating ocean freight rates present a strong incentive to intraregional trade among the developing countries.

The international steel market

The international steel market is based on intergovernmental negotiations and agreements, and the industry is usually arranged in a monopolistic or oligopolistic manner at the national level. These agreements may encompass: voluntary import and export quotas; market-sharing arrangements for quantities and types of products traded; guidelines for investment and specialization policies; and "gentlemen's agreements" concerning pricing policies.

A developing country entering the international steel market, be it as an exporter or importer, must take into account the trade constraints and arrangements already in operation.

THE TECHNOLOGY OF STEEL-MAKING

Choice of processes

The various processes involved in steel-making are described in this study with a view to attempting to assess raw material, energy and capital requirements.

Given that the introduction of a new steel process, from conception to wide-scale commercial application often takes as long as a decade, only processes that are currently in commercial use or under development should be included in any assessment of steel production technology up to the year 1985.

Iron-making

Iron blast furnace

In the last two decades, the iron blast furnace - the principal iron production process - has undergone major improvements and grown enormously in size. Although the practical scale for blast furnace use ranges from 0.5 million to approximately 3.5 million tons of hot metal per furnace, large integrated steel plants have furnaces with capacities of 7,000 to 12,000 tons of hot metal per day, i.e. 2.5 million to 4 million tons per year.

Blast furnace operations in the coming three decades are expected to follow several major trends.

Reduction of coke rate by fuel injection

Where coke is expensive or supplies are limited, the coke rate can be reduced by injecting fuels into the tuyeres and hot gases into the stack. By 1985, coke consumed during normal operation should be equivalent to the lowest level currently attainable, i.e. perhaps 350 kg per ton of pig iron, with an auxiliary tuyere-injected fuel consumption of 100 kg (equivalent) per ton. Total energy consumption should therefore be about 3.1 G cal per ton of pig iron, diminishing after 1985, with the injection of gases into the stack, to 3.0 G cal per ton; with coke consumption being reduced to possibly 250 kg per ton of pig iron. Where supplies of reasonably good coking coals are available up to the end of the present century, coke rates can be expected of 475 to 525 kg and the equivalent in injected fuels of 25 to 50 kg per ton of pig iron, i.e. a total of 3.7 G cal per ton of pig iron.

Substitution of form coke for metallurgical coke

Where coal not suitable for coking but suitable for conversion to form coke is in adequate supply, it will probably become the principal fuel used in blast furnaces with a corresponding drop in the use of injected fuels. This material will most likely be commercially available within the next five years.

Substitution of charcoal for coke

Provided that it is in abundant supply, charcoal can be used as a blast furnace fuel. Although highly reactive, it is not strong enough to withstand the abrasion of the charge in a standard-height furnace; it can, however, be used most satisfactorily in smaller furnaces. When this form of substitution is made, afforestation programmes should be introduced in the interest of environmental conservation.

Direct reduction

Processes employed to reduce iron ore to solid metallic iron - other than the iron blast furnace - are called "direct reduction" processes. Depending on the processes used, several of which have found industrial application, the end-products are sponge iron, metallized iron ore, reduced pellets, direct reduced iron etc.

Direct reduction processes are generally classified according to the reductant and fuel employed. While gas is used as the fuel and reductant in the shaft furnace, gas retort system and fluidized bed, solid fuels are used in the rotary kiln and in the retort system of the same name.

It is to be noted that all direct reduction processes enjoying large-scale commercial application utilize gas, primarily reformed natural gas, as both fuel and reductant.

Processes employing various types of solid fuel have been in use for several years, albeit on a modest scale. The present capacity of direct reduction systems tends to be small, at the most that of a small blast furnace. Where production capacity of more than 0.6 million tons per year is required, several direct reduction units will be necessary. In 1975, only 1.5 per cent of the world's pig iron was produced using direct reduction processes. This notwithstanding, in 1976 no less than 50 new plants were under construction or being planned, 20 of which should be operational by 1980. Most of these new plants are larger than those existing at present. Some 5 per cent (30 million tons) of the world's pig iron in 1980, and possibly 8 per cent by 1985, will be produced by these new capacities.

Steel-making

The principal processes by which common steels, such as carbon and low-alloy, are produced on an industrial scale are: the basic oxygen type of furnace (LD/BOF or OBM/Q-BOP); the basic Bessemer; the electric arc furnace; and the open-hearth furnace. The principal raw materials from which the steel is made are pig-iron (hot or cold), iron and steel scrap, and direct reduced iron.

Basic oxygen furnaces

Current advances in steel-making attributable to these furnaces are: decreased heat times; improved slag control and lining life; improved furnace control; better furnace charging methods; and improved facilities for collecting and utilizing waste gases. Although the OBM/Q-BOP process was developed several years after the LD/BOF process, it offers only limited advantages and is not expected to replace the LD/BOF process to the same extent that the latter process replaced the open-hearth and basic Bessemer furnaces in the years between 1950 and 1965.

Basic Bessemer process

This is reasonably well suited to the production of many steels of commercial quality. Although it has fallen into disuse, its operation is simple and inexpensive and may still be considered for the refining of hot metal with a high phosphorus content (1.5 - 2 per cent).

Open-hearth furnaces

The principal disadvantages of these are the high cost of the plant and refractories. A further constraint is the high degree of labour required for operating the furnace, which is otherwise very flexible in terms of size, raw materials and fuels.

Electric furnace

The principal electrically powered furnace employed in the production of steel is the arc furnace which operates on a three-phase alternating current. Several methods for melting direct reduced iron have been developed. However, the conventional electric arc furnace is not ideally suited to melting directly reduced materials, especially those containing more than 4 per cent gangue, as this leads to the formation of a large volume of slag.

Casting operations

Two types are now in general use: traditional ingot casting used extensively in large and small steel plants, and continuous casting which is currently used in approximately 10 per cent of all steel produced in the United States and approximately 20 per cent in Japan.

The continuous casting process can be expected to spread further, on account of its savings in energy and its high yield compared with conventional ingot casting.

Changing technological patterns of steel-making

Despite the difficulty of forecasting the evolution of individual steel-making processes known today, certain trends are identified in this study:

(a) The decline of the Bessemer and Thomas processes, to some 1.5 per cent of world steel production in 1975;

(b) A decrease in open-hearth steel-making, although the process is still used in steel plants in various parts of the world (30.8 per cent of the world steel production in 1975).

(c) The phenomenal spread of basic oxygen furnaces since the mid-1950s, accounting for 50.8 per cent of crude steel production in 1975.

(d) An increase in electric furnace processing, which has more than doubled from 7 per cent in 1950 to 16.9 per cent of steel production in 1975.

Considering all the steel-making projects under construction and in preparation, it can be anticipated that the use of basic oxygen furnaces will increase to nearly 70 per cent of crude by 1985.

In the light of expanding use of direct reduction and the trend towards transforming primary energy (including nuclear energy) into electricity, the electric furnace will be used to an increasing degree in world steel-making (about 20 per cent in 1985, and 38 per cent in 2000) at the expense of the open-hearth process in particular, which will probably decline to 10 per cent of world steel production in 1985 and to 2 per cent by the year 2000.

Whereas the basic oxygen furnace will have achieved its highest share in world steel production by 1985, it is expected to decline subsequently to 60 per cent of world production in the period 1986-2000.

Various levels of integration in steel-making

In planning the iron and steel industry, the choices to be made are not solely linked to the technology of iron and steel-making processes, since consideration should also be given to the level of integration of the various processing stages.

According to the traditional classification, an integrated plant would carry out all operations from the production of pig iron using iron ores and coal to the production of finished products. Non-integrated steel plants need not have smelting furnaces; they could rely on steel scrap as the principal raw material.

In the past, in a period of growing iron and steel demand with consequent low scrap availability, the construction of integrated steel plants with coking facilities was considered necessary. Today, however, the direct reduction process offers an alternative to total dependence on scrap supplies and, if combined with electric arc furnaces and continuous-casting, offers another possibility of integrating iron- and steel-making in one plant. It is to be expected that as regards processing, the main cost/price relationships in iron- and steel-making will be determined by the large complexes with 10-20 million tons capacity.

Small and medium-sized units will still be able to work efficiently with supplies of local scrap or reduced ore. Their proximity to markets, raw material and energy sources, as well as their ability to respond flexibly to specific requirements, could overcome the cost advantages enjoyed by large-scale plants.

Environmental considerations

The iron and steel industry is responsible for the production of air, water, and solid contaminants, as well as such others as noise and aesthetically undesirable architecture. In large plants, the air contaminants are gaseous, such as sulphur and nitrogen oxides, ammonia, and carbon oxides, as well as particulates such as iron, silica, and limestone. The water contaminants include tars, oils, phenols, cyanides, ammonia, heavy metals, low pH, and suspended solids. Solid wastes are largely raw material fines, such as carbon, iron, silica and limestone.

Most contaminants in the conventional process originate in the preparation of pig iron, i.e. in coke ovens, sintering and pelletizing, and blast furnace operations. The coke ovens contribute most of the chemical contaminants while the other units generate the solid matter. In addition, the finishing operations in hot-forming and cold-rolling give off metals, acids, and oil as well as iron scale, while power plants exude oxides of sulphur and nitrogen.

Air contaminants can be controlled by baghouse filters, cyclone separators, electrostatic precipitators, and both solid and liquid scrubbers. Water contaminants can be removed by neutralization, sedimentation and flotation as well as by concentration and re-use. In certain instances, biological treatment is required. Solid wastes are settled in or filtered out of scrubber and process water wastes; they can also be refined from blast furnace and basic oxygen furnace slag. No positive steps have been taken on an international scale to reduce noise levels or prevent aesthetic contamination.

As a plant becomes "environment conscious" it tends to convert more and more of its air and water contaminants into solid wastes which in turn become one of its major concerns. It is very important to the economics of the industry to recover and re-use as much of these solids as possible. The re-use of solids found in mill-scale, blast furnace dust, sinter plant dust, slag, lime dust, scrap and scarfing powder is recommended for reasons of economics as well as pollution abatement. All the particulate solids recovered - with the exception of slag - can be incorporated in sinter mix, pellet-making, coke-making, and powder metallurgicals. The blast furnace slag can be re-used in the production of cement, insulation, building materials, and aggregates for road building. Basic oxygen furnace slag is also valuable for both its iron and relatively high phosphorous content. The iron can be reclaimed for re-use in the plant, while the remaining phosphorous can be used as a fertilizer.

The major process changes which reduce environmental pollution are:

(a) Dry instead of wet quenching of coke;

(b) Hydrochloric acid instead of sulphuric acid pickling;

(c) Direct reduction instead of blast furnace methods.

The environmental consequences of steel production at a given site should be studied and evaluated prior to approval of the project. Environmental quality guidelines should be established during plant design and construction so as to prevent excess environmental contamination. The site of a steel mill must be selected carefully to ensure that there is ample air and water for dilution and land to serve as a buffer zone and receptacle for residual unusable solids. In iron and steel production some environmental degradation is almost inevitable, but the degree of degradation should not exceed the minimum standards acceptable to the local community and government, nor should it be arbitrarily set by the industrial plant. Furthermore, care should be taken to ensure that the clean air and water at present abundant in many developing countries are not squandered through indiscriminate use as waste receptors. In general, stricter environmental controls should be exercised in iron and steel plants constructed in the developed countries, since heavy industrialization in these countries no longer permits the use of the natural environment as an effluent receptacle.

Air and water pollution control costs can be expressed either as a percentage of production costs or in dollars per ton of product. In the first instance, the factor will be 1 to 2 per cent, in the second $2 - 5 per ton of steel produced. These costs are sufficiently low to be spent by plants in developing and developed countries alike. They should be absorbed in the price of the steel and passed on to the consumer. These costs may be reduced still further in future by establishing integrated industrial complexes containing steel mills and such auxiliary industries as fertilizer and agro-industrial plants. Though the production of iron and steel results in the discharge of numerous contaminants, it need not be constrained by environmental factors since control technology is known and abatement costs are relatively insignificant in relation to other production costs.

Plants should be located primarily but not solely in developing countries on minimum-cost sites, preferably in integrated industrial complexes so that both production and environmental costs can be minimized through the utilization or re-cycling of wastes. Considerable research and pilot experimentation is necessary in order to optimize these industrial complexes (which may contain a different mix of industries for each site). Wherever possible, steel products should be manufactured using direct reduction, electric arc furnaces and continuous casting sequences, thereby minimizing environmental damage.

The design and manufacture of steel plant equipment

Steel plant equipment is manufactured by a large number of enterprises operating as independent firms, or as associates of major steel-making companies.

The development of local spare parts manufacturing capacity is a complex process. It can be assumed that the average annual requirement of spare parts ranges from 2,400 tons to 3,200 tons per million tons of production capacity, depending on the age of equipment and standard of maintenance. Local manufacture of spares may help obviate production delays and reduce import bills as well as promote the development of local engineering skill and manufacturing capabilities.

In developing local steel plant engineering and production capabilities, priority should logically be given to light- and medium-weight rolling mills and finishing line equipment. In building up a steel plant manufacturing industry:

(a) A design and engineering company can be formed to specialize in the purchase and development of equipment designs;

(b) Manufacturing companies producing similar equipment could expand and restructure their organization to meet local requirements;

(c) A new company could be set up to manufacture equipment and spare parts.

The design and manufacture of steel plant equipment will of necessity lead to a strengthening of the heavy engineering sector. In a sector such as the heavy capital goods industry, the appropriate balance of engineering, production and marketing capability can only be assessed in the long term.

RESOURCES

In considering the resources necessary for the development of the iron and steel industry, resource availability and geographical distribution are of paramount importance. These factors are considered here as they relate to energy resources, mineral reserves, scrap availability and manpower requirements. An attempt has been made to assess the prospects of an increased share in production for individual countries, in terms of resource availability. It is hoped that the assessment will assist in the decision-making process regarding the establishment of production capability, concomitant with the aims of these countries in terms of their desire for import substitution, export targets and self-sufficiency.

However, availability of resources is not the only factor vital to the development of an iron and steel industry. Some countries have achieved a successful development record in this sector without the advantages of domestic mineral or energy resources; with trained manpower, acquired technological skills and financial creditability, they have been able to produce and export. Nevertheless, it is considerably easier for a country having its own resources to enter the production field.

Eight major parameters have been identified with respect to energy and mineral resources. Four of them relate to energy - total coal, natural gas, potential oil and hydraulic energy; and four relate to raw materials or are combined fuel and reductants - coking coal, ferrous ore, charcoal and manganese ore.

Identified reserves of these, by geographical region, are shown in Figure 2. It can be seen that the most significant hindrance to the establishment of steel production facilities in the developing countries is the lack of coking coal. This lack will, to some extent, limit the technologies that can be utilized in the desired over-all expansion pattern, but it will not necessarily preclude development by individual countries; in 1970, over 50 per cent of crude steel was produced by countries which imported 45 per cent of their fuel requirements for energy alone. Such a wide choice of production options exists that, given marketing, technological and financial ability, few developing countries exist in which the industry cannot be developed. The direct reduction process, in particular, offers opportunities for the establishment of steel industries in developing countries.

It has been possible to identify those developing countries which, in the sense of known mineral and energy reserves, are in a favourable position to establish an iron and steel industry. In Figure 3, developing countries are designated favourable (when they have five of the eight parameters mentioned above), less favourable (three parameters), or least favourable (less than three parameters).

It is emphasized, however, that this assessment has been made in the light of known resources only, and must be considered in this respect. Furthermore, the concept of five favourable parameters does not necessarily imply that all resources for any particular production route exist; some countries in this category may need to import essential resources in order to complement those existing. Again, other countries, classified as less favourable, may have an abundance of one or more resources which, taken in conjunction with other factors, such as proximity to markets, may warrant further consideration by decision-makers.

The most significant conclusion to be drawn from these figures is that while the developing countries have a dominant share of world resources of gas, oil and hydraulic energy potential, and a good share of ores, they suffer from a lack of coal, particularly coking coal. It would appear, therefore, that for many developing countries the electric furnace method, utilizing both scrap and directly reduced iron, offers the most favourable development possibility; this method has the added advantages of flexibility of size and lower plant costs.

In the blast furnace method, the substitution of charcoal for coke is an acceptable and fully feasible technology. Its utilization will call for an early decision with respect to forest establishment, however, in order that sufficient supplies can be ensured by long-term harvesting and replanting strategies. The paramount importance of preserving environmental balance in the developing countries may limit the utilization of charcoal, if programmes for adequate replanting are not given priority.

Because the pattern of production methods that will result from development decisions is unknown, and because of the variations in energy requirements for each method, it is not possible to predict with any degree of accuracy the longevity of energy resources. Indications are, however, that sufficient traditional fuel reserves will be available to cover all industrial and community needs to the year 2000 at least.

If it is assumed that world steel production will reach 1.9 billion tons in the year 2000, requiring some 2 billion tons of ferrous ore, world resources as they currently stand (689 billion tons) would provide ample capacity for development for at least 300 years.

In addition to virgin raw materials, the generation and utilization of scrap, which would provide a varying proportion of furnace charge, according to the production method adopted, have been studied. In most processes, revert scrap accounts for as much as 29 per cent of production, while the consuming industries have a scrap return of 15-30 per cent. A further major supply comes from obsolete material - estimated to be of the order of 14-18 per cent of the total steel consumed in the developing countries. These predictions depend of course on the level of industrialization reached, and can therefore only be very approximate.

Total scrap requirements for 1985 and 2000 are estimated to be 470 million tons and 1 billion tons respectively, most of which will be generated by the developed countries. This will mean high import costs for countries with low scrap generation.

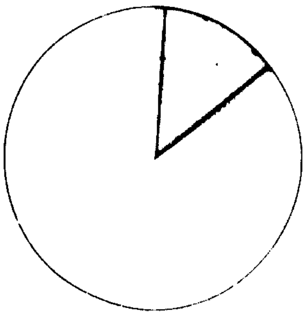
Providing sufficient skilled manpower to ensure efficiency will probably be the most difficult task to be tackled by the developing countries. Table 3 shows the requirements calculated for the developing countries in this respect.

Table 3: Total work force to be trained, 1975-2000

	Engineers	Technicians	Administrative workers	Skilled workers	Semi and unskilled workers	Total
Total demand to 2000	60,000	150,000	230,000	640,000	920,000	2,000,000
Average annual demand, 1975-1985	1,800	4,500	7,000	19,500	28,000	61,000
Average annual demand, 1986-2000	2,800	7,000	11,000	30,000	43,000	93,000

Figure 2. Distribution of resources of raw material for the iron and steel industry

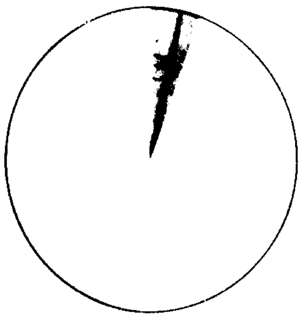
TOTAL COAL



Developing Countries	**14.6** %
Africa	0.7 %
Asia	13.5 %
Latin America	0.4 %

World total: 8,100 billion tons

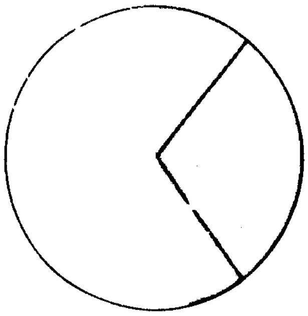
COKING COAL



Developing Countries	**5.2** %
Africa	0.0 %
Asia	4.6 %
Latin America	0.6 %

World total: 430 billion tons

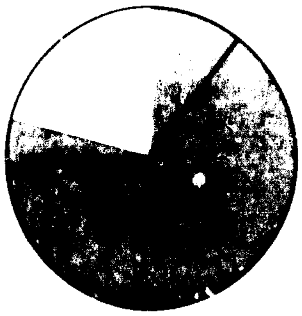
NATURAL GAS



Developing Countries	**45.8** %
Africa	10.8 %
Asia	31.3 %
Latin America	3.7 %

World total: 63,000 billion nm³

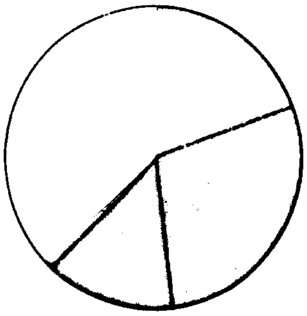
OIL



Developing Countries	**79.0** %
Africa	10.3 %
Asia	63.3 %
Latin America	5.4 %

World total: 74 billion tons

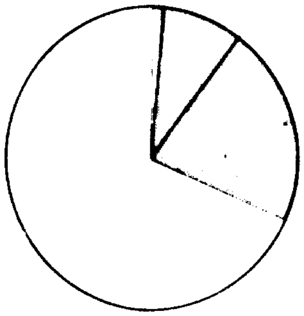
POT. HYD. RES.



Developing Countries	**62.7** %
Africa	19.1 %
Asia	28.3 %
Latin America	14.5 %
Oceania	0.8 %

World total: 2,261 GW

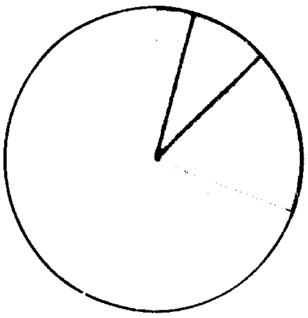
GROWING STOCKS IN FORESTS



Developing Countries	**30.2** %
Africa	1.2 %
Asia	8.2 %
Latin America	20.8 %

World total: 400 billion m³

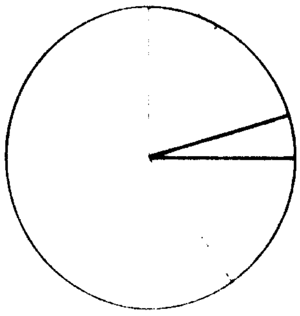
IRON ORE



Developing Countries	**30.4** %
Africa	4.2 %
Asia	8.6 %
Latin America	17.6 %

World total: 689 billion tons

MANGANESE ORE

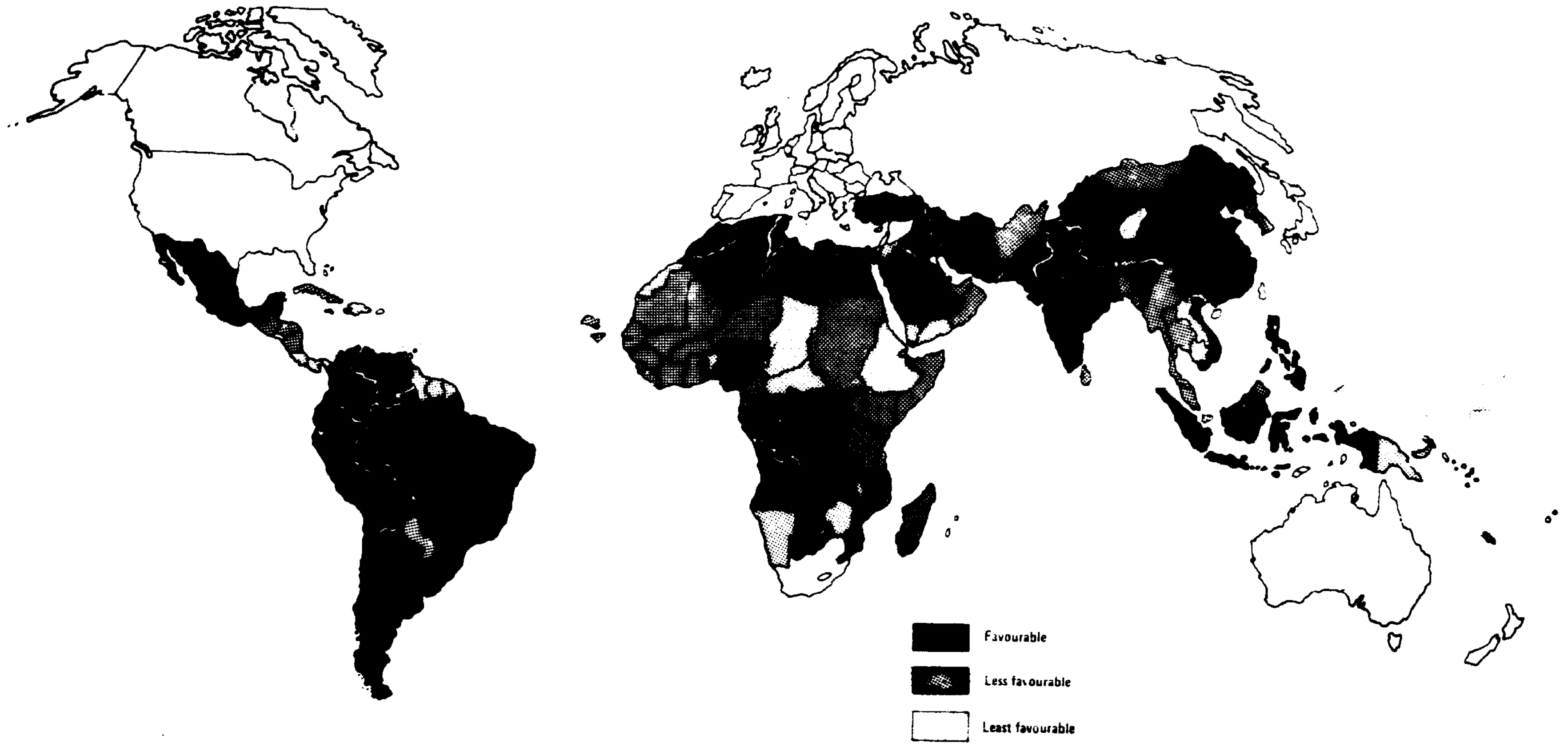


Developing Countries	**40.2** %
Africa	20.4 %
Asia	4.7 %
Latin America	15.1 %

World total: 3 billion tons

Percentage of world resources:
Developing countries
Developed countries ☐

[illegible] . Assessment of developing countries' natural resources for establishment of an iron and steel industry



CAPITAL REQUIREMENTS

Replacements and new investments: their order of magnitude

It is expected that new iron and steel production facilities with a total capacity of 380 million tons will be added to the world's steel-making capacity over the period 1975-1985 with a possible further 765 million to 1,080 million tons being added over the period 1986-2000. In the two periods cited above, replacement of existing capacities will most probably be of the order of 240 million and 450 million tons respectively. The developing countries' share in these new production capacities and replacements would be 115 million tons (1975-1985) and 339 million tons (1986-2000). [6]

The estimated average annual expansion of production is shown in Table 4:

Table 4. Expansion of iron- and steel-making facilities

(Annual averages in millions of tons)

	1975-85		1986-2000	
	World total	Developing countries a/	World total	Developing countries a/
New capacity	38	10.9	51-72 b/	19.6
Replacement	24	0.6	30	3.0

a/ China is not included.

b/ 51 million tons would involve an increase in investment of 37 per cent, 72 million tons an increase of 89 per cent.

The 38 million tons additional annual capacity estimated for the period 1975-1985 is very close to the present level of investment in iron and steel plants. Bottlenecks may occur in certain regions or countries owing to infrastructural shortcomings or lack of skilled labour.

Calculating average capital costs

New steel-making capacities of the magnitude of 35-40 million tons annually are currently under construction. However, as these are based on

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[6] Although several production variants are presented in the first chapter, only one steel production capacity variant is examined here, corresponding to the production by the year 2000 of 378 million tons with a plant utilization factor of 85 per cent.

contracts agreed upon in various years and under widely differing conditions, their capital cost can only be approximately indicated. For the purposes of this study, an average price of $600 per ton has been taken. The rationale for the assumption of this figure was:

(a) The capital cost figure selected is based on installed capacity of crude steel-making; it would have been higher had it been calculated on the basis of the expected operating rate of 75-95 per cent capacity.

(b) The expansion of steel-making capacities involves investment in both new and existing plants (green field investments and roundouts). The capital cost figure quoted for iron and steel mills covers:

- Mills of different size, hence at different points on the capital costs degression curve;
- Mills using different production methods, such as blast furnace and basic oxygen furnace; direct reduction and electric furnace; and scrap melting;
- Mills with rolling and finishing facilities, greatly varying in terms of size and equipment.

(c) Using aggregate data relating to the current decade, the capital costs have been elaborated separately for plants using blast and basic oxygen furnace ($648 per ton of capacity) and those using direct reduction and electric furnace techniques ($302 per ton of capacity). For the latter, a steel-making capacity of 0.5 million tons was assumed as was a direct reduction capacity to meet 70 per cent of the metallic requirements of the electric furnace.

(d) For developing countries unable to afford the plants described above, smaller steel-making capacities of 200-300 tons per day can be achieved through the installation of an integrated plant using direct reduction and electric furnace methods, or through the expansion of existing re-rolling or scrap-melting plant to include electric furnace operations.

Given appropriate bar, rod and section-rolling facilities, the capacity of these integrated mills using direct reduction and electric furnace methods may be as high as 0.5 million tons, whilethe investment costs may be as low as $180 per ton of steel-making capacity. Depending on the product mix, operation may be deemed economic at an annual production level of 200,000 - 400,000 tons. Capital cost degression in respect of both direct reduction and electric furnace methods is considered low at levels above 500,000 tons per year.

(e) Rolling and finishing facilities have an appreciable effect upon capital costs, though the exact extent thereof is often only vaguely defined in investment figures published. The capital costs usually vary between $90 and $300 per ton, but they may be much higher, depending on the size of the operation and its end product. In this area, the economies of scale are particularly important.

(f) The manufacture of "rounds", such as wire rod, concrete reinforcing bars and light and medium structurals, which account for more than half of the steel consumed in the developing countries, is deemed economic at an annual production level of more than [illegible],000 tons. The investment needed in a merchant bar mill is of the order of $70 per ton of capacity. An efficient level for the manufacture of most flat-rolled products is in the range of 1-3 million tons.

(g) In view of the capital cost degression of the rolling and finishing capacity as well as the local demand for steel, the priority given by developing countries to self-sufficiency in non-flat products would appear logical. It might be economically desirable for these countries to export continuous-cast slabs, billets and bloom until such time as demand (1-3 million tons) for flat products justifies the installation of rolling and finishing facilities. The capital cost figures are certainly influenced by the fact that, in the developing countries, rolling and finishing operations are assumed to be less diversified, and manufacture is more oriented towards non-flat products.

(h) In the case of mills using blast and basic oxygen furnaces, the fixed assets account for 68.9 per cent of total capital costs, whereas in the case of mills using direct reduction and electric furnace methods, they account for 74.5 per cent. Project implementation and pre-operational expenses account for 9.6 per cent of total capital costs in the case of the first mills and 8.2 per cent in the second mills. In respect of the mills using blast and basic oxygen furnace methods, the infrastructural investment estimates given in the study were based on experience gained in projects executed in Latin America and Europe, whereas the infrastructural investment figure quoted for the mill using direct reduction and electric furnace methods is a pro-rata estimate.

(i) The working capital required for a mill using blast and basic oxygen furnace methods was based on experience gained in Latin America, while that of the mill using direct reduction and electric furnace methods was assumed to be much lower.

(j) Investments necessary for the extraction and beneficiation of iron ore may amount to $40-50 per ton (including pellet plant), and those for coal mining $30-40 per ton, or even more. These investment costs are not included in the average capital costs per ton of steel cited in the report: however, they would have to be taken into consideration if mining operations were carried out locally or if the level of past export earnings were to be maintained

(k) No attempt has been made to estimate price escalation in the long term. However, this must be taken into consideration, should specific national studies on financing be made. For example, steel plant equipment went up some 80 per cent in price in the period 1965-1975, while building and construction costs increased by an even greater amount in many parts of the world.

(l) Interest payments may account for an additional $42 per ton in the case of the capital costs estimated for a plant using blast and basic oxygen furnace methods, and an additional $10 per ton in those plants using direct reduction and electric furnace methods. However, these additional costs have not been considered in this study.

(m) The proportion of foreign to local capital is of major importance to steel projects in the developing countries. This proportion differs in respect to the various fixed assets, such as plant and spares, transport, construction and civil engineering works. On an average, this proportion might be 60:40.

Capital requirements, 1975-2000

The estimated capital expenditure requirements are shown in Table 5:

Table 5. Cost of replacing and expanding iron- and steel-making facilities
(Billions of dollars, 1975)

Plant	Per year, 1975-1985 World	Per year, 1975-1985 Developing countries	Per year, 1986-2000 World, variant A	Per year, 1986-2000 World, variant B	Per year, 1986-2000 Developing countries
Replaced	7.2	0.2	9.0	9.0	0.9
Expanded	6.4	0.8	9.5	14.7	2.1
New	11.8	5.2	14.4	18.0	8.3
Total	25.4	6.2	32.9	41.7	11.3
Grand total, period	254.0	62.0	493.5	625.5	169.5

Assuming that on an average, 40 per cent of the capital costs would be met from local currency, some $3.7 billion and $6.8 billion foreign exchange would be required annually in the respective periods. Further assuming that, on an average, 50 per cent of these amounts would be financed through medium- and long-term loans, foreign resources required to finance the steel industry in the developing countries (not including China) would be of the order of [illegible] billion in the period 1975-1985, and $4 billion in the period 1986-2000.

As a comparison, reference is made to the flow of financial resources from selected developed countries[7] to developing countries and multilateral institutions which amounted to $26.8 billion in 1974 and an estimated $37.5 billion in 1975, and comprised both official and private net disbursements.[8] The sharp increase from 1974 to 1975 was linked with the rise in private export credits from [illegible] billion to [illegible] billion.

In determining the total capital expenditure, consideration should be given to the cost of establishing or adapting the infrastructure: these costs, however, have not been included in the study owing to their high degree of variance.

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[7] Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany (Fed. Rep.), Italy, Japan, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom and United States.

[8] World Bank Annual Report 1976, table [illegible], p. 100

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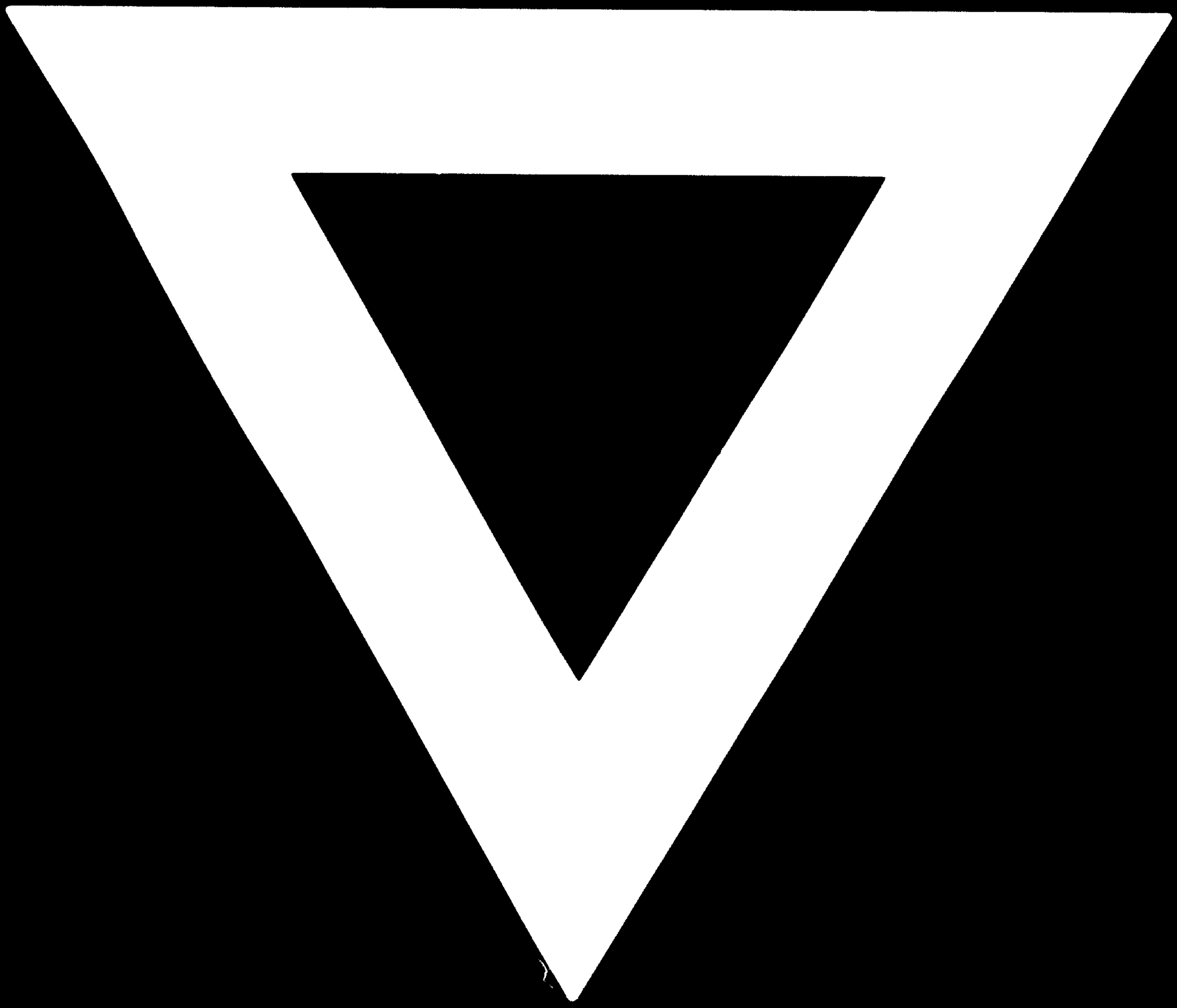

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