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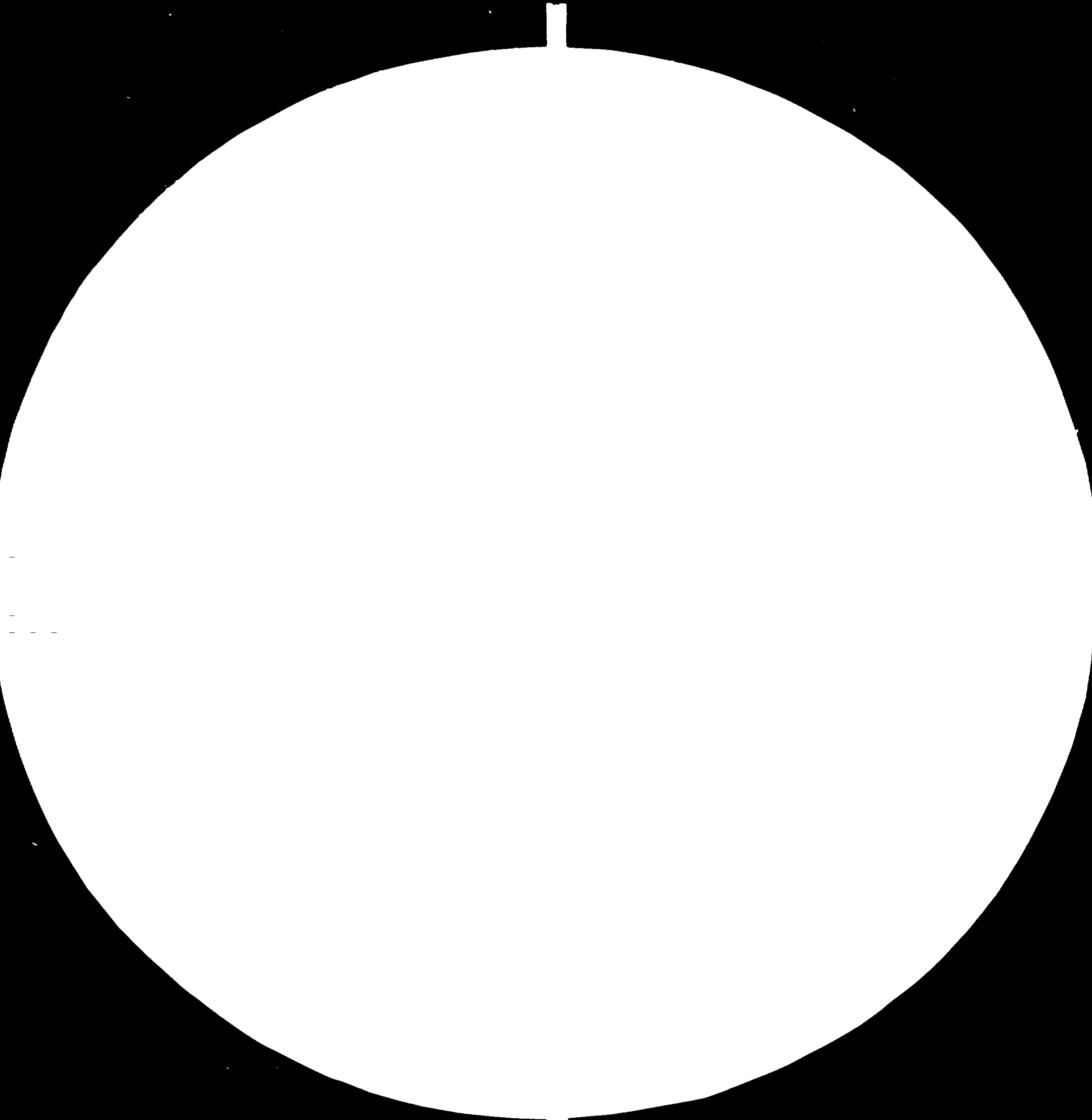

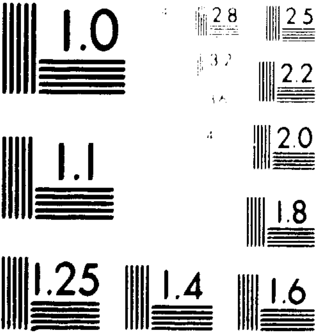

MICROCOPY RESOLUTION TEST CHART

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The United Nations Industrial Development Organization, Vienna

Report
on
World Wide Study on the Iron and Steel Industry

(Contribution to the World Iron and Steel Scenarios up to 1990)

October 1980

001571

Dautur Engineering International GmbH
Consulting Engineers
Düsseldorf

The United Nations Industrial Development Organization, Vienna

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PREFACE

With a view to enable the developing countries to raise their share in the global capacity to 25 per cent by 2000 AD from about 11 per cent in 1979, in accordance with the goal set in the Lima Declaration and Plan of Action on Industrial Development and Cooperation in 1975, the International Centre for Industrial Studies at the United Nations Industrial Development Organization has been elaborating scenarios of development of the world iron and steel industry upto 1990. In this context, Dastur Engineering International GmbH, Consulting Engineers, Düsseldorf, have been entrusted under the terms of UNIDO contract No. 80/77 dated 6th June 1980 to prepare a brief study to identify generally the factors and the constraints that influence healthy growth of the steel industry, and to illustrate cases of developing countries where such bottlenecks have been overcome.

Accordingly, this report presents outlines of the data base comprising demarcation of the system of scenario, determination of the essential variables, an explanatory analysis of the role of these variables and a broad pattern of interaction of these variables to the extent these could influence world-wide development of the steel industry till 1990.

REPORT

on

WORLD-WIDE STUDY ON THE IRON AND STEEL INDUSTRY

(Contribution to the World Iron and
Steel Scenarios upto 1990)

to

THE UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION, VIENNA

The main troupe actors on the global scenario setting of the steel industry are economic, commercial, technological, political, social and historical. Their dynamics is universally conditioned externally by the systems of planning and implementation and internally by the system of operations, though the multifaceted strategies and actions of these actors will be motivated and conditioned by the differences in the settings of individual regions and countries. The variables of each of these three complex systems can be classified into groups and sub-groups as shown in Figures 1 to 3. The salient roles of these individual groups, their actions and limitations are described seriatim in this report. The actions and limitations relevant to the development of steel industry upto 1990 are discussed with a view to distinguish their influence on industrialised and developing countries so that the latter could derive benefit from the relevant experience and examples of the former. The interaction of variables is arranged in matrix form for each dynamic system. The report is concluded with an overall interaction matrix of variables of all the three systems.

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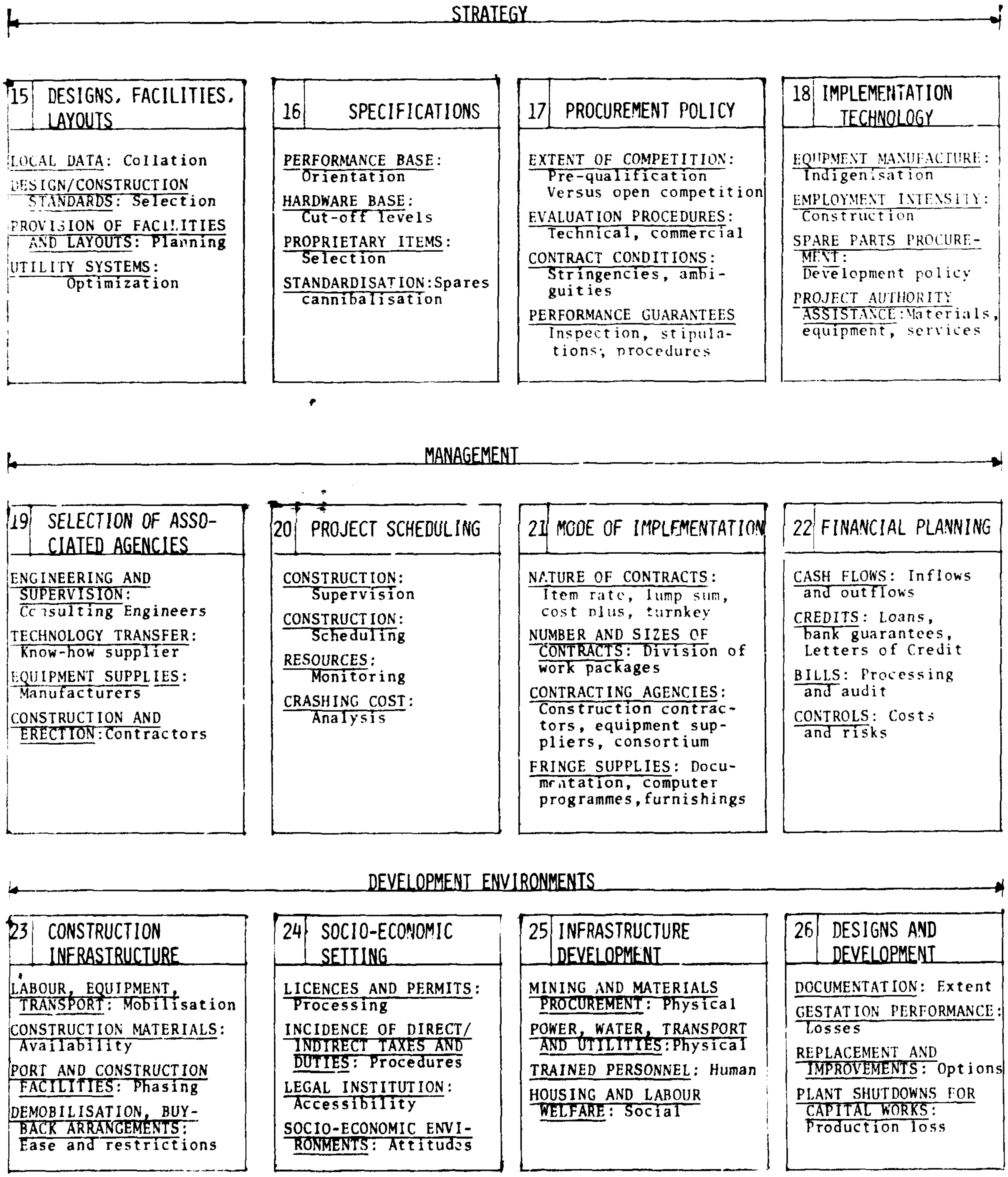

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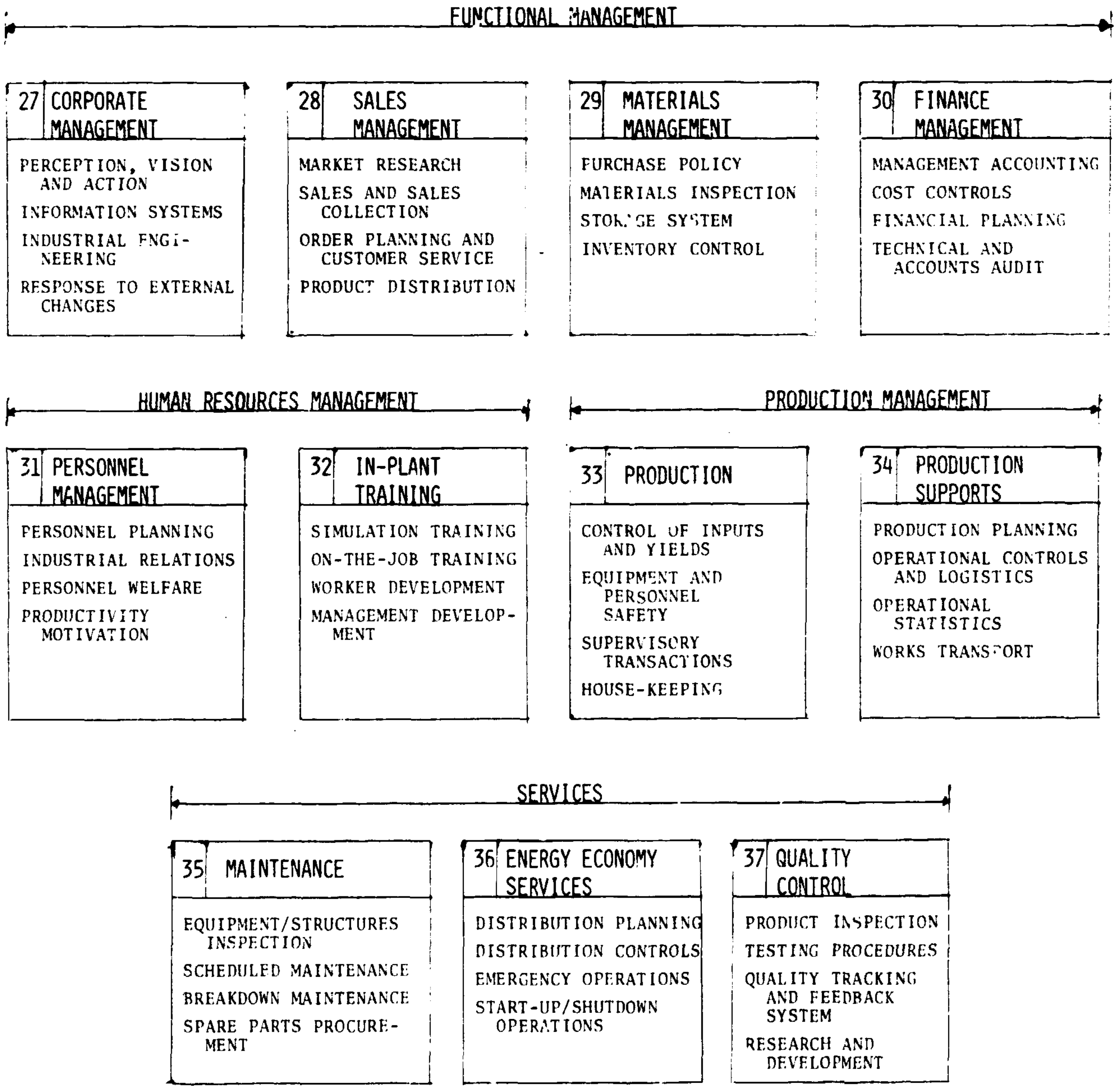

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FIG.3 - INTERNAL STEEL DYNAMICS - OPERATIONS VARIABLES

MARKETS

Domestic markets

After 25 years of steady increase in the consumption till 1973, the per capita consumption of steel in OECD countries, which account for about 54 per cent of the current world consumption, has tended to decline sharply as is evident from the following trends:

Apparent Crude Steel Consumption (kg per capita) in OECD countries

Year	USA	Japan	West Germany	Canada	Belgium/ Luxembourg	Italy	Australia
1973	711	805	671	640	474	434	537
1977	618	512	587	550	415	395	365

Source: Statistiisches Jahrbuch - 1979 Verlag Stahl Eisen, Düsseldorf

On the other hand, in the centrally planned COMECON countries which account for about 28 per cent of the world steel consumption, the per capita consumption has continued to increase as shown below:

Apparent Crude Steel Consumptiom (kg per capita) in COMECON countries

Year	Bulgaria	Czechoslovakia	GDR	Hungary	Poland	Rumania	USSR
1973	232	688	497	314	475	392	518
1977	276	748	591	343	540	506	..

Source: The Steel Market, UNO, Various issues.

In developing countries, which consumed about 18 per cent of the world steel product in 1977, the demand for steel had generally been rising as shown below excepting the Far East countries:

Apparent Crude Steel Consumption (kg per capita) in developing countries

Year	Middle-east	Latin America	Africa	Far East
1973	67	83	32	69
1977	96	91	36	55

Source: The Steel Market, UNO, various issues.

The price elasticity of steel for manufactured products in developed countries have induced some substitution by the competing non-ferrous engineering materials and by special steel with superior engineering properties. Presumably this, together with changes in the engineering technologies, has led to decline in the specific consumption of steel in manufactured products as may be seen from the following trends:

Specific steel consumption (in kg) per unit engineering product

Country	Year	Elec.machinery	Ship building	Rolling stock	Nuts & bolts	Bus	Private automobiles
West Germany							
Per 1000 kg weight	1970	412	873	612	883	-	-
	1977	370	668	557	783	-	-
Japan							
Per unit	1966	-	-	-	-	2 900	900
	1972	-	-	-	-	1 950	620

According to Mr Kono of Nippon Steel Corporation, the unit consumption of steel and castings in the manufacture of Chevorlet Impala car decreased during 1974-1977 from 1 228 kg to 1 007 kg and 313 kg to 281 kg respectively, while that of plastics and aluminium increased from 63 kg to 91 kg and 27 kg to 31 kg respectively. This trend of reduction in the steel use seems to be one of the factors that has retarded the growth of steel demand in OECD countries.

The predominant determinant for the steel market in developing countries, the centrally planned economies and even in some developed countries is the investment, the consumer products claiming a secondary role. The economic Commission of Africa had concluded in 1966 that the investment demand for steel in Africa during the sixties was six times that for consumer products. During the seventies, the highest growth in steel consumption had been recorded in some middle-income developing countries such as South Korea and Taiwan in the Far East Asia, and the Middle-East and North African countries where the gross domestic investment in 1978 was at the high levels of 27 per cent and 31.4 per cent respectively of the gross domestic product.

Demand for certain categories of steel products is generated exclusively by a single economic activity and consequently their offtake becomes highly vulnerable to the business cycles of the respective activity. Thus, for example:

i) With decline in the shipbuilding activity from 17.8 million gross tons in 1974 to 4 million gross tons in 1978, the apparent consumption of plates in Japan fell from 15 million tons to 7.25 million tons during the same period.

ii) Production of rails in India - a country with one of the largest railway networks in the world has declined as follows:

Year	1969	1971	1973	1975	1977
Production '000 tons	425	376	262	319	235

iii) Steel shipments for railway vehicles in Japan have declined from 176 000 tons in 1974 to 117 000 tons in 1978, and

iv) the demand for large diameter seamless pipes varies more or less directly with the activity of drilling of oil and gas wells.

Considerable parallelism is observed between the post-war world production of liquid steel and the number of automotive vehicles. Unlike the automobile-oriented past, the pattern of steel demand during the 1980s will also be influenced by the expected global technological developments such as,

- electronics, especially micro-processors
- off-shore energy exploitation and sea-bed mining
- development of new forms of energy
- bio-industry.

Of these, the electronic apparatus and instruments require steel in very small quantities and increasing use of electronics will tend to retard steel demand.

Off-shore energy exploitation and sea-bed mining will call for production of flat steel products of highly specialised qualities. The energy price hike has shifted focus of research from conventional petroleum fuels to other fuels such as shale oil and sand tars and also better utilisation of coal, lignite etc. The exploitation of off-shore oil and gas reserves will stimulate demand for steel. For example, presently around 10 000 km long cross-country coal slurry pipelines of diameters larger than 75 cm are in various stages of implementation in USA. Considering that 500 000 tons of high strength steel pipes were required for construction of 1 277 km long Alaska oil pipeline in USA in early 1970s. 220 km long pipeline for transporting off-shore natural gas to Western Java in Indonesia had required 42 000 tons of steel pipes and miscellaneous shapes; the future development in the exploitation of off-shore oil and gas reserves, and installation of bio-industrial plants is expected to stimulate the market of both ordinary and special steels.

Export markets

With the shrinking of steel markets in most OECD countries during the second half of seventies, the spirit of protectionism against international trade has grown in these countries. The protectionism has become manifest through increasing voluntary restraint agreements for exports, anti-dumping law suits, trigger price mechanism, broder prices and several non-tariff barriers through monetary, administrative and discriminatory trade practices. On the other hand, the steel exports of industrialised countries to developing countries grew at an average annual real rate of 6 per cent and the share of these in the global steel exports increased from 24 per cent in 1970 to 29 per cent in 1976.

The volume of international trade in steel, expressed as a proportion of world steel production, rose from about 11 per cent in 1950 to 20 per cent in 1970, jumped to 24 per cent in 1974 and has stabilised around this level thereafter as shown in Table 1.

TABLE 1 - GROWTH OF WORLD TRADE IN STEEL

Year		Total steel trade(1) mill.tons	Total ingot steel production mill. tons	Share of trade %
1950	..	20.5	192.0	10.7
1960	..	52.7	345.5	15.3
1970	..	117.5	595.4	19.7
1974	..	169.6	709.0	23.9
1976	..	163.6	676.4	24.2
1978	..	178.1	717.2	24.8
1979 E	..	180.0	747.5	24.1

Source: World Steel in Figure
International Iron and Steel Institute

This levelling off in the international trade is mainly due to the shrinking of the annual growth rate in the imports by industrialised countries which declined precipitiously from 9.1 per cent during 1960-1973 to 2.8 per cent during 1973-1978. Simultaneously with the increase in the trade volume, the number of countries entering the steel export markets has progressively increased as shown by the following trends:

Steel-exporting countries

		Subsequent additions		
By 1950		By 1965	By 1975	By 1980
OECD		OECD	OECD	Developing
Belgium	Norway	Denmark	Spain	South Korea
Luxembourg	United Kingdom	Finland	East Europe	Taiwan
Netherlands	United States	South Africa	East Germany	Malaysia
FR Germany	Canada	East Europe	Developing	
France	Australia	Yugoslavia	India	
Italy		Hungary	Greece	
Austria		Romania	Ireland	
Japan		Developing		
Sweden		Portugal		
East Europe				
USSR				
Poland				
Czechoslavakia				

In contrast, several developing countries have established since 1960 steel industry with the encouragement of international organisations which promote industrialisation in developing countries. A list of these new entrants to the steel industry is given on the next page. The international steel trade has shrunk to the extent these countries have succeeded in their import substitution. In some cases this development has changed the pattern of international trade as exemplified by large scale imports during 1974-1977 period by Iran of steel semis instead of rolled steel products.

International trade in steel does not rest exclusively on the price competitiveness but is also influenced by a few trade channels peculiar to the steel industry - such as the exchange trade and group trading.

The world trade in semi-finished and finished steel can be broadly classified into two groups according to the nature of demand satisfied by the trade. Deficit trade arises when the desired steel products are not produced

New entrants to the steel industry in the developing countries

Region	Integrated plants			Semi-integrated plants		
	DR-EAF route	BF-Oxygen steel route				
	Long products	Long products	Flat products	EAF & rolling mill	Rerolling mill	Pipe mill
1960-1965 PERIOD						
Latin America	Mexico	Venezuela (1964)	Venezuela (1964)		Ecuador (1963) Peru (1962)	Venezuela (1960)
Asia		Malayasia (1961)	Malayasia (1961)	Jordan (1965) Singapur (1961) Thailand (1963)	Sri Lanka (1961)	Iran (1960) Malayasia (1961) Singapur (1961) Thailand (1961)
Africa		Algeria (1964) Tunisia (1965)	Algeria (1964)	Ghana (1963) Uganda (1961)		Algeria (1964) Tanzania (1960) Malta (1961)
1966-1970 PERIOD						
Latin America					Dominican Republic (1968)	
Asia		Bangladesh (1967) South Korea (1968)	South Korea (1968)	Malaysia (1967)		Kuwait (1967)
Africa				Angola (1968) Kenya (1966)	Mauritius (1966)	Mozambique (1970)
1971-1975 PERIOD						
Latin America	Brazil (1975)	Burma (1973)		Dubai (1974)	Vietnam (1975)	Lebanon (1975)
		Iran (1973)		Israel (1972) Syria (1971)		
Africa						Morocco (1971) Tanzania (1971)
1976-1980 PERIOD						
Latin America	Argentina (1977) Venezuela (1978)					
Asia	Indonesia (1979) Iraq (1978) Iran (1978) Qatar (1978)					
Africa						Libya (1977)

or are not available temporarily in the consuming countries and have to be imported. Exchange trade results from bilateral agreements involving import of steel against export of other commodities or other categories of steel. Table 2 shows the breakdown of the world steel trade since 1950 into deficit trade and exchange trade.

TABLE 2 - WORLD TRADE IN SEMI-FINISHED AND FINISHED STEEL DURING 1950-1975 PERIOD

Year	Total volume of world trade	Deficit trade		Exchange trade	
	million tons	million tons	% of total	million tons	% of total
1950 ..	15.8	12.6	79.8	3.2	20.2
1957 ..	30.8	20.4	66.2	10.4	33.8
1961 ..	38.7	22.7	58.7	16.0	41.3
1965 ..	56.7	33.3	58.8	23.4	41.2
1970 ..	80.0	37.4	46.7	42.6	53.3
1974 ..	122.5	57.6	47.0	64.9	53.0
1975 ..	110.4	39.7	36.0	70.0	64.0

Source: (1) World Trade in Steel and Steel Demand in Developing Countries, 1968, United Nations, New York

(2) Statistics of World Trade in Steel - 1970, 1974 and 1975, ECE, United Nations, New York.

It will be seen from Table 2 that the role of exchange trade has steadily increased during the last three decades. The proportion of exchange trade doubled from 20 per cent in 1950 to 40 per cent in early 1960s and to 64 per cent during 1966-1975 period.

The role of group trading in the international steel trade also increased substantially during the last two decades. The intra-Comecon trade increased from 3.2 per cent in 1960 to 8.4 per cent in 1970 and to 11.5 per cent in 1979. During the same period the share of intra-EEC trade doubled from 11 per cent in 1960 to 22 per cent in 1970 and almost trebled to 32 per cent in 1979. The pattern of international trade is also characterised by the predominant pull of raw material resources for the developing countries and of the market forces for industrialised countries in steel exports and is evident from the analysis of metal trade in the boom years of 1973 and 1974 given in Table 3.

TABLE 3 - STRUCTURE OF STEEL EXPORTS ACCORDING TO PROCESS STAGE
(Figures are in per cent)

Country group	Raw materials	Processed raw materials	Semi processed product	Transformation stage of finished product First	Second	Complex(1)
Iron & Steel Trade - 1973						
Developing to						
(i) industrialised	50.5		37.2		12.3	...
(ii) developing	6.1		75.5		18.4	...
Industrialised to developing	-		87.7		12.3	
World Metal Exports - 1974						
(i) industrialised	11.1	16.1	5.2	27.9	21.6	18.1
(ii) developing	31.5	45.9	1.0	7.0	6.5	8.1

NOTE: (1) Data on export of complex finished steel product in 1973 are not available readily.

Source:
1. World Industry since 1960 - Progress and Prospects; Special Issue of Industrial Development Survey for the Third Conference, UNIDO for 1974 data.
2. Data collected by UNCTAD for the iron and steel trade - 1973 from 50 developing countries.

Steel exports especially of finished products from developing countries to industrialised countries a number of hurdles in addition to non-competitive pricing such as escalation of import tariff rates with the advancement of the processing stage of exported steel product. In an analysis of Restrictions on International Trade in Steel in 1974, C. McPhee has identified 32 non-tariff barriers which militate against imports in USA, Canada, Japan and EEC member countries. These restrictions relate to foreign trade policies, administrative practices, internal policies and regulations and private practices (cartels, restrictive exclusive supply agreements and in the case of Japan on freight rate discrimination). While the competitive strength on f.o.b basis can be improved by the developing countries only by upgrading their steel industry on sound basis, some advances are being made in the Multi-lateral Trade Negotiations under the auspices of GATT in securing better terms of trade for group trading. The pattern of this group trading was established in the 1976-Lome Convention and the Generalised System of Tariff Preferences which was introduced progressively during the 1970s and which is due in 1981 for renewal for another decade, subject to the developing and industrialised countries reaching an accord on this subject.

Aggressive sale of steel in the international markets requires a chain of complementary services which are many a times beyond the reach of exporters of developing countries. For example, considerable quantity of steel is exported to the Middle-east as part of turnkey contracts for projects. Many developing countries face chronic shortage of foreign exchange and they are often compelled to import steel against a tied credit extended by an industrialised country. The non-petroleum developing countries are unable to extend credit of this type to exporters. Some industrialised countries notably Japan promote exports of flat products with a small equity participation in the installation of steel-processing units in developing countries. Examples of this export strategy are:

(i) galvanising industries in many developing countries for producing corrugated galvanised sheets from imported thin black cold rolled strip; and

(ii) tinning in Thailand.

Product-mix

The product-mix for steel industry in developing countries may be based on strategies of internal demand, self-reliance or mere import substitution and export orientation. After a careful appraisal of the target export markets in the Arabian Gulf countries, it was decided by Qatar Steel Company in 1974 to set up a single purpose mill of about 330 000 tons per year capacity to roll bars. In India, though railway materials such as rails, wheels and axles are not very profitable items, they are still required to be produced from the national viewpoint of self-reliance. Steel industry's product-mix generally includes items of major tonnages for techno-economic reasons. In some cases, this entails exclusion of minor-demand items such as certain sizes of unequal angles, joists, special sections etc.

For example, the transmission tower manufacturing industry in Western India had to set up their own moderate capacity rolling mills to ensure adequate supply of equal and unequal light angles for tower fabrication which could not be rolled economically by the Indian integrated steel plants.

The existence of downstream processing facilities, such as coating, metalworking etc will generally affect product-mix of proposed steel capacity. In case downstream processing facilities are not available, these may have to be included in the planning of steel capacity.

The large assortment of long and flat rolled steel products in small quantities required by the markets in many developing countries warrants judicious selection of cut-off and trade-off points in respect of shapes, sizes and finishes of rolled steel products for serving the target markets. Selection of single-purpose mills versus multi-purpose mills for long products and narrow mills versus wide mills for flat products have far-reaching effect on the commanded market sizes and sales realisation.

The selection of rolling facilities determines a given plant's production capability and therefore needs careful evaluation. It may be pointed out that the rolling mills account for almost half of the investment in the production facilities in integrated plants.

The effect of the selected product-mix on the rolling mill investment cost is shown below:

Long Products	US $ annual ton	Flat Products	US $ annual ton	Coating lines	US $ annual ton
Heavy structurals	450-550	Plates	250-320	Galvanising	250-300
Bars	210-225	Hot rolled strip	110-130	Tinning	225-270

Distribution cost and pattern

The cost of steel to the consumer is the sum of the delivery price ex-steel plant and the cost of transport from the plant to the consumption point. Hence differential distribution costs would influence cut-off levels of the market area commanded by the steel industry. In September 1977, the railroad freight from Pittsburgh to San Fransisco and Los Angeles for sheets, plates and structurals was $ 67 per ton whereas the shipping freight rates from Japanese ports to the USA destinations on the Pacific coast - Los Angeles, Portland and Seattle were around US $ 28 per net ton on various categories of steel products. Thus in the West Coast market of USA the Japanese steel industry enjoyed freight advantage over the American steel plants in Pittsburgh/Chicago area. This decisive advantage in the early 1970s in distribution cost was a significant factor that enabled the Japanese to supply the 0.5 million ton pipes for Alaska pipeline.

In contrast, with the freight equalisation fund administered in India, mainly for purposes of balanced and decentralised growth of industry, the railway freight on steel to all railheads in the country from the integrated steel plants which are largely concentrated in Eastern India is equalised. This system nullifies any worthwhile advantage in distribution costs of market-based mini-steel plants which may compensate partly or fully for the disadvantages of lower scale of operation as compared to integrated steelworks.

SCALE OF OPERATION AND STEEL SUPPLIES

The capital as also the operating costs of steel industry are sensitive to economies of scale.

Escalation

Table 4 shows the relative capital costs of plants of different capacities with alternative process routes. It will be seen from the table that the specific capital cost per annual ton varies as follows:

(i) For the blast furnace-oxygen furnace process, it decreases rapidly as the capacity is raised from 0.2 million tons per year to 2 million tons per year.

(ii) For the direct reduction-electric steelmaking process, it decreases substantially in the capacity range of 0.2 to 0.5 million tons per year and tends to stabilise for capacities in excess of 0.6 million tons.

TABLE 4 - RELATIVE CAPITAL COST OF PLANTS OF DIFFERENT CAPACITIES WITH ALTERNATIVE PROCESS ROUTES

Plant size '000 T/yr	Relative index of plant capital cost per annual ton(1)					
		DR/EAF process				
	BF/BOF process	DR plant	Site and other costs	DR cost	EAF cost	Total(2)
200	213	103	27	130	79	170
300	180	88	23	111	67	145
400	164	80	20	100	61	131
500	155	75	18	93	56	121
600	146	71	17	88	52	114
700	140	69	16	85	51	111
1 000	129	68	15	83	50	109
2 000	115	68	15	83	49	108
3 000	110	68	14	82	49	107
5 000	100	..	..	..	..	..

NOTES: (1) The base index of 100 is not the same for DR/EAF and BF/BOF facilities

(2) EAF capital cost plus 70 per cent of direct reduction cost

Source: Commodities Research Unit Survey, 1976

The relative investment costs of semi-continuous and continuous mills for rolling different products are shown in Table 5 on the next page. It will be noted from the Table that the investment requirements per annual ton are generally 25 per cent higher for semi-continuous mills as compared to continuous mills.

TABLE 5 - RELATIVE INVESTMENT COSTS OF SEMI-CONTINUOUS AND CONTINUOUS MILLS

	Heavy sections	Rails	Medium sections	Light sections	Wire rods	Hot strip	Cold strip
Annual capacity (million tons)							
Semi-continuous	0.3	0.3	0.25	0.2	0.2	0.7	0.25
Continuous	0.7	0.7	0.5	0.4	0.4	2.0	0.7
Relative index of total investment							
Semi-continuous	63	60	60	62	62	55	42
Continuous	100	100	100	100	100	100	100
Relative index of investment per annual ton							
Semi-continuous	124	141	120	125	124	158	118
Continuous	100	100	100	100	100	100	100

Source: Study of Development possibilities of Iron and Steel Industry in Arab Countries for the Industrial Development Centre for Arab States 1973, Arab Iron and Steel Union.

A study of the economies of scale for steel plants of small sizes ranging from 0.1 million ton to 0.3 million ton per year which can be set up by the developing Latin American countries had analysed the investment economies for major production facilities. The relative capital costs estimated in this study are indicated in Table 6 on the next page.

TABLE 6 - RELATIVE CAPITAL COST OF SELECTED PRODUCTION FACILITIES

Capital cost of integrated steelworks for long products
(capacity: '000 tons/year)

Production department	Relative index of investment					
	Total			Specific per annual ton		
	100	200	300	100	200	300
Coke ovens ...	42	100	129	76	100	86
Sinter plant..	-	100	128	-	100	85
Blast furnace.	65	100	131	124	100	87
Steelmelt shop (LD) ...	70	100	124	140	100	83
Continuous casting ...	59	100	132	118	100	88
Rolling mills ...	64	100	135	130	100	90
Weighted average ...	61	100	131	109	100	87

Source: ECLA study on Economies of Scale of Small Integrated Steelworks for Economic Commission of Latin America.

Higher capacities in production units have been achieved through (i) increase in the unit capacities of process equipment like ironmaking and steelmaking furnaces, (ii) higher powering of equipment (as in electric arc furnaces), (iii) increase in the number of strands of continuous casting machines and multi-strand bar and rod mills, (iv) reduction of down-times through strengthening of auxiliary supports and adoption of plug-in inter-changing devices (for example, inter-changeable mill stands), (v) integration of batch operations into continuous lines and (vi) instrumentation and on-line computer controls.

The blast furnace capacities in the Japanese integrated steelworks have been steadily increased with every successive installation as shown below:

Integrated plant		Useful volume of blast furnaces				
		No. 1	No. 2	No. 3	No. 4	No. 5
Kashima,	Start-up year	1971	1973	1976		
Sumitomo Metal	Useful vol. m3	3 159	4 080	5 050		
Kimitsu,	Start-up year	1968	1969	1971	1975	
Nippon Steel	Useful vol. m3	2 705	2 884	4 063	4 930	
Ogishima,	Start-up year	1976	1979			
Nippon Kokan		4 052	4 000			
Kakagowa,	Start-up year	1970	1973	1978		
Kobe Steel	Useful vol. m3	3 090	3 850	4 500		
Mizishima,	Start-up year	1967	1969	1971	1973	
Kawasaki Steel		2 156	2 875	3 363	4 323	
Oita,	Start-up year		1976			
Nippon Steel	Useful vol. m3	4 158	5 070			
Fukuyama,	Start-up year	1967	1968	1969	1971	1973
Nippon Kokan	Useful vol. m3	2 004	2 620	3 016	4 197	4 617

The module capacities of direct reduction plants increased through the sixties and seventies as follows:

Process	Output Unit	Sponge iron output per module			
HyL	'000 t/year	1957 - 95	1960 -260	1974 -400	1976 -630
Midrex	'000 t/year	1969 -200	1971 -400	1977 -600	

Blue prints for a megamodule Midrex plant (capacity - 1.0 million tons per year of sponge iron) are reported to be currently under preparation.

Japan built its first BOF in 1957. The vessels capacity of BOF installations in Japan increased from 100 tons in 1960 to 170 tons in 1965 and 250 tons in 1968. BOFs of over 300 tons were installed after 1971.

The capacities of continuous casting machines were matched world-wide with the increasing heat sizes of BOFs and electric arc furnaces during the 1960s and 1970s by increasing the number of strands in the machines and cross sections of cast semis. For example, minimum billet size for wire rod rolling has been increased from 100 to 130 mm and slab width to about 2.8 m to match the BOF capacity. Installations are now in operation adopting practice of cutting the slab width to suit available mill. Establishment of continuous-continuous casting practice in several plants in the industrialised countries has raised the productivity and scale of operation by additional 30 per cent as compared to the conventional practice of batch casting.

The annual capacites (expressed in thousand tons/year) of different types of rolling mill installations have steadily increased as follows:

Wire rod mill

Year ..	1966-1971	1971-1976	1976-1979
Capacity: 2-strand mill	350	460	570
4-strand mill	640	840	1 000

Hot strip mill

Year ..	1953	1961	1971
Capacity ..	1 000	1 800 to 3 000	3 500 to 4 500

Cold mill

Year ..	1960	1977	1977 (endless rolling
Capacity ..	900	1 200	2 000

With the application of computer controls a new generation of continuous section mills are now in operation with capacities double that of discontinuous mills.

The consumer industries in the industrialised world constitute the major consumers of flat products - hot rolled and cold rolled coils, plates and coated sheets etc. The large-scale rolling of flat products in continuous mills became an established technology long ago in the industrialised world. The requirement of capital-intensive technology for production of flat products, coupled with the high level of operation needed as compared to the long products, has placed the developing countries at a disadvantage. It is for this reason that the flat products in all forms including welded pipes and tubes and coated strip have accounted for about two-thirds of exports of rolled steel products to developing countries from Japan.

The conversion costs are higher at the stages of ironmaking and steelmaking than those at the rolling stage and the operating costs of ironmaking and steelmaking are generally higher in developing countries due to lower thermo-dynamic efficiencies and batch operations which are to some extent inherent in the operations on a smaller scale. For instance specific consumption of power, electrodes and refractories reduces with the increasing size of electric arc furnaces and powering as shown in Table 7 on the next page.

TABLE 7 - ECONOMIES OF CONSUMABLES IN ELECTRIC FURNACE STEELMAKING ON DIFFERENT SCALES

Furnace dia m	Operating power level MW	Average production ton/hr	Consumption			
			Electrodes Kg/ton	Power kWH	Refractories kg/ton	4-man crew Manhour/tor
6.1	35	28	6	500	6.25	0.130
6.7	55	48	5.75	485	6.00	0.083
7.3	60	50	5.4	475	5.50	0.080
9.8	100	86	4.3	460	5.00	0.046
11.6	110	91	4.3	455	4.5	0.044

Source: Large Arc Furnaces and the Effect of Key Dimensions on the Performance of Ultra-high powered Furnaces, by OK Hill of Lectromelt Corporation and G.G. Robinson, April 1978, Chicago

The continuous-continuous casting which is generally possible at higher levels of operation has reduced theoperating costs due to minimisation of the crop end losses of semis and reduced consumption of refractories.

In an ECAFE study for the South-East Asian countries, a mission of the Japan Iron and Steel Federation and the Iron and Steel Institute of Japan had estimated in 1969 the cost of pig iron as well as steel ingots for blast furnace-LD converter process route to be 14 per cent higher and 10 per cent lower at plant capacity of 0.25 and 5 million tons per year respectively in comparison to 2 million ton capacity.

De-escalation

All processes which originated initially for operation on a moderate scale have continued to increase in capacities to have advantages of economies of scale. However, all the developing countries are obviously not in a position to go in for such large capacity units for reasons of demand, finance availability etc. In this context, it must be mentioned that the developing countries which are interested in moderate or small-scale steel industry are today in a position to achieve this objective provided local conditions allow minimum pre-requisites for the implementation of such viable units of mini-integrated or semi-integrated units are to be satisfied. The possibilities in this direction would include units based on backward or forward integration in stage-wise expansion by adopting suitable technology which might match with low-level production - such as use of charcoal blast furnace or electric smelting for hot metal production; small capacity direct reduction kilns/retorts using coal as reductant; low level/horizontal continuous casting; compact rolling facilities with swing forging, GFM continuous forging, Kock's 3-roll rolling etc.

Depending upon local conditions, it may be possible to build plants upward 15 000 tons per year capacity, for example, based on Kinglor Metor solid reductant based direct reduction process, electric furnace/continuous castig or pencil ingot teeming and rolling.

While large scale integrated steel production facilities have definite merits on account of economies of scale of operation, there are handicaps, a few of which are discussed below:

(i) large capacity steel plants require corresponding consumer base; such dispersed consumers base results in multiple handling of products, leading to higher haulage costs.

(ii) the steel production at high level of scale of operation can be maintained in most countries only by supplementing the domestic markets with exports. As the f.o.b. prices realisable from the steel exports are generally lower than the ex-plant domestic steel prices and exports entail additional financial, marketing and inventory costs, the lower sales realisation from exports per unit of production implies a penalty attributable to the scale of operation. The continuous process plants such as the coke ovens, coke oven by-product plants, the direct reduction plant and the oxygen plants cannot be operated when the demand of their respective product drops down to the level of turndown ratio of each equipment. Hence higher the scale of operation, higher is the absolute capacity of the equipment that has to remain idle during the turndown operation. Underutilisation of plants of larger capacity leads to increased unit production cost as (a) bulk of the labour cost and the annual financial charges for investment remain fixed in absolute terms and (b) the specific consumption of utilities and consumables is higher than the values attainable at the maximum production capacity.

(iii) the steel production processes are vertically integrated and interwoven so extensively not only amongst themselves but also among the capital-intensive backward linkages such as the mining and the infrastructure facilities - the power plant and the port - as also the ferro-alloys manufacturing industry as in the case of Japan that the capacity underutilisation of one section in the steel industry exerts a snowballing penalty effect on a number of vertically integrated downstream as also the upstream units of the complex.

Production alignments

The wide assortment of semis and rolled products in respect of shapes, dimensions along with a wide range of steel grades burdens the production facilities. This in turn entails disaggregation of production campaigns into small batches which lower the equipment productivity and raise operating costs. The diverse customers' need is made compatible with the economies of scale of operation by either horizontal or vertical production alignments. In the horizontal alignments, the production scheduling (or the order scheduling when steel is produced to order) is segregated and lumped into specific shapes, semis, finishes and grades and channelised to (i) different steel plants under the same corporate management or (ii) different modules of vertically linked production units in the same plants or (iii) phased out for production so that for a given reference period the production batches for steelmaking, continuous casting, rolling and coating facilitate continuous campaigns.

Over 60 per cent (around 72 million tons in 1979 of crude) steel production in Japan was contributed by four companies and each of these companies have several integrated and semi-integrated steelworks as follows:

Nippon Steel	..	Integrated steelworks	8
		Seamless pipe plant	1
		Special steel plant	1
Nippon Kokan	..	Integrated steelworks	2
		Semi-integrated plants	2
Kawasaki Steel	..	Integrated steelworks	2
		Special steel plant	3
Sumitomo Metal	..	Integrated steelworks	3

The Japanese steel exports are regulated by three exports cartels, which are permissible under the Japanese law. In co-operation with these cartels, it is possible to evolve very large batches for continuous campaigns. For example, since the commissioning of Oita mill towards end of 1978, Nippon Steel has been able to sustain production of very wide hot rolled strip at this plant by diverting production of narrower strip to other steelworks under the same management. Kobe Steel have eight bar and rod mills and hence they can align their production on different mills so as to get minimum changes in the sizes to be rolled in any of these mills.

In India, a joint plant committee allocates quarterly production programmes among the six integrated steel plants (five in the public sector and one under private management) to maximise the sizes of production campaigns in each plant especially the rolling mills. The benefit of economics of operating costs resulting from these production alignments has been invoked as a reason in some countries for grouping several steel plants under one public sector authority such as the British Steel Corporation in United Kingdom, Finsider in Italy, Usinor in France and Ensidesa in Spain.

Imbalances between the capacities of ironmaking and steelmaking facilities of some integrated steel plants in West Germany are reduced by transporting hot metal produced in blast furnaces in one plant over long distances to steelmelt shop in another plant. In India, it is proposed to adopt the vertical pattern of production alignment for production of cold rolled stainless steel sheets. Stainless steel slabs will be produced at the Alloy Steels plant, Durgapur, hot rolled in the existing hot strip mill at Rourkela and cold rolled in the new mill presently under installation at Salem after transporting hot rolled strip over a distance of more than 1000 Km.

Examples of mergers of integrated steelworks in recent years based on considerations of economies of vertical as also horizontal production alignments are

- Hoogovens, Netherlands and Hoesch-Werke, Germany into a single group Estel; and
- Neunkirchen-Eisenwerke and Rochling Burbach both of West Germany into Arbed, Luxembourg.

Global supply potential

As already mentioned, the international trade in steel accounts for about one-fourth of the world steel production and the massive inputs of steel industry such as iron ore, coking coal, pellets, scrap, ferro-alloys, graphite electrodes, mill rolls, refractories etc are in many cases either procured through overseas investment or are traded very widely. The international prices of steel products and to a considerable extent the inputs are set by the operating rate (ratio of production to the installed capacity) of the industry. The foreign exchange savings through development of steel industry in developing countries depend on the trends of these international prices. Therefore, global performance of the industry and its steel supplies influence its course in developing as also the industrialised countries.

The global supply potential can be assessed with reference to the installed capacities, capacity increases in existing installations due to productive innovations and modernisation accompanying replacement of older plants.

Following the technological innovations of agglomeration for ironmaking, oxygen steelmaking, continuous casting and strip mills and escalation of scale of operations necessary to realise economies of most of these innovations, the steel industry in Japan and the European Coal and Steel Community (ECSC) expanded at a rapid pace through 1960s and early 1970s as will be evident from the following pattern of evolution of capacities in three major steel producing regions:

Regional steel capacity - million tons

Year	USA	ECSC-6	Japan	Total of regions
1960	135	76	25	236
1970	141	127	104	372
1978	143	174 E	144 E	461
Annual growth rate 1968-78 %)	0.3	4.6	9.7	

Source: The Economies of the Current Steel Crisis in OECD Member Countries by Dr Crandall, OECD Symposium on the Steel Industry in the 1980s, 1980, Paris.

The unprecedented massive expansion of steel industry in ECSC and Japan which added 217 million tons of steelmaking capacity between 1960-1978 followed by an equally unprecedented recession in the steel consumption of industrialised countries since 1975 has brought about a situation of excessive idle capacity in these regions.

The proportion of continuously cast steel output has been rising rapidly throughout the world as shown below:

Region		Proportion of continuously cast crude steel output-%		
		1974	1978	1979
EEC-9	..	12.6	28.9	30.9
USA	..	8.1	15.2	16.7
Japan	..	25.1	46.2	52.0

Source: World Steel in Figures, 1980, IISI

As the yield from liquid steel to semis with continuous casting is about 10 per cent higher than that with the ingot casting and primary rolling, the capacity of all backward integrated facilities upto steelmaking stage increases effectively in terms of finished steel production with the introduction of continuous casting. During 1974-1979 period, EEC-9 have achieved approximately five per cent increase in yield thereby raising their effective capacity in terms of finished steel for the same liquid steel capacity. Japan rolled substantially larger quantity of finished steel in 1979 than the boom year of 1973 from lower quantity of crude steel as can be seen from the following comparison:

		Production - million tons			
Year	Crude steel	Ordinary steel products	Special steel products	Total steel products	Yield from crude steel - %
1979 ..	111.7	..	..	100	89.5
1973 ..	119.3	85.6	9.2	94.8	79.5

With replacement of every 2 per cent of crude steel ingots by continuously cast semis in EEC, USA and Japan, their installed steelmaking capacity will increase by one per cent or about 5 million tons. Similarly, the production capacity of some steelmelt shops has been raised above the nominal capacity through measures such as upgrading of raw materials quality and installation in electric arc furnaces of water-cooled panels, oxy-fuel injection and by increasing furnace power input.

The theoretical life cycle for replacement of old plants is generally accepted as 25 years. However, in practice this replacement is accelerated by certain factors and retarded by others as illustrated below:

Accelarating factors	Retarding factors
1. Innovation of new technological processing such as emergence of oxygen steelmaking which led to a steep fall of open-hearth steelmaking.	1. Escalation of plant installation costs and interest rates due to inflation.
2. Burden of higher operating costs of old plants due to sharp increase in raw material and labour costs	2. Financial stringency due to non-availability of funds from the internal and external sources.

The capital-output ratio of steel industry improves substantially upto a certain limit with augmentation of steel capacity through expansion as compared to greenfield plant installation due to more intensive utilisation of the existing in-plant and infrastructure facilities. The expansion can be accomplished by brownfield expansion - that is, addition of an entire capacity module of all or almost all vertically linked stages of steel production or by rounding out expansion of one or several of the vertically linked production stages. The investment requirement for round-out method may range between 55 and 65 per cent of that for greenfield installation, the corresponding requirement for brownfield expansion are higher and may vary from 65 to 75 per cent of that for greenfield installations. Though the operating costs with brownfield installation may be comparable or somewhat lower than that of the greenfield installation, the operating costs with rounding out may not be much different from that of the original plant, unless process changes or improvements are adopted. The available potential for capacity expansion (in million tons per year) in the three major steel-producing regions is estimated to be of the following order:

	USA	Japan	ECSC	Total of 3 regions
Brownfield expansion ..	10	20	15	45
Round-out expansion ..	20	20	15	55

These convenient expansion opportunities available to developed countries can be regarded as competition to development of steel industry elsewhere in the world.

RAW MATERIALS

The quality of raw materials influences the process selection and the productivity of the primary production units, viz. iron and steelmaking.

Iron ore

The iron ore quality for blast furnace/direct reduction use is improved by agglomeration, sizing and blending to achieve consistency and desired standards of physical and chemical characteristics. The average Fe content of ores used in blast furnaces is estimated to have moved up by 10 per cent during 1955-1976 period due to development of high quality ore mines and improved beneficiation and concentration technologies. For direct reduction processes however, supergrade iron ore/pellets with plus 66% Fe are used to minimise gangue content in sponge iron. On a global basis the role of lump ores in ironmaking by blast furnace has declined precipitiously whereas that of sinters and pellets has increased steadily as may be seen from Table 8.

TABLE 8 - CHANGING PATTERN OF IRON ORE CONSUMPTION IN THE WORLD - 1955-1976

Iron ore	Unit	1955	1960	1965	1970	1976
Average Fe content	Per cent	47	49	52	56	57
Production	mill.tons	378	512	624	768	877
Use as:						
Lump ores	mill.tons (per cent)	309 (77)	319 (63)	298 (48)	273 (35)	237 (27)
Sinter fines	-do-	92 (23)	171 (34)	281 (45)	381 (50)	455 (53)
Pellet feeds	-do-	2 (0)	16 (3)	47 (7)	118 (15)	167 (20)

Source: Calculations based on iron ore (actual weight and Fe content), sintered ores and pellet production data in UNCTAD tabulation TD/B/IPC/IRON ORE/AC/4

Closer sizing of the ore and screening out the fines before charging into the furnace significantly improves the blast furnace productivity and reduces coke consumption. In Japan, for instance, the lump ore is sized to 8 to 25 mm for use in large blast furnaces to ensure best performance. The fines are screened out at the blast furnace plat itself so that the -5 mm fraction going into the furnace is less than 2 per cent. In contrast, in the Indian blast furnace practice, the top size limit of the lump ore used ranges from 50 mm to 80 mm, while the bottom size limit is 10/12 mm. In the absence of rescreening facilities at all Indian steel plants except one, the lump ore charged into the furnace carries with it a high proportion of fines.

Uniform blending of ore requires an elaborate system of stockpiling, bed blending in large piles and reclamation of the pile over its entire cross-sectional face. In the latest integrated Indian steel plant where similar facilities except blending are installed, the blast furnaces have shown more consistent and efficient performance than those in the older plants.

Agglomerates

Proportions of sinter and pellet in the feed are determined by various considerations such as optimisation of the furnace productivity, characteristics of available ore and utilisation of waste materials in the steel plant. The cold state strength of (acid) pellets is superior to that of sintered ore. Sintered ore has better high temperature strength (or better melting characteristics) and wider range of chemical composition adjustment. Development of self-fluxed and super-fluxed sinters has made the metallurgical and economic advantages of the use of sinter quite attractive. Use of sinter leads to improved productivity of blast furnaces, savings in coke consumption, reduction in the dust loss from blast furnace and smoother smelting operation. Sintering enables use of lower grade iron ores after beneficiation, ores containing sulphur and arsenic as well as various plant wastes such as coke breeze, mill scale, limestone and dolomite fines, lime fines and flue dust which would otherwise have to be dumped and would add to the operating costs.

By operating the blast furnace on 30 per cent lump ore and 70 per cent superfluxed sinter burden, addition of raw limestone in the blast furnace can be totally eliminated. Blast furnace productivity could thereby be raised. It is estimated that under Indian conditions, the productivity of blast furnace could thereby be raised by about 20 per cent and the coke consumption could be reduced by about 150 kg per ton of hot metal. The economies of sintering is so attractive that in many Japanese plants, lump decrepitating ores are crushed and sintered with advantage (instead of being charged directly into the blast furnace), thus avoiding the troubles caused in smooth furnace operation.

By virtue of their size uniformity, high strength and uniform micro-porosity which ensure good gas permeability and reducibility, use of pellets reduces coke consumption rate, increases output and improves operation of blast furnaces like sinter. In the Whyalla plant in Australia, substitution of 100 per cent lump ore with 80 per cent pellets and 20 per cent lump ore in the charge improved the blast furnace productivity from 1.43 to 1.77 tons per day per cu m of useful volume and reduced coke consumption rate from 674 kg to 567 kg per ton of hot metal.

Generally, sinter fine tends to be cheaper form of feed material for blast furnace. The TEX manual for iron ore shows 1976 prices for the three forms of feed materials for Japan as follows:

Ore type	Fe content %	1976 price -f.o.b.Australia	
		US $/Ore ton	US ¢/unit Fe
Sinter fines	62	11 - 14	18 - 23
Pellets	63 - 67.5	21 - 24	33 - 36
Lump ore	64 - 66	13 - 18	20 - 27

The use of pellets produced from beneficiated taconite ores is common in USA, whereas in Japan and Western Europe - both of whom depend predominantly on imported ores and also in USSR, high percentage of sinter is used for furnace charge. However, among developing countries sintered ores are estimated to account presently for less than 40 per cent of the blast furnace burden. In some developing countries such as India, higher proportion of sinter is used.

Mines

Development of mines and infrastructure for the mines is highly capital-intensive. The investment to develop the mines and the infrastructure to produce 30 million tons of ore per year at Carajas, Brazil was estimated at 1978 price at US $ 2.33 billion (about US $ 80 per ton of ore/year) including an amount of US $ 1.08 billion for the railway transport. Construction of the railway to the mines involves laying of 887 Km long railway track, 75 million cu m of earthwork, 8 Km of bridge, construction of deep water port to handle 300 000 dwt ships and deployment of block trains with gross payload of 13 000 tons consisting of 160 wagons and locomotives with 3 600 HP.

The original project size had to be curtailed from mining of 50 million tons of ore per year to that of 30 million tons when the US Steel who held 49 per cent of the shares of Amazonia Mineragao sold their participation to CVRD, Brazil in 1978.

Long-term contracts for ores and pellets

In view of the far-reaching effects of the quality of raw materials on the steel plant production and also to protect against wide fluctuations in prices, the major steel producers have either their own captive mines or enter into long-term contracts with iron ore suppliers. Traditionally the steel industry has developed near the raw material sources. Concentration of steel plants around the Lorraine ores in France and around the Great Lakes ores in USA are good examples. To meet their increasing ore requirements, some steel companies operate captive mines in other countries also. For instance, the Quebec Cartier Mines in Canada is owned by the US Steel Corporation, and the Iron Ore Company of Canada is owned by Bethelehem and Republic Steel Corporations. The Sidbec-Normine pellet plant at Firelake in Canada is a joint venture of Sidbec (Canada), British Steel Corporation and Quebec Cartier Mining Company.

Since the 1960s, there was a marked swing towards the use of imported ores in many developed countries as can be seen from the following chronological increase in the percentage of imported ores in a few selected countries:

Country	Percentage of imported ore		
	1950	1961	1975
U.S.A.	8	28	33
U.K.	41	47	77
West Germany	34	63	93
Japan	63	94	99

The spectacular rise in the Japanese steel production was all based on imported ores. All Comecon countries except USSR have developed steel industry based predominantly on imported ores as the Fe content of their domestic ores ranges only from 25 to 35 per cent. The iron ore resources of the major steel producing Western countries (except three Scandinavian countries and South Africa) were getting depleted, and at the same time there was a growing demand for iron ore due to the global increase in steel production. These factors led to the development of large mechanised mines in several countries endowed with vast reserves of high grade ores. Simultaneously, bulk carriers for transport of iron ore were introduced to cut down ocean freight on long hauls. As a result, the international trade in iron ore got a tremendous boost and several countries established coastal plants similar to those in Japan, based on imported ores.

In order to ensure uninterrupted and adequate supply of ore, Japan has adopted from 1960s the policy of entering into long-term contracts with the iron ore suppliers. The first long-term contracts for supply of iron ore were signed by the iron ore mines in Peru and Chile with the Japanese steel mills. Following discovery of vast iron ore deposits in Australia, several long-term contracts were concluded between the Australian suppliers and overseas buyers mainly the Japanese steel mills during 1965-1973. The increasing dependence on distant overseas suppliers has promoted steel producers in other countries to ensure security of supply on the same pattern as exemplified by the long-term contracts of the Pohang steelworks in South Korea and Kaohsing in Taiwan with the Australian mines.

Many steel companies have also financial participation in the development of the mining ventures in other countries. For instance, the Nimba mines in Liberia involve American and Swedish capital. The Miferma Company which operates mines in the Fort Gourad area in Mauritania comprises majority holding by the French with additional British, Italian, German and Japanese investment. It is understood that Mifergui Nimba is owned 50 per cent by Guinea Government and the balance 50 per cent by a number of other countries. Table 9 shows the pattern of investment and the financial support extended by the Japanese to develop iron ore mines round the world. With partial contribution of Japanese steel industry's investment during 1969-79 period on the iron ore mines, the relevant transport infrastructure and township in Australia has amounted to $ A 2.2 billion (about $ 4.4 billions at 1979 prices).

TABLE 9 - MAJOR JAPANESE IRON ORE MINE DEVELOPMENT OVERSEAS PROJECTS AND LONG-TERM CONTRACTS

Name of mine (country)	Year of start	Output t/yr	Supply to Japan t/yr	Japanese investment share	Japanese companies' investors or financiers	Remarks
		'000 t	'000 t	%		
Already producing or starting construction work Savage River (Australia)	1968	2 500	2 500	50	Mitsubishi Corpn Sumitomo Corpn	
Mt.Newman (Australia)	1969	40 000	22 650	10	Mitsui & Co Ltd C. Itoh & Co Ltd	
Robe River (Australia)	1972	15 000	10 300	30	Mitsui & Co Ltd	
Hamersley (Australia)	1966	40 000	24 500	6.2	Six major steelmaking companies; Mitsubishi Corpn Marubeni Corpn	Bought stock in 1973
Aguas Claras (Brazil)	1973	10 000	7 000	20	Six major steelmaking companies; five trading companies	Indirect investment and direct finance
Nibrasco (Brazil)	1977	6 000	6 000	49	Six major steelmaking companies; Nissho-Iwai Co Ltd	Pellet production facilities
El Algarrobo (Chile)	1977	3 500	3 500	Finance only	Mitsubishi Corpn	Pellet production facilities
Chowgule (second pellet facility) (Goa, India)	1978	1 800	1 800	Finance	Six major steelmaking companies; Okura & Co Ltd Mitsubishi Corpn	Pellet production facilities
Miferma (Mauritania)	1973	10 000	2 200	Finance only	Nichimen Co Ltd Toyo Menka Kaisha Ltd	Production facilities for Japan in 1972

Source: Japan's Iron and Steel Industry, Annual Review - 1978

Scrap

The current international annual trade in steel scrap is of the order of 18 to 20 million tons, of which a major part is accounted for by the scrap movement within ECSC, especially to Brecia region of Italy from other member countries of ECSC. (Over 50 per cent of the current annual steel production of 24 million tons in Italy is by electric steelmaking). Outside ECSC, the countries surplus in scrap are USSR and USA. USA exports scrap to the tune of about 8 to 10 million tons per year. Eight countries, viz Canada, Spain, Italy, Japan, Mexico, South Korea, Taiwan and Turkey have together accounted for about 85 to 90 per cent of USA scrap exports during 1973-1978. Outside Comecon, scrap exports from USSR have been of the order of 1.5 million tons a year.

Worldwide, the share of electric steel in the total crude steel production has increased from about 14 per cent in 1970 to about 19 per cent in 1978; by the turn of the century, this is expected to rise to about 40 per cent. In the USA, the proportion of electric arc furnace steel has correspondingly increased in recent years as follows:

	1976	1977	1978	1979
Electric steel proportion,% of total	19.2	21.9	24.5	26.0

Further, with a view to maximise recycling of secondary material resources within the country, the Findlay Amendment of the Export Administration Act of USA has imposed certain restrictions on export of scrap from USA.

Availability of cheap labour in South-East Asia and to some extent Spain has favoured creation of a flourishing trade of breaking of discarded ships and establishment of mills to reroll this ship scrap.

Sponge iron

Scrap had been the only raw material for steelmaking in electric arc furnaces. With the increasing proportion of electric arc furnace steel in the world steel production and the limited supply of scrap, the use of sponge iron to substitute part of the scrap is becoming attractive. Besides, sponge iron will have a stabilising effect on the rising prices of scrap, and providing a high quality feed stock free of tramp elements, which are increasingly contaminating steel scrap.

Future reduction of exports of steel scrap from USA could lead to increase in the production and international trade of sponge iron to fill in the supply gap. The worldwide direct reduction capacity in 1979 was about 22 million which is expected to increase to about 34 million tons in the next 5 to 6 years. Jointly with Korf Stahl AG, A/S Sydvaranger, Norway is presently installing 0.88 million ton capacity sponge iron plant - Nord Deutsche Ferrowerke AG at Emden, West Germany. The project has been financed through German loans and investment funds of the German authorities. The pellets for the plant operation will be supplied from the Kirkene plant in Norway. Though the plant is expected to be commissioned only in 1981, full future production of sponge iron is already sold on long-term contracts to consumers in West Germany, Italy and UK. Korf Stahl is now planning to raise the annual capacity of this plant by an additional 1.3 million tons. The feasibility of setting up a sponge iron plant based on HyL process is reported to be under examination for supplying sponge to substitute steel scrap in several electric furnace installations in Mexico. The direct reduction (HyL) plant at Khor-el-Zubair in Iraq has provision for export of about 700 000 tons per year of sponge iron during the period of transition till expansion of the plant through the second phase.

ENERGY

The iron and steel industry is the largest single energy consuming industry of the world. For example in 1973, it accounted for about 7 per cent of the total global energy consumption. In the United States and Western Europe, it required about 13 per cent of final energy consumption and 30 per cent of industrial energy consumption. In the iron and steel industry, the energy is used both as reductant and as fuel. The wide variation in the energy consumption per ton of crude steel in different plants is largely due to the influence of a number of local factors such as the quality of raw materials, the scale of operations, the process route and the energy-saving devices employed.

It is observed that between 1960 and 1973 the energy consumption rate per ton of crude steel dropped by 47 per cent in Japan, 35 per cent in UK and 27 per cent in USA. With judicious selection of energy saving equipment and raw material controls, the Japanese steel industry has brought down the energy consumption per ton of liquid steel to 5.5 G Cal per ton as compared to the current average consumption of

7, 8 and 12.5 G Cal per ton in the integrated steel plants of West Germany/USA and India respectively.

Coking coal

The availability and cost of energy has been one of the major factors guiding the technological changes. For the conventional iron and steelmaking route based on coke ovens, blast furnace and oxygen steelmaking process, the availability of metallurgical coke is an important factor. Good quality metallurgical coke is scarce and expensive. Following the increase in oil prices, the c.i.f price of imported American coking coal to Japan has increased three-fold from US $ 26 per ton in 1970 to US $ 81 in May 1980. Various techniques, such as selective preparation of coal, briquette blending, hot charging and dry quenching of coke have been developed which enable use of increased amounts of inferior coal in the coal blend and production of improved quality coke. Dry quenching of coke permits heat recovery, equivalent to about 1 370 MJ (or 0.327 G Cal) or 0.5 ton of steam per ton of coke. Apart from the energy recovery, dry quenching also reduces environmental pollution. As already mentioned, coke consumption in the blast furnace is being reduced by suitable raw material preparation techniques, use of high percentage of agglomerates such as pellets and sinter, increase in the blast temperature etc.

Limited and expensive supply of coking coal continues to be a serious constraint on development of steel industry in developing countries. Unlike iron ore, the coking coal deposits of developing countries are limited to only 5.2 per cent of the known world deposits and bulk of these are concentrated in six countries as follows:

	Total developing countries	China	India	Colombia	Mexico	Brazil	Chile
Quantity (mill.tons)	22 167	9 500	10 077	2 100	210	150	70
Share of world (per cent)	5.2	2.2	2.34	0.5	0.05	0.03	0.016

Of these, the net availability of coal for use at the coke ovens in India is estimated variously at 5 100 million tons and it is apprehended that these reserves may not last beyond 100 years The cost of production of the Brazilian steel industry and the foreign exchange drain on the Brazilian state exchequer continues to be high due to the necessity to import coking coal. The ash content of coking coal in the iron and coal belt of India is reported to be rising as deeper seams are being worked. The current ash content of coking coal is as high as 28 per cent against only 8 per cent in the coking coal used in the Japanese steel industry. As a result of this increase in the ash content, either the output of washed coal from the washeries which were installed to minimise ash content of the run-of-mine coal has to be reduced or the ash content in washed coal needs to be raised which affects the blast furnace productivity adversely. Following successful laboratory and bench scale tests, pilot plant work has been recently taken up to release mineral matter (that is ash) by agglomeration technique to reduce ash content to range of 5 to 12 per cent. Coals recovered from different seams in India show variations in volatile content, coking property and ash content. These variations in the quality are carried over to the blast furnace feed through the coal washeries and those also affect the blast furnace operations. Efforts are being made in India to obtain supplies from collieries for washeries which do not vary widely in their ash and volatile contents.

The energy price hike of 1973 has brought about global revival of the decadent collieries and stimulated investments on an unprecedented scale. In the European Economic Community, the annual capital expenditure on collieries which had declined from 400 million European units of Accounting (EUA) in 1965 to 250 million EUA in 1973 has galloped every year since 1974 reaching a level of 1 000 million EUA in 1979. The capital investments on the collieries in the Community have consistently exceeded the annual investment target of 500 million EUA (at 1973 prices) laid down for the period 1975-1985 in the 'Medium-term Guidelines for Coal'.

In contrast, the Far East countries - Japan and South Korea have ensured security of long-term supply of coking coal through long-term contracts with financial participation in the overseas coal mining projects. The major coking coal mine development projects which financed or are partly controlled by the Japanese shareholding are summarised in Table 10.

TABLE 10 - MAJOR [illegible] OF [illegible]

Mine (Country)	Year of start	Output	Supply to Japan
		'000 tons per year	'000 tons per year
Moura (Australia)	1965	4 000	4 000
Goonyella (Australia)	1971	5 000	4 000
Peak Downs (Australia)	1972	5 000	3 000
Saraji (Australia)	1975	4 000	2 700
Balmer (Canada)	1970	5 000	4 750
Smoky River (Canada)	1970	2 000	1 500
Lancashire No. 20 (United States)	1972	714	714
ICC VP4 (United States)	1974	1 800	1 800
Kellerman (United States)	1974	1 300	1 300
Mulga (United States)	1975	1 500	1 000
Cerro (United States)	1975	1 800	1 000

[illegible] JAPAN

Japanese investment share	Japanese investors & financiers	Remarks
%		
20	Mitsui & Co. Ltd.	
15	Mitsubishi Corpn	
15	Mitsubishi Corpn	
1&	Mitsubishi Corpn., major steelmaking companies; gas, coke companies	Steel, gas, coke making companies financing a railroad.
27.9	Mitsubishi Corpn., seven major steelmaking companies; gas, two coke companies	Buying additional shares
Finance only	Eight major steelmaking companies; gas, two coke companies	Financing in 1974
Finance only	Tokyo Boeki Ltd	
Finance only	Nissho-Iwai Co. Ltd.	
10	Ataka & Co. Ltd.	Expansion from 600 000 tons to 1 300 000 tons owing to Japan's entry in 1974
Finance only	Sumitomo Corpn.	
Finance only	Sumitomo Metal Industries Ltd Mitsubishi Corpn.	Expansion in 1975

Non-coking coal

With the installation of briquette-blend coke plants, it has become possible to use in the coke ovens briquettes of non-coking and weekly coking coals with pitch binder up to 20 to 25 per cent to minimise the impact of rising coking coal prices. Further innovations and perfection in the formed coke techniques during the eighties - which are being currently tried out in the pilot plants - may permit use of non-coking coals to a much greater extent.

The gradual improvements in performance of kilns for direct reduction of iron ore with the use of non-coking coal as a solid reductant at Dunswart plant in South Africa and another at Glenbrook in New Zealand, Piratini in Brazil etc open up possibility of using non-coking coal of certain grades. Recently, Siderperu are planning to install direct reduction kilns and electric arc furnaces for their Chimbote plant expansion to save recurrent foreign exchange outgoing on import of coking coal that would become necessary with the installation of an additional blast furnace.

Charcoal

Argentina, Brazil and Malaysia have operating blast furnaces based on charcoal derived from their extensive forest resources. Brazil, leading in this mode of hot metal production, has produced about 4.4 MT pig iron in 1979 from 134 blast furnaces. Production of hot metal through charcoal was considered uneconomical and cumbersome since recently in view of its requirement of huge forested area as well as manpower compared to the conventional coke-based blast furnaces. However, the rise of fossil fuel prices has changed the economies and Brazil alone is thinking of producing about 10 MT pig iron in 1990 by use of charcoal. Other parameters which have made charcoal-based production attractive are improved production methods of charcoal, improved forestration and better utilisation of by-product. Present estimation is production of 0.5 MT per annum pig iron could be maintained by 50 000 hectares area of forest.

However, hot metal production by use of charcoal could only be limited to those countries which have suitable climate for the growth of woods, availability of land in abundance and also shortage of or no supply of metallurgical coke. In countries, where metallurgical coke is available, there have been no or very limited growth of charcoal-based blast furnaces for production of pig iron.

Electricity

In some industrialised countries, steel industry accounts for about one-tenth of the total electricity consumption the generation of which is highly capital intensive. Assuming the capital requirement for thermal power generation to be of the order of US $ 500 per kW of installed capacity, 60 to 75 per cent annual load factor and stand-by capacity of 25 per cent of the firm generation capacity, capital requirement for electricity generation to operate the steel plants is approximately of the following order:

Process route	Specific power requirement kWh/ton(1)	Firm generation requirement kW/ton	Investment for power generation $/ton
Blast furnace-Basic oxygen steelmaking	450 - 500	0.085	53
Direct reduction-electric arc furnace route	1000 - 1100	0.2	125

NOTE: (1) per annual ton of liquid steel including power requirement for rolling

Natural gas

The price of natural gas which has been used for ironmaking by the direct reduction route and also as a clean fuel for preheating of ladles in the steel-melt shop and annealing furnaces in the cold rolling mills has risen manifold, the current price of natural gas supply to some of the integrated plants in West Germany being of the order of DM 30 (US $ 16.66) per Gcal. The high price of natural gas is already reported to have led to the closure of direct reduction plant in Oregon, USA. The insistence of Oil & Natural Gas Commission of India to supply natural gas to Western India only at a price that will maintain parity with that of petrol is reported to have deterred growth of direct reduction plants in the coastal belt of Western India. This region is favourably situated with respect to supply of iron ore/pellets from the South-west India and piped natural gas supply from the major off-shore 'Bombay-high' oilfield. On the other hand, supply of natural gas at the rate of US 20 cents per million BTU has been the raison d'être for establishment of steel industry in Qatar - a small territory with a population of 200 000. The Norwegian government has stimulated and fostered establishment of market-based direct reduction plant in North Europe at Emden by assuring supply of natural gas at low price from the North Sea Ekofisk fields.

The specific natural gas consumption in some of the Midrex direct reduction plants is reported to have been reduced to values as low as 2.6 Gcal/ton of sponge iron. with the use of preheaters to heat air with the waste gases; research is now directed to lowering it down to 2.4 Gcal/ton which is close to the thermo-dynamic requirement of 2.3 Gcal/ton, with 100 per cent operation efficiency. The major advantage claimed for the Purofer direct reduction process is the possibility of hot sponge charging (70%) leading to electricity saving of approx. 150 kW-/ton of liquid steel produced in electric arc furnace.

Energy recovery from waste heats

Nippon Steel has invested about US $ 200 million during 1978 and 1979 in energy-saving installations - blast dehumidifiers (to reduce moisture from 15 g/Nm3 to 5 g/Nm3), expansion turbines with power generators operated with high pressure blast furnace top-gas and waste heat recovery from hot stoves. As of the end March 1978, there were in Japan seven blast furnace top pressure turbines in operation with an aggregate output of 80 000 kW. Evaporative cooling of reheating furnaces recover the heat in the form of steam. A steam generation process to recover sensible heat of the red hot slabs with the installation of slab cooling boiler before the cooling beds was installed in 1976 at the Mizushima Steelworks of Kawasaki Steel. Hot charging and direct rolling of slabs was tried first in 1974 in Nippon Steel's Nagoya works in Japan. By March 1978, seven other steel plants in Japan had adopted this technique. The energy-saving in direct rolling is of the order of 0.25 to 0.30 Gcal per ton of steel product. The continuous casting route, compared to the ingot practice has substantially contributed towards energy saving - 70 to 80 per cent lower energy consumption than the ingot route. For instance in Japan, the energy saving per ton of continuously cast semis is reported to be between 0.17 to 0.32 Gcal Many converter shops recover the LD gas which has calorific value of about 2000 Kcal per cu m. The gas recovery is about 55 to 60 cu m per ton.

TECHNOLOGY

The salient technological trends of innovations for raising the equipment productivity, improving the product quality and reducing the operating costs at the different stages of ironmaking, steelmaking and rolling are summarised in Table 11. Evolution of innovations in the rolling mill technology during the last 25 years which has multiplied the production capability of rolling mills is illustrated in Table 12 with reference to the important performance parameters.

Ironmaking and steelmaking

With the implementation of the various innovations on blast furnaces, Japan has been able to reduce the coke rate to 410 kg/ton iron (supplemented with injection of 50 kg of heavy oil per ton), which is the lowest in the world.

In the field of basic oxygen steelmaking, the advantage claimed for the bottom blown process over the top blown process is saving in operating cost to the extent of about US $ 1.5 to 2 per ton of liquid steel resulting from the improvement in yield by about 0.5 to 1.5 per cent due to the absence of slopping, lower iron oxide in the slag and lower fume and dust losses. This process enables the production of extra low carbon steel as well.

Combined oxygen blowing process which includes the facilities for top blowing as well as blowing from the bottom is being tried. This process offers the advantages of higher scrap melting capacity of the top blown process as well as quiet blowing conditions of the bottom blown process.

TABLE 11 - TRENDS OF TYPICAL TECHNOLOGICAL INNOVATIONS AT DIFFERENT PROCESSING STAGES

Coke ovens

Tall ovens to increase throughput
Pipeline charging of hot coal to reduce time of carbonisation

Sintering

Increase in suction grate areas (upto 550 sq m)
" On-strand " cooling to ensure pollution control, improve availability, sinter quality, reduce coke breeze and return fines

Ore preparation and agglomeration

Higher quality raw materials
- Improve beneficiation process to meet demand for higher grade ores for DR-process
- Closer sizing to ensure uniform feed
- Improved bedding to ensure constant ore chemistry
- Increased use of fluxed pellets and sinter to improve BF productivity

Blast furnace

Higher productivity
- Better sizing and blending of raw materials
- Better coke
- Use of pellets and sinter in increased proportions
- Higher hot blast temperature (over 1200°C)
- High top pressure operations (upto 3 kg/cm^2)
- Use of demoistured and oxygenated blast with oil and tar injection
- Improved burden distribution and control

Basic oxygen furnaces

Higher productivity and thermal efficiency
- Development of sensors and computer systems for accurate end-point control
- Improved refractory performance
- Improvement in off-gas recovery rates

Electric arc furnaces

Higher productivity
- Continuous feeding of sponge iron
- Addition of oxy-fuel burners
- Ultra-high powering
- Water-cooled wall panels and roofs
- Split shell design

Continuous casting

Higher productivity and better product quality
- Higher casting speeds
- Larger-sized cast products
- Improvements of turrets, tundish rotation, tundish linings, liquid metal stream protection
- Automatic mould width adjustments during casting
- Automatic controls for ladle metallurgy, mould level, secondary cooling, product cutting and discharge
- Electro-magnetic stirring

Wire rod mill

Higher rolling speed/strand capacity
- No-twist finishing blocks and controlled cooling lines contribute closer tolerances and improved surface quality of wire rods; use of carbide rolls result in shorter downtimes.
- Design of 1-strand and 2-strand mills to match annual production of 2-strand and 4-strand mills of first generation

Merchant bar/medium section mill

Rolling of sections in cortinous mills
- Improvement in design of mechanical equipment
- In-line controlled cooling of bars from rolling temperature

Higher dimensional accuracy
- Development of measuring instruments permitting continuous check of tolerance & avoiding defects

Higher billet weights (upto 4 to 6 tons)
- Improved rotary hot shears to permit accurate cutting of the bar from end

Shorter downtimes
- Quick changing devices for stands, rolls and guides

Minimisation of short-lengths and their quick removal
- Development of special shear, cooling bed and bundling devices

Heavy section mill

Higher stand rigidity, shorter downtimes, closer product tolerance
- With development of compact mill stands

Plate mill

Closer product tolerance and better surface finish
- High rigidity stands with 4-motor screwdown, computerised thickness control and work roll bending device

Shorter delay time
- Automatic quick roll-changing device
- Hydraulic screw-down system

Improved finishing facility
- Forced air cooling
- Carrier-grid cooling beds
- High-speed pilers
- "Roll-on" type side trimming shears

Hot strip mill

Higher productivity and product quality
- Finishing train stands with
  - i) housing mounted roll balancing systems
  - ii) hydraulic screw-down
  - iii) quick roll changing device
  - iv) coil box before finishing stands to minimise temperature difference between head and tail ends of coils
  - v) Accelerated rolling on the finishing stands

Cold rolling mill

Higher productivity and product quality
- High degree of process automation
- Quick work roll changing device
- Hydraulic screw-down, work-roll bending and automated flatness measuring and control devices
- Endless cold rolling

Processing lines

Higher productivity and low cost strip Processing
- Continuous annealing and processing line (CAPL) including electrolytic cleaning, annealing, coil cooling, temper rolling and inspection
- High-speed compact electrolytic galvanising lines
- Higher speeds in continuous aluminising, galvanising and copper-plating lines

TABLE 12 - PACE OF TECHNOLOGICAL DEVELOPMENTS IN ROLLING MILLS FOR SELECTED PRODUCTS

Consideration	Unit	Generation of mill design 1	2	3
Wire rod mill				
Evolution period ..	Year	1966-1971	1971-1976	1976-1979
Rolling speed on finished stand 5.5 mm dia rod - guaranteed ..	m/sec	43-40	50-61	61-75
Max. billet size ..	mm	110	110-120	120-130
Average output per strand ..	tons/hr	19-26	29-34	37-50
Average production per strand as no. of strands increases				
One ..	'000 t/yr	180	240	300
Two ..	'000 t/yr	165	220	270
Three ..	'000 t/yr	145	200	240
Four ..	'000 t/yr	130	180	210
Hot strip mill ..	Year	1953	1961	1973
Type ..		Semi-continuous	Three-fourths continuous	Continuous
Typical installation ..		Fairless	Great Lakes	Bremen
Coil weight - final stage	kg/mm width	10	18	23.6 (36)
	tons	8-10	20-25	30-45
Slab length ..	m	6.1	9.2	15
Max rolling speed on finishing stand ..	m/sec	11.8	15.2	23.6 (28)
Range of strip thickness ..	mm	1.5-6.3	1.2-12.7	1.2-20.0
Roughing stands ..	number	1	1 to 2	2
Finishing stands ..	number	5 to 6	6 to 7	7
Motor rating of finishing train ..	kW	21 600	35 200	81 000
Strip width ..	mm	2 057	2 032	2 300
Annual production ..	'000 t	1 000	1 800-3 000	3 500-4 500
Product tolerance ..		Coarse	Semi-coarse	Close

Tandem cold rolling mill		Initial mill	Mill after modernization
	Year	1960	1977
Coil weight at entry ..	tons	18	46
Work roll change time	minutes	15	4
Screw-down speed ..	mm/min	12	140
Mill utilisation ..	per cent	65	80
Annual output ..	'000 t	900	1 200
Tolerance ..	per cent	± 2	± 1
Off-tolerance ends/coil	metre	60	15
Operators ..	number	9	6

External desulphurisation of hot metal is gaining increasing popularity not only because of the need to produce steels with very low sulphur levels to meet the stringent quality requirements of several grades of steel but also to increase the blast furnace productivity by operating with leaner slag even at the cost of higher sulphur levels in the hot metal.

In order to achieve higher production rates from the main steelmaking units such as the oxygen-blown converters and electric arc furnaces, secondary refining processes in the ladle are being adopted in many steel plants. This enables refining and final adjustments to be carried out in the secondary refining treatment, which increases the yield, reduces ferro-alloy consumption and considerably improves the steel quality.

Productivity of electric arc furnaces have been substantially improved by ultra-high power (UHP) operations, split-shell design, water-cooled side panels and oxy-fuel burners etc.

Continuous casting

The shapes of continuously cast semis are being diversified to approach more closely the requirements of attaining minimum mechanical reduction ratio. One continuous casting installation at Algoma in Canada and another in Japan are regularly casting dog-bone shaped semis for joists and channels which increase productivity of section rolling mills by lowering the mechanical reduction through rolling. In contrast, a slab caster in USA has been installed in 1978/1979 to cast wide jumbo slabs which are slit longitudinally with

with oxy-acetylene flame cutters into the required narrow widths to increase productivity of continuous casting machine and minimise in-process inventory of slabs through standardisation of sizes. Research has been concentrated to achieve breakthrough in the low-cost horizontal continuous casting technique which is being developed by different companies. Recently order for a horizontal continuous casting machine for commercial operation has been placed on a Japanese company. During the last few years, the centrifugal continuous casting process has been developed and adopted in a few plants for the production of round billets for seamless tubes. Electro-magnetic stirring is another development aimed at reducing the defects in the cast billets. More recently, the Magnetogyr process has been developed by IRSID, which is claimed to produce very high quality cast products.

Rolling mills

Walking beam furnace is being increasingly preferred to pusher furnace for reheating of semis for many applications in view of its higher flexibility of operation, higher yields and reduced operating costs. The investment difference between these two types of furnaces has tended to narrow down in recent years.

In the continuous annealing/processing lines (as installed at Nippon Steel's Kimitsu works and Nippon Kokan's Fukuyama works), it takes only 10 minutes to perform the job that required 10 days in batch processes connected with the annealing cycle.

The rolling speed on the finishing stands of hot strip mill has increased from 1 000 m/min to 1 600 m/min in a decade, whereas that for the cold mill has doubled from 1 250 m/min to 2 500 m/min. Similarly, for a new wire rod block to be installed at Oberhausen, West Germany, by 1981 the guaranteed rolling speed has been raised to 100 m/second from the corresponding current speed of 75 m/second.

Yields

High yields can be ensured with judicious equipment selection at the planning stage. As compared to the conventional rolling of ingots, the process of continuous casting improves yield by about 10 per cent. As aready mentioned, the OBM process could raise the liquid steel yield by 0.5 to 1.5 per cent compared to the LD process. The metallic scaling losses of the semis could be reduced with the walking beam type of reheating furnaces as compared to pusher type furnaces. Use of fine ore particles in certain direct reduction processes using gaseous reductants, recycling of sludge from the gas cleaning plant of LD converters for sintering and injection of sponge iron fines in electric arc furnaces can improve yields at the iron-making stage. Yield improvements have been realised by endless cold rolling (compared to rolling of individual coils) through reduction of crop losses and off-gauge material - plants using this arrangement are in operation in Japan and USA.

Constraints on technology

The technology and equipment of integrated steelworks in many developing countries generally tend to become outdated faster than in industrialised countries and the non-integrated steel industry in developing countries themselves. This is because developing countries start realising benefits of a new proven technology only after a lapse of 12 to 16 years of the commencement of its operation in industrialised countries due to following pattern of time-table:

Activity	Duration Years
1. Lead period of technology for demonstrable operation success in an industrialised country ..	3 to 5
2. Construction period for integrated steelworks after feasibility study	6 to 7
3. Gestation period for building up production near to rated capacity	3 to 4
Total ..	12 ro 16

Continuous innovations and development in industrialised countries during this lag period of 12-16 years renders the technology in developing countries considerably less modern. The technologies in developing countries tend to be even more outdated when the plants are set up under 'aid' from foreign countries.

The choice of technology for ironmaking and steel-making in the developing countries often gets conditioned to the capabilities of the supplier country in case of tied-aids. The technological developments in any particular field never take place simultaneously in all developed countries and even amongst them there is a time lag in their perfection. For example, in the mid 1950s when India embarked upon three major integrated steel plants, the Rourkela Steel Plant supplied by Germans included LD, the most modern steelmaking process at that time. On the other hand, the other two plants one at Bhilai built with Soviet aid and the other at Durgapur with British aid adopted the open-hearth steelmaking process.

In respect of blast furnace technology, the Soviets had provided facilities for high top pressure operation at Bhilai as early as mid-1950s; however this technique was not included for the other two plants at Durgapur and at Rourkela. A slabbing mill with capacity of 5.5 million tons per annum was supplied for the integrated steel plant at Bokaro, India for which aid agreement was concluded with the Soviet Union in 1966. This mill became operative only in 1975 by which time many integrated steel plants were set up in other countries for 100 per cent continuous slab casting.

In contrast in many industrialised countries technological obsolescence and maintenance costs increase with the plant vintage and consequently replacement economics becomes more favourable with increasing plant age. According to the Institute for Iron and Steel Studies, the repair and maintenance costs were over US$ 45 per ton in USA in 1976 largely due to their overaging plants as most of the American steel industry was established prior to 1955. In comparison, according to the same source these costs averaged only US$ 9 per ton in Japan mainly reflecting the young age of the Japanese steel industry. Among the three major steel producing regions of the free economies, USA, ECSC and Japan could be placed in descending order in respect to the vintage of their steel plants. The technological superiority in these three regions can be inversely correlated with their vintage as will be evident from the structural characteristics of their steel industry in 1976 as shown in Table 13.

TABLE 13 - INDICATORS OF OBSOLESCENCE WITH PLANT VINTAGE

	Unit	Japan	ECSC-6	USA
Steel capacity added since 1956				
Total ..	million net tons	151	119	44
Greenfield only..	million net tons	108	35	11
Steel capacity added since 1967	million net tons	107	64	59
Capacity of plants with deep water harbour	per cent	82	24	10
Capacity of 10 largest plants	million tons	115	63.6	59.1
Plant with crude steel capacity more than 6 million net tons	number	11	7	5
Blast furnaces with useful volume greater than 2000 cu m	number	37	17	6
Output per BOF in operation	million net tons	1.4	1.2	0.9
Average output of the largest BOF shops ..	million net tons	7.8	7.8	5.0
Output per operating mill				
Hot strip mill ..	million net tons	2.0	1.85	1.26
Cold strip mill	million net tons	0.52	0.36	0.23
Steel output with open-hearth and Bessember/Thomas converters	per cent	0.5	12.3	18.3
Proportion of crude steel output continuously cast	per cent	35.1	22.0	10.5
Operating practice				
Labour per ton of products	man-hours	9.31	11.94	11.57
Fuel rate in blast furnaces				
Coke plus oil ..	kg/ton	479	598	624

Source: Steel Industry Economics - A Comparative Analysis of Structure, Conduct and Performance by Hans Mueller and Kiyoshi Kawahito, 1976.

Automation

Simultaneously with increase in the size and operation speed of production equipment, process computers along with a new generation of instruments and automatic operation devices have been introduced in the steel industry in industrialised countries to optimise instantaneous operations of the production facilities and match the development of auxiliary facilities such as materials handling and product finishing.

For example by 1975, the Japanese steel industry had 381 process computers in operation for different functions as follows:

Production/process	Units	Auxiliaries	Units
Ironmaking	53	Raw material handling	37
Steelmaking	43	Energy control	17
Semi-product rolling	44	Chemical analysis	23
Rolling	142	Others	22
Sub-total	282	Sub-total	99

Total .. 381

As of January 1979, the number of computers in the steel industry in Japan increased to 853. These have led to higher productivity and yield, reduction of running inventories, greater uniformity in product quality, improvement in working environment, virtual elimination of errors with wider application of automatic data gathering and improvement in overall service to customers.

Automatic sequential controls for materials handling, crushing, screening, bedding and automatic sampling for raw materials have improved the burden preparation for ironmaking and coking. For agglomeration processes such as sintering, pelletising and also coking and blast furnaces, the on-line computer control is being fast perfected. In some plants the top-gas flow and temperature in blast furnace is being monitored and 'Stop-Go' system for close furnace operation control has been introduced. With the 'dynamic control' system for sub-lance operation the 'hit rates' have improved from 40% to over 90% in LD/OBM thereby minimising necessity of oxygen reblows. The major benefits accruing from this control system are reduction in refractory consumption, improved yield and better quality of steel. Automation of mould level control and mould powder feeding, secondary cooling and metal cutting and discharge operations has increased productivity of continuous casting machines and improved product quality.

Automation of rolling mills with on-line process computers requires considerable initial outlay (about 10 per cent or more of the plant cost in the case of three-quarters continuous hot strip mill) but it reduces human interference, improves reproducibility of results, reduces strain on the operators and reduces downtimes and yield losses. Computerised control for correlating and adjusting loads on reheating furnaces with the sizes and grades of individual semis and their surface conditioning, as also inspection and flow of semis and coils improve yields, reduces requirements of auxiliary equipment, storage areas and manpower. With the application of automation, endless cold rolling with 50 per cent higher productivity over individual coil rolling has been established. Plate mill automation from receipt of slabs to final shipment of products gives market improvement in productivity, product quality and lowering of operating costs. In slab reheating furnaces, automation has led to optimisation of fuel distribution to each furnace zone resulting in energy saving. The next phase of automation in mills would involve the 'touching-up' of auxiliary process and seeking an over-all continuity of processes.

Some steelworks in industrialised countries are now operated by integrated information system to control the entire plant operation from order receipt to product shipment.

Auxiliaries and utilities technology

From an analysis of installation costs of several integrated steelworks in Western Europe and UK, Worthington had estimated in 1962 that the materials handling facilities within and outside the production shops together accounted for 35 per cent of the equipment costs. Technological improvements in the materials handling and ancillary facilities which account for 25 to 30 per cent of the steel plant cost can also influence the plant economics. The range of selection of mobile equipment for works transport has greatly improved with the perfection of self-loading and unloading trucks. With the use of torpedo ladle cars for transporting hot metal from the blast furnace shop to LD converters, the higher investment on hot metal mixers is saved. At the new Oghishima plant of Nippon Kokan, no torpedo ladles or hot metal mixers are used; the hot metal is received in the steelmelt shop directly in blast furnace ladles and charged into the converters. This system reduced capital investment as well as fuel consumption. Design of cooling water circulation system with the recycling of cooling water in the increasing temperature cascade can reduce investment requirements for the pipelines and pumps. Installation of evaporative water cooling system for reheating furnaces and blast furnaces raise investment costs but lower the operating costs. The utilities system design in steel plants tend to spiral with liberal factors of safety in the utility data furnished by the equipment suppliers, adoption of safety margin in the designs and selection of auxiliary facilities of the next higher standard size by the utilities network contractor/s. The scattered non-pressurised guns provided traditionally for manual addition of greases and lubricant oil in certain equipment may get replaced in future by automatic gas-pressurised disposable grease and lubricant pots. New innovations during the 80s are expected on the economic recuperation of waste gases at lower temperature of 200°C as the current waste heat recovery equipment are considered to be economical only for recovering heat from waste gases at temperature higher than 400°C.

Pollution control

In response to the growing public consciousness of the negative social contribution of the various pollutants generated by the steel industry, stringent pollution control regulations have been promulgated in industrialised countries. Accordingly, the steel industry has evolved during the last decade a variety of techniques to control these pollutants which are briefly summarised hereunder:

Pollutant	Control techniques
Sulphur oxide (sintering plant generates about 50% of total sulphur oxide emission from steelworks)	- Use of low sulphur raw materials and fuels - Use of higher stacks - Desulphurising of the gas before discharge
Nitrogen oxide	- Major research and development efforts being directed towards removal of NOx from flue gas (e.g. selective contact reduction and electron-beam radiation techniques)
Dust and particulate matter	- Primary and secondary flue dust collection systems - BOF gas recovery system
Effluent water	- Water recirculation and treatment systems
Heat	- Cooling and ventilation systems
Noise	- Better design of machines, slow speed equipment and noise absorbing enclosures

The main areas of the steel industry in which the environmental pollution aspects remain to be adequately resolved are:

Area	Outstanding problems
Mining of iron ore	Presence of asbestos-like fibres in taconite ore tailings which pass into effluent discharges
Raw materials handling	Fugitive emission arising from dust entrainment during handling and stocking
Coke ovens	Pollution of working environment and atmosphere
	Treatment and disposal of liquid effluents
Sintering and pelletising	Equipment design and cost problems for removal of sulphur oxides, nitrogen oxides and fluorides from gaseous emissions
	In high basicity sinter, the high resistivity of dust makes dust arrestment difficult in electrostatic precipitators
Blast furnace	Environmental problems due to fugitive emissions during tapping of hot metal and slag
Steelmaking	Fugitive emissions during charging, tapping, etc
Rolling mills	Disposal of effluents
	Removal difficulty of oil and grease from effluents

The share of pollution control installations in the total investment in the steel industry increased from 10 per cent in 1970 to around 16 per cent in USA and from 9 per cent in 1971 to 20-21 per cent in 1976 in Japan. As Japan completed bulk of retrofitting work on pollution control devices in the existing plants by

1976, this share has levelled off to 10 per cent since 1977. In absolute monetary terms, USA and Japan each have invested around US $ 3.5 billion from 1971 to 1978 on the pollution control measures. During 1974-1978, the Japanese universities, research institutes and other related organisations were granted fund of US $ 6.6 million to carry out further research for abatement and removal of pollution by the steel industry. The investment requirement for pollution control equipment in new installations in steel industry is variously estimated to range between 10 to 18 per cent of the total investment.

Finding it difficult to comply with the stringent regulations of the Environmental Pollution Control Authority, several old coke ovens have been shut down in USA - a fact which has compelled USA to import coke in recent years. The Federal Republic of Germany has imposed a virtual ban on the installation of new sintering capacity in the country as a pollution control measure. In contrast, developing countries may show greater tolerance and acceptance of the pollution in a bid to woo creation of new steelmaking capacity.

Climatic influence

The climatic conditions prevailing at a plant site affect the auxiliary facilities as also the human productivity in steel industry. For example, iron ores containing high alumina and hydro-oxides (like those occurring in India) cannot be screened efficiently in dry sizing plants during rainy months as moist ores have a tendency to stick to the side walls of bins, conveyor belts and drains in stockpile areas. Therefore, scrubbing and wet treatment of ores at mines becomes necessary to enhance flowability of sized ore and fine ores. At locations with considerable seasonable variations of the relative humidity, the rate of coke consumption in blast furnace increases during period of high humidity and these fluctuations of humidity in the air blast also become detrimental to the stock movements in blast furnaces. In some of the integrated steel plants in India, the coke consumption rate generally increases during the rainy months from June through September every year. Elimination of these adverse effects on the blast furnace productivity requires investment on facilities to maintain constant humidity in the air blast round the year. The air pressure diminishes and the air becomes thinner at high altitudes. This disadvantage needs to be offset with the installation of turbo-blower of higher powering for injecting cold blast to furnaces and air compressors as has been done for the integrated steelworks at Paz del Rio in Colombia. Steel plants built at sites which are vulnerable to sand storms need to be protected against intrusion of sand with a wind-breaker belt of trees and creepers as exemplified by the rolling mills in Ahwaz, Iran. Also the buildings have to be of enclosed type and need to be equipped with motorised movable louvres and ventilators which can be closed against sand storms. In the plants exposed to corrosive or salt-laden environments, the steelwork for buildings and equipment need to be treated with more expensive paints such as the zinc primer and finishing paints such as the chlorinated rich rubber or vinyl.

Copper sizes of components of electricity distribution system in the steel plant are required to be of larger sizes in plants located in areas with high ambient temperatures. The current ratings of components get lowered at higher temperatures due to upper limitations of temperature for insulation in cables, oils in transformers and mechanical and thermal properties of metals in circuit-breakers.

Increasing evidence of the linkage of climatic conditions with human productivity has been gathered as follows:

i) Coal miners working in temperatures from 17 to 32°C showed a 59 per cent fall-off in working efficiency at the higher temperatures (studies by Vernon, Bedford and Warner).

ii) Mental agility and consequently accuracy of telegraphists declined by 2 per cent per deg. C as the temperature rose above 30° C (studies by Mackworth).

iii) Herrington found that accidents increased by 40 per cent as the temperature rose from 19°C to 29°C; in other studies the number of accidents in industries were found to increase from 200 per 1000 labour-years at 21°C to over 300 at 27°C.

iv) Absenteeism in the ships due to crew sickness was observed to have increased with the rising temperature of the ship decks as follows:

Deck temperature at noon	..	°C	10	27	38
Crew absenteeism due to sickness	..	%	3.5	5	9

v) Of the four tinplate shops investigated, the output increased by only 3 per cent with ventilation improvements in the best ventilated shops but by as much as 13 per cent in the unventilated shops. Comparison of the change in work output showed fall-off in effort of about 1 per cent per °C rise in temperature even in continuous process like tinning.

The ambient temperatures in a predominantly large number of developing countries are generally higher than 25°C during the daytime for about six months in a year. As the minimum temperature difference with the standard natural ventilation system cannot be reduced to less than 5°C, the temperatures under the working environments of the steel industry in developing countries lower the productivity. Consequently either more equipment facilities or more manpower become necessary in developing countries than those in the industrialised countries.

EQUIPMENT SUPPLY SCENARIO

The designers and suppliers of equipment exert a potent influence on the global development of many heavy industries especially steel.

Research and design trends

The empirical nature of operations involving industrial chemistry and circumspection required to scale up the plant designs for ironmaking, steelmaking and to some extent continuous casting require that every new process or innovation be proven through the three successive stages of laboratory tests, pilot plant and industrial prototype plant for reliable operations on a viable commercial scale. Generally a period of 6 to 10 years is required to complete this chain of tests to perfect the process and its applications to the equipment.

Though the necessary laboratory work was carried out by the Surface Combustion Division of Midland Ross Corporation, USA in the mid-60s and the first 200-module direct reduction plant with Midrex process was installed in Oregon, USA in 1969, extensive modificiations had to be carried out till 1973 on the scale-up 400-module installed in Georgetown and Hamburg in 1971 and 1972 respectively to inspire confidence of process reliability. A period of five years was required for trials and innovations to bring only the installation of the first recuperator of wasteheat in the Midrex process to acceptable performance level. Though the first pilot plant based on the Purofer direct reduction process was installed in January 1970 at Oberhausen, West Germany, the two commercial plants were established - one in Brazil in 1976 and the other in Iran in 1977. The Brazil plant has been shut down due to technical problems in the oil gasification unit and the Iran plant has not yet been operated on regular basis. Though the first high-head continuous casting machine was set up at Atlas Steel, Canada in 1954, the commercial possibilities of continuous casting started gaining world-wide recognition only since 1960. The laboratory research work to exploit the huge potential of magnetic taconite ores in the Mesabi range initiated in North America in 1938 paved way for installation of pelletisation plants only after successful operation of the large pilot scale concentrators and shaft indurating furnaces which were set up in 1952.

In most cases, the process innovators have to stake heavy financial risks in the development and installation of a commercial prototype plant. This is the main reason why purchasers of commercially proven processes and equipment might have to bear indirectly a part of this high risk investment on development of technology. Such sharing of risk investments incurred by purchasers of commercially proven processes might also include a part of costs of earlier failure installations which have of course in the process helped perfect the technology.

The current on-going research in some industrialised countries for producing low cost steel strip and sections from iron ore by a new direct reduction route could be of great interest to developing countries. The research work presupposes that about 80 per cent of the steel sheets, strip and bars used in developing countries are overspecified in relation to ultimate requirements of low stress roofing and structural members for housing, agricultural implements and intermediate and consumer products such as nails, wires, containers etc. The process under experimentation basically consists of two stages. The first stage includes production of high purity concentrates from ores by conventional mineral dressing techniques, agglomeration to pellets or blocks and reduction in vertical shaft kiln using gaseous or solid reductants to a very high degree of metallisation (+99% Fe). In the second stage this high purity concentrate is hot rolled in a single pass under protective atmosphere to the stage of the final product. Property of the final product depends on the purity of the concentrate. When purity exceeds 99%, the mechanical properties correspond to those of mild steel (ultimate tensile strength approximately 300 MN/m2, elongation approximately 40%). With concentrate purity diluted down to 96-98%, the elongation drops to 5-10% while the tensile strength remains relatively unaffected. Should this research prove successful, many developing countries will be in a position to set up small steel industries to satisfy a part of their steel needs for low-duty applications.

Equipment design and manufacturing concentrations

The leading designers and manufacturers of metallurgical equipment have sought vertical integration with the companies operating steel plants and horizontal integration with similar designers and manufacturers to bring about increasing sophistications in the equipment with reduced competition.

Korf Engineering GmbH, West Germany - the Licencee designer of Midrex direct reduction plant have vertically integrated the design capability for complete mini-steel plants comprising direct reduction plant, steelmelt shops and rolling mills. Korf's recent acquisition of Ashlow Steel and Engineering Company, UK has added rolling mill supply capability.

Schloemann - the leading designers of rolling mills, continuous casting machines and forging presses, is a subsidiary of GHH - manufacturers of ironmaking and steelmelt shop equipment. Vertical integration of the design and manufacturing capability of this group from ironmaking to rolling equipment was strengthened with the merger of Siemag - the manufacturers of rolling mills and forging presses. Examples of acquisition of control of equipment manufacturers by companies operating steel plants are:

i) Voest-Alpine, Austria acquiring interest in Didier Engineering, West Germany, a leader of coal processing, coke ovens and refractory equipment

ii) Merger of Dr C. Otto, Bochum, West Germany - a coke oven manufacturer in the government-owned Peine-Salzgitter

iii) Full takeover by Krupps of Koppers, West Germany - designers of coke ovens, coal gasification and sinter plants

iv) Demag - a prominent manufacturer of a wide range of heavy metallurgical equipment including LD vessels, blast furnaces, continuous casting machines, rolling mills, pipe mills and overhead travelling cranes becoming a subsidiary company of Mannesmann.

Yet another recent merger in France is that of Heurtey - the French manufacturers of special furnaces and steel plant equipment with an engineering consultancy company, Sofresid.

MECAN-ARBED - the metallurgical equipment manufacturers in Luxembourg operate as a subsidiary of the Arbed steel industry. The three leading steel producers of Japan - Kobe Steel, Kawasaki Steel and Sumitomo Metals are also the established manufacturers of metallurgical equipment. In the USSR, Tiajpromexport exports metallurgical equipment designed by Gipromez (the iron and steel institute of USSR) which is closely interconnected with the operating steel plants. In developing countries, the vertical integration tends to develop through the state sector. For example, in India, Metallurgical and Engineering Consultants (MECON) - a government organisation was set up to render consulting services in 1960s (then known as the Central Engineering and Designs Bureau). However, they acquired subsequently the design rights for selected types of metallurgical equipment through collaboration with foreign companies and are offering plant and equipment on this design arrangement basis.

Forms of backward vertical integration in which the design or the process licencees have acquired control of the licensor companies are illustrated by -

i) purchase of 51 per cent shares of Concast AG, Zurich - the world-wide licensers of designs of continuous casting machines by Schloemann-Siemag, the one-time licensee of Concast AG, and

ii) Takeover of Midrex Corporation, USA holding world-wide licensing rights for Midrex direct reduction process in 1974 by the Korf Group, West Germany which had set up direct reduction plant based on Midrex process at Georgetown and Hamburg under process licence from Midrex Corporation.

Typical examples of horizontal integration of equipment manufacturers are the -

i) Mergers of Moller Neumann and Sack for rolling mill equipment

ii) Successive mergers of Davy Engineers, UK with Lowey and Robertson (rolling mill manufacturer)

iii) Agreement between Dravo and Lurgi - two leading designers and suppliers of sintering machines.

Business cycles in metallurgical equipment trade

The metallurgical equipment manufacturing industry and consequently their pricing is subject to periodic global recessions. According to a United Nations Study on the export of engineering goods conducted in the late 60s, this industry had suffered three recessions during the decade of 50s. In the early 70s, even against cash payment it was difficult to obtain proper competitive offers from suppliers due to the prevailing booming order position, whereas in the late 70s, the industry has been in the grip of a severe recession resulting in aggressive sales efforts on the part of equipment manufacturers.

Equipment sales pattern

According to a study by the UN Conference on Trade and Development (UNCTAD), the recipient country of tied-aid incurs substantial indirect excess costs which range as high as 30 to 50 per cent. As no single country can be expected to possess the best in all areas of the steel plant technology, India received a 'mixed bag' of technology on the projects built with foreign financing. A cost reduction study commissioned by the Government of India on one of these projects had shown that the cost of the project as planned under the aid was 40 per cent more expensive than the corresponding cost estimates for a plant that could be obtained from competitive bidding and adoption of worldwide technology.

INFRASTRUCTURE

Location and site

With the growing international trade in raw materials, energy and steel semis and finished products, the emphasis on the siting of integrated steel plants has shifted in industrialised and semi-industrialised countries away from the pull of local material and energy sources to coastal locations with deepwater fronts. An econometric model drawn up in mid-1974 for the steel industry in ECSC-9 had established that a coastal plant with a nearby market for its products enjoys a price advantage of about US $ 11 per ton of finished steel over a competing plant located some 250 Km from the coast. This advantage will be reduced to US $ 3 to US $ 5 per ton if the market to be supplied is more distant. An analysis of annual accounts of 22 leading steel companies (Japan-1, USA-2, Netherlands-1, Luxembourg-1, UK-1, Italy-2, Belgium-4, France-5 and West Germany-5) for 1967-1972 period had established that the six companies which had the lowest ratio of cost burden (that is ratio of the sum total of costs of all inputs of materials, energy and consumables as also salaries and wages to the product value) in the range of 77 to 82 per cent had their plants located on coasts regardless of the age of the plant. A disadvantage of this location planning however, is the need in some cases for extensive land reclamation and site preparation work usually necessary at such locations. For example, the site levelling and preparation cost accounted for 10.7 per cent of the plant cost for Fukuyama works at the first stage of 1.5 million tons capacity per year.

Nevertheless, the pull of raw materials still continues to be an important consideration in the location of resource-based integrated steel plants in developing countries. For instance, the fourth integrated public sector steel plant in India was located at Bokaro as it involved the lowest haulage of 842 ton-km of the three principal raw materials (iron ore, coal and limestone) per ton of ingot steel production, the comparative haulage in ton-km being 880, 881 and 1 617 for the three existing plants at Rourkela, Durgapur and Bhilai respectively.

The locational advantage of new integrated steel plants in countries with established steel industry with the same location pattern (that is coastal location or resource-based inland location) may reduce progressively with newer locations as the infrastructure facilities tend to get saturated in zones of of established steel industry. The proposed locations of the fifth and the sixth integrated steel plants outside the iron and coal belt in India, would help in reducing the load on the Indian railway network system for transporting iron ore, coal, limestone and other raw materials as also finished products of the steel industry.

The permissible tolerances for environmental pollution could influence the location planning in many cases. For example, the surroundings of Los Angeles, USA could hardly attract any new mini-steel plants as the environmental pollution control agency has already compelled the existing electric arc furnace installations to provide the expensive secondary fume extraction system. Kawasaki Steel has established a 5-million ton capacity sintering plant in Philippines primarily to obviate the pollution control regulations in Japan. It is possible that many countries may adopt in future the system of pollution control credit rating in which pollution credit and penalties become an exchangable right among industries located in a demarcated area with differing pollution characteristics. This mode of legislation is reported to have been enacted by one of the States in USA.

With a view to circumvent the stringent environmental pollution controls in the home country and also with a view to avail of the lower construction costs, a section of the steel industry in industrialised countries is looking out to establish new steel plants in promising resource-rich developing countries. The Government of India has received proposals from three consortia of British and Germany equipment suppliers and the Rumanian Government to establish an integrated steel plant at Paradip on the east-coast, with the initial financing arranged by the equipment suppliers. An integrated steel plant with 3-million ton capacity slabbing mill for exclusive production and export of slabs is being set up at Tubarao, Brazil with investment by Kawasaki steel and the Italian state enterprise-Finsider International each to the extent of 24.5 per cent of the plant cost (with a Brazilian Government company investing the balance 51 per cent). Proposal for establishing a similar resource-based plant for production of semis is being examined on the northern-coast of Australia.

Power, water and gas supply

Installation of electric arc furnaces in many developing countries for operation with 100 per cent scrap charge is impeded by the limited quantum of electricity and more importantly the low stiffness of electrical distribution network which precludes installation of high-powered and ultra high-powered electric furnaces. Sometimes a large captive power generation capacity with high investment is required to operate mini steel plants in developing countries. For the Irosteel works in Indonesia, a 60 MW gas turbine power plant installation had to be set up to operate the plant equipped with two 25-ton, 12 MVA electric arc furnaces. However, this constraint can be partly overcome by supplementing power requirements through installation of oxy-fuel burners in electric arc furnaces as at the Himeji Steelworks of Toshin Steel in Japan (where the electric power consumption has been lowered down to level of 381 kWh/ton for 100 per cent scrap charge). Continuous feeding of sponge iron to electric arc furnace lowers the short circuit level demands on the power supply system by easing the peaks.

As the entry and exit of slabs into the roughing stands of hot strip mill give rise to acceptance and rejection of heavy instantaneous step loads, sizable in-plant power generation capacity supplementing the available power system is often needed in developing countries to support the operations. The 1.8 million ton capacity Rourkela plant and 1.7 million ton capacity Bokaro plant (which is being expanded presently to 4 million ton capacity) had to be equipped with in-plant power generation capacity of 125 MW and 122 MW respectively to take up the peak electrical loads of the hot strip mill. Firm in-plant generation capacity of about 70 MW had to be established for the integrated steel plant at Jamshedpur (with the present capacity of 2 million ingot tons per year) to ensure its bulk production against interruption from uncertainties of power supply from public electricity grid networks. Operations of the 3 million ton capacity hot strip mill and cold rolling mill of the Wuhan integrated steel plant in China ran into trouble at the end of 1978 as the mill consumed the entire quantum of the provincial power supply. The power supply had to be stabilised subsequently by combining power grids of several provinces.

To meet the large water requirements of the steel plant and the related physical and social infrastructure facilities, special arrangements with heavy capital outlays had to be made for the Indian steel plants to draw water from irrigation dams on the nearby rivers. The arrangements proposed to meet the water requirements of the first integrated Indian coastal steel plant at Visakhapatnam presently under implementation include construction of a dam on the river Yelluru, and a canal of about 124 Km length. The Sparrows plant, USA is compelled to use the municipal sewage effluent after purification to meet its industrial water requirements. The steel plant in Qatar which was commissioned in 1978 is operated with the expensive desalinated sea water.

Very often gas pipelines have to be laid over a long distance to supply oilfields and gasfields to the steel industry. Natural gas is transported to the Sidbec plant - a distance of nearly 300 Km. At the Wuhang plant in China, when the power supply problem was resolved, lack of adequate gas and water supply kept the plant output down.

Port and transport

Low-cost mass movement of materials is the sine quanon of successful steel industry. Construction of a deepwater port to handle iron ore and coal imports could cost at the current prices about US $ 120 million for a 1.25 million tons per year capacity plant. Thus the port cost alone could raise the capital requirement by about US $ 100 per annual ton of capacity. Construction of approach roads as well as the railway siding connections and procurement of fleet of special-purpose container highway truck and railway wagons also demand investment ranging between one and three per cent of the plant cost. During the first five years of the commissioning of three 1 million ton capacity public sector plants around 1960, the steel industry in India suffered a major transport crisis at the interface with the Indian railways due to bunching of wagons, receipt of raw materials and coal in wrong types of wagons (55-ton open box wagons and 22-ton closed wagons instead of self-unloading hopper wagons), mixing of different types of coal in the same wagon. These difficulties precluded effectively the control of raw materials and coal bedding and blending needed for furnace operations. These railway transport problems were resolved gradually with better management of railway rolling stock, installation of mechanised wagon tipplers in the steel plant railway siding and in the case of Indian Iron and Steel Company, Burnpur (in the State of West Bengal) with the installation of a long ropeway to transport coking coal from the captive collieries. It is only after the research work of a decade that the Research and Development Wing of the Indian railways could evolve design of BOY wagons for the same gross payload as that of 55-ton BOX wagons but with 30 per cent higher net payload. For the Salem Steel Plant under construction in South India, the Indian railways have insisted on transport of LPG from Western India in rake loads for which special storage facilities comprising 500-ton capacity hortonspheres are required to be established at Salem. Provision of these special facilities along with the necessary loading/unloading equipment and fire-protection devices is estimated to add 2 to 2.5 per cent of the estimated capital investment cost for the first phase.

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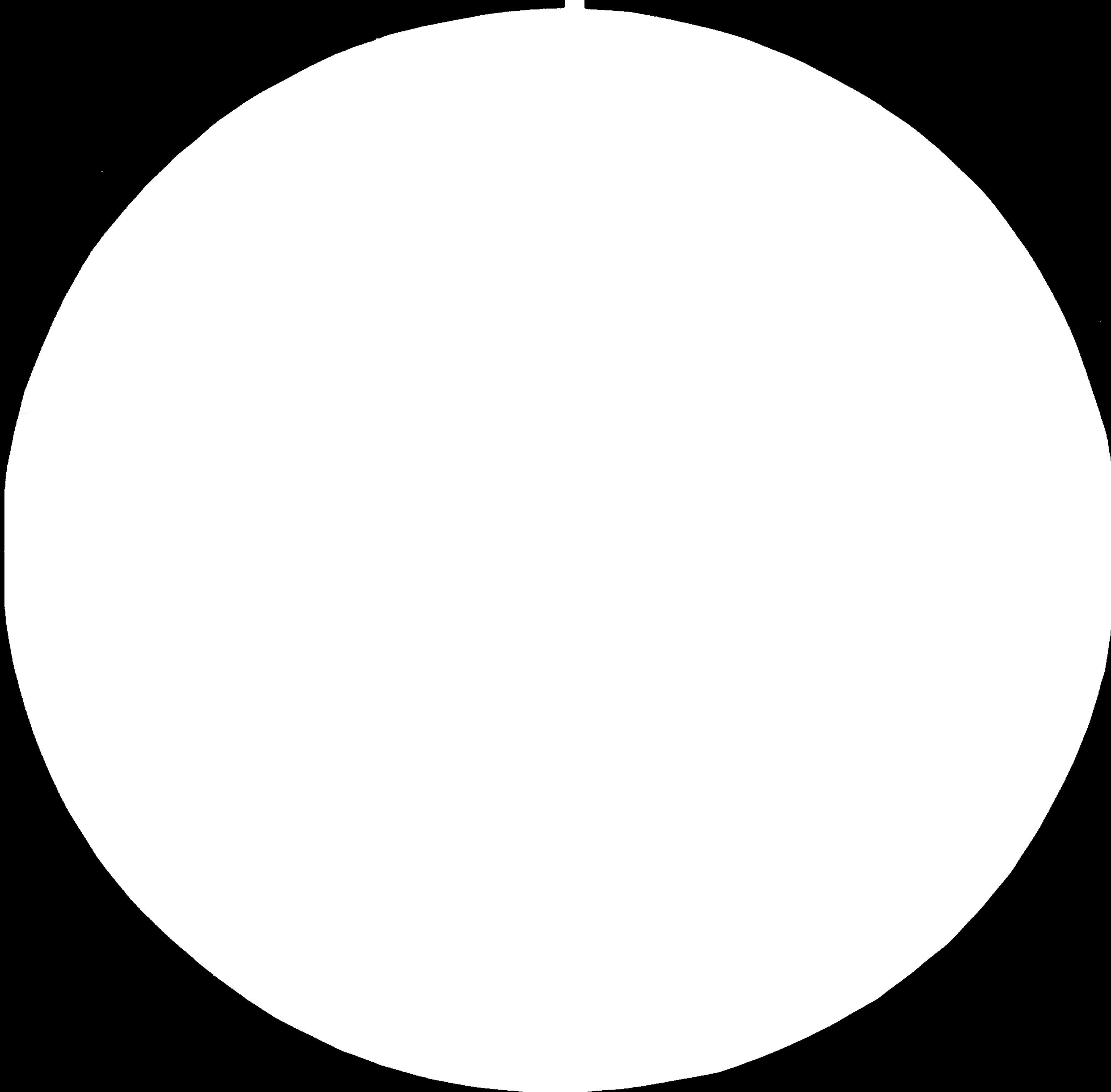
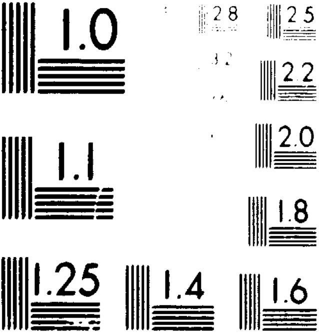




MICROCOPY RESOLUTION TEST CHART

Housing and township

Provision of adequate housing and civic amenities in the vicinity of steel plants has been found to have a far-reaching effect on the industrial relations between the employers and employees. In industrialised countries, it contributes to minimising turnover of skilled and trained workforce. In developing countries, it tends to keep the workforce free of discontent and strife, brings organised medical facilities within the reach of workers' families and prevents dissipation of employee's energy in the long to and fro journeys to steel plant.

At the Burnpur Steelworks of the Indian Iron and Steel Comapny where only about one-fourth of the work-force is provided with housing by the company, lack of housing for a majority of the workforce has been a disturbing factor in management-union relationships. The turnover of newly recruited officers in the same plant has increased since 1973 with the company's inability to provide accommodation. Difficulty of commuting long distances from the non-company houses to the steel plant is reported to be the cause of increased absenteeism of workers in the rainy months in some Indian steel plants.

However, housing and township construction requires massive capital investment. It is estimated that the current cost of establishing township in the Federal Republic of Germany is of the order of 50 000 DM per inhabitant or DM 200 000 per employee with a family of four members.

MANPOWER

The manpower situation is influenced by the requirements, availability, industrial discipline, organisation structure and compensation policy.

Requirements - Number, Skill, Education Standards

The technological advancements of steel manufacturing, the enlarging scales of operation and computerisation have progressively shifted the emphasis from labour to capital. In the Japanese steel industry, the man-hours worked per ton of finished steel (including the sub-contracted labour) declined steadily as shown below:

Year	1955	1960	1965	1970	1974	1976
Man-hours/ ton	69	55.64	31.92	14.43	10.20	10.26

Though the fall of labour component has not been so precipitous in other major steel-producer countries of the world, the employment in steel industry has declined by 10 to 15 per cent during 1973-1978 period in major steel-producing countries as shown below:

	Employment - thousand persons in					
Year	USA	JAPAN	ESCS-6	UK	AUSTRIA	SWEDEN
1973	508.2	458.0	577.0	192.7	41.9	48.3
1978	449.2	400.9	507.2	159.2	39.6	47.0

Source: World Steel in Figures - 1980, IISI.

In contrast, employment in the steel industry is expanding in developing countries. Employment in the Brazilian steel industry increased by about 41 per cent (from 101 000 persons in 1973 to 142 000 persons in 1978). Also the following comparison of production and employment data for several countries for 1978 shows that the employment intensity (as measured by the number of employees per thousand tons of crude steel production) is generally inversely proportional to the state of industrialisation of a country.

Employment intensity per thousand tons of crude steel production

Country	Yugoslavia	South Africa	Brazil	Spain	UK	France	Japan, USA & ECSC-6 except France
Employees	20.71	13.77	11.64	7.82	7.8	5.75	Under 4

The manpower required to operate an integrated steel plant based on direct reduction - electric furnace route may be only two-thirds of that for a plant of equal capacity with blast furnace-basic oxygen furnace due to elimination of several backward linkages (raw materials bedding and blending, coke ovens, sintering, pig casting machine), by-product installations (coke oven by-products, slag granulation, scrap and salve unit), simplification of auxiliary facilities, utilities etc.

Greater capital intensity requires commensurate elevation of skills. The proportion of unskilled manpower in the Indian steel plants has declined with the establishment of more modern works as can be judged from the following trends in 1978 in the composition of work force in three selected integrated steel plants:

Integrated steel plant	Year of start-up	Plant capacity in 1978 mill t/yr	Persons employed(1) Total No.	Persons employed(1) Unskilled No.	Proportion of unskilled workers in total %
Tata Iron & Steel Co.	1907	2	36 000	15 000	41.7
Indian Iron & Steel Co.	1939	1	28 600	11 000	38.5
Bhilai Steel Plant	1959	2.5	53 000	9 600	18.1

NOTE: (1) The employment count includes infrastructure facilities such as ore mines, township, in-house power generation plant etc and also the sub-contractors' labour force.

The standard of education in a country affects the training cost for the steel industry. During the post-war reconstruction in the 50s in Japan the secondary school graduates were recruited in the steel industry for supervisory posts with three years of training, whereas during late 60s and early 70s, only graduates were recruited for these posts. The shortage of metallurgical engineers in India during the late 50s, when the three integrated steel plants were commissioned, was made good by recruiting mechanical engineers and science graduates with necessary training.

Availability

The heritage of a pool of skilled workers specialising in different trades of steel industry who had survived the second world war had fostered rapid recovery of steel industry during the 1950s in Japan. Availability of steelmaking skills in the Brescia region catalysed rapid expansion of steel industry in Italy through mini steel plants and has conferred on Italy the distinction of producing over 50 per cent of steel in electric arc furnaces amongst all countries producing steel in excess of 5 million tons.

Heavy turnover of skilled trainees and supervisory trainees is a common phenomenon in developing countries when they embark upon a rapid programme of industrialisation. During the early 60s, the integrated steel plants in India witnessed a high turnover of these personnel. In OPEC countries where the steel industry is being installed (Iraq, Venezuela, Indonesia and Iran), operations during the gestation period are reported to have been adversely affected by the high turnover of the trained employees to more lucrative jobs.

Skills are in short supply in many developing countries. Diversion of educated and semi-trained manpower for military training aggravates this shortage in some countries. Many OPEC countries have to depend heavily on the expatriate labour to overcome absolute paucity of manpower to run their steel industry. Over 95 per cent of work force in the Qatar Steel Plant consists of expatriate personnel.

Industrial discipline

Subjecting employees of steel industry to the rigours of working by rotation in three shifts poses problems in many developing countries where the steel industry is established for the first time. At the Helwan steel plant in Egypt, three-shift operations could not be stabilised for several years after start-up due to lack of adequate background of industrial discipline. High proportion of absenteeism of the workers in developing countries requires deployment of greater reserve work force on the payroll. Steel industry in industrialised countries is gradually falling under the newly emerging code of industrial discipline of working fewer hours per week and week-end holidays. The number of hours worked per year by the steel plant employees in the Japanese steel industry have progressively declined as follows:

Year	1960	1965	1970	1974	1976
No.of hrs	2 510	2 315	2 284	2 119	1 988

Highly organised trade unions in industrialised countries have begun to influence development of their steel industry. Start-up of large blast furnaces in recent installations in the British Steel Corporation, UK was delayed by over 12 months as the trade unions insisted that the operators required to work on furnaces of larger capacity should get higher wages than those operating furnaces of lower capacity. The 4-month-long labour strike in steel industry in 1959 in USA paved way for initial penetration of the Japanese steel products in USA which has eventually changed the pattern of development of the American steel industry. Reluctance of the workers to accept automation as a way of life in the steel industry, for fear of loss of job is a factor which has retarded full scale application of automation in the EEC countries.

Organisation structure

The levels of heirarchy and the centralisation/decentralisation of maintenance, quality control and service functions affect the organisation structure and consequently the operation cost of installation in steel industry. For a typical 1.25 million ton capacity steel plant presently under implementation in a developing OPEC country, the manpower requirement estimated by prospective equipment suppliers varies from 5 000 to 7 000 owing to different organisation structures assumed by them. The 400 000 tons per year capacity steel plant in Qatar is manned by only 850 employees - a remarkably low figure for a developing country largely due to centralisation of quality control and maintenance functions.

The complexity of management and organisation structure often transcends linear relationship with the number of employees. For reasons of economy as this, several plant activities are entrusted to sub-contractors in certain countries. For example, the proportion of contract workers to the own employees in the Japanese steel industry has progressively increased by 4 per cent every five years from 36 per cent in 1960 to 48 per cent in 1975.

Compensation policy

The compensation policy takes different forms in different countries. The long-term employment guarantee by the employers has accelerated the growth of the Japanese steel industry. The policy of giving preference in employment to employees' children and dependents has enabled a private sector integrated steel plants in India to ensure loyalty of a large number of employees and abated pressure for construction of new houses in the steel plant townships. On the other hand, the French government and the British Steel Corporation are confronted with the dilemma of setting up automobile and other industries to provide alternative employment opportunities to the employees of the uneconomic plants which they plan to shut down. Though the difference of worker productivity of the Japanese and the American steel industry is only marginal, low compensation policy and consequently higher wage-productivity ratio has enabled Japan to score a decisive cost advantage in the American steel market as shown in Table 14 on the next page.

TABLE 14 - COMPARISON OF TRENDS OF LABOUR COSTS IN JAPAN AND USA

Year		Labour cost, US $ per ton	
		JAPAN	USA
1956	..	26.66	54.67
1960	..	23.01	71.83
1965	..	22.11	65.06
1970	..	23.22	80.81
1974	..	42.60	100.91
1976	..	49.64	143.55

Source: US Federal Trade Commission, Staff Report on the United States Steel Industry and its international rivals. Trends and Factors Determining International Competitiveness, November 1977.

As the trade unions of employees of the steel plant are generally better organised than those for the other sectors of the economy in developing countries, wages and fringe benefits of the employees of the steel industry tend to grow faster than those for other industries.

HUMAN RESOURCES DEVELOPMENT

Human resources for the steel industry can be developed through training, consolidated through systems, acquired through know-how purchase arrangements and supplemented with technical assistance.

Training programme

Knowledge and skill of the employees make up the engine of production in the steel industry. Realising importance of this motive power, the British parliament established in 1964 training boards to develop the human resources of United Kindgom. Of the four training boards set up in that year, two were for the steel and the engineering industry. These training boards continue to provide skill base of craftsmen and technicians to these two industries.

Development of human resources for the steel industry in the developing countries has a long gestation period and a long range plan of integrated education and training schemes has to be formulated well ahead of setting up the industry.

Simulatenously with the development of steel industry, the existing system of education in many developing countries needs reorientation of the educational curricula and institutions with emphasis on specific acquisition of knowledge and skills required for operation of steel plants. For example at the level of craftsman, steel trades of ironmaking, melting, rolling etc have to be introduced and at the university level, metallurgical engineering courses in ironmaking and steelmaking should be introduced.

A multi-pronged strategy was adopted in the late 50s and early 60s to train personnel for the three public sector integrated steel plants in India. By 1962 over 1 500 graduate engineers and 477 operators were sent abroad to receive training mainly in USSR and USA. The Ford Foundation had organised in USA the In-Step (Indian Steel Training and Education Programme) for the Indian trainees with the assistance of several American steel companies, universities and other organisations. Many skilled workers were hired from the two existing integrated steelworks in the private sector at Jamshedpur and Burnpur. Several new recruits were imparted orientation training at the existing Jamshedpur Technical Institute. Training programme of 18 months and 24 months' duration for the graduate mechanical, electrical and metallurgical engineers and diploma holders were established at the technical training centres of new steel plants. A management training institute was set up in Ranchi with multi-tier programmes to train managers and supervisory personnel. As a result of this multi-pronged training strategy, the number of graduates receiving training abroad was reduced to under 100 by 1970.

The cost of imparting three-year training for a high school graduate to render him into a skilled worker is reported by some German steel plants to exceed DM 50 000 per trainee. In other words, the investment required for technical training per employee is of the same order as that required to provide housing and township and civic amenities to a person in West Germany.

Operation system

There is inadequate realisation in many developing countries of the importance of introducing effective functional systems in the steel plants during the gestation period. Of the three one-million ton capacity greenfield integrated steel plants which were commissioned in India during 1960 and 1961, performance of one plant during the gestation period had a lead over that of the two other plants. One of the factors that led to the superior performance of the former steel plant was that the technical personnel deputed by the equipment suppliers introduced the systems whereas the other two plants had to evolve gradually functional systems on their own.

Know-how transfer

The operation know-how for the steel industry can be set up in many ways: (i) importing operation know-how from operating steel plants through know-how agreements; (ii) obtaining know-how as a part of financing arrangement; (iii) receiving know how through deployment of technical assistance experts; and (iv) generating know-how with learning the hard way from trials and errors. The approach of generating know-how within an organisation can be relied upon when experienced, specialist personnel can be hired in adequate numbers to have training within the industry for the inexperienced employees. The successful operation of the know-how arrangements, marketing and sales in the Qatar steel plant under an agreement between the Government of Qatar and Kobe Steel, Japan illustrates the extent to which the know-how arrangement can place the steel industry on a sound footing and pave the way for its expansion.

Technical assistance

It has been observed that in those greenfield Indian installations which had the benefit of technical assistance, the plant operations have stabilised faster than those which did not have this benefit. For the Rourkela Steel Plant in India under a technical assistance agreement a specialist group known as COLETI had to be engaged to strengthen the knowledge of operation personnel for the cold rolling mill complex. Developing countries should enlist technical assistance experts very judiciously as the cost of these experts involve high payments on salaries, allowances, accommodation and other perquisites.

ECONOMICS

Traditionally, the steel industry has been capital-intensive and the contribution of value added by capital in the production cost is second only to that of raw materials as can be seen from the following typical percentage composition of the production cost analysis of the resource-based Brazilian steel industry in the late 1960s:

	Proportion of production cost-per cent			
			Value added	
Industry	Raw materials		Labour	Capital
Pig iron	Ore, coal	55-74	2-4	19-30
Crude steel	Pig iron	65-74	2-5	10-13
	Ore, coal	36-55	3-7	24-34
Rolled steel	Crude steel	55-74	1-4	17-38
	Ore, coal	21-30	3-8	40-50

The addition of pollution control and automation during the 1970s along with sharp escalation in the equipment costs have only raised the capital intensity of the steel industry. The capital intensity of steel industry also depends on the extent to which the various linkage industries are included within the battery limits of the steel plants.

Conceptual battery limits

In practice, the steel industry is a complex agglomerate of several industries and hence the investment, operating and conversion costs, the manpower requirements and the organisation structure depend on the spectrum of backward, forward and by-product linkages and services within the battery limits of individual steel plants. A typical list of these optional linkages and installations is given on the next page.

The stage-wise range of investment costs prevailing in early 1978 indicated in Table 15 illustrate various investment costs possible with the addition or deletion of a few typical backward and forward linkages.

Backward linkages	Forward linkages	By-product linkages	Services
Ore mine Coal mines	Bar re-rolling mill Cold strip mill	Coke-oven by products Scrap recovery from slag	Refractories Oxygen plant
Coal washeries	Cold twisting of bars	Slag granulation for cement	Repair and maintenance facilities
Limestone and dolomite quarries	Wire drawing	Paints from ferrous oxide in pickling bath	Ferrous and non-ferrous foundries
Ferro-alloy plants	Wire galvanising	Skull cracking	Transport
Pelletising plant	Corrugating plant	Nitrogenous fertilizer plant	
Sintering plant	Sheet galvanising	High phosphorous slag granulation for fertilizers	
Coke ovens Scrap pre-heating	Tin plates Welded tube mill		
Mill roll foundries	Spiral pipe mill		
Auto-shredder Baling, briquetting and other scrap processing	Seamless tube mill Cold formed sections Cold slitting lines		
Lime and dolomite kilns	Welded beam plant		
Direct reduction plant			

TABLE 15 - STAGEWISE RANGE OF INVESTMENT COSTS IN EARLY 1978

Facility	Investment range US $ annual/ton	Facility	Investment range US $ annual/ton
BF ironmaking		Primary rolling	
Coke oven & by products plant	160-235	Slab/bloom mill	95-115
Sinter plant	25-40	Hot rolling	
Blast furnace	150-175	Heavy structural mill	450-550
DR ironmaking		Bar mill	210-255
		Plate mill	250-320
Gaseous direct reduction plant	110-140	Hot strip and finishing mill	110-130
Steelmaking and continous casting		Cold rolling	
BOF with billet caster	155-195	Pickling and cold rolling mill	280-340
BOF with slab caster	135-175	Annealing and tempering mill	130-160
EAF with billet caster	170-205		
EAF with slab caster	150-185	Coating	
		Galvanising line	250-300
		Tinning line	225-270

Source: Capital Investment in Steel Industry in Developing countries - by R.J. Kuhl 1979 Symposium, South East Asia Iron and Steel Industries.

The steel industry in industrialised countries often enjoys the industrial agglomeration economies and can pare down the investment costs on linkages. For example, many steel plants in the north-west USA, Ruhr region of West Germany and Belgium purchase calcined limestone and dolomite from independent kilns of large capacity operated on commercial basis near the quarries (such as Wulfrath in West Germany) from which calcined lime and dolomite are distributed in moisture-sealed containers.

In contrast, the weaker Indian engineering infrastructure necessitated heavy investment on repair shops in the first phase of Bokaro steel plant. This was several times higher than the corresponding facilities in integrated steel plants set up in three developed countries during the 1960s as can be seen from the following indices:

		Steel plant			
Indicator	Unit	Fukuyama, Japan	Spencer works, UK	Taranto, Italy	Bokaro, India (1)
Capacity	mill ingot tons/year	1.5	1.4	2.5	1.7
Investment in repair shops:					
- proportion of total plant cost	%	0.28	1.27	1.47	2.96
- relative index	Number	0.20	1.0	1.52	1.56

NOTE:
(1) The repair facilities actually provided by the suppliers were 2.8 times these rationalised estimates.

A major Japanese steel producer recently reported that it pays annual rental of US $ 4 million on installation of computers. This type of rental and maintenance facility for computers may not be available in many developing countries. A few typical cases of the extent to which the forward and backward linkages influence the investment costs of plants of different capacities in the range of 50 000 tons per year to 8 million tons per year are shown in Table 16. It will be seen from the table that the investment requirement per ton of finished product can vary by as much as 3.6 times depending on the linkages and the plant capacity.

[illegible] PLANTS OF BACKWARD INTEGRATION AND FORWARD LINKAGE

[illegible]	Plant capacity														
Liquid steel, '000 tons	50	[illegible]0	100	120	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Finished steel, '000 tons	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BACKWARD INTEGRATION															
Coke ovens	-	-	-	-	-	-	-	-	X	-	-	-	-	X	X
Sintering	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
Ironmaking															
Type	-	DR	-	-	-	-	-	DR	BF	-	-	DR	DR	BF	BF
No.	-	1	-	-	-	-	-	1	1	-	-	1	[illegible]	1	..
Unit capacity	-	-	-	-	-	-	-	[illegible] MT/Y	[illegible] T/D	-	-	[illegible] MT/Y	[illegible] MT/Y	[illegible]000 T/D	..
STEELMAKING															
Furnace type	EAF	EAF	EAF	EAF	EAF	EAF	OH	EAF	BOF	EAF	EAF	EAF	EAF	BOF	BOF
No.	1	1	1	1			[illegible]		1	[illegible]	[illegible]	[illegible]	[illegible]		..
Unit heat capacity	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	100	150	..
PROCESSING AT LIQUID-SOLID INTERFACE															
Casting	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Primary rolling	-	-	-	-	X	-	-	-	-	X	-	-	-	-	-
ROLLING MILLS															
Long products															
Bar	X	X	X	X	-	-	-	-	-	-	-	-	-	-	X
Merchant	-	-	-	-	X	X	X	X	X	X	X	-	-	X	X
Structurals	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X
Hot strip mill	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X(1)
FORWARD LINKAGE															
Cold mill	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X
Coating lines	-	-	-	-	-	-		-	-	-	-	-	X	-	X
INVESTMENT COST(2)															
Unit investment															
Crude steel $/ton	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Finished products $/ton	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	600	[illegible] to [illegible]
Total Million $	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

NOTES:
(1) Also a plate mill
(2) At 19[illegible] prices

Source: Paul Marshall "A Study of Steel Prices", Washington D.C., 19[illegible]

ABBREVIATIONS:			
DR - Direct reduction		OH	- Open-hearth Furnace
BF - Blast furnace		CC	- Continuous Casting
EAF - Electric arc furnace		IC	- Ingot Casting
BOF - Basic oxygen furnace		Merchant Mill	- Combination Bar and Rod Mill

Fiscal and monetary policies

The post-war recovery and growth of the Japanese steel industry till mid-1960s was stimulated by a number of monetary and fiscal concessions from the government. The Japanese government prevailed upon the commercial banks to advance preferential loans for development of steel industry at low interest rates. About 61 per cent of machinery and equipment required for modernization of the war-ravaged industry was imported and these imports were totally duty-free. Accelerated depreciation for three years and development rebate at the rate of 50 per cent of installation cost for the first year were admitted as deductible expenses for computation of taxable profits. Foreign exchange was freely released for import of equipment and raw materials. Japan's current imports of steel industry exceeded the corresponding export earnings till 1962.

In India, the exemption conferred on the scrap-based mini steel plants in late 60s from payment of excise duty of Rs. 75 (about US$ 10) per ton, which was payable by the integrated steel plants on their production of ingots gave a fillip and saw a massive proliferation in the establishment of over 100 electric arc furnace units in various parts of India. However, with the withdrawal of these concessions in mid-1970s, the growth of the mini steel industry ceased in India.

Bokaro steel plant-Phase I installation in the public sector was exempted from payment of interest charges on investment during its nine year construction period (whereas the Steel Authority of India, the holding company for this plant, has recently invited three-year loans from the public at compounded interest rate of 14.5 per cent per annum).

With the annual inflation rates touching two-digit figures in many industrialised countries, the interest rates on capital funds are steadily rising. In the latest World Development Report - 1980, the World Bank has forecast that the spread between the lending and the borrowing rates of commercial banks will increase through the 1980s. Therefore possibility of the availability of funds at low interest rates which had stimulated phenomenal growth of steel industry through 1960s is to be considered as remote during the 1980-1990 decade.

The direct and indirect tax systems impose differential cost burdens on the steel industry in different countries. The import duty levied at the rate of 45 per cent of the c.i.f value raises the steel plant cost by about 15 per cent in India.

State participation

The steel industry in many industrialised countries is owned and run by the joint stock companies with private stock-holding, though examples of public ownership of steel industry can also be seen in the Finsider in Italy, British Steel Corporation in the United Kingdom, Sacilor and Usinor in France and Peine Salzgitter in West Germany. Creation of the Steel Tripartite Committee of the government, industry and labour in 1979 and the government backing of loan, guarantees to steel firms herald a radical change in the attitude of cooperation in USA where arms-lengths relationship prevailed between the government and industry for three decades. As the massive outlays required for installation of integrated steel plants are beyond the financing capacity of entrepreneurs in most developing countries except Brazil, Mexico and to some extent Argentina, the integrated steel industry in developing countries is generally set up by the State governments, whereas semi-integrated steel industry (the so-called mini-steel plants) are installed in the public as well as private sectors.

A survey of financing modes of mini steel plants carried out in 1976 had revealed that over half of the funds for the mini steel plants under private ownership were raised from the financial institutions and commercial banks. The increasing role of state ownership in development of steel industry in developing countries can be seen from the trends shown in Table 17 on the next page.

Even in industrialised countries, the situation of financial distress brought about by the unprecedented recession has compelled the steel industry to seek State funds. In a contradictory stream, there is growing disillusion with the State ownership of steel industry. Mounting losses in steel industries run by the State are burdening the Italian national budget heavily and serious thinking on turning some state enterprises back to private ownership is being considered. With recurrent massive losses, the British Steel Corporation continues to strain the government resources in UK.

TABLE 17 - PUBLIC SECTOR CONTROL OF STEEL CAPACITY IN SELECTED DEVELOPING COUNTRIES(1)

Country		Steel capacity controlled by public sector - per cent	
		1975	Estimated for additions till 1988
Latin America			
Argentina	..	70	80
Brazil	..	60	80
Mexico	..	50	65
Venezuela	..	86	90
Europe			
Spain	..	52	65
Turkey	..	90	90

NOTE (1) Chile, Peru, Iran, South Korea and Taiwan all had 100 per cent capacity in the public sector and the same role is foreseen for the public sector in future.

Source: Various issues of Metal Bulletin, Iron and Steel International, Stahl and Eisen and Siderurgica Latinamericana.

Product pricing

The domestic controls either in voluntary of statutory form have tended to keep down the domestic steel prices to unremunerative levels in most countries. In the early 1960s, the USA authorities had compelled the major steel producers to hold the steel price line as an anti-inflationary measure. The prices of steel products in India have been regulated at periodic intervals by the tariff commissions on cost plus basis which limited return on investment to 8 per cent per annum.

The continuing slackness in steel markets and sizable excess steelmaking capacity in the industrialised countries have tended to push down the international export prices of steel products. However, as soon as the markets improve (expected around mid-1980s), the international prices are anticipated to surge forth.

Undervaluation of local currency at the official exchange rates in developing countries favours import of intermediate goods such as steel as also high import content in the locally manufactured goods. Gurmendi, a major private steel company in Argentina, was compelled to lay off 600 workers at its Avellaneda works when it suffered US $ 10 million operating loss in the first quarter of 1980 after a profitable year in 1979. The main reason for this debacle was the massive import of foreign steel which was favoured by the prevailing foreign exchange rates, as the internal production costs inflated at a faster rate than the devaluation of peso.

SOCIAL BENEFITS

Defence mobilisation

Established steel industry provides a ready base for rapid mobilisation for national defence. During the Second World War, Krupp mobilised their entire steel industry for the German war action and in collaboration with the railroad, rolling stock and automobile manufacturing and ship-building industry, the US steel industry could gear their vast base to the Second World War. The highest steel production in Japan during the first half of the twentieth century was 7.5 million tons in 1943 - the peak year of Second World War. In India, during the Second World War, the Tata Iron and Steel Company developed various special steels such as armour plate, shell bar etc for the defence purposes. For quite sometime after the outbreak of open hostilities with China in 1962, the Indian emergency defence mobilisation efforts were initiated through the steel industry. This defence potential could become one of the strategic considerations for many developing countries to establish and consolidate their base of national industry.

External Economies

Being a massive consumer of a wide range of raw materials, consumables, utilities and public services, steel industry transplants economies of scale on several sectors. Thus steel industry establishes a steady and substantial base demand for output of mines and quarries, water and electricity supply systems, communications, greases and lubricants, railways, roads etc. Thereby the marginal cost of raising additional outputs for other economic sectors is reduced due to agglomeration economies. Thus the steel industry contributes to boosting economy of backward regions in developing as also industrialised countries. Installation of public sector steel plants at Salem in South India and Visakhapatnam on the south-east coast of India are expected to diversify the economy of those backward regions and lead to decentralisation of the steel industry in the country. Similar considerations have prompted the Italian and French governments to establish integrated steel plants at Toronto in South Italy and Fos-Sur-Mer in Southern France.

Skill dissemination

The skills required for production and maintenance of the steel plant cover a wide spectrum of metallurgical, chemical, mechanical and electrical engineering disciplines. In India, the skills developed through the operation and the technical training institutes of the integrated steel plants have gradually disseminated into various downstream engineering units such as forging, welding, sheet metal work automobile body building etc. The training institute set up by Thyssen near Duisburg, West Germany in 1976 with an outlay of DM 30 million is currently engaged in training technicians for West Germany - over half of whom are absorbed by the engineering industry and only the balance by Thyssen steel industry.

Diversification

Based on the inter-industry input-output analysis of USA, Norway and Japan in selected post-war years, Hirschmann has observed that the steel industry takes the place of pride in the diversification of economic base with the highest backward and forward linkage amongst all manufacturing industries. After an analysis of the investment options for establishment of heavy industries, the planning authorities in Hungary had reached a conclusion in 1957 that the steel industry had the highest employment potential per unit of investment when all backward and forward linkages possible in the country are taken into account.

FINANCE

Capital requirements

The capital requirements for development of steel industry have risen to staggering heights even in many developed countries. A recent report of the US Office of Technology Assessment has recommended that the steelmakers in USA increase their capital spending by 50 per cent over the next 10 years to the level of $ 3 billion annually with Federal financial aid to improve the competitive position of industry. Among the developing countries, the 1-million tons per year capacity of integrated steel plant proposed for Nador, Morocco involved outlay equivalent to country's total investments for one year. In some developing affluent OPEC countries, the investment requirement for steel plants of size adequate to realise economies of scale is equivalent to their extraction of crude oil for six months.

According to the British-North American Committee on New Investment in Basic Industries, the cost of equipment for basic industries has increased three times faster than the cost of inflation in the 'dear-energy' 1973-1979 period. The impact of inflation on the evolution of unit investment costs as estimated by the IISI, Brussels is shown in Table 18.

TABLE 18 - IMPACT OF INFLATION ON INVESTMENT IN STEEL PLANTS

Plant type	Estimated investment range per annual ton of capacity in current US $		
	1973	1976	1979
Integrated - greenfield	500-550	710-800	1000-1250
Integrated - brownfield	350-400	420-540	575-750
Integrated - replacement	250	350-375	450-500
Mini-mill	250	340-375	450-500

As a result of the interaction of numerous factors described in the foregoing analysis, the investment requirement for greenfield integrated plant construction in many developing countries is presently estimated to have risen to US $ 2 000 per ton for greenfield site. If the requirements for infrastructure are added, this unit investment may rise to US $ 3 000 per annual ton.

Foreign exchange requirements and savings

The foreign exchange requirements for development of steel industry in developing countries will vary with the implementation procedures, construction infrastructure and capacity of the country to indigenise manufacture of equipment. Nevertheless a broad pattern of the foreign exchange requirements emerging from the project reports scrutinised by the World Bank is shown in Table 19. Adding other pre-operative expenses like training costs and technical assistance, the proportion of investment in foreign currency in the integrated steel plants could be assumed to be around 60 per cent.

TABLE 19 - GENERAL STRUCTURE OF EXPENDITURE FOR FIXED ASSETS IN LOCAL AND FOREIGN CURRENCIES
(1 to 2 million tons capacity - Blast furnace-BOF route)

	Percentage of expenditure in currency					
	Foreign		Local		Total	
Item of fixed asset	Proportion of fixed assets	Proportion of respective asset	Proportion of fixed assets	Proportion of respective asset	Proportion of fixed assets	Proportion of respective asset
Plants and spares	74	80	25	20	50	100
Structures	6.5	60	6.5	40	8	100
Transport	6.5	88	1	12	4	100
Erection	12.0	33	34.5	67	23	100
Civil works	1.0	3	33	97	15	100
Total	100	57	100	43	100	100

Source: World Bank Steel project reports.

Table 20 shows the order of foreign exchange benefits from the operation of an integrated steel plant with blast furnace/basic oxygen steelmaking facilities that can accrue to a developing country utilising local ore and employing mostly local personnel. Thus according to UNCTAD estimates, the net foreign exchange saving at 1975 prices can range between US $ 161 to US $ 196 per ton of finished steel.

TABLE 20 - ORDER OF SAVINGS IN FOREIGN EXCHANGE FROM STEEL PRODUCTION AT 1975 PRICES

Notation: FE - Foreign exchange

Case	Percentage of FE cost borne		FE cost in producing steel $/ton	Gross FE saving $/ton	Net FE saving $/ton
	Capital	Operating			
A	70	30	100	261	161
B	50	30	81	261	180
C	70	15	84	261	177
D	50	15	65	261	196

Assumptions:
- (i) Integrated steel plant of 5 million tons per year capacity with blast furnace/basic oxygen plant
- (ii) Capital charge for interest and depreciation - 15 per cent
- (iii) Capital cost per annual ton - US $ 639
- (iv) Production cost = Operating cost + Capital cost = $ 110 + $ 95 = $ 206;
- (v) Operating costs include allowance for scrap losses and credits
- (vi) Final price $ 261

Source: UNCTAD estimates, 1975

The capital requirements for replacement, modernisation, maintenance, pollution control and raw materials development for the existing steel capacity have to compete with the capital requirements for additional steel capacity through greenfield installations, brownfield expansion and the roundout expansion for appropriation of funds from the available capital. Typical 1976 cost estimates of capital requirements for the three major producer regions were as follows:

	Cost - US $/annual ton of finished product capacity		
	USA	JAPAN	EEC
Greenfield plant ..	1 050	700	800
Brownfield expansion ..	700	470	500
Roundout expansion ..	520	400	460
Maintenance cost ..	15	5	10
Replacement cost ..	10	6	9
Pollution control-retrofitting	2.5	2	2.25
Raw materials development	1.0	0.8	1.0

Financing of capital requirements

The sources of funds available to finance the steel industry are self-financing through retained earnings and depreciation and external finance through equity capital, long-term debt and state funds, credits and aid. Export credits for steel plants from OECD countries increased from US $ 867.5 million in 1966-69 to US $ 3 593.3 million in 1976-77.

The main recipients of these credits in the developing countries were Brazil, Mexico, South Korea, Indonesia, Taiwan and Algeria, whilst in the East Europe they were USSR and Poland. Steel plant exports to the developing countries during 1974-1977 were facilitated by official aid amounting to 15 per cent of these export credits.

At the current trend of unremunerative steel prices, the net income of steel industry has been declining. The availability of depreciation funds for financing is strictly related to the unwritten depreciation of the past installations. The inability of steel industry to pay high interest rates ranging from 8 to over 10 per cent which rule the capital market is acting as a deterrent to raising of new debits (For the first time, the financing of the American and Japanese steel industry through new debt was nil in 1978).

A financing pattern of steel industry that has achieved some success in three developing countries - Qatar, Malaysia (Malayawata plant) and Brazil (USIMINAS plant) - is the equity participation by the equipment and know-how supply company. However, under the present uncertain trends of the steel industry, this pattern does not seem to be acceptable to equipment suppliers. Nippon Steel now seems to be reluctant to have equity participation in SOMISA, Argentina and the Japanese steel mills have refused to participate in the Mindanao project in Philippines.

Table 21 on the next page summarises a few recent cases of the way in which the external finance was raised partially from the various financing sources in developing countries.

TABLE 21 - TYPICAL CASES OF STEEL INDUSTRY FINANCING

Case	Financing source	Project cost share financed %	Role of intermediaries	Interest rate(1) %	Repayment period years	Grace period years	Repayment instalments month
1	Deposit notes of National Bank	10	Cooperation of USA bank	+ 1/2(2)	3	..	6
	EXIM bank, USA	40	Guarantee cover of EXIM	+ 1	7 to 14	4	6
3	Unsecured loan from bank	20	..	+ 2	5	3 after first advance	6
4	Project 1						
	European export credit orgn.	15	..	7.5-8.5	12	6 months after plant start up	6
	Project 2						
	-do-	50	..	7.5-8.5	12	-do-	6
5	Euro-currency loan	15	British merchant bank	$+1\frac{7}{8}$ to $2\frac{7}{8}$	3 tranches 5/6/7	..	..
6	World Bank	7	Guarantee of national finance institution	9	15	5	..
7	Iron ore importing country	100 (mining project)	..	13	20	..	Regular ore deliveries
8	USSR Govt to National Govt (in 1965)	50	..	2.5	12	..	..

NOTE:
(1) + sign indicates interest rate above LIBOR-London Inter-Bank offering rate
(2) Above LIBOR for 6-month US dollar deposits

Source: Note on aspects of Financing Steelworks and Ore Field Development in Developing Countries, UNIDO January 1979. Proceedings from Second Consultation Meeting.

The World Bank has estimated in mid-1979 total availability of medium and long-term foreign borrowings to developing countries for overall economic development namely, (i) bilaterial and multilateral concessional loans and grants as official development assistance, (ii) medium and long-term private and multilateral loans and (iii) official export credits at market prices to increase at constant prices by 25 per cent between 1980 and 1985 and level off thereafter. However, in the third annual world development report released in August 1980, the World Bank is less sanguine about the availability of these credits due to gloomier growth rate projected for industrialised countries. Only the cpital-exporting OPEC members like Saudi Arabia, Kuwait, Venezuela and United Arab Emirates will be in a position to maintain and step up the rate of lending of development funds.

Gestation period

At the partial capacity utilisation of the installed capacity during the gestation period, the finances of a steel plant become critical and hence shortening of gestation period has a salutary effect on the cash liquidity and returns on investment. With highly skilled labour, a few Japanese mills have attained production to rated capacity within 18 months of commissioning. The semi-integrated plant of Sheerness Steel Comapny in UK is reported to have attained production to the rated capacity within one week of commencement of trial runs on completion of erection of facilities. In the course of appraisal of the feasibility report for Sicartsa's integrated steel plant on the West coat of Mexico, the World Bank found profitability of investment to be so highly sensitive to the assumptions of gestation period that the Bank recommended deployment of technical assistance experts to Sicartsa to minimise the gestation period.

Profitability

Under the interaction of high capital intensity of steel industry, capacity underutilisation, rising production costs, depressed international prices and voluntarily or statutorily regulated domestic prices, the profitability of steel industry has been very low in industrialised as also developing countries. An analysis of the history of industrialisation in seven developing countries leading in industrialisation had revealed that the rate of return declined as the capital intensity of industry increased. Since 1960s the return on equity investment in the American steel industry has continually declined and presently it is lower than the return on secured no-risk loans. These declining returns induced many American steel industrial companies to divert their investments to overseas steel industry in Spain and Italy and to other more remunerative industries in USA such as aluminimum, while the Japanese steel industry continued with the expansion and modernisation programmes drawing a part of their funds from the American commercial banks.

Underutilisation of installed capacity due to bottlenecks of infrastructure facilities, long gestation periods and low productivity tend to aggravate the situation in developing countries.

IMPLEMENTATION

A majority of the groups and sub-groups of implementation enumerated in Fig. 2 are self-explanatory. Hence only a few typical aspects are elaborated in the following paragraphs:

Management

(i) Competent consultants having no tie-up with the equipment suppliers and or contractors can render objective advice for selection of the appropriate processes, equipment, equipment suppliers and contractors.

(ii) Installation of integrated steel plant requires manufacture and erection of massive quantities of equipment and structural steelwork. As a general rule of thumb, the equipment weighs one-tenth of the annual production capacity of the steel plant. Closer estimates of these quantities are as follows:

Item of manufacture/ erection	Weight in tons for plant with capacity - million tons/year			
	0.5	1.0	2.0	5.0
Direct reduction-electric furnace process with long product mills				
Equipment	45 500	85 500	160 000	
Structurals	20 000	35 000	60 000	
Blast furnace-basic oxygen furnace with long and flat product mills				
Equipment			220 000	400 000
Structurals			175 000	320 000

Source: "Steel production in the Arab world by the year 2000 with particular reference to capital equipment, M.M. Luther, Chairman, Projects and Equipment Corporation of India, New Delhi, June 1976, Annexes III and IV

The heavy magnitude of fabrication and installation activities of the equipment and structurals as also the construction of steel plant requires well-organised, resourceful contractors for successful and timely execution. In many developing countries such contracting agencies are scarce. Even in a developed country like United Kingdom, a critical country-wide survey and analysis of the capacity of fabricators was necessary to ensure timely realisation of the "Anchor" project for modernisation of Scunthorpe plant by British Steel Corporation.

(iii) Plant installation on turnkey basis and on consortium basis raises the implementation costs substantially and minimises customer's exposure to opportunities to acquire know-how. The prices of civil works alone for two of the three 1 million ton capacity integrated steel plants in India installed on turnkey basis during 1950s were found to be 70 per cent higher than those calculated on item rate basis.

(iv) Construction periods of integrated steel plants tend to get inordinately prolonged without authoritative monitoring for various reasons such as (a) difficulties of land acquisition; (b) non-receipt of equipment supplies in proper sequence and phased manner to match the construction schedule; (c) delays in receipt of technical data, and documentation and drawings for the equipment to be manufactured locally; (d) promotional and development efforts for indigenisation of equipment manufacture; (e) sporadic shortages of essential construction materials such as cement and refractories for construction and rolled steel in matching sections; (f) delays on the part of construction contractors due to their organisational inadequacies, lack of resources and frequent labour troubles; and (g) shortages of oxygen, acetylene, welding electrodes etc. The start of construction activities for the different production facilities for the first 1.7 million tons per year capacity phase of the integrated steel plant at Bokaro, India was delayed by periods ranging from 6 months to 1 year but the completion was delayed by periods ranging from 3 to 5 years with reference to the original construction schedule. In contrast, almost all the production facilities for all the two phases of expansion of Pohang steel plant, South Korea upto 5.5 million ton capacity are reported to have been commissioned on-schedule, with the continuous monitoring and enforcement of timely corrective action on the construction activities.

Strategy

(v) Insufficient investigation of sub-soil conditions leads to increased costs of foundation engineering and delayed implementation. On encountering rocky sub-stratum during implementation, the site for steel plant at Rourkela, India had to be shifted.

(vi) A judicious risk-sharing approach between the contractors and clients in respect of contract conditions and performance guarantees for equipment can yield substantial economies in implementation costs.

(vii) In large semi-industrialised developing countries like Brazil and India, indigenisation of equipment procurement also delays the implementation and increases costs. In their capacity as an international money lender for developing countries, the World Bank also authorises award of contracts to local industries at 15 per cent higher price than the international competitors. In India, the proportion of local manufacture has increased with the installation of successive steel capacity as shown in Table 22.

TABLE 22 - PROPORTIONS OF FOREIGN AND LOCAL SUPPLIERS IN INDIAN STEEL PLANTS (by value)

Steel Plant	Capacity mill.ton	Equipment Indian %	Equipment Imported %	Structurals Indian %	Structurals Imported %	Refractories Indian %	Refractories Imported %
1955-1961							
Rourkela	1.0	-	100	4	96	22	78
Bhilai	1.0	13	87	22	78	6	94
Durgapur	1.0	13	87	28	72	50	50
1961-1966							
Rourkela Expn	1.8	25	75	78	22	57	43
Bhilai Expn	2.5	18	82	29	71	44	56
Durgapur Expn	1.6	49	51	74	26	96	4
1964-1976							
Bokaro 1st stage (completed)	1.7	60	40	94	6	61	39
1976							
Bokaro Expn (in progress)	4.0	88	12	100	-	100	-

(viii) The spare part requirements for a million ton capacity may range between 2 400 and 3 300 tons per year. The spare parts and proprietary consumables to be procured along with the equipment purchase could cover the operational requirements ranging from one to two years (and even five years as in the case of Saudi Arabia) depending on the status of development of local engineering industry and skills. The magnitude of initial capital investment and the inventory burden to be carried by the steel plant during initial years of operation will depend on the selection of cut-off levels for capital procurement of spare parts and proprietary consumables.

(ix) At the Bokaro steel plant site in India, resources of all construction contractors working on the projects had to be pooled together to the exclusion of all concreting activities at other construction sites of the steel plant for about 8 days to cast massivemonolithic foundations for hot strip mill with about 80 000 cu m of concrete according to the specification of the equipment suppliers.

Development environments

(x) The massive nature of construction for steel plants requires economic set-up of construction infrastructure in advance. For instance, the Ministry of Steel, Mines and Fuel, Government of India discovered in late 1958 only after virtual completion of the construction of the Bhilai steel plant that the construction equipment and temporary works and structures required for construction which were not provided in the project estimates of suppliers had amounted to 11.5 per cent of the project cost. The Chinese authorities expressed in July 1980 their disappointment with the unplanned diversion of construction materials and resources to the huge construction site of 6 million ton capacity steel plant as this is causing delays and damage to other projects.

(xi) Delays in construction and mobilisation of permanent infrastructure - power supply system, water supply, township and harbour often lead to delays in commissioning of steel plant facilities in developing countries.

(xii) Scheduling rectification, renovation and modernisation of existing steelworks with minimum interruption of production from existing facilities is another area in which the industry in developing countries can improve its performance with sufficient advance planning. Hoesch works, West Germany had managed to keep production from their existing semi-continuous hot strip mill almost intact while renovating the mill in 1970 to make it three-fourths continuous. Though the renovation operation was spread over a period of two years, the mill was shut-down continuously only for 10 days and intermittently for 36 days.

INTERNAL DYNAMICS

While the planning and implementation systems influence the capital investment, the availability of regenerative finance for repayment of debt, dividends, plant depreciation and expansion is determined by the efficiency of operation. Steel demand is price elastic over short-term and the efficiency of operation is vital in an industry with products which exhibit such elasticity. Of the various groups and sub-groups of internal variables related to operations shown in Figure 3 only the key aspects are discussed in this brief study.

Corporate management

As the steel industry is a vast conglomerate of several industrial units linked vertically and horizontally and because of the increasing internationalisation of steel, the vision, perception and action of corporate management influences the destiny of the industry. In the countries where the industry is established in the private and public sectors as in UK, Italy, Brazil and India, the private sector companies have shown better financial performance under their management. Despite the global recessionary trends in the industry, the profitability of Japanese steel industry in 1978 was more or less equivalent to that in 1973 - a year of booming market conditions. The Japanese management has fought the recession with rigorous rationalisation programmes of borrowings, energy management, streamlining of personnel structure, product-mix adjustments etc. With adjustments in product-mix alone, the Japanese realisation from exports rose to US $ 12 billion from US $ 10.5 billion, though the exports volume declined from 37 to 30 million tons between 1976 and 1978.

In contrast, as acknowledged by the US Congress Committee on Assessment of Steel Technology, the American management had been slow in realising implications and implementing the rapidly changing technology especially in steelmaking and continuous casting which has adversely affected its competitiveness against Japanese industry. It is widely believed that the American attitude to assess performance of industries largely on the basis of quarterly and annual financial ratios has kept the corporate management pre-occupied with short-term financial management and success to the detriment of long-term dynamism of the American steel industry.

Sales management

With continuously rising installation and production costs of steel industry, product research can help in mitigating the impact of inflation and recession in the market.

The Japanese steel industry has reoriented its product-mix in recent years from mass production towards high value special steels, increasing the proportion of hot rolled special steel products from 10.6 per cent in 1976 to 11.4 per cent and 13 per cent in 1977 and 1978 respectively, while the total crude steel output declined by 5 per cent during the same period. (The steel output from BOF accounted for 61.3 per cent of the total special steel output of Japan in 1978).

U.S. Steel industry has introduced the new product of one-side galvanised sheets for the automobile industry for duty conditions in which only the external side of sheets need to be protected against corrosion.

The Alaska oil pipeline required pipes of high tensile strength and low temperature toughness to withstand severe climatic conditions. Ten years ago, technology to meet such specification was not available. The Japanese steel industry developed this technology with

i) mass production of clean low carbon steel with tensile strength of 60 kg/mm2 in BOFs
ii) controlled rolling with controlled temperatures to ensure strength and toughness of steel during rolling
iii) accurate pipeforming techniques for larger diameter high-tensile strength pipe and
iv) on-line inspection system

This product research enabled the Japanese mills to win the export contract for 0.5 million tons of steel pipes for the Alaskan oil pipeline.

Materials Management

With pragmatic long-term contract policy, Japan has succeeded in securing imports of iron ore supplies generally at lower f.o.b. prices than the European steel producers. In 1976, the price difference between CVRD fines (the leading brand of ore in Europe), and Hammersley fines (the leading brand in Japan) was 5.4 cents per Fe unit. Also for the same brand of CVRD fines in 1979 the Europeans werepaying 23.9 cents per Fe unit, whereas the Japanese paid 21.9 cents. Emulating this pattern of materials procurement, the Bethelehm Steelworks (USA) has introduced of late a new policy of stockpiling its scrap requirements one year ahead to take advantage of the low spot prices in the USA which prevailed during July 1980.

Inventory control helps in reducing capital requirements and thereby helps to improve the cash liquidity of a plant. Hoesch Huttenwerke, Dortmund have reduced the number of lubricants and other oil products used in the plant from 300 to 90 with a vigorous programme of laboratory testing. A similar attempt to standardise greases, lubricants and other products at the Burnpur works of the Indian Iron and Steel Company recently yielded very attractive returns through better inventory control.

With a judicious combination of pragmatic procurement policies, raw materials selection and continuous upgradation of technologies, the Japanese steel industry has succeeded not only to nullify its cost disadvantage of imported materials but taken a lead over its competitors as shown by the long-term trends in Table 22.A

TABLE 22A- COMPARISON OF LONG TERM TRENDS OF BASIC MATERIALS COST IN JAPAN AND U.S.A

Year	Basic materials cost - US$ per ton(1)		
	USA	Japan	Ratio of Japan to USA
1957	49.76	106.42	2.14
1960	48.35	62.07	1.28
1965	47.93	54.27	1.13
1968	49.03	46.95	0.96
1970	60.95	54.83	0.87
1972	65.59	51.59	0.79
1973	73.90	65.65	0.89
1974	114.64	104.70	0.91
1976	151.10	112.29	0.74

NOTE: (1) Basic materials include only iron ore, scrap, coal, oil natural gas and electricity.

Source: US Federal Trade Commission, Staff Report on the United States Steel Industry and Its International Rivals: Trends and Factors Determining International Competitiveness, November 1977.

Personnel management

A comparison of the performance of four integrated steel plants in the iron and coal belt of India shows that the plants with healthy management-labour relations have done better than those which suffer from poor relations and rivalries between multiple trade unions. In the American and the German steel industry, collective bargaining for the workers is negotiated only by one union, whereas there are 17 labour unions for the steel plants under the control of British Steel Corporation. Difference between the performance of the American as well as the German industry and the British industry appears in part to be attributable to this difference in labour union movements.

The system of 'Jishu Kanri' in which the employees contribute to productivity increase through voluntary group discussions has benefited the Japanese steel industry considerably; one integrated Japanese steelworks has recently acknowledged saving of US $ 5 per ton of steel due to this personnel management system.

Human productivity

One of the classical ways in which skilled work-force in the steel industry raises its level of earnings is the increased productivity through steady improvement in yields. Exploiting fully the advantages of economies of scale and computerisation, the skilled Japanese work-force steadily raised the average national yield from 80 per cent in 1965 to 88 per cent in 1976 and the Japanese steel industry now seems to have set the yield target at 93 per cent for 1983. At the plate mill in Mizushima plant, Kawasaki Steelworks have steadily raised yield of plates to 94 per cent improving their own performance of the highest yields in the world for the two successive preceding years. Developing countries could accelerate growth of steel industry if they succeed in improving their yields by emulating the Japanese practice of controlled selective inputs.

In the capital-intensive steel industry, the human productivity and the resultant efficiency of operation can offset some disadvantages as borne out by the success of steel industry in Japan and South Korea. In this connection, it is worth recalling the following observations of the Japan Iron and Steel Institute team on their visit to United Kingdom in April-May 1964 (reference - Journal of the Iron and Steel Institute of Japan, Volume 4, Number 3, September 1964).

> "When calculating construction cost per ingot ton of production capacity, the main problem is how this production capacity should be calculated. If we use the British figures for the R.T.B. Spencer Works (excluding the tinplate and galvanising facilities), the construction cost works out at ¥ 107 000 per ton of capacity, compared with the figures for our own Tobata works of ¥ 53 000 per ton/year (including tinplate and galvanising facilities). However, if we calculate the capacity of these works according to the Japanese method, it becomes 2.1 million tons

> per year, instead of its rated capacity of 1.4 million tons, and further, if we take as our basis the 130 tons per heat which were being charged to the furnaces at the time of our visit, the figure rises to 2.45 million tons. If this figure is now used to calculate the construction cost per ingot ton of capacity, the figure becomes much lower and fairly close to the Japanese figure".

Industrial engineering observations have shown that the unlogged delays due to human factors in the operation of rolling mills in certain developing countries account for about 25 per cent of the net available hours, while in many industrialised countries the corresponding factor is reported to be only 5 per cent. Thus the output from an identical rolling mill in some developing countries is 21 per cent lower due to human factors than that in the industrialised countries.

Maintenance efficiency

As acquisition of engineering skills for maintenance requires larger duration than the operative skills, many steel plants in developing countries suffer during the initial years from the lower inspection and maintenance efficiency and greater downtime of equipment. Damage to a critical component of the crop-end shear in the slabbing mill of the Rourkela Steel Plant in India in 1963-64 (that is within a period of four to five years of its commissioning) had resulted in shut-down of production of the hot and cold strip mills for two months. A few years later, the roof over the LD converter steelmelt shop collapsed under the accumulated weight of dust particle emissions which disrupted production programmes for the whole plant for a few months. The maintenance and inspection procedures were improved in this plant by introducing the rolling maintenance programmes which were evolved in Germany during the Second World War. The productivity of steel industry in developing countries may improve through the adoption of the recently evolved "condition diagnosis" technique which permits on-line inspection of rotating equipment thereby averting stoppage of these equipment without adequate forewarning.

Energy economy

Substantial energy economy has been achieved in the operating steel plants in USA, Sweden, UK and Italy with the adoption of model tests for determining the optimum blend and pattern of charging materials to the blast furnaces, programmes for regulating power inputs to the electric arc furnaces with manipulation of the most appropriate voltage and current inputs during different stages of melting and refining, and hot charging of semis to the reheating furnaces by-passing the cooling banks. In one of the electric arc furnace steelmelt shops in United Kingdom, a programme for optimising the power input was established after trials with 70 programmes over a period of four years.

By introducing the system of direct charging of continuously cast semis into the reheating furnaces for rolling and regulating the various operating parameters of the furnaces, the specific energy consumption for reheating has been steadily improved by the Japanese rolling mills as shown in Table 23.

TABLE 23 - TRENDS IN REDUCTION OF SPECIFIC REHEATING CONSUMPTION IN THE JAPANESE ROLLING MILLS

Mill type	Specific reheating consumption - 1000 Kcal/ton					
	1973	1974	1975	1976	1977	1978
Slabbing	313	246	194	177	166	157
Tandem hot strip mill	515	481	417	388	365	344
4-high plate mill	575	485	449	420	389	360
Wire rod mill	393	381	357	324	316	299
Tandem cold strip mill	305	304	299	292	281	271

Source: Annual Reviews, Iron and Steel Industry, Japan

INTERACTION OF VARIABLES

While variables described in this study will influence development of steel industry through 1980s, many of these individual variables in turn will be influenced by a few other variables. Interaction of the variables within each system for systems of planning, implementation and operations are shown in matrix form in Tables 24 to 26. The variables described and designated with digital numbers and alphabetical codes on the left side of each table constitute the full set of independent variables acting on the system. The same digital and alphabetical nomenclature arranged in the horizontal row on the top of the table represents the same variable as a dependent variable.

The total number of dependent variables on which an independent variable interacts in the Indian context can be readily read from the total horizontal row under 'plus'(+) column on the extreme right side of the table and the additional number of dependent variables that may be influenced by the same independent variable in the global context outside India are juxtaposed under 'minus' (-) column. Thus the independent variables 1A, 1B, 1C and 1D in Table 24 influence in India dependent variables of planning which total up to 12, 1, 4 and 0 respectively. The corresponding number of dependent variables that are influenced in the global setting by these independent variables are 24 (12 + 12), 15 (1 + 14), 8 (4 + 4) and 2 (0 + 2) respectively.

Explanatory notes for Tables 24 to 27

The following explanatory notes are offered to decodify the notation system adopted in Tables

(i) On the left side of Table 24, the independent variable of location and site is designated the c are grouped together under one digital code on the left side of this table and each of these fo alphabetical notation. Thus under the digital code of 9, four independent variables are identi follows:

Independent variable	Nomenclature
Location and site	9A
Power, water and gas supply	9B
Port and transport	9C
Housing and township	9D

(ii) The nomenclature 12A in the horizontal row at the top of the table represents linkages and servi

(iii) Influence of these four independent variables on this dependent variable is shown in the square vertical column under 12A and 12C and two horizontal rows against the pair of independent variab square indicates that at least one of the four independent variables could influence the extent industries on a global scale (that is in some countries except India). Inside of this symbol 'C influence is considered to be relevant to the Indian steel industry also.

(iv) The global influence of four independent variables on the dependent variable is denoted separat of symbol 'O' with - sign as follows:

Independent variable	Position allocation for - sig
A	Left side, top
B	Right side, top
C	Left side, bottom
D	Right side, bottom

to + when the independent variable interacts on the dependent variable in the context of the Ind

(v) As the linkages and service industries are influenced in India by the independent variable 9A - establishment of cement plant using the by-product of blast furnace slag) and the independent va facilities (for example, establishment of repair and maintenance facilities for the shunting loc existence of influence is acknowledged with + symbol on the left side top and the left side bot under the vertical column 12A. Possibility of by-product industries being set up on the basis c desalinated water could materialise in certain arid countries but not in India and symbol of - c is a recognition of such possibility. Housing and township do not generate any linkage or serv the steel plant. Lack of - or + sign in the right hand, bottom corner confirms this absence of

(vi) The notation adopted in Table 27 is identical to that in Tables 24 to 26 with one modification. group of 'Raw materials and energy' are designated codes 3A to 3F and their interaction with each amplified on the two sides along the horizontal axis of Symbol 'O' in addition to notation on f as follows:

Independent variable	Position allocation
A	Left side, top
B	Right side, top
C	Left side, centre
D	Right side, centre
E	Left side, bottom
F	Right side, bottom

d to decodify the notation system adopted in Tables 24 to 27:

ent variable of location and site is designated the code number 9A. Four independent variables
e on the left side of this table and each of these four variables is coded with an
ital code of 9, four independent variables are identified with separate alphabets as

		Nomenclature
	..	9A
supply	..	9B
	..	9C
	..	9D

at the top of the table represents linkages and service industries as a dependent variable.

les on this dependent variable is shown in the square demarcated by the intersection of
horizontal rows against the pair of independent variables 9A and 9B. Symbol 'O' in this
four independent variables could influence the extent of linkages and service
some countries except India). Inside of this symbol 'O' is cut (θ), if this
the Indian steel industry also.

ariables on the dependent variable is denoted separately in the four corners outside

		Position allocation for - sign
	..	Left side, top
	..	Right side, top
	..	Left side, bottom
	..	Right side, bottom

ts on the dependent variable in the context of the Indian steel industry also.

re influenced in India by the independent variable 9A - Plant location (for example,
-product of blast furnace slag) and the independent variable 9C - Transport
repair and maintenance facilities for the shunting locomotives), the
n + symbol on the left side top and the left side bottom of the solid symbol 'O'
y of by-product industries being set up on the basis of the brine discharge of
rtain arid countries but not in India and symbol of - on the top, right corner
using and township do not generate any linkage or service industries within
he right hand, bottom corner confirms this absence of interaction.

cal to that in Tables 24 to 26 with one modification. The six variables under the
signated codes 3A to 3F and their interaction with each dependent variables is
zontal axis of Symbol 'O' in addition to notation on four corners of the symbol

		Position allocation
	..	Left side, top
	..	Right side, top
	..	Left side, centre
	..	Right side, centre
	..	Left side, bottom
	..	Right side, bottom

SECTION 2

TABLE 24 - INTERACTION MATRIX OF EXTERNAL DY

INDEPENDENT VARIABLES			DEPEN											
			1A 1C	1B 1D	2A 2C	2B 2D	3A 3C	3B 3D	4A 4C	4B 4D	5A 5C	5B 5D	6A 6C	6B 6D
1. MARKETS A. Domestic market B. Global market	A	B	○		⊖	⊖	○	○	○		⊖		⊖	⊖
C. Product-mix D. Distribution system	C	D	⊖	⊖	⊖	⊖	⊖	○					○	⊖
2. SCALE OF OPERATION A. Escalation B. De-escalation	A	B			○		⊖	○			○	⊖	⊖	⊖
C. Production alignments D. Supply potential	C	D	○	⊖	⊖	○			○		⊖	○	○	○
3. RAW MATERIALS A. Iron ore and mines B. Sinter and pellets	A	B			○	○		○	⊖		○	⊖		
C. Scrap D. Sponge iron	C	D					○	○			⊖			
4. ENERGY A. Coking coal B. Non-coking coal, charcoal	A	B			○	○		○		○		⊖		
C. Electricity D. Natural gas and fuel oil	C	D					○	○		○	○			
5. TECHNOLOGY - IRONMAKING AND STEELMAKING A. Pelletisation/sintering B. Blast furnace/BOF	A	B			⊖	○		⊖	○	○		○		
C. DR/Electric arc furnace D. Continuous casting	C	D	○	⊖		○	⊖	○		○	⊖	○	○	
6. TECHNOLOGY - ROLLING MILLS A. Multiple/special products B. Mass products	A	B	⊖	○	⊖	⊖							⊖	⊖
C. Reversing/planetary mills D. Finishing/coating	C	D	⊖	○	⊖	○						○		
7. AUTOMATION AND AUXILIARIES A. Automation B. Auxiliaries and utilities technology	A	B			○		⊖		○		○	○		○
C. Pollution controls D. Climatic influence	C	D			○	○				○	○	○		○
8. EQUIPMENT SUPPLY SCENARIO A. Research/Design trends B. Manufacturing concentrations	A	B			○	○	○		○	○	⊖	⊖	○	⊖
C. Business cycle D. Sales patterns	C	D	⊖			○					⊖	⊖	○	○
9. LOCATION AND INFRASTRUCTURE A. Location and site B. Power, water and gas supply	A	B			○	○	○	○						
C. Port and transport D. Housing, township	C	D					○							
10. HUMAN RESOURCES DEPLOYMENT A. Need, availability, education B. Industrial discipline	A	B				○						○		○
C. Organization D. Compensation policy	C	D									○	○	○	○
11. HUMAN RESOURCES DEVELOPMENT A. Operation systems B. Training programmes	A	B												
C. Know-how transfer D. Technical assistance	C	D												
12. ECONOMICS A. Linkages, service industries B. Monetary/fiscal policies	A	B					○	○	○					
C. State participation D. Product pricing	C	D					○	○		○				
13. SOCIAL BENEFITS A. External economies B. Defence mobilisation	A	B			○					○				
C. Skill dissemination D. Diversification	C	D								○				
14. FINANCE A. Capital funds B. Foreign currency funds	A	B			⊖	⊖	○	○	○		○	○	○	○
C. Financing pattern D. Gestation period and profitability	C	D	○					○			⊖	⊖	○	○
TOTAL of independent variables affecting a dependent variable	A	B	+1 −3	0 −2	+4 −13	+3 −14	+2 −9	+1 −11	+2 −11	0 −5	+1 −9	+4 −11	+5 −4	+6 −11
	C	D	+6 −7	+5 −2	+3 −3	+2 −10	+3 −6	0 −12	0 −1	0 −6	+6 −8	+2 −11	0 −8	0 −10

TABLE 24 - INTERACTION MATRIX OF EXTERNAL DYNAMICS (PLANNING)

DEPENDENT VARIABLE

A	1B	2A	2B	3A	3B	4A	4B	5A	5B	6A	6B	7A	7B	8A	8B	9A	9B	10A	10B	11A	11B	12A	12B	13A	13B	14A	14B	TOTAL	
C	1D	2C	2D	3C	3D	4C	4D	5C	5D	6C	6D	7C	7D	8C	8D	9C	9D	10C	10D	11C	11D	12C	12D	13C	13D	14C	14D	+	-
○		⊖	⊖	○	○	○		⊖		⊖	⊖					○											⊖	12 1 4 0	12 15 4 2
⊖	⊖	⊖	⊖	⊖	○					○	⊖			○						○		⊖	○			⊖	○		
		○		⊖	○			○	⊖	⊖	⊖	○	○	○	○	⊖	⊖	⊖		⊖		⊖		⊖		⊖	⊖	16 6 6 6	10 4 9 3
○	⊖	⊖	○			○		⊖	○	○	○					⊖	⊖	⊖	⊖			○	○			⊖	○		
		○	○		○	⊖		○	⊖					○		⊖	○					⊖		⊖		⊖	⊖	7 2 4 0	5 3 3 7
				○	○			⊖								⊖													
		○	○		○		○		⊖				○	○		⊖	○					⊖		⊖		⊖	⊖	8 0 3 0	6 3 6 14
				○	○		○	○								⊖							⊖				○		
		⊖	○		⊖	○	○		○				○	○	○		⊖	⊖		○	⊖	⊖		⊖		⊖	⊖	3 12 7 4	8 12 15 9
○	⊖		○	⊖	○		○	⊖	○	○				○				○		○	○	⊖	⊖				○		
⊖	○	⊖	⊖							⊖	⊖			○	○			⊖		○	⊖	⊖		⊖		⊖	⊖	9 11 2 7	7 10 8 6
⊖	○	⊖	○						○					○						○	○	○	⊖				⊖		
		○		⊖		○		○	○		○		○	○	○	○	○	⊖		⊖	⊖					⊖	⊖	2 6 0 1	17 7 11 1
		○	○				○	○	○		○			○				⊖	⊖		⊖						○		
		○	○	○		○	○	⊖	⊖	○	⊖	⊖	⊖	○	○	⊖					⊖					⊖	⊖	0 0 0 17	19 8 6 3
⊖			○					⊖	⊖	○	○	⊖								⊖	⊖		○			⊖	⊖		
		○	○	○	○								○			⊖		⊖				⊖		⊖		⊖	○	6 4 6 4	7 5 6 2
				○								○	⊖			○		⊖	○			○	○		⊖		⊖		
			○						○		○	○				○		⊖		○	⊖					○		2 3 1 2	8 13 2 1
								○	○	○	○						⊖	○	⊖	○	○		⊖				⊖		
												○						○		⊖	⊖				⊖	⊖	⊖	3 4 0 4	4 0 7 1
																		⊖			○						⊖		
				○	○	○								○		⊖	⊖	○		○	○	○		○		○	○	0 3 2 0	12 11 9 2
				○	○		○					○				⊖	○	○					○		○				
		○					○					○				⊖						○				○	○	1 0 0 0	7 0 0 0
							○																						
		⊖	⊖	○	○	○		○	○	○	○	⊖	○	○		○				⊖	⊖	○	○			⊖	⊖	9 6 3 2	20 21 10 6
					○			⊖	⊖	○	○	○			⊖	○	○			○	○	⊖	⊖			⊖	⊖		
	0 -2	+4 -13	+3 -14	+2 -9	+1 -11	+2 -11	0 -5	+1 -9	+4 -11	+5 -4	+6 -11	+3 -9	+1 -12	0 -18	0 -8	+12 -11	+6 -6	+12 -5	0 0	+7 -10	+12 -7	+9 -8	0 -2	+6 -5	+1 0	+21 -15	+19 -13		
	+5 -2	+3 -3	+2 -10	+3 -6	0 -12	0 -1	0 -6	+6 -8	+2 -11	0 -8	0 -10	+1 -8	+1 0	0 -6	+2 0	+6 -4	+2 -2	+2 -9	+3 -5	+1 -10	+2 -13	+4 -6	+9 -11	0 0	+1 -1	+4 -2	+12 -13		

SECTION 2

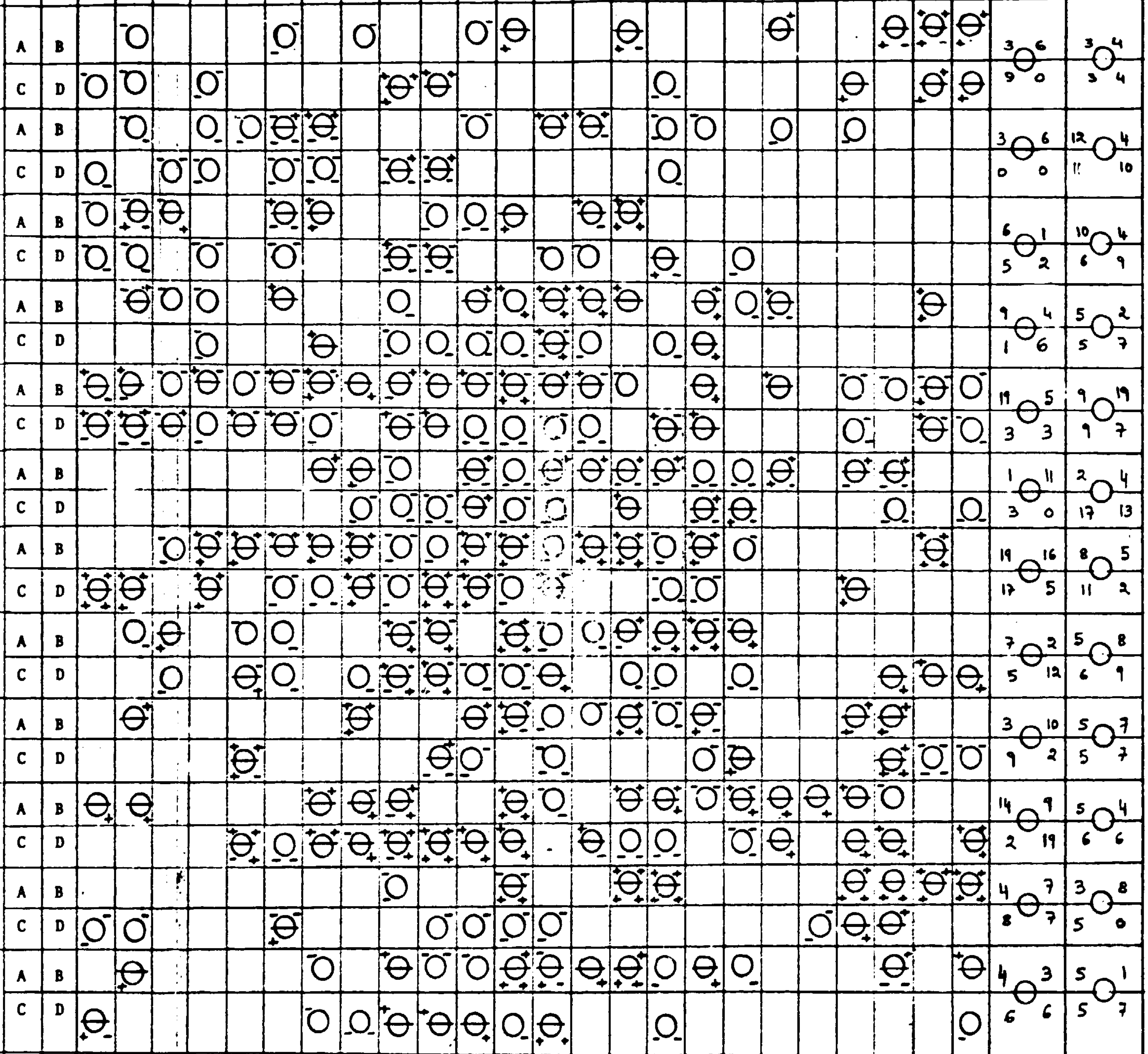
TABLE 25 - INTERACTION MATRIX OF

INDEPENDENT VARIABLES			15A 15C	15B 15D	16A 16C	16B 16D	17A 17C	17B 17D	18A 18C	1
15. DESIGNS, FACILITIES, LAYOUTS A. Collation of local data B. Selection of design/construction standards	A	B		O				O		O
C. Planning of facilities and layouts D. Utility systems - optimisation	C	D	O	O		O				
16. SPECIFICATIONS A. Performance orientation B. Hardware cut-off levels	A	B		O		O	O	⊖	⊖	
C. Proprietary selection D. Standardisation	C	D	O		O	O		O	O	
17. PROCUREMENT POLICY A. Extent of competition B. Evaluation procedures	A	B	O	⊖	⊖			⊖	⊖	
C. Contract conditions D. Performance guarantees, inspection	C	D	O	O		O		O		
18. IMPLEMENTATION TECHNOLOGY A. Equipment indigenisation B. Construction employment	A	B		⊖	O	O		⊖		
C. Spare parts development D. Assistance from project authority	C	D				O			⊖	
19. SELECTION OF ASSOCIATED AGENCIES A. Consulting engineers B. Know-how suppliers	A	B	⊖	⊖	O	⊖	O	⊖	⊖	⊖
C. Manufacturers D. Contractors	C	D	⊖	⊖	⊖	O	⊖	⊖	O	
20. PROJECT SCHEDULING A. Construction supervision B. Project scheduling	A	B							⊖	⊖
C. Resource monitoring D. Crashing cost	C	D								O
21. MODE OF IMPLEMENTATION A. Nature of contracts B. Division of work packages	A	B			O	⊖	⊖	⊖	⊖	⊖
C. Types of contracting agencies D. Fringe supplies	C	D	⊖	⊖		⊖		O	O	⊖
22. FINANCIAL PLANNING A. Cash flows B. Loans, bank guarantees, Letter of credit	A	B		O	⊖		O	O		
C. Bill clearance and audit D. Administration and controls	C	D			O		⊖	O		O
23. CONSTRUCTION INFRASTRUCTURE A. Mobilisation B. Construction materials availability	A	B		⊖						⊖
B. Construction facilities - phasing D. Demobilisation restrictions:buy-back arrangements	C	D					⊖			
24. SOCIO-ECONOMIC SETTING A. Processing licences, permits B. Direct/Indirect taxes and duties	A	B	⊖	⊖					⊖	⊖
C. Access to legal institutions D. Socio-economic environments	C	D					⊖	O	⊖	⊖
25. INFRASTRUCTURE DEVELOPMENT A. Mining and materials procurement B. Power, water, transport and utilities	A	B								
C. Trained personnel D. Housing and labour welfare	C	D	O	O				⊖		
26. DESIGNS AND DEVELOPMENT A. Documentation B. Gestation performance	A	B		⊖					O	
C. Replacement and improvements D. Plant shut-downs for capital works	C	D	⊖						O	O
TOTAL of independent variables affecting a dependent variable	A	B	+2 -2	+6 -8	+2 -6	+4 -3	+3 -4	+6 -9	+11 -4	+ -
	C	D	+7 -8	+5 -6	+1 -4	+3 -9	+8 -4	+2 -14	+3 -9	+ -

TABLE 25 - INTERACTION MATRIX OF EXTERNAL DYNAMICS (IMPLEMENTATION)

DEPENDENT VARIABLE

		15A 15C	15B 15D	16A 16C	16B 16D	17A 17C	17B 17D	18A 18C	18B 18D	19A 19C	19B 19D	20A 20C	20B 20D	21A 21C	21B 21D	22A 22C	22B 22D	23A 23C	23B 23D	24A 24C	24B 24D	25A 25C	25B 25D	26A 26C	26B 26D	TOTAL +	 -
A	B	+2 -2	+6 -8	+2 -6	+4 -3	+3 -4	+6 -9	+11 -4	+9 -2	+6 -11	+3 -6	+7 -9	+26 -5	+8 -10	+11 -5	+24 -5	+9 -9	+11 -8	+3 -7	+6 -4	+1 0	+7 -4	+7 -7	+13 -3	+7 -1		
C	D	+7 -8	+5 -6	+1 -4	+3 -9	+8 -4	+2 -14	+3 -9	+4 -6	+12 -17	+18 -15	+7 -10	+2 -13	+7 -11	+1 -5	+1 -3	+2 -14	+3 -6	+2 -8	+1 0	0 -2	+5 -2	+7 -2	+4 -5	+5 -7		

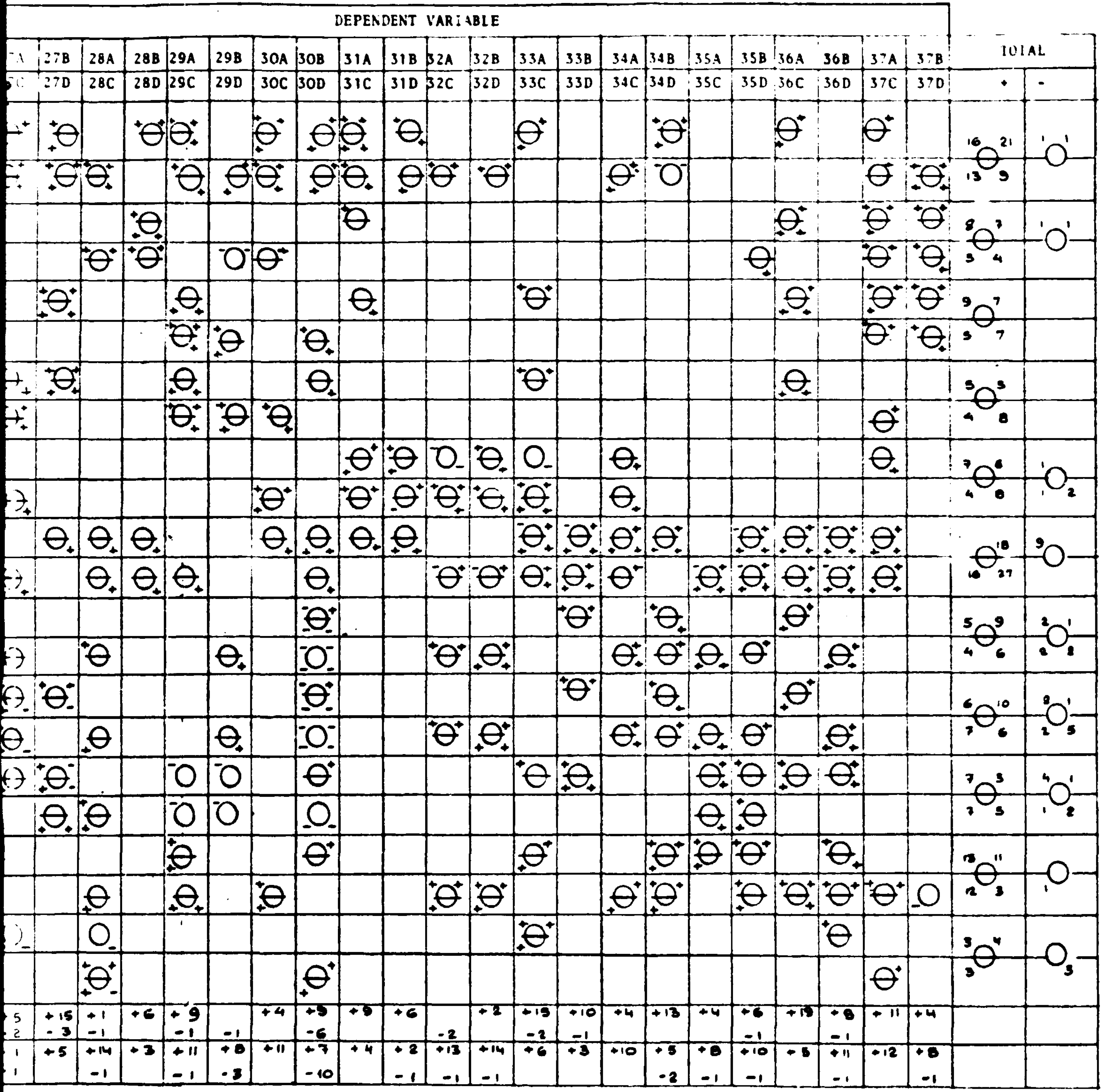


SECTION 2

TABLE 26 - INTERACTION MATRIX INTERNAL DYNAMICS (

INDEPENDENT VARIABLES				DEPEN 27A 27C	27B 27D	28A 28C	28B 28D	29A 29C	29B 29D	30A 30C	30B 30D	31A 31C
27. CORPORATE MANAGEMENT A. Perception, vision and action	B. Information systems	A	B	⊖	⊖		⊖	⊖		⊖	⊖	⊖
C. Industrial engineering	D. Response to external changes	C	D	⊖	⊖	⊖		⊖	⊖	⊖	⊖	⊖
28. SALES MANAGEMENT A. Market research	B. Sales and sales collection	A	B				⊖					⊖
C. Order planning and customer service	D. Product distribution monitoring	C	D			⊖	⊖		○	⊖		
29. MATERIALS MANAGEMENT A. Purchase policy	B. Materials inspection	A	B		⊖			⊖				⊖
C. Storage system	D. Inventory control	C	D					⊖	⊖		⊖	
30. FINANCE A. Management accounting	B. Cost controls	A	B	⊖	⊖			⊖			⊖	
C. Financial planning	D. Technical/accounts audit	C	D	⊖				⊖	⊖	⊖		
31. PERSONNEL MANAGEMENT A. Personnel planning	B. Industrial relations	A	B									⊖
C. Personnel welfare	D. Productivity motivation	C	D	⊖						⊖		⊖
32. TRAINING A. Simulation training	B. On-the-job training	A	B		⊖	⊖	⊖			⊖	⊖	⊖
C. Worker development	D. Management development	C	D	⊖		⊖	⊖	⊖			⊖	
33. PRODUCTION A. Control of inputs and yields	B. Equipment/personnel safety	A	B								⊖	
C. Supervisory transactions	D. Housekeeping	C	D	⊖		⊖			⊖		○	
34. MAINTENANCE A. Equipment/structures inspection	B. Scheduled maintenance	A	B	⊖	⊖						⊖	
C. Break-down maintenance	D. Spare parts procurement	C	D	⊖		⊖			⊖		○	
35. ENERGY ECONOMY SERVICES A. Distribution planning	B. Distribution controls	A	B	⊖	⊖			○	○		⊖	
C. Emergency operations	D. Start-up/shut-down operations	C	D		⊖	⊖		○	○		○	
36. PRODUCTION SUPPORTS A. Production planning	B. Operational controls & logistics	A	B					⊖			⊖	
C. Operational statistics	D. Works transport	C	D			⊖		⊖		⊖		
37. QUALITY CONTROL A. Product inspection	B. Testing procedures	A	B	○		○						
C. Quality tracking/feedback systems	D. Research & development	C	D			⊖					⊖	
TOTAL of independent variables affecting a dependent variable		A	B	+5 -2	+15 -3	+1 -1	+6	+9 -1	-1	+4	+5 -6	+9
		C	D	+11 -1	+5	+14 -1	+3	+11 -1	+8 -3	+11	+7 -10	+4

- INTERACTION MATRIX INTERNAL DYNAMICS (OPERATIONS)



	27B 27D	28A 28C	28B 28D	29A 29C	29B 29D	30A 30C	30B 30D	31A 31C	31B 31D	32A 32C	32B 32D	33A 33C	33B 33D	34A 34C	34B 34D	35A 35C	35B 35D	36A 36C	36B 36D	37A 37C	37B 37D
5 2	+15 -3	+1 -1	+6	+9 -1	-1	+4	+5 -6	+9	+6	-2	+2	+15 -2	+10 -1	+4	+13	+4	+6 -1	+19	+8 -1	+11	+4
1 1	+5	+14 -1	+3	+11 -1	+8 -3	+11	+7 -10	+4	+2 -1	+13 -1	+14 -1	+6	+3	+10	+5 -2	+8 -1	+10 -1	+5	+11 -1	+12	+8 -1

The total under each vertical column at the bottom of table shows the total number of independent variables which influence a dependent variable. The total with 'plus' (+) sign corresponds to the Indian context and the total with 'minus' (-) sign shows the additional number for the global context transcending the Indian setting. Thus the dependent variable 14A for 'Capital funds' is influenced by 21 independent variables in India and by 36 (21 + 15) independent variables in the general global context.

The overall interaction matrix of the variables of the three systems of external and internal dynamics is shown in Table 27. To facilitate future quantification of this matrix thorough evolution of suitable computer programmes, only the key variables of planning dynamics are selected for this exercise. The number of external variables of implementation and the internal variables of plant operation is reduced by grouping every set of four variables into a single variable. The number of variables in the matrix is reduced with this approach to 64 from a total of 148 covered by the foregoing analysis of individual variables encompassing the three dynamic systems - planning, implementation and operations.

CONTRIBUTION TO 1990 SCENARIO

A quantitative summary of the four interaction matrices in the Indian as well as the global context is given in Table 28. The following broad conclusions of the contribution of the several variables to the world-wide iron and steel industry up to 1990 can be drawn from this summary table.

SECTION 1

TABLE 27 - OVERALL INTERACTION MATRIX OF EXTERNAL AND INTE
INDEPENDENT VARIABLES AND SUB-VARIABLE

INDEPENDENT VARIABLE

1. MARKETS
A. Domestic market — B. Global market
C. Product-mix — D. Distribution system

2. SCALE OF OPERATIONS AND SUPPLY SITUATION
A. Escalation — B. De-escalation
C. Production alignments — D. Supply potential

3. RAW MATERIALS AND ENERGY
A. Iron ore, mines, agglomerates — B. Scrap
C. Coking coal — D. Non-coking coal, charcoal
E. Sponge iron — F. Natural Gas

4. TECHNOLOGY - IRONMAKING, STEELMAKING AND ROLLING
A. *Blast furnace/BOF — B. DR/Electric arc furnace
C. Continuous casting — D. Rolling mills

5. TECHNOLOGY - AUTOMATION AND AUXILIARIES
A. Automation — B. Utilities and auxiliaries
C. Pollution control — D. Climatic influence

6. EQUIPMENT SUPPLY SCENARIO
A. Research/design trends — B. Concentration and sales patterns

7. LOCATION AND INFRASTRUCTURE
A. Location and site — B. Power, water and gas supply
C. Port and transport — D. Housing, township

8. HUMAN RESOURCES DEVELOPMENT
A. Requirements, availability — B. Compensation policy
C. Training programmes — D. Systems/know-how, technical assistance

9. ECONOMICS
A. Linkages, service industries — B. Monetary/fiscal policies
C. State participation — D. Product pricing

10. FINANCE
A. Capital funding — B. Foreign currency funding
C. Financing pattern — D. Gestation period, profitability

11. SOCIAL BENEFITS
A. External economies — B. Defence mobilisation

12. IMPLEMENTATION - STRATEGY
A. Designs, facilities, layouts — B. Specifications
C. Procurement policy — D. Implementation technology

13. IMPLEMENTATION - MANAGEMENT
A. Selection - associated agencies — B. Implementation mode
C. Project scheduling — D. Financial planning

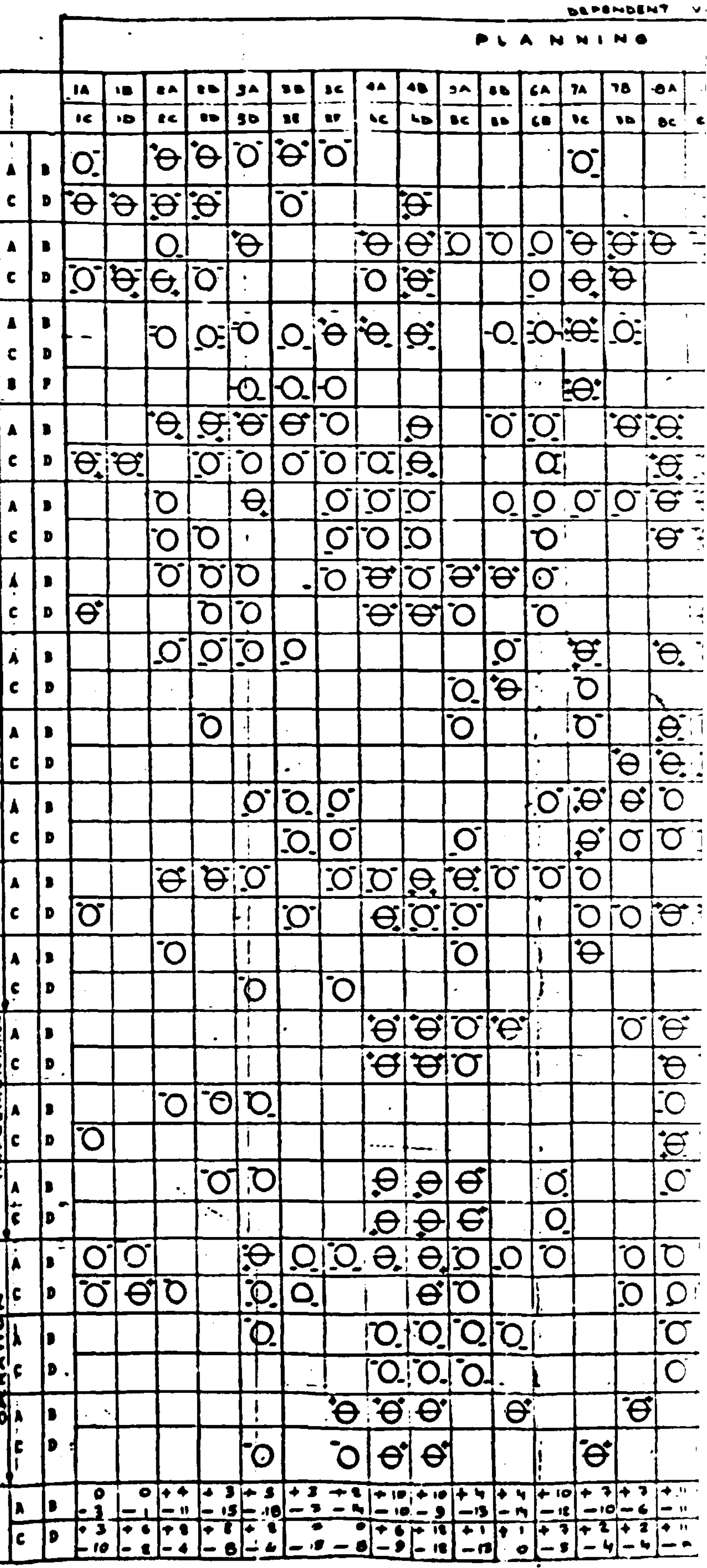
14. DEVELOPMENT ENVIRONMENTS
A. Construction infrastructure — B. Socio-economic setting
C. Infrastructure development — D. Designs and development

15. FUNCTIONAL MANAGEMENT EFFICIENCY
A. Corporate — B. Sales
C. Finance — D. Materials

16. IN-PLANT HUMAN RESOURCES EFFICIENCY
A. Personnel management — B. In-plant training
C. Finance — D. Materials

17. PRODUCTION SERVICES
A. Energy economy services — B. Supports for production, quality control

TOTAL of independent variables affecting a dependent variable§



		1A 1C	1B 1D	2A 2C	2B 2D	3A 3D	3B 3E	3C 3F	4A 4C	4B 4D	5A 5C	5B 5D	6A 6B	7A 7C	7B 7D	8A 8C
A	B	0 -3	0 -1	+4 -11	+3 -15	+5 -18	+3 -7	+2 -4	+10 -10	+10 -9	+4 -13	+4 -14	+10 -12	+7 -10	+7 -6	+11 -11
C	D	+3 -10	+6 -8	+8 -4	+8 -6	+8 -4	0 -9	0 -8	+6 -9	+18 -18	+1 -13	+1 0	+3 -3	+2 -4	+2 -4	+11 -

§ NOTES: 1. This notation does not apply to variables 3A to 3F, 6A and 6B, 11A and 11B, 17A and 17B.
2. This notation should be read as:
$\frac{A}{B}$ For variables 6A and 6B, 11A and 11B and 17A and 17B only.
$\frac{ABC}{DEF}$ For variables 3A to 3F

e 27 - OVERALL INTERACTION MATRIX OF EXTERNAL AND INTERNAL DYNAMICS
INDEPENDENT VARIABLES AND SUB-VARIABLES

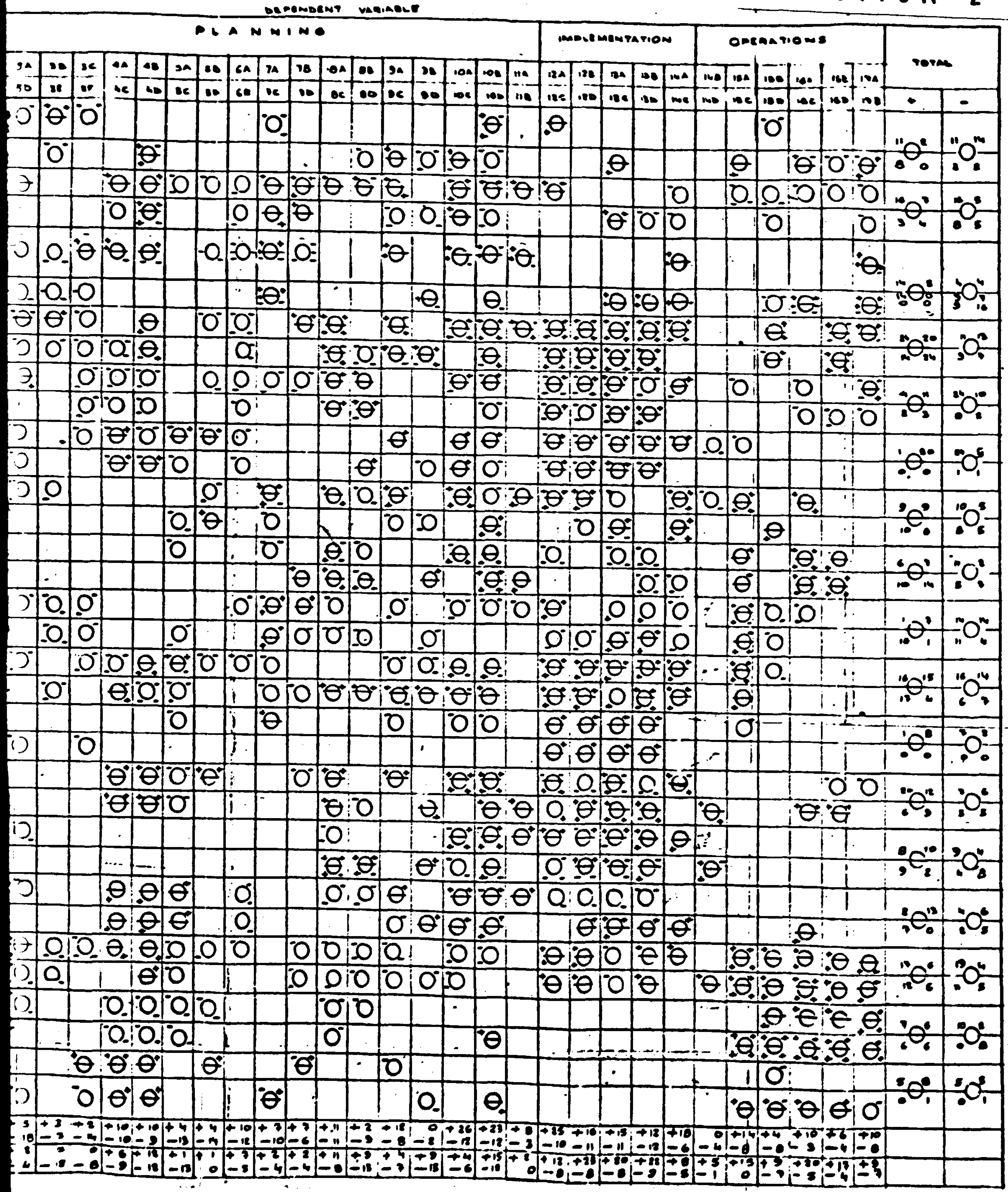


TABLE 28 - NUMERICAL SUMMARY OF INTERACTION OF VARIABLES OF THREE DYNAMIC SYSTEMS

	Individual system				Overall dynamics			
	A		B		A		B	
	C		D		C		D	
Group of variables	i	ii	i	ii	i	ii	i	ii
PLANNING								
Markets	50	17	26	12	51	21	25	9
Scale of operations and supply situation	60	34	52	12	64	30	49	11
Raw materials	31	13	44	6)	82	33	78	10
Energy	40	11	25	21)				
Technology								
Ironmaking and steelmaking	70	26	52	13)	122	82	78	38
Rolling mills	60	29	44	11)				
Automation and auxiliaries	45	9	34	5	75	20	50	10
Equipment supply scenario	58	17	34	2	52	21	25	-
Location and infrastructure	41	20	49	26	62	34	57	26
Human resources								
Deployment	32	8	42	23)	62	37	74	33
Development	23	11	62	22)				
Economics	39	5	49	22	62	19	53	25
Social benefits	8	1	13	7	18	9	13	10
Finance	77	20	98	55	95	52	110	68
Sub-total 'PLANNING'	634	221	656	226	745	358	612	240
IMPLEMENTATION								
Strategy	166	67	174	76	66	47	114	70
Management	262	128	292	144	54	29	113	73
Development environments	190	113	148	82	39	22	47	31
Sub-total 'IMPLEMENTATION'	618	308	614	302	159	98	274	174
OPERATIONS								
Functional management	135	131	149	119	80	41	65	42
In-plant human resources	169	139	111	100	45	25	69	53
Production services	83	71	112	106	23	14	34	19
Sub-total 'OPERATIONS'	387	341	372	325	148	80	168	114
TOTAL	1639	870	1642	853	1052	536	1054	528

NOTE: 'A' as independent variables; 'B' as dependent variables;
'C' influencing dependent variables in } (i) Global context
'D' influenced by independent variables in } (ii) Indian context

1. The technological factors which encompass technologies of ironmaking, steelmaking and rolling, automation and auxiliaries in the planning system and strategy in the implementation system have the most pervading influence on the development of steel industry with a score of influence over 263 dependent key variables out of a total of 1052 in the global context.

2. Bracketing together the four factors viz. human resources deployment and development in the planning system, management in the implementation system and the functional management and in-plant human resources in the operations system, the human resources emerge as the second most extensive independent variable influencing course of 241 dependent key variables out of a total of 1052 in the global context.

3. The socio-economic independent variables of economics, social benefits and finance in the planning system and the development environments in the implementation system rank only next to those pertaining to technology and human resources in their quantitative influence over the key dependent variables. However, if the independent variables of infrastructure are also included in this group, interaction of socio-economic variables becomes more dominant than that of either technological factors or human resources.

4. The variables related to demand-supply (markets, scale of operations and supply situation) and the primary resources (raw materials and energy) also exercise substantial influence on a large number of dependent variables.

5. The steel industry should be developed in developing countries with an integrated strategy to reflect the optimum solutions for the three dynamic systems of planning, implementation and operations. The deficiencies of planning and implementation may be often beyond the reach of corrective influence of the operations systems which have a relatively low score of interaction with the key dependent variables.

6. The role played by the various variables in India is considerably different from that in the global setting. Therefore, practical assessment of the contribution of the individual variables in the steel dynamics of different developing countries calls for special studies for individual countries.