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INTEGRATED DEVELOPMENT OF THE STEEL INDUSTRY, PARTICULARLY MINI-STEEL, LINKED TO CAPITAL GOODS AND AGRICULTURAL MACHINERY*

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INTEGRATED DEVELOPMENT OF STEEL INDUSTRY, PARTICULARLY MINI-STEEL, LINKED TO CAPITAL GOODS AND AGRICULTURAL MACHINERY

1. INTRODUCTION

One of the significant developments in the twentieth century has been the phenomenal growth of the iron and steel industry as a basic input in the social, economic and industrial development of countries around the world. Since the end of the second world war, there has been an accelerated growth of the industry. The world crude steel production has increased from 113 million tonnes in 1945 to a peak production of 747 million tonnes in 1979. During this period, a large number of countries have emerged as independent states, engaged in building up a sound economic base to serve the aspirations of their people by developing their own natural resources. As a result, there has been a steady, though uneven, growth of the iron and steel industry in the developing countries as well.

By 1975, while Western Europe, North America and Japan accounted for 58.5% of world steel production and USSR and the Eastern European countries accounted for 29.9%, the developing countries including China accounted for around 9.3% of the steel production and around 16% of the steel consumption. By 1982, the share of the developing countries including China has increased to around 16% of the world steel production and their consumption has increased to around 22% of the world steel consumption.

From 1973 onwards, cost of energy, particularly oil, has gone up steadily and steeply. This has had a dampening effect on investments in energy intensive industries, which in turn affected the off-take of steel. At the same time the cost of iron and steel making as well as the investment costs for steel plants have sharply risen. While the lower off-take resulted in a glut in the global steel market, the higher costs of investments as well as operation of steel plants acted as a disincentive to development of the steel industry. This has resulted in a cut-back in steel production in developed countries and the world steel industry which has just started showing signs of a slow recovery.

A developing country, launching on the planned development of its economy from scratch, will need an integrated approach, so that the development of capital goods industry, services, consumer sectors and agriculture are balanced and mutually sustaining. Usually, in such countries, the internal generation of capital and resources is low and there are large, pressing and conflicting demands on the resources mobilised. In countries with large populations, high domestic potential in resources and a traditional availability of entrepreneurship backed by administrative cadres, the emphasis could well be on basic heavy industries which could act as a stimulant to the development of down stream industries and provide the necessary "push" in developing light industries, service sectors and agricultural machinery. Typical examples of such countries are Brazil and India where such development has taken place and Nigeria where such a development is possible.

In smaller countries or countries not endowed with the infrastructure potential mentioned above, the reverse process viz., development of light industries including manufacture of simple types of capital goods and agricultural tools and implements may have to take precedence in the development programme. A large majority of countries in Africa and Asia fall in this category.

Irrespective of the planning model adopted, establishment of a steel industry of requisite size and product-mix, based on the natural resources available, as an integral part of planned development, will help in stimulating a healthy economic growth of the country.

Where practically no industries exist, the establishment of a small steel industry at the initial stages will exert the necessary "push" due to increased domestic availability of iron and steel,towards establishment of downstream light capital goods industries and agricultural implements, thereby sustaining the development of agriculture and catering to service and consumer industries.

In countries where, already, light capital goods and agro-industries exist, they would provide the necessary stimulus and exert a "pull" towards establishment of an iron and steel industry to cater to their needs.

In either case, the establishment of the steel industry makes the economy more resilient and self-reliant. However, since the iron and steel industry is capital intensive and calls for a high degree of skills, it is essential that, depending on the requirements of the economy and the availability of natural resources, a proper and judicious selection of the steel plant and process as well as the product-mix is made by the planners.

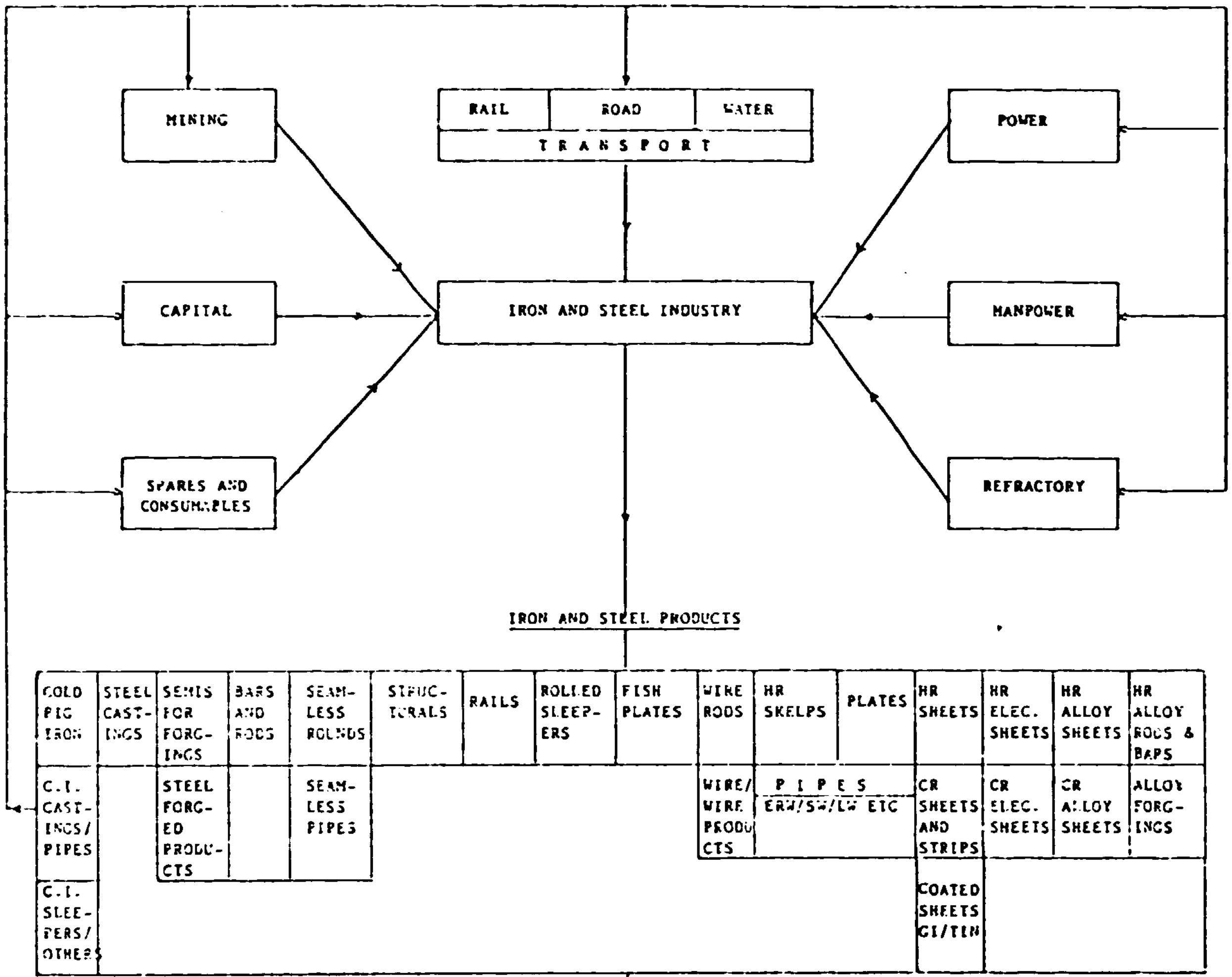
This paper brings out the basic approach to the integrated development of a national iron and steel industry on a modest scale for those developing countries which are yet to go in significantly for iron and steel production and are not particularly endowed with resources linked with traditional process route for iron and steel.

A number of internationally accepted and known abbreviations in iron and steel industry have been used in the text. For ready reference, a compendium of abbreviations and their full expansion has been given at the end of the Annexures.

2. AN APPROACH TO THE INTEGRATED DEVELOPMENT OF STEEL INDUSTRY IN THE NATIONAL ECONOMY

An illustrative model of the inter-relationship between the various iron and steel products and the various sectors of agriculture and capital goods industry, relevant to developing countries, is given schematically in Figure-I. From the figure it may be seen that initially it will be relevant for developing countries to go in for long products or light sections such as bars, rods, structurals etc. in addition to forgings and castings. A certain amount of flat products to take care of limited demands of galvanised sheets, tin plates, pipes etc., may also be necessary, depending on end-use of the industries. There will be need for producing limited quantities of machine tools to cater to the local demands of the capital goods industries. Gradually, as the economy develops and the needs get more sophisticated, larger quantities of flat rolled products may be required such as hot and cold rolled plates and sheets of various specifications to cater to diverse needs of expanding industries.

PROCESS OF INTEGRATED ECONOMIC DEVELOPMENT WITH IRON AND STEEL INDUSTRY



AGRICULTURE

AGRICULTURAL IMPLEMENTS - (FORGINGS & PLATES)

AGRICULTURAL MACHINERY - (FORGINGS, ALLOY RODS, PLATES)

AGRICULTURAL SHEDS/SILOS - (BARS & RODS, HR SHEETS, GALVANIZED SHEETS)

CONTAINERS AND PACKAGING - (HR/CR SHEETS, GALVANIZED SHEETS, TINPLATES),

IRRIGATION - (BARS AND RODS, STRUCTURES, PLATES, PIPES)

CAPITAL GOODS

INDUSTRIAL BUILDING AND SHEDS - (BARS & RODS; STRUCTURALS; PLATES; HR SHEETS; PIPES; GALVANIZED SHEETS)

HOUSING - (BARS & RODS, STRUCTURALS; GI SHEETS; CASTINGS; PIPES)

RAILWAYS - (RAILS; SLEEPERS; FISHPLATES; PLATES; ENG. CASTINGS AND MOST OTHER STEEL ITEMS)

DEFENCE - (PLATES; CASTINGS AND MOST OF OTHER STEEL ITEMS)

POWER - (STRUCTURALS; PLATES; GALVANIZED SHEETS; BARS AND RODS, ETC)

MACHINE TOOLS - (CI CASTINGS; STEEL FORGING ALLOY RODS, FORGINGS ETC.)

PETROLEUM - (PIPES; STRUCTURALS)

AUTOMOTIVE - (HR AND CR SHEETS; ALLOY FORGINGS)

CYCLE/MOTOR CYCLE - (CR STRIPS; PIPES)

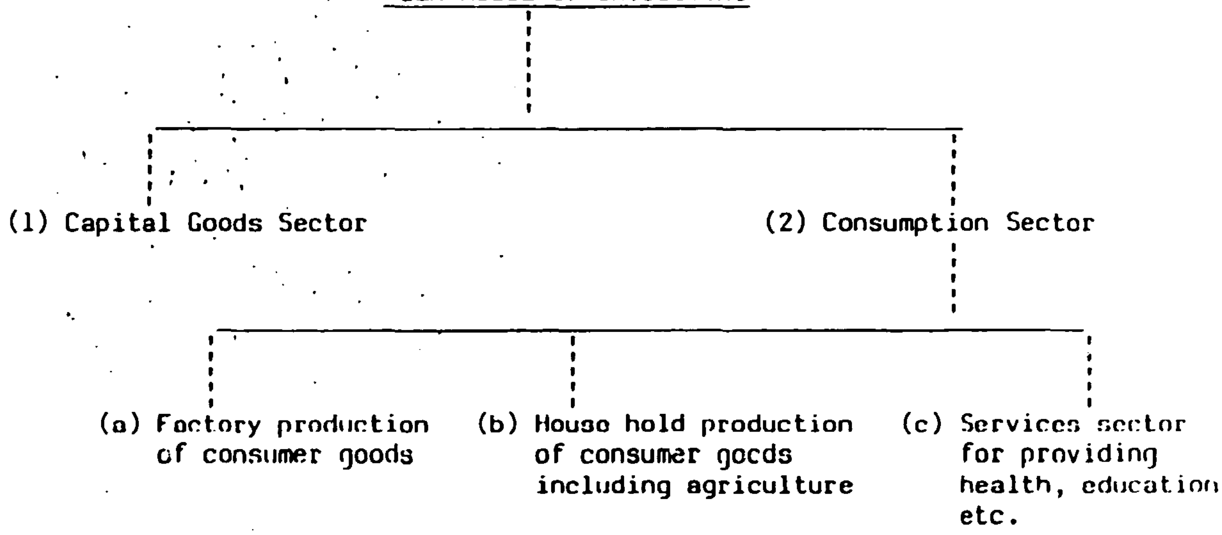
FASTNER - (WIRE RODS; RODS)

ELECTRICAL MACHINE - (ELECTRIC SHEETS)

Planned Development of Steel Industry in India .

Before touching upon the needs of the small developing countries with more limited potential for growth, a brief mention may be made of a country like India where a certain amount of industrial skills and infrastructure existed at the beginning of the plan period and where the requirements of a large populous country led to the emphasis on heavy industries. While the first 5-year Plan was a simple decision model, for the second 5-year Plan a two sector model was adopted with one of the sectors further sub-divided into three sectors as indicated below:

Plan Model of Investment



The allocation of investments between sectors was determined for achieving specified increases in income and employment at the end of the plan period. It was essentially an adaptation of the Harrod-Domar model, with the implicit assumption that the savings rate is a reflection of the behavioural characteristics of the decision making units such as the house-hold, the corporate sector and the Government. In the Indian model, the savings rate was made a rigid function of certain structural features such as the capacity of the domestic capital goods industry and capital output ratios of the capital goods sector and the consumer goods sector.

Though the assumptions underlying the above model were found to have their draw-backs, the model served its purpose in as far as the necessary push was provided to the economic growth rate in the second and third 5-year plan periods by the spin-offs from investments in the capital goods industries including the basic industries such as iron and steel. The percentage investments in the various sectors of the economy during the second and third five year plans is indicated in Table-1 below:-

Table - 1

2nd and 3rd Plans - Analysis of Investment

Head	Second Plan(%)	Third Plan (%)
Agriculture and Community Development	12	14
Major and Minor Irrigation	6	6
Power	7	10
Village and Small Industries	4	4
Organised Industry and Minerals including steel	23	25
Transport and Communication	21	17
Social Services and Miscellaneous	19	16
Inventories	8	8
TOTAL	100	100

Source : Five Year Plans of India

The first census of manufacturing industries undertaken in 1946 in the pre-independent India revealed that the engineering and allied industries were comparatively dormant. The hundred and odd iron and steel factories had less than 9% of the total productive industrial capital of the country. Around 90% of the steel demand, which was about 1 million tonnes of finished steel, was met by two integrated steel plants, producing around 1.25 million tonnes of crude steel annually. There were about 32 registered rerolling mills with a production of only about 75,000 tonnes. Scrap rerolling, particularly rolling of scrap rails, for meeting the need of medium carbon steel for agricultural implements was important. The Railways and the

Defence goods were the two prominent capital sectors to consume steel and had their own miniature captive iron and steel industry. The historical growth of iron and steel products in India through the different plan periods, starting from the pre-independence base, to cater to the needs of the national economy is given in Annexure-1. This shows the gradual sophistication in the steel products that became necessary to ensure integrated development of the economy during successive plan periods.

A quantitative idea about utilisation of steel rolled products in the various sectors of the Indian economy is indicated in Table-2.

Table - 2

Sectorwise Consumption of Steel - 1979-80 and 1984-85 (Projected)

		Consumption (Million Tonnes)	
		1979-80	1984-85
1.	Manufacture of Machinery and Metal Products	4.50 (56%)	7.472 (58%)
i)	Transport Equipment	0.726	1.230
ii)	Electric Power Equipment	0.197	0.347
iii)	Industrial Machinary	0.401	0.645
iv)	Other Metal Manufactures	1.148	1.885
v)	Misc. Steel Consuming Industries	0.594	0.987
vi)	Small Scale Industries	1.394	2.316
vii)	Processing loss in Wires, Forging etc.	0.040	0.062
2.	Construction Sector	3.500 (44%)	5.400 (42%)
		8.000	12.872

Source: A technical note on 6th Plan of India.

From the table it may be seen that even after several plan periods and the firm establishment of a fairly well developed capital goods manufacturing industries for machinery and metal products, the demand of the construction sector continues to consume 42 to 44% of the total steel produced.

Initial Development of Steel Industry in Japan

Japan is today, a highly industrialised country with the second largest steel production in the world. It is singularly lacking in the basic raw materials for production of iron and steel. At the end of the Second world war, the Japanese Iron and steel Industry was practically destroyed. Initially the recovery was slow, but during the rebuilding of the industry, the Japanese decided to incorporate the latest and the best technology available. During that period, the decision was taken to develop basic and heavy capital goods industries, besides the traditional textile and light industry. The investment was concentrated in large key industries. The finances, which came in substantial amounts from domestic resources, were sustained by a very high rate of personal savings, e.g., 20% of GNP was saved for investment in 1961. Full advantage was taken of the comparatively low capital cost of building steel plants during the fifties. Moreover, with the plants based on the coast with direct unloading of raw materials from the ships, compactness of design and installation of large capacity integrated steel plants,operating costs were kept low. By 1961, Japan produced almost 28 million tonnes per annum of crude steel achieving a four fold increase from 7 million tonnes per annum in 1953. Steel products accounted for 3% of the GNP in 1962. By 1979 Japan became the second largest producer of steel in the world with an output of 111.7 million tonnes of crude steel. The handicap of raw materials for making steel was overcome by the import of the best quality of coal and iron ore in large bulk carriers to reduce ocean freight and by using the optimum technology and economy in size due to large scale production with minimum capital investments. They ensured lower operating costs and became highly competetive in the world market.

About 40% of the steel items produced in Japan in 1962 were flat products, of which 19% were plates for ship building. The rapid growth of steel industry to a certain extent was also due to the large amount of steel consumed in construction of factory-sheds, high rise buildings, elevated highways and harbour development. Steel piles were an important rolled steel item. The expansion of the strip rolling facility coincided with the rapid progress of Japanese automobile industry, refrigeration plants and a large variety of durable consumer goods items. At the same time, high agricultural yields were ensured from limited land resources by scientific farming, development of ocean fishing and development of supportive chemical and other industries in a highly integrated and balanced manner.

The Japanese steel and other capital goods industries have been export oriented from the beginning and the development of sophisticated steel and engineering products has been based on the world market demand in addition to the domestic demand.

Approach for Smaller Developing Countries.

As mentioned earlier, while the above growth models with bias on heavy industries may be suited for large populous developing countries with innate potential of natural resources to be exploited, it will not be applicable to a great majority of developing countries where the resources are limited and the economy does not have the resilience to absorb shocks on accounts of delayed returns and large bulk capital in capital intensive industries with comparatively longer gestation periods and where difficulties are encountered in developing large numbers of highly trained cadres in a relatively short time.

In all such cases the choice would be for light capital goods industries and simpler agricultural tools and implements to be manufactured with moderate sized steel industry to back up their requirements of steel.

The scope and extent of development of a steel industry depend upon the potential for development and the economic conditions prevailing in that particular country. Factors such as per capita income, steel consumption, level of steel import and local availability of raw materials are important. These indices for a few selected developing countries are given in Annexures-2, 3 and 4. The per capital GNP/GDP and the steel consumption levels, however, do not always represent the true picture of the state of socio-economic development unless one considers the size of population and the quality of life enjoyed by the vast majority of the people.

Certain developing countries have already made great strides towards development of national steel industry in recent years, notwithstanding serious imbalances in the domestic raw materials availability. For instance, Latin American countries, such as Brazil and Asian countries like South Korea and India deserve special mention in this regard. Pakistan has set up an iron and steel base near Karachi mostly on imported raw materials, which will give a boost to their industrial growth.

Considering the size and the present level of steel consumption, there is considerable scope for future development of iron and steel industry in Africa. The present status of the iron and steel industry in the African continent is indicated in Table - 3 below :-

Table - 3

Iron and Steel Industry in the Developing Countries of Africa

1.	Nigeria :	Delta Steel Corporation - Warri - Electric Arc Furnace process of Steel making started 1982		1 MT capacity
		Ajaokuta - Projected		1.3 MTa (1st phase) 2.6 MTa (2nd ") 5.2 MTa (Final ")
		Niger Steel, Emena	EAF	14,000 t/year
		CISCO, IKEJA	EAF	70,000 t/year
2.	Algeria	El-Hadjar	BOF/EAF	1.6 MT/yr/0.35 MT/yr.
3.	Angola	Luanda	EAF	30,000 t/year
4.	Ghana	Tema	EAF	35,000 t/year
5.	Kenya	Mombasa	EAF	10,000 t/year
6.	Tunisia	Mansel Bou	BOF	0.145 MT/year
			EAF	0.030 MT/year
7.	Uganda	Jinja	EAF	24,000 t/year
8.	Zaire	Maluka	EAF	120,000 t/year
9.	Zimbabwe	Redcliff	BOF	1 MT/year
10.	Egypt	The Egyptian Iron and Steel Co.		
		Helwan Works	BF-BOF	1.45 MT/year
		El Dekheila(Projected)	DR. EAF	0.80 MT/year
		Delta Steel Mills	EAF	70,000 t/year
		National Metal Industries	OH	100,000 t/year
11..	Morocco	Sonasid (Projected)	BF-BOF	0.95 MT/year
12.	Libya	Misurata (Projected)	DR-EAF	1.26 MT/year

Source: Chase Econometrics - World Steel Outlook - July 1982

The steel industry, besides being a multiplier for economic growth, has vital strategic significance. Every country should therefore, attempt to set up a national steel industry specific to local needs. The variants possible in the magnitude of the iron and steel industry and the various process alternatives are dealt with in the following pages.

3. CHOICE OF APPROPRIATE TECHNOLOGY

A variety of technological and economic choices are available for the establishment of a steel industry to suit the natural resources of different countries.

The countries can be broadly classified as under :

A. Those having iron ore and fossil fuel resources* to sustain iron production.

B. Those having iron ore but lacking in fossil fuel resources

C. Those having fossil fuel resources, but lacking in iron ore resources.

D. Those lacking in both iron ore and fossil fuel resources.

Countries in category (A) would have a wide choice of technology. Both Blast Furnace as well as Direct Reduction routes of iron making could be considered depending on the quality of ore and type and quality of fossil fuel. Even where the raw materials may justify the setting up of a conventional Blast Furnace - BOF route, the present cost of setting up an integrated steel plant (1600-1800 US $ per tonne of crude steel) and the high economic size (around 3.0 million tonnes/year capacity) would weigh in favour of mini steel plants based on scrap and/or some of the established Direct Reduction Processes. It should be mentioned here that most of the developing countries which have both ore and coking coal have already a reasonable sized iron and steel industry based on the classical route.

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* Fossil fuel resources include coal, natural gas and oil.

Countries in category (B) would have to depend on other countries in the region for their fuel needs. They could consider developing natural gas pipe grids with neighbouring countries having natural gas to make gas based DR units feasible. Alternately, they could export iron ore in exchange for directly reduced iron from other countries. Such fruitful tie-ups could possibly be thought of between ore-rich Liberia and countries like Ivory Coast, Congo, etc. For countries lacking fossil fuel resources but having wide equatorial rain forest, the alternative of using charcoal in blast furnaces (Annexure - 5) may prove to be very useful.

Countries in category (C) will have to import iron ore or pellets. Scrap based electric steel-making also could be considered in these countries. Since the developing countries do not generate enough scrap, the electric arc furnaces should have a provision of use of directly reduced iron (DRI) as a substitute for scrap. Availability of power is certainly a prerequisite for development of steel industry by alternate routes. The power requirement of steel-making by Electric Arc Furnace (EAF) route would be of the order of 400-600 kwh per tonne. Development of hydro-power and power from poor grade coal or lignite, which are more abundantly available in developing countries, are certainly a distinct possibility.

For countries belonging to category (D), production of iron may not be feasible. The steel industry could be based on imported scrap/DRI, provided adequate and steady power is available. Import of semis for rolling of bars, rods and structurals and further processing of steel is also possible. Setting up of pipe plants on imported skelp, galvanising lines, wire drawing, wire mesh manufacture and small scale foundry and forge shops to cater to agriculture and agricultural goods processing industry could also be thought of based on imported semis.

Based on the present availability of raw materials, the developing countries of the African countinent have been categorised in the following four groups (Table - 4):

Table - 4

Categorisation of Countries in the African Continent Based on Natural Resources Connected with Iron and Steel Industry

Category	Description	Countries
A.	Countries with both iron ore and fossil fuel resources. (Fossil fuel includes oil, natural gas and coal).	Algeria, Angola(*), Egypt, Gabon, Mozambique.
B.	Countries with only iron ore. (Economic reserves)	Ghana(*), Guinea, Liberia, Mali, Morocco, Senegal, Somalia, Zimbabwe(*), Zambia.
C.	Countries with only fossil fuel.	Chad, Congo(*), Cameroon, Ivory Coast, Libya, Zaire(*).
D	Countries lacking in economic deposits of iron ore and substantial fossil fuel resources.	Botswana, Burundi, Central African Republic, Equatorial Guinea(*), Ethiopia, Gambia, Kenya(*), Lesotho, Madagascar, Malwi, Niger, Uganda(*)

Note: This table is based on Annexure-4.
(*)Countries having hydropower potentials.

A comparison with Table-3, which indicates the present status of iron and steel industry in the African continent, brings out the potential for further development. The various technological alternatives and the categories of countries to which these are most applicable, have been brought out in Annexure-6.

Mini-Steel Plants for Developing Countries:

Two to three decades ago, the mini-steel plants or mini-mills used to be relatively low tonnage steel works based on electric arc furnace steel-making and rolling of pencil ingots or billets to plain carbon reinforcing and merchant sections in cross country mills. Many of these mills are in operation still in most developing countries with established industrial base. In India, for example, a mini steel plant capacity (excluding capacity of rerolling mills) of 3.4 million tonnes of crude steel exists today.

The mini (or market) mills which the developing countries should adopt in future are of a technologically higher level. These have economies of scale (400, - 500,000 annual tonnes), reduced operating cost and increased productivity. The product range is also wider, including medium structurals, wire rods and bars. The following descriptions typify the mini mills suitable for developing countries:

DR Based Mini Mills : Gas or solid reductant based iron plant, Electric Arc steel-making with about 20% purchased scrap, continuous casting and market mill of about 500,000 tonnes/year capacity for rods, bars and light to medium structurals.

EAF Based Mini Mills: Electric arc furnace based on purchased scrap and DRI, continuous casting and market mill to produce 100,000 - 250,000 tonnes/year of rods, bars and light to medium structurals.

Mini Mills for Re-rolling: Only rolling facility for 50,000 tonnes/year of bars, rods and structurals from purchased billet feed stock.

The approximate comparative cost, site area requirement, energy, electrical supply capacity, oxygen and water consumption of these three types, as compared to an integrated steel plant of economic size are indicated in Table-5:

Table - 5

Particulars	Unit	Rerolling Mill	EAF Mini Mill	DR Based Mini Mill	Integrated Steel Plant
i) Capacity	tonne/year	50,000	250,000	500,000	3,000,000
ii) Site area	Hectares	2.5	16	35	330
iii) Energy (including electricity, solid, liquid & gaseous fuels)	GJ/day	400	4500	30,000	300,000
iv) Rated capacity of electrical supply	MVA	3	75	120	300
v) Water	m^3/day	100	2,000	5,600	65,000
vi) Oxygen	t/day	0.2	25	25	750
vii) Capital (for works only)	Million US $	10.0	70.0	300.0	3000.0

Source: Proceedings of SEAISI Conference held in Singapore in Sep'80.

While the sizes for the various process routes given in the above table are indicative of optimum sizes, it is possible to install substantially lower capacity units and operate them at reasonably economic levels if local conditions dictate this.

Process developments in the area of Mini-Steel Plant Operation:

(a) Direct Reduction

As an alternate to blast furnace technology, the only commercially viable route for iron making today is the Direct Reduction route. Iron ore lumps and/or pellets are reduced in the solid state into DRI (directly reduced iron) with the help of gaseous or solid reductant in a shaft of rotary kiln. The highly metallised DRI is subsequently melted into steel with the help of electric power in the electric arc furnaces. The following Tables (6 and 7) give a summary of some of the well known coal and gas based direct reduction processes along with important features:

Table - 6

Features of Some Direct Reduction Processes Using Non-coking Coal

	SL/RN	Krupp	Allis Chalmers	TDR	DRC	Kinglor Metor
1. Raw materials	Ore fines, lumps and pellets	Ore fines, lumps and pellets	Lump ore and pellets	Lump ore and pellets	Lump ore and pellets	Lump ore/pellets and/or scale
2. Desired analysis of oxide feed, Fe(%)	64 min	64 min	65 min	64 min	64 min	64 min
Total gaugue, $(SiO_2+Al_2O_3)$(%)	4 max preferred	4 max preferred	4.5 max preferred	4 max preferred	4 max preferred	4 max preferred
SiO_2 (%)	-	-	1.5 - 3.0	-	-	-
Al_2O_3 (%)	-	-	1.0 - 2.0	-	-	-
S (%)	-	-	0.05	-	-	-
P (%)	As low as possible	As low as possible		As low as possible but 0.080% max	As low as possible	As low as possible
3. Size range of iron bearing materials(mm)	Wide size range acceptable	Wide size range acceptable	10-50(lump ore) 10-16(pellets)	5-20(lump ore) 6-22 (pellets)	5-25	5-20
4. Reductant used	Non-coking coals and fossil fuels (solid, 10 mm size)	Non- king coals and solid fossil fuels (- 10 mm)	Non-coking coals(solid-6/50 mm)oil and gas	Non-coking coal/non-coking coal & oil/non-coking coal and coal-oil slurry	Non-coking coal, lignite, anthracite etc.Co-current coal size=(-32mm). Blown coal size =(-10 mm)	Non-coking coal 5-20 mm
5. Desirable properties of the reductant	Low sulphur	Low sulphur	Low sulphur in oil/gas; (0.75% S), low ash coal.	Low sulphur (preferably below 1%)	Low sulphur	Low sulphur
6. Type of reduction reactor	Rotary kiln	Rotary kiln	Ported rotary kiln	Rotary kiln	Rotary kiln	Shaft reactor

Table - 7

Essential Features of Some Gas Based DR Processes

Sl. No.	Item	HYL	HYL III	MIDREX	PUROFER	FIOR	NSC
1.	Raw materials	Lump ore/pellets	Lump ore/pellets	Lump ore/pellets	Lump ore/pellets	Ore fines	Lump ore, pellets
2.	Desired analysis of oxide feed, % Fe.	64, min	64, min	64, min	High iron content preferred	64, min	High iron content preferred
	Total gangue, %(SiO_2+Al_2O_3)	4 max preferred	4 max preferred	4 max preferred	Low gangue preferred	-	Low gangue preferred
	%SiO_2	-	-	-	-	2.0 - 2.5	-
	% Al_2O_3	-	-	-	-	0.5 - 1.5	-
	% S	-	-	-	No restriction on S claimed	-	-
	% P	0.05 max	0.05 max	0.05 max	As low as possible	0.01 - 0.03	As low as possible
3.	Size range of iron bearing materials, mm	12-50 (lump ore); 9-16 pellets	16-30	6-30 (lump ore) 6-30 (pellets)	6-25 (lump ore) 8-20 (pellets)	0.04-12.7(-0.04mm should not exceed 20%)	5 - 25
4.	Reductant used	Reformed natural gas, coke oven gas,gasified coal or tar.	Reformed natural gas, coke oven gas gasified coal or tar.	Reformed natural gas, coke oven gas, gas from Naptha or LPG, gasified heavy oil or coal low shaft off gas	Reformed natural gas from liquid hydrocarbons, coke oven gas	High H_2 content gas from hydrocarbon feed stock, such as heavy crude oils, fuel oil, naphtha, LPG and natural gas	Natural gas, light oil coal gasification
5.	Desirable properties of the reductant	Low sulphur	Low sulphur	Low sulphur	Low sulphur	Low sulphur	Low sulphur
6.	Gas reformer	Ni catalytic recuperative type	Ni catalytic recuperative type	Ni catalytic recurperative type	Catalytic regenerative	Ni catalytic recuperative type	Based on Texaco process
7.	Reforming agent	Steam	Steam	Recycled top gas	Recycled top gas	Steam/particle oxidation	Steam (when using natural gas)
8.	Reducing gas analysis:						
	% CO_2	8.0	-	2	2		2.7
	% CO	14.0	-	35	45		42.0
	% H_2	75.0	-	53	47	Essentially hydrogen	45.0
	%(N_2+CH_4)	3.0	-	5	3		0.1
	% H_2O	-	-	5	3		10.2
9.	Type of reduction reactor	Static bed	Counter-current moving bed(shaft fce)	Counter-current moving bed (shaft fce)	Counter-current moving bed (shaft fce)	Fluidized bed	Counter-current moving bed (shaft fce)

India too has contributed significantly towards development of coal based DR processes. DR plants of 30,000 tonnes/year and 150,000 tonnes/year, based on SL/RN and ACCAR technology respectively are in operation and a DR plant of 90,000 tonnes/year, based on indigenously developed TDR technology is under construction. Table - 8 gives the actual investments in some DR plants installed/under construction in developing countries.

If, in a particular region, natural gas is available, then from technical stand point, any gas based DR process would be automatically preferred. Gas based DR processes are easier to control, the reactor availability is higher and they produce cleaner sponge iron compared to solid reductant based processes where the process control is difficult, the reactor availability could be poor and the product invariably contains 1 - 2% char, even with the best type of magnetic separation. In addition, gas or oil based processes generally consume less energy because of the presence of hydrogen. Investment per tonne of annual capacity in gas based DR plants is generally lower compared to solid based DR plants. The module capacity of the former can vary from 100,000 to 750,000 tpa whereas module size of a rotary kiln for coal based reduction is limited, at present, to 150,000 tpa capacity.

Table - 8

Actual Reported Investments in Some DR Plants

Installed/under Construction

Process	Plant	Reference year	Capacity 1000 t/y	Investment Million US $
HyL	Puebla, Mexico,	1969	335	9.0
	Monterrey, Mexico	1972-73	450	16.0
	LISIBA, BAHIA, Brazil	1970	325	10.5
	Sidor I, Venezuela	1974	360	21.0
HyL III	SICARTSA, Mexico	1980	2000	230.0
Midrex	BSC, Hunterston, UK	1975	800	114.0
	Sidor II, Venezulla	1976	1200	125
	OSKOL, Kursk, USSR	1977	1600	223
	ISCOTT, Point Lisas, Trinidad	1980	400	76.0
	NFW, Enden, FR Germany	1980	880	226.0
	ISP, Misurata, Libya	1981	1100	285.0
	Sabah, Malaysia	1981	600	138.0
FIOR	Fior de Venezulla, Montazas, Venezuela.	1975	400	32.0
KM	Burma	1980	20	16.0
SL/RN	New Zealand Steel	1969	150	9.0
	STELCO, Canada	1975	350	34.5
	SIIL, India	1978	30	16.0
	ISCOR, South Korea	1982	600	110.0
CODIR	Dunswart, South Africa	1971	150	14.0
ACCAR	OSIL, India	1980	150	30.0
TDR	IPITATA, India	1983	90	33.4
NSC	Trengganu, Malaysia	1983	600	238.0

A reference to iron-making would not be complete without a reference to the several new iron-making processes in laboratory and pilot plant stages of development in different countries. Most of these processes aim at production of liquid hot metal which can be subsequently processed into steel in the highly energy efficient Basic Oxygen Furnaces or supplied as pig iron for foundries. Annexure-7 describes some of these processes, based on non-coking coal.

(b) Electric Arc Furnaces:

(i) DRI as charge material: The Electric Arc Furnaces to be installed in the mini mills of the developing countries must have the provision to use DRI as a charge material even if the plant may not basically depend on DRI. The most accepted method of accomplishing this is to provide continuous feeding by means of a single chute from a storage bin and feeding mechanism which delivers the DRI at the bath surface or near its mid point. Because of the relatively low density of a DRI particle it must have enough velocity in order to penetrate the slag layer which is accomplished by ensuring enough free fall. The DRI-scrap-EAF steel making differs somewhat from the all scrap-EAF steel making because of residual FeO in the DRI and also difference in the carbon content at the melt down - a certain amount of in-house experimentation on the best charging and melting methods would be required by every mini mill operator.

(ii) High power and ultra high power operation: The high power (HP) and ultra high power (UHP) operation of the furnace is the most spectacular development of EAF technology in recent times. This has decreased the melting time of the solid charge and enabled optimization of maximum power utilisation and operating time of the furnace. Furnaces of capacity ranging from 20T to 60T and specific transformer ratings 600-1000 KVA per tonne can be termed as standard UHP furnace today.

(iii) Water Cooled Panel System

With the advent of ultra high power technology and continuous charging of sponge iron, the thermal conditions prevailing within the furnace become more severe. The adoption of water cooled panel system for the furnace side wall and roof has solved the problem of high refractory wear. Reduction in refractory consumption is important in many developing countries who may have to import it fully, since the volume of refractory consumption would be too low to set up a separate refractories plant.

(iv) Supplementary Fuel Injection

Supplementary fuel injection such as oxygen, natural gas, oil and coke breeze or a combination of these is being experimented in many EAFS. A typical case is the use of oxyfuel burner during the melting period to increase the melting rate. For developing countries with natural gas resources this facility would be valuable. It is reported that 15% reduction in melting time is possible without any adverse metallurgical effect. It is estimated that about 4 litre of oil and 10.14 nm^3 of oxygen per tonne of steel can reduce electrical energy consumption by 50 kwh/t for a 100% scrap heat. Other significant developments in the EAF area are computerisation of melt shop and ladle treatment facilities for temperature equalisation prior to casting, desulphurisation and for making alloy addition to the steel.

(c) Continuous Casting

Continuous casting facility is now an integral part of a mini steel plant. In fact, the growth and development of mini steel plants has coincided with the introduction and acceptance of continuous casting. For billets, continuous casting provides around 95% yield from liquid steel against 82 - 83% in the ingot-soaking pit - blooming mill - billet mill route. Ladle slidegates, quick restart capacity and sequence casting operation are some of the features of the present continuous casting plants. Stream protection while pouring steel from ladle/tundish and tundish/mould is also being increasingly used if higher quality of product is demanded.

Another promising innovation is 'horizontal' continuous casting. This process has been under development since 1970. The first industrial scale unit has been installed in the Fukuyama Works of NKK in Japan, as a part of joint Davy Lowey/NKK development. This caster has been in operation for a little over 5 years. This single strand unit is able to produce billets in the range 75 to 150 mm. The results so far have been encouraging. Further development will include multi-strand horizontal casting also. It is claimed that horizontal continuous casting technology will involve lower capital and production costs than curved mould or radial machines.

(d) Rolling Mills

The available rolling mills for mini steel plants are now radically different from the open train cross country mills employed earlier for production of reinforcing bars and rods. Continuous trains are now normally provided,incorporating reduced cost. Variable speed DC individual drives also have replaced the older group driving system. Other features include control of reheat furnace atmosphere for reduction of scale loss, temperature control, descaling practice, application of roller guides and horizontal-vertical no-twist mill configurations. These so-called market mills have a wide range of products and can accept smaller economic lot sizes with uniform high productivity for the entire product range. This is achieved with a layout providing both cooling bed for conventional long products as well as coilers for smaller rods. Even a common reheating furnace facility can be utilised for basically two mills (one for medium bar-rod and structurals and the other for wire rods) under the same roof to reduce the cost. al market mill products are given in Annexure-8,which a single mini s lant can produce from a group of close knit mills. It is desirable that while planning for rolling mills, the developments in the rolling mill finishing area - like automated and accelerated cooling of wire rods, bundling of rods and sections, high speed in-line straightening and mechanical stacking of products also should be kept in mind. Many rolling mills of even integrated steel plants set up in the past suffer from shortcomings in these areas.

4. LINKAGES OF STEEL INDUSTRY WITH CAPITAL GOODS AND AGRICULTURAL SECTORS

The less developed countries located in Africa are importing around 7.39 million tonnes per annum in terms of crude steel to meet a total demand of 8.60 million tonnes of crude steel equivalent. In all probability, greater availability of steel would have led to higher consumption. So while planning for steel the demand-pull effect can not be the sole deciding factor. Rather, in the early stages of development the supply-push effect may be more relevant in stimulating the growth of other sectors of the economy. The linkages of steel with the growth of national economy are broadly listed below :

- Mining of raw materials.
- Transport of raw materials.
- Development of power to support steel industry, its township and ancillaries.
- Development of ancillaries to supply spares to steel plant.
- Development of transport - road and rail - for supplying the products to consumers.
- Development of capital goods industry based on steel products for other sectors of economy like power, irrigation, machine tools and transport.
- Development of agro based industries to supply agriculture with its needs of improved tools and implements, tractors and tillers.
- Sprayers for pesticides, pumps for irrigation.
- Development of small to medium insect proof silos based on steel/cement for proper storage of agricultural produce.
- Development of industries based on agricultural produce e.g. canning, oil expeller, sugar, flour mills etc.
- Development of light consumer goods industry such as cycles, articles of domestic consumption, low cost housing, road making machinery etc.

The illustrative norms of consumption of rolled plain carbon steel for various sectors of economy as assumed in the 6th plan of India given in Tables 9 and 10 indicate the demand-pull effect of the economy.

Table - 9

Specific Consumption of Steel per unit Output in the Capital Goods and Agriculture Sectors (Finished Plain Carbon Steel Rolled)

	Consuming Industry	Unit of Output	Consumption Norm (Tonnes/Unit)
1.	Machine Tools	Million $	160
2.	Boilers	Million $	397
3.	Chemical Machinery	Million $	84
4.	Metallurgical Machinery	Million $	298
5.	Mining Machinery	Million $	1092
6.	Textile Machinery	Million $	263
7.	Cement Machinery	Million $	1253
8.	Sugar Machinery	Million $	319
9.	Paper Machinery	Million $	392
10.	Dairy Machinery	Million $	497
11.	Printing Machinery	Million $	1011
12.	Conveying Machines	Million $	399
13.	Weighing Machinery	Million $	1014
14.	Reduction Gears	Million $	1697
15.	Diesel Engine (Stationery)	1000 Nos.	66.8
16.	Petrol Engine	1000 Nos.	28.2
17.	Crawler Tractors	1 No.	19.4
18.	Agricultural Tractors	1000 Nos.	475
19.	Power Driven Pumps	1000 Nos.	4.3
20.	Hurricane Lantern	Million Nos.	634
21.	Ball and Roller Bearings	Million Nos.	120
22.	Bolts, Revets and Nuts.	Thousant tonnes	1180
23.	Fabricated Structurals	Thousand tonnes	1200
24.	Transmission Towers	Thousand tonnes	1100
25.	Black and Galvanised Pipes	Thousand tonnes	1150

Note: Tonnage/Million Rs. based on 1979-80 price in India 1 US $ = 10.50 Rs. (approx.)

Source: A technical Note on the Sixth Plan of India, Government of India - Planning Commission - July 1981.

Table - 10

Norm of Finished Steel Consumption in Agriculture, Construction and Allied Sectors, 6th Plan Period of India (1980 - 1985) per million $ Investment.

(Tonnes/one million $)

	Sector	Norm of finished steel consumption
1.	Agriculture and allied activities including irrigation and flood control	357
2.	Energy (Electric, power petroleum and coal)	210
3.	Industry and mineral	420
4.	Transport and Communication	756
5.	Social Services including housing	420
6.	Others	210

Note:- Cost of services based on 1979-80 prices prevailing in India

A quality-wise and item-wise break up of steel required for a wide variety of agricultural implements and agro-based industries is given in Annexures 9 and 10. Annexure 9 gives the requirements of cast iron components and mild steel products such as bars and rods, light and heavy structures, plates, CR and HR sheets, galvanised and tinplates, steel castings, steel forgings, wires and pipes. Annexure 10 gives the requirements of alloy and special steel products categorised under heads such as stainless, high speed, high carbon, alloy tool and die steel, spring steels, constructional steel, free cutting high carbon, die block and electric steels. This detailed information may serve as a useful reference for newly developing countries poised to set up a national steel industry for supporting the agricultural and consumer goods sectors through capital goods.

A reference to Figure-1 which illustrates the basic input-output relationship of agricultural and capital goods industries with steel reveals that the steel product type, quantities and complexities are to be chosen for a specific situation. Three typical models are given in Annexure - 11, which broadly lists out the steel requirements of a developing country, assuming different levels of economic base and suggests the pattern of the national iron and steel industry including secondary finishing operation on iron and steel. Metal working based on imported semis has been the basis of model - 1. This could serve for countries earlier categorised as 'D' i.e., lacking in adequate resources of both iron ore and fuel. This could as well be the initial base for iron and steel industry for countries of the other categories over which the facilities of iron and steel making can be added in phases. Model-2 starts with steel making and Model - 3 with iron making in the DR route. These two models have assumed increased sophistication of the finished products. It may be noted that all developing countries having adequate natural gas resources are opting for a pattern somewhat similar to model - 3 for their national iron and steel industry based on either imported ore/pellets or indegenous iron ore resources.

For meeting the requirements of iron and steel castings, foundries with cupolas and induction or electric arc furnaces and adequate casting facilities will be needed. For meeting the requirements of water supply pipelines, spun pipe units with ductile iron could be put up. Similarly forge shops for stamping and forging various steel products may be needed. Fabrication units for fabricating various steel items may be needed, particularly by the construction industry. Therefore, a whole range of industries may be put up, depending on the products required for end-use as listed in Figure-1.

By correlating the investments in the iron and steel industry to suit the specific requirements for the growth of the capital goods and agricultural sectors, optimum utilisation of investments can be ensured, thereby avoiding excessive imports on the one hand and under utilisation of installed iron and steel capacity on the other hand. A glance at some of the steel imports by developing countries, listed in Annexure - 3 will give a fair idea of the scope of developing the steel industry in some of these countries.

5. PROBLEMS IN INTEGRATED DEVELOPMENT AND ROLE OF NATIONAL AND INTERNATIONAL AGENCIES

In the less developed part of the world, the following difficulties are well known :

- Low level of literacy.
- Shortage of qualified and trained manpower.
- Lack of an industrial culture.
- Shortage of capital.
- Lack of adequate infrastructural support in the form of transport, power and energy etc.
- High degree of dependence on other countries for know-how for engineering and technology.

The problems listed are no doubt formidable, but these are not insurmountable. Judicious application of modern technology, adapted to local conditions and rapid training of local cadres capable of absorbing such technology, coupled with careful integrated planning of balanced infrastructural support, will help in overcoming these shortcomings. The initial industrialisation programme can aim at creating :

- an industrial infrastructure like rail and road transport, power, energy resources etc.
- products that help the agricultural sector to improve its output and productivity.
- employment opportunities which in turn will increase purchasing power, thus creating a demand for goods other than the basic needs of food, clothing and shelter.
- skilled manpower and supervisory cadres. (Annexure - 12 gives a list of skills required in an Iron & Steel Industry)
- qualified engineers, technicians, economists and managers for industry.
- attitudinal changes in people from traditional to modern through education and training. This, in turn, will exert a pressure on the society and government for more rapid industrial and economic growth.

One of the major problems in national planning has been the allocation of resources between the consumer sectors and capital goods sectors and the ability of the economy to absorb investments and sustain growth till the take-off stage is reached when the economy will become self-sustaining. Balancing a minimum growth rate without unduly over-extending credit is a very difficult feat. A pragmatic approach to avoid over-centralisation and at the same time ensure adequate coordination of centres of growth will be needed.

In the context of setting up a steel industry, the investment will be fruitful only if balanced investments have been made in developing the necessary infrastructure facilities, and the product-mix is relevant to the needs of the consumer sectors including the agriculture, light industries and services of the country. The capital costs are substantially influenced by site conditions such as topography and soil, accessibility of site, availability of proper agencies locally for project management, procurement and site erection, extent of off-site costs needed to ensure reliable infrastructure and service facilities, extent of availability of indigeneous building materials, structures and equipment, location of the plant etc. Similarly, operating costs will be influenced by availability and cost of raw materials, trained manpower, fuel and power, refractories. In case of re-rolling mills the raw materials would be semis such as billets, in scrap-based plants they would be scrap and in case of D.R.-based plants they would be iron ore or pellets. The location and accessibility of the plant play a major role in operational costs. Therefore a careful sensitivity analysis will be needed to determine optimal investment.

The right selection of the process route and plant capacity, based on natural resources available and end-use of steel products is crucial. Some deficiencies in raw materials could be made up by imports against export of surpluses in other raw materials.

One of the most time-consuming areas is the development of competent entrepreneurial, administrative and skilled industrial cadres to man the enterprises successfully.

To ensure long-term success in running the enterprises, development of indegenous ability to absorb and adapt imported technology to suit local conditions is essential.

The role of national agencies in formulating integrated planning of the economy, enforcement of balanced sectoral investments, monitoring of the progress of such planned development and timely mid-stream corrections of distortions in the phases of development need not be gainsaid. Unless a modicum of national planning to guide the economy is introduced, there is likely to be frittering away of the scarce capital resources, leading to stagnation in growth and repeated situations of economic crises. Development of the steel industry, which is capital intensive, as an integral part of planned growth, will naturally require careful evaluation by the national planning agencies of the developing countries. The national agencies will have to ensure development of the necessary infrastructure of power, water, transport and raw materials to ensure proper functioning of the steel industry, the pre-training of cadres and the simultaneous development of the downstream consumer industries for the steel. Ensuring easy availability of essential stores and spares within the country or on a basis of regional cooperation is an essential prerequisite.

As already mentioned, many countries are deficient in one or other raw material or energy resource for developing an iron and steel industry. By establishing regional cooperation, they could complement each other in providing for deficiencies in input resources to their mutual benefit. Moreover, those developing countries that have already gone through a good deal of the developmental process could share their experience with others so that some of the pitfalls could be avoided. It would be relevant to learn from the past experiences of the developing countries which have by now established the iron and steel industry. Several organisations in the developing countries, including India, are now capable of providing technical know-how on mini mills based on technologies assimilated in economic and social conditions similar to countries where an iron and steel base is yet to be initiated. Similarly, selective help and assistance from the developed countries could be sought in establishing the iron and steel industry with the appropriate technology.

In all these areas, the role played by international organisations such as the UNIDO in bridging the technology gap of the developing countries would be invaluable. Conferences, such as the present one, provide a forum for focussing attention on the problems faced and for exchange of information which could lead to subsequent closer bilateral tie-ups between countries. The international agencies could arrange for consultancy at low costs, provide specialists to help the concerned developing country in making the choice of technology, planning investments and subsequent follow-up for establishment of the necessary facilities. They also help in lining up appropriate training abroad of cadres for manning the industries at little or no cost.

International financial institutions such as the World Bank, the International Development Association, the Asian Development Bank etc. provide financial back-up in terms of long term loans at low interest rates. Tied loans against specific projects are provided after careful analysis of the techno-economic viability and social cost benefits of the proposal.

While international cooperation and assistance in various forms is thus available, the ultimate success of the industrial growth plans of each developing country will have to depend on the initiative and imaginative planned use of available resources by the concerned Government.

A pragmatic approach regarding the type of industries and products needed and the size and type of iron & steel base to be established to meet their requirements, in the context of resources and skills available, will provide the keystone to success.

6. SUMMARY

(i) Since the end of the second world war, the share of the developing countries in production and consumption of steel has gone up to 16% and 22% of the world steel production and consumption respectively. The establishment of the steel industry in a developing economy provides the "push" in growth of light capital goods industries, service sectors and agricultural machinery. Conversely, the existence of such industries exerts a "pull" in the establishment of a small steel industry to cater to their needs, thereby making the economy more resilient and self-reliant. However, as steel is a capital-intensive industry, the careful evaluation and selection of the plant, process and products should be an integral part of the planning process.

(ii) The interrelationship between the iron and steel industry and the various segments of agriculture and capital goods industry in developing countries is illustrated in Figure 1. Initially the demand is predominantly for long products, forgings and castings but as the economy develops, the demand for flat products goes up gradually. The initial plan model for investment may comprise the capital goods sector and the consumption sector, the latter subdivided into the consumer goods industries, household production of consumer goods, including agriculture and the services sector.

In large populous developing countries, possessing a certain amount of industrial and entrepreneurial skills and infrastructure, the bias could be towards capital goods sector with special emphasis on heavy and basic industries, as the economy will have the innate resilience to absorb the shock of heavy investments and the ability to ensure returns in a reasonable time span, while the economy as a whole gains the necessary momentum. But in a majority of developing countries, at the initial stages, it would be necessary to develop the light capital goods industries and simpler agricultural implements with a small steel industry to back-up its specific needs.

(iii) The choice of appropriate technology for the steel industry would depend on the natural resources and the end use of steel products. Most developing countries may be classified as follows :-

A. Countries with iron ore and fossil fuel resources including coal, oil and gas.

B. Countries with iron ore only.

C. Countries with fossil fuels but no iron ore.

D. Countries with neither iron ore nor fossil fuel.

Countries of category A can choose the BF-BOF route with Continuous Casting and Rolling Mills or DR-EAF route with Continuous Casting and Rolling Mills of fairly large capacities. Countries of category B will have to depend on imported coal or gas. They could choose the gas-based DR-EAF route. Countries having proper climatic conditions for energy forestry could also go in for charcoal-based BF-BOF route. Countries in category C would have to import iron ore or pellets. Scrap-based EAF could also be used by them with provision for DRI usage. Cheap perennial hydro-power would be of great advantage. Countries in category D may find it difficult to sustain anything but re-rolling mills of small sizes, or have the EAF route based on imported scrap and DRI.

Appropriate technologies for a group of developing countries in Africa and the Middle East are illustrated in the paper.

The various module sizes of mini-steel plants based of DR-EAF route and Re-rolling Mills for making bars, rods and structurals are illustrated with comparative costs, area requirements and power, water and oxygen specific consumption ratio, as well as optimum installed capacities. Details of different DR processes as well as EAF and continuous casting have been briefly dealt with. In case of Rolling Mills, modern market mills having a wide range of products in smaller economic lots, while retaining high productivity, make the mini-steel plant very attractive for making a variety of merchant bars and structurals.

(iv) The multiplier effect of the steel industry in stimulating all-round growth of the economy and giving a thrust to other industrial sectors is a major factor to be kept in mind. There are linkages with mining, power, transport, engineering industries, agro-industries, irrigation, storage and processing of agricultural produce, light consumer industries etc., resulting in the growth of all these sectors. Illustrative figures of specific consumption of steel per million dollars of investment in different sectors and industries indicate the all pervading influence of the steel industry in other sectors of the economy. The specific products required for end-uses have been elaborated so that the steel plant is oriented to the specific needs of the consumer sectors.

(v) Low levels of literacy, shortage of qualified and trained man-power, lack of industrial culture and discipline, shortage of capital and entrepreneurialskills, inadequate infrastructure facilities, high dependence on imported technology and inability to assimilate such technology, are major shortcomings hindering the establishment and management of steel and allied industries in developing countries. A proper strategy planning will be needed to overcome these deficiencies.

A balanced allocation of resources will be needed between consumer sectors and capital goods sectors, to ensure planned growth rates without unduly over-extending credits.

A pragmatic strategy at the national level will ensure proper coordination of growth centres while avoiding over-centralisation.

Pre-training of cadres to man the industry and ensuring adequate development of domestic capacity to supply requisite stores and spares to maintain the plant are essential prerequisites.

International agencies such as the UNIDO provide requisite consultancy for planning and implementation of projects, training facilities for manpower and provide a forum to focus attention on problems that need solutions. International financial agencies such as World Bank, International Development Agency & Asian Development Bank etc., provide credit facilities at low interest rates.

While such aid, advice and assistance are invaluable, the ultimate success will depend on the pragmatism, initiative and imaginative resource mobilisation, planning and execution of projects by the concerned Government and its nodal agencies.

Annexure - 1

Growth of Iron and Steel Products During the Different Plan Periods of India

Period	Iron and Steel Products Available/Introduced	Utilisation in the Economy
Pre-Plan Period	Pig Iron :	
	Basic grade, Foundry grade, Low Sulphur Charcoal Blast Furnace grade.	
	Steel Sections:	
	Beams - 100x70 - 450x150	Construction of buildings
	Channels - 75x40 - 300x90	and industrial structures
	Angles - up to 200x200	Bridges, wagon building,
	Rounds - 12 - 200	roofing, railways,
	Squares, Octagon, flats, bulb angles etc.	defence etc.
	Plates - 900-2000 mm, 6mm - 32 mm	
	Sheets - Black sheets - 0.63 to 3.. 600 - 1200 mm width.	
	Galvanised - plane and corrugated	
	Rails - 24 lb/yds, 30 lb/yds; 60 lb/yds, 75 lb/yds, 90 lb/yds.	
	Bridge Rails	
	Wheel & Axles	
	Agricultural Products :	
	Shovels, Spades, Crowbars, Picks and Beaters, Hammers etc.	Agriculture
1st and 2nd Plan Period	Beams - 500x180, 600x210	Heavy industrial structures.
	Channels - 400x110, 41x32	
	Crossing Sleeper bars (rolled/pressed)	Railways.
	Bearing Plate & Fish Plate bars	
	Skelps - up to 311 mm width	E R W Pipe plants
	Plates - up to 2500 mm w[illegible]	Wagon building
	Sheets - Hot rolled in coils upto 1550 mm width	
	Seamless pipes	

3rd Plan Period	Cold Rolled Sheets - 0.63 - 1.6 mm up to 1400 mm wide	Automotive body industry
	Tinned Plates	Food Packaging Industry
	ERW Pipes - 8⅝" - 18"	Domestic and industrial fluid transport
	Electric pig iron Ferro silicon/Ferro manganese	High grade castings
	52 kg/m and 60 kg/m Rail	Railways.
4th Plan Period	Wire Rods 6 - 10 mm	Wire drawing and fastner industry
	Galvanised Sheets - 900-1200 mm width	Roofing of domestic and industrial sheds and packaging
	Electrolytic tinplates Hot rolled Electric Sheets	Electrical machinary
	Alloy Steel and Constructional Steel Bars, rods, die blocks, rings. Stainless hot rolled and cold rolled sheets up to 1000 mm width.	Machine tools, automotive engines, pumps, Railways, chemical and food processing industries.
	Cold twisted reinforced Roads/ Squares/Hexagons	Building construction.
5th Plan Period	Spirally Welded Pipes up to 64" OD	Agriculture, Water lines Sewarage pipelines in cities.
	Hot Rolled & Cold Rolled Wide Strips up to 2000 mm	
6th Plan Period	Wide Plates upto 3200 mm wide	Ship building
	Micro Alloyed High Strength Plates and Structurals	Structures, wagon building
	Cold Rolled Grain-oriented and Nongrainoriented Electric Sheets	Electrical machinery industry
	High Strength Rails	Railways

ANNEXURE-2

Per Capita GNP/GDP and Apparent Crude steel consumption in Selected developing countries.

Country	Per Capita GNP/GDP-1980 US $	Per Capita Consumption of Crude Steel (Kg) 1980	1982
Algeria	1920	130	87
Morocco	860	30	15
Nigeria	1010	46	46
Tunisia	1310	36	52
Argentina	2390	140	91
Brazil	2050	120	83
Chile	2160	79	28
Colombia	1180	34	35
Mexico	2130	130	117
Peru	980	50	25
Venezuela	3630	237	221
Egypt	580	35	45
Iran	2160('77)	90	89
Iraq	3020	150	75
Kuwait	22,840	475	849
Lebanon	1070	139	131
Libyan Arab Republic	8640	375	106
Saudi Arabia	11,260	446	681
Syrian Arab Republic	1,340	75	16
Burma	180	-	3*
Bangladesh	120	-	2*
China	290	45	41
India	240	17	16
Indonesia	420	21	22
Korean Republic	1506	137	184
Pakistan	300	8	7
Korea DPR	730	270	311
Malayasia	1670	162	179
Philippines	720	28	26
Thailand	670	44	34
Sri Lanka	270	-	5*

Note: Countries like Gabon, Ivory Coast, Zimbabwe, etc. have not been included due to lack of data for per Capita steel consumption though the per capita GNP/GDP is comparatively higher.

* Estimated Approximate figures based on import of steel products.

Source: Per Capital GNP/GDP: The Statesman's Year Book 1983-84 - Macmillan Press, London.

Per Capita apparent consumption of crude steel : Steel Statistical Year Book - 1983, IISI, Brussels.

Annexure - 3

Steel Imports by Developing Countries

Country	Steel Imports (Thousand Metric Tonnes)		
	1980	1981	1982
Argentina	1084	691	639
Bolivia	80	60	80
Brazil	657	898	422
Chile	85	67	41
Colambia	392	580	464
Costa Rica	125	65	70
Cuba	132	193	90
Dominican Republic	100	60	100
Equador	350	250	350
El Salvador	65	45	65
Guatemala	125	100	100
Honduras	90	65	90
Mexico	2723	3210	1470
Peru	144	330	153
Venezuela	918	987	734
Algeria	1404	1536	822
Kenya	186	128	90
Morocco	460	487	242
Nigeria	2700	2500	2800
Tanzania	68	32	66
Tunisia	48	99	183
Zaire	60	51	43
Zambia	23	12	9
Egypt	988	738	325
Iran	2515	1887	1847
Iraq	1593	1208	796
Kwait	775	1000	1100
Lebanon	285	287	275
Libyan Arab Republic	865	1044	262
Oman	100	192	200
Qatar	58	60	60
Saudi Arabia	3054	4040	5000
Syrian Arab Republic	918	434	113
China	5000	3200	4000
India	1658	1270	1430
Indonesia	2078	2091	2250
Republic of Korea	1947	1972	2450
DPR Korea	50	55	30
Malayasia	1530	1570	1900
Pakistan	490	482	450
Philippines	906	784	1193
Singapore	1605	1896	2050
Taiwan	2459	2269	1800
Thailand	1250	1266	1100
Total developing countries (excluding China and North Korea)	42727	43114	40445
Total Global Import	137020	136154	130060

Source: Steel Statistical Year Book - 1983, International Iron and Steel Institute.

Annexure - 4

Raw Material Resources in the Developing Countries of Africa and Middle East Relevant to Iron and Steel Industry.

I. IRON ORE

(A) Africa

1.	Algeria	Iron ore is mined in Algeria since the end of last century. Resources amount to 145 - 150 million tonnes of which 130 million tonnes situated in the twin deposits of Ouenza - Bow Kadra. Gara Ojebilet in South West Algeria has oolitic ore rich in magnetite with estimated 765 million tonnes of reserve and is of good potential. Production of iron ore in 1982 was 3.892 Mt.
2.	Angola	Known iron ore reserves are at present estimated at 130 million tonnes distributed in Cassinga detrital pebble ore, Cassinga massive hematite, Cuima massive magnetite and M'Bassa massive magnetite. Production of iron ore restarted since 1980.
3.	Cameroon	Known reserves are estimated 120 million tons at 35-42% Fe. Not considered economic deposits at present.
4.	Egypt	The known iron ore deposits are estimated at 280 million tonnes distributed in Aswan (46.9% Fe), Baharya (50%), Redsea (43%).
5.	Gabon	The known reserves of iron ore amount to over 1000 million tons distributed in Me'cambo, Tchibanga, Mebanga - N'Gama and Mount Bilans. Exploitation of the Me'cambo deposit (near Be'linga in the North East) awaits completion of branch railway lines.
6.	Ghana	Known deposits estimated at 270 million tonnes containing 46 - 52% Fe (upgradable to 50-55% Fe) are in the Yendi district (Shiene deposits)
7.	Guinea	Known reserves are estimated at 1200 million tonnes. 1000 million tonnes are lake superior type haematite in the Nimba - Simandou deposits and 200 million tonnes are laterite ores of Conakry deposits. Mining from the former deposits has been started now following exhaustion of the easily mineable deposits of the latter.
8.	Liberia	Total known reserves amount to 975 million tonnes contained in Bomi, Mano, Bong and Nimba (Lamco) ore bodies. The ore is Magnetite, Hematite an Magnetite-Hematite with iron content going over 66%. Iron ore mining is highly developed in Liberia. 1982 iron ore production was 22.0 million tonnes.

9.	Mali	Known reserves at 10 million tons of magnetite at 63% Fe at Nior West Mali.
10.	Mauritania	Measured and indicated reserves amount to 150 million tonnes of which 135 million tonnes are in the ore bodies of the Kedia d'ldjil and 15 million tonnes in the Legbital deposit near Akjoujt. Fe content varies from 55% to 69%. Mining activity is developed in Mauritania. 1982 production - 8.2 million tonnes.
11.	Morocco	Known reserve are estimated at about 200 million tonnes of hematite, magnetite, Geothite etc. Fe 46 - 62%. Production of iron ore continuing since 1963.
12.	Mozambique	Known reserves are estimated 50 million tonnes of titaniferous magnetite at 50% Fe, 18% TiO_2 and 0.7% Va situated at Machedua in the Tete district. Exploitation yet to start.
13.	Nigeria	Known reserves amount to 266 million tonnes distributed in Agbaga (oolitic limestone 45% Fe) and Enugu (Laterites at 32% Fe). The low grade ore is being planned to be used in the national iron and steel industry after beneficiation.
14.	Senegal	Known reserves are 125 million tonnes at Saraya near Kenieba. 80 million tonnes are magnetite martites at 60% Fe and 45 million tonnes are of 45% Fe upgradable to 58-59% Fe.
15.	Sierra Leone	Known reserves are estimated 200 million tonnes as either weathered powdery hematite quartzites (45 - 47% Fe) or surface enrichment capping (55 - 57% Fe) on magnetite schist. Production of iron ore from Marampa started since 1933.
16.	Somalia	A possible 250 million tonnes at 50% Fe has been reported 250 Km West-North-West of Mogadiscio.
17.	Sudan	Known reserves amount to over 51 million tonnes distributed in Sophia (magnetite - 60%Fe) Abu Tulu (magnetite - hematite - 61% Fe) and Fodikwan (hematite - 60% Fe).
18.	Swaziland	Known reserves are estimated 148 million tonnes. N'Gwenya has hematite (61 - 64.3% Fe) and is being exploited since 1964.
19.	Togo	42 million tonnes of ore occur at Bajneli in North-West Togo (45% Fe).

20. Tanzania — Known reserves amount to 53 million tonnes of titaniferous magnetite in Liganga and Hundusi deposits (49% Fe and 13% TiO_2) and 68 million tonnes banded iron stone at Manyore.

21. Tunisia — Iron ore is being mines in Tunisia since the end of the last century and reserves have been considerably depleted. Present reserves are estimated 45 - 50 million tonnes of which 32 million tonnes are at the Djerissa mines (54% Fe)

22. Zambia — 150 million tonnes of 60% Fe ore known to exist. Development of mining industry is hampered by long distance of the deposits from coast.

23. Zimbabwe — Known iron ore reserve amount to 90 million tonnes at over 55% Fe in and South of Salisbury area. Production of iron ore - 1.1 million tonnes in 1981.

B. Middle East

1. Iran — Several deposits containing 10 - 30 million tonnes of ore ranging from 40 -60% Fe have been reported.

2. Saudi Arabia — The Quadi Fatima deposits contain roughly 20 million tonnes of indicated and inferred ore of 45 - 47% Fe.

II. NATURAL GAS AND OIL

(A) Africa

1. Algeria — Major oil field in Algeria - Edje'le, Hassi Messaoud, El Gassi. Natural gas fields - Djebel Berge, Hassi-R'Mel. Oil production was 51.5 million tonnes (1980) and natural gas 14.823 million cubic metres (1980)

2. Angola — Angola produced 7.4 million tonnes of oil in 1980.

3. Cameroon — Oil production from Kole oil field was over 4 million tonnes.

4. Congo — Oil reserve is estimated 500 - 1000 million tonnes. Output in 1982.5 million tonnes from offshore.

5. Egypt — Crude oil production in 1979 was around 25 million tonnes. Gas is also available.

6. Gabon — Oil extraction from offshore fields totalled 7.56 million tonnes in 1981.

7. Ivory Coast — Small offshore production of petroleum.

8.	Nigeria	Oil production in 1981 was 73.3 million tonnes and natural gas 601 million cft (1972)
9.	Sudan	Two oil wells in the South West produce 15,000 bbls. per day of high quality oil.
10.	Tunisia	1980 production of oil was 5.6 million tonnes and natural gas 360 m cubic metres.
11.	Libya	Oil production - 420 m bbls (1981) and natural gas 29,000 m cubic metre.
12.	Zaire	Small offshore oil production 6.6 m bbls (1980)

(B) Middle East

1.	Baharin	One of the major oil producing countries. Production of crude was 16.9 m bbls in 1981. Natural gas - 163,101 m cft in 1981.
2.	Iran	1980 production of crude - 73.7 million tonnes, Natural gas 44,300 m cubic m.
3.	Iraq	Total crude petroleum production 130.2 million tonnes (1980) and natural gas 1760 m cft (1980).
4.	Kuwait	Production of crude oil 71.2 million tonnes (1980) and natural gas - 310,066 m cft (1980).
5.	Oman	Oil production - 330,000 bbls per day in 1981.
6.	Quatar	Oil production - 147,800,000 bbl (1981), natural gas - 220,000 m cft (1981).
7.	Saudi Arabia	Oil production 3,623.8 m bbl (1980) with natural gas.
8.	United Arab Emirates	Oil and gas production:

Abu Dhabi	- 660.2 m bbl (1981) with gas liquidification provision
Dubai	- 127.8 m bbl (1981)
Sarajah	- 3.7 m bbl (1980)

III. COAL (Mostly Non-coking)

(A) Africa.

1.	Mozambique	Estimated coal reserve 400 million tonnes awaiting full exploitation.
2.	Nigeria	Estimated coal reserve - 245 million tonnes.
3.	Swaziland	Coal is mined at Mpaka, extensive deposits of low voltile coal exists at Lowveld.
4.	Tanzania	Recently coal has been found.

Sources: - The World Market for Iron Ore - United Nations- New York - 1968
- The Statesman's Year Book - (1983-84) Macmillan Press - London

Annexure - 5

Charcoal Blast Furnace Alternative

Use of charcoal, in place of coke, in small blast furnaces up to 800 t/day is an established technology. The process can deliver very high quality hot metal suitable for SG iron production, in addition to steel-making. In certain areas of the world, particularly those with a lower density of population and located in the equatorial rain forest zone, this alternative could be found viable. Brazil has developed charcoal BF technology to substantially high levels. Production of iron from charcoal blast furnaces in South America was reported to be nearly 4 million tonnes in 1980.

The advantages offered by this technology are as follows:-

(1) Large number of unskilled persons can be employed in energy plantations, which are required to sustain charcoal production on a regular, systematic basis.

(2) Charcoal is a renewable source of energy and hence, its cost will be stable over long periods.

(3) Land, which is unsuitable for agricultural purposes, can be used for energy plantation profitably.

(4) Domestic fuel needs can also be met along with the needs of the steel plant.

Besides Brazil, Thailand and Malaysia are also using this technology today, for steel production. Since this technology can provide employment to a large number of people, with practically no training, countries which have a large number of unskilled unemployed can opt for this technology, provided enough land is available for energy plantations and climatic conditions are suited for social forestry. Typically, an area of 350 square miles under energy plantation can sustain a production of 500,000 tonnes of iron by this route.

Annexure - 6

Technological Alternatives for Iron and Steel Production

Sl. No.	Material - Process - Product	Type of Resource base in a country to which most applicable.	Capacity of Works (1000 t/a)	Number of Employees (Persons)	Period of Construction (Years)	Capital Investment (Million $)
1	2	3	4	5	6	7
1.(a)	Coke / Ore --BF-BOF-CC-Rolling Mill -Flats & Non-flats	Countries in category 'A' with both iron ore and coking coal. Large domestic market and relatively high level of industrialisation is needed. Could also be based on partly imported coal/ore if the other conditions are favourable.	1000 (At present economic size is above 3000)	6000	5 - 6	1600-1800
(b)	Gas (or Coal) / High Grade Ore —DR-EAF-CC-Rolling Mills - Flats & Non-flats	Countries in category'A' with gas (or coal). Also countries in category 'C' with gas but without iron ore can adopt this route based on import of ore/oxide pellets. Availability of power is required.	500 (150 - 1500)	3000	3 - 4	250-400

Annexure - 6 (contd.)

1	2	3	4	5	6	7
(c)	Coke----- / Ore------ --BF-BOF-CC-Semis	Ore rich countries - Category 'B' may have this type based on imported coal for long range export of semis. Good industrial base is required.	2000 (2000-10,000)	4000	5 - 6	1200
(d)	Gas (Coal)------ / High grade ore-- --DR-DR Pellets	Gas (or coal) rich countries of category 'A' or 'C' can cooperate with others for supply of DR pellets.	1000 (1000-5000)	1500	3 - 4	150
(e)	Gas (or coal)--- / High grade ore-- -DR-EAF-CC-Semis	Gas (or coal) rich countries of category 'A' or 'C' may have this type with long range export arrangement.	1000 (1000-3000)	2500	4 - 5	400
2.(a)	Charcoal-- / Ore-------- --Charcoal BF-Foundry Pig Iron	Recommended for category 'B' countries (with only iron ore) having forest resources.	10	50	2	1
(b)	Charcoal-- / Ore------- -Charcoal BF-BOP-CC--Rolling Mills - Non flat	As above	200 (150-400)	2000	2 - 3	100

(c) Non-coking Coal, Ore	--Electric Reduction--BOF-CC-Rolling Mills--Non flats/Flats	Countries with abundant electricity in category 'B' can adopt this based on imported good coal.	200 (150-400)	2000	2 - 3	100
3.(a) Scrap, Sponge iron, Cold pig	--EAF-CC-Rolling Mill - Non flats	Countries of category 'D' can adopt this based on imported scrap and DRI. Availability of power is needed.	100 (20-400)	800	2	25
(b) 1) Billet-Bar/Section Mill-Bar and Light products 2) Cold Rolled Coils-Coating line-Galvanised Sheets Tinplates 3) Hot Rolled Coil-Tube/Pipe Plant-Tubes/pipes		Countries of type 'D' with low steel consumption and without any significant raw material can adopt this.	30	200	2	5
4) Hot Rolled Coil-Cold Rolling-Cold Rolled Sheets/Strips 5) Bloom-Billet/Bar Mill/Section - Non flats 6) Slab-Hot Rolling-Cold Rolling-Coating-Flats		Alternative for category 'D' in cooperation with countries of other type.	500 (100-1000)	1200	2 - 3	75

Note: EAF = Electric Arc Furnace; CC = Continuous Casting; BF = Blast Furnace; BOF = Basic Oxygen Furnace; DR = Direct Reduction

Annexure - 7

Emerging Iron Making Processes Producing Hot Metal Using Non-coking Coal

Process	Input	A short description of the process
1. INRED (Intensive Reduction)	Ore concentrate (average grain size less than 0.25 mm), Coal and Oxygen.	The heart of the process is a steam generating system containing an integral flash smelting chamber, a submerged arc furnace and a power plant combined with an oxygen plant. Iron ore concentrate, coal and oxygen are blown as jets into the flash smelting chamber (constructed with membrane walls for steam generation) tangentially through the roof, so as to create a vortex. The pre-reduced ore concentrate is finally smelted in the electric furnace which form the lower part of the same reactor.
2. ELRED (Electric Reduction)	Ore concentrate (average grain size less than 0.1 mm and iron content above 65%), fine coal.	This process also employs a two stage reduction of iron ore concentrate with coal. In the first stage, the fine grained concentrates are pre-reduced in a fluidised bed with gas generated from coal powder and air in the same bed. In the second stage, the pre-reduced product from the first stage under-goes final smelting in the plasma below the electrode in a d.c.arc furnace. The combustible flue gases from both reduction stages are cleaned and utilised to generate electricity in a combined cycle power plant.
3. PLASMASMELT	Iron ore fines, non-coking coal, coke and heavy oil (in addition or alternate to coal)	Iron ore fines are pre-reduced in fluidised bed in two steps in series by reducing gas generated in plasma furnace. The final reduction and smelting of pre-reduced product take place in a plasma furnace.

4.	KR PROCESS (Korf Reduction)	Sized ore (6-20 mm)/pellets, Coal (upto 12 mm), Oxygen.	This process employs a reduction shaft furnace located on top of a melter gasifier. In the melter gasifier, the hot sponge iron (produced in the reduction shaft furnace) is liquified to hot metal by the excess heat generated during the partial oxidation of coal with oxygen. After preliminary cleaning and temperature adjustment, the hot reductant gas generated in the melter gasifier is sent to the reduction shaft to reduce lump ore or pellets. The top gas from the reduction furnace, along with the gas not required for direct reduction, is a valuable byproduct which can be used to generate electricity and indirectly oxygen.
5.	SUMITOMO PROCESS	Iron ore lump/sinter/pellet, Non-coking coal and coke.	The process involves pre-reduction of iron ore lump/sinter/pellet in the reduction shaft by reducing gas generated in melter-gasifier,located below it after partial cleaning and temperature adjustment. The melting and final production of iron taken place in the gasifier smelter. Heat and reducing gases are generated by combustion of coal with the help of oxygen in a fluidised bed inside the gasifier - smelter. Waste by-product gas having chemical energy is available for further use.
6.	KAWASAKI PROCESS	Iron ore fines, Low grade coke.	The fine ore particles are partially reduced in fluidised bed by hot ascending reducing gases (coming from the smelting furnace) in the pre-reduction furnace. Final reduction and smelting of the pre-reduced product take place in the smelting reduction furnace. Pre-reduced iron or fines are injected through the dual tuyeres along with hot blast of air/oxygen. Low grade coke is charged from the top which serves as heat source as well as carbon for production of reducing gases. By-product gases are available as a fuel or for production of electricity.

Annexure - 8

Market Mill Products

Summary of rolled products which can be produced from market mills:

1.	Wire rods	6 mm to 14 mm
2.	Bars	8 mm to 14 mm
3.	Merchant products	8 mm to 80 mm
	Flats	20x4 mm to 150x50 mm
	Equal & Unequal Angles	20x20 to 90x90 mm
	Channels	30 to 100 mm
	Beams	80 to 100 mm
4.	Medium Sections	20 to 180 mm
	Flats	50x5 to 300x30 mm
	Equal and unequal angles	50x50 to 200x200 mm
	Channels	30 to 300 mm
	Beams	80 to 400 mm
5.	Tubular products (including API Quality)	Both seamless and welded pipes
6.	Weld Formed profiles	Thin gauge structural, and other sections which cannot be hot rolled.
7.	Cold formed profiles	Wide range of products.

Annexure - 9

Iron and Steel Input Requirement in Agriculture and Agro-based Industries

(Cast Iron & Mild Steel)

(tonnes)

Item	Unit	Iron castings	Bars and Rods	Light structurals	Heavy structurals	Plates	CR Sheets and Strips	HR Sheets and Strips	Galvanised Sheets	Tin plates	Castings (steel)	Forgings	Wires	Pipes and Tubes
		CI	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
Buckets	Million Units	-	410.0	--	- -	- -	- -	- -	2400.0	- -	- -	- -	- -	- -
Wood Band Saw	1000 Units	--	--	--	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
Cane Crushers	Million $	2000.0	500.0	--	- -	300.0	- -	- -	- -	- -	- -	- -	- -	- -
Rice, Pulses and Flour Mill Machinary	-do-	1000.0	200.0	200.0	- -	50.0	50.0	150.0	50.0	- -	- -	- -	- -	- -
Power Driven Pumps	1000 Units	8.0	20.0	7.0	3.0	- -	10.0	- -	- -	- -	40.0	0.10	0.05	3.50
Tractors (Agricultural)	-do	604.0	200.0	--	- -	100.0	65.0	300.0	- -	- -	80.0	21.0	-	15.0
Tractor Drawn Agricultural Implements	-do-	-	10.0	10.0	-	200.0	70.0	70.0	-	-	500.0	20.0	10.0	-
Other Agricultural Implements	'000 tonnes	40.0	450.0	150.0	-	150.0	-	350.0	-	-	-	15.0	-	10.0

Annexure - 9 (contd.)

(tonnes)

Item	Unit	Iron castings CI	Bars and Rods MS1	Light structurals MS2	Heavy structurals MS3	Plates MS4	CR Sheets and Strips MS5	HR Sheets and Strips MS6	Galvanised Sheets MS7	Tin plates MS8	Castings (steel) MS9	Forgings MS10	Wires MS11	Pipes and Tubes MS12
Crawler Tractor	Unit	2.20	2.23	2.15	0.60	2.30	-	2.25	-	-	5.27	1.00	-	-
Dumper & Scraper	Unit	1.37	3.41	0.95	0.18	9.10	0.23	1.23	-	-	3.52	0.48	-	-
Deep Freezers	1000 units	-	-	-	-	-	150.0	25.0	8.0	-	-	-	-	16.50
Central Plant including Ice Plants	'000 tonnes	-	-	-	-	-	-	-	60.0	-	-	-	-	-
Sewing Machine	'000 units	20.0	1.40	-	-	0.25	1.8	0.23	-	-	-	-	0.03	-
Sewing Machine Needle	Tonnes	-	-	-	-	-	-	-	-	-	-	-	-	-
Dairy Machinary	Million $	350.0	42.5	46.5	-	450.8	-	23.5	-	-	8.8	2.4	-	21.8
Pen Stocks	1000 Tonnes	-	-	100.0	-	900.0	-	40.0	-	-	-	10.0	-	-
Conduit Pipe	Million metres	-	-	-	-	-	1300.0	-	-	-	-	-	-	-

Annexure - 9 (contd.)

(tonnes)

Item	Unit	Iron castings	Bars and Rods	Light structurals	Heavy structurals	Plates	CR Sheets and Strips	HR Sheets and Strips	Galvanised Sheets	Tin plates	Castings (steel)	Forgings	Wires	Pipes and Tubes
		CI	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
Bolt - Nut - Rivets	1000 Tonnes	-	150.0	-	-	-	-	-	-	-	-	-	-	-
Wire Netting and Wire Products	-do-	-	-	-	-	-	-	-	-	-	-	-	1110.0	-
Wire Nails	-do-	-	-	-	-	-	-	-	-	-	-	-	1050.0	-
Hurricane Lanturns	Million Units	-	-	-	-	-	50.0	-	-	500.0	-	-	28.50	-
Oil Pressure Lamps	1000 Units	-	0.20	-	-	-	0.60	0.30	-	-	-	-	0.10	-
Steel Files	Million Units	-	-	-	-	-	-	-	-	-	-	-	-	-
Tool Bits	1000 Units	-	-	-	-	-	-	-	-	-	-	-	-	-
Arc Welding Electrodes	Million Metres	-	-	-	-	-	-	-	-	-	-	-	112.0	-
Diesel Engine Stationary)	1000 Units	310.0	-	30.0	-	-	4.50	6.00	-	-	-	50.0	-	5.0
Diesel Engine Vehicular	-do	150.0	12.0	6.92	-	24.2	1.98	14.32	-	-	30.0	-	-	5.0

Annexure - 9 (contd.)

(tonnes)

Item	Unit	Iron castings	Bars and Rods	Light structurals	Heavy structurals	Plates	CR Sheets and Strips	HR Sheets and Strips	Galvanised Sheets	Tin plates	Castings (steel)	Forgings	Wires	Pipes and Tubes
		CI	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
Pipe Line Valves	1000 Tonnes	-	240.0	17.60	-	27.0	-	-	-	-	198.0	50.0	-	-
Electrical Transmission Tower	-do-	-	50.0	900.0	50.0	50.0	-	-	-	-	-	-	-	-
Motors (Fractional HP)	1000 HP	0.76	1.37	-	-	-	-	10.53	-	-	-	-	-	-
Motor (1-20 HP)	-do-	4.0	2.0	-	-	2.0	4.00	4.0	-	-	-	-	-	-
Motor Starters	1000 Units	-	-	-	-	-	1.71	-	-	-	-	-	-	-
Domestic Fans (Ceiling)	-do-	5.42	0.48	-	-	-	0.11	2.20	-	-	-	-	-	1.22
Domestic Fans (Table)	-do-	4.0	1.0	-	-	-	0.40	0.10	-	-	-	-	1.40	-
Domestic Fan (Pedestal)	-do-	12.17	0.4	-	-	-	0.05	1.21	-	-	-	-	1.40	1.32
Fans & Blowers	-do-	-	40.0	-	-	-	-	8.0	-	-	-	-	-	-
Switchgear and Control gears	Million $	-	25.0	50.0	125.0	35.0	90.9	32.6	-	-	8.5	3.5	-	13.6

Annexure - 9 (contd.)

(tonnes)

Item	Unit	Iron castings	Bars and Rods	Light structurals	Heavy structurals	Plates	CR Sheets and Strips	HR Sheets and Strips	Galvanised Sheets	Tin plates	Castings (steel)	Forgings	Wires	Pipes and Tubes
		CI	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
Bicycle (excluding parts given below)	1000 Units	-	1.96	-	-	0.23	6.0	1.0	-	-	-	1.5	-	5.0
(a) Chains	Million Units	-	-	-	-	-	-	-	-	-	-	-	-	-
(b) Chain Wheel and Cranks	1000 Units	-	1.0	-	-	-	-	1.0	-	-	-	-	-	-
(c) Rims	Million Units	-	-	-	-	-	1100.0	-	-	-	-	-	-	-
(d) Spokes	-do-	-	-	-	-	-	-	-	-	-	-	-	7.80	-
(e) Tyres	-do-	-	-	-	-	-	-	-	-	-	-	-	80.0	-
PACKAGING														
Milk and Milk Products	1000 Tonnes	-	-	-	-	-	-	-	-	80.0	-	-	-	-
Milk Powder	-do-	-	-	-	-	-	-	-	-	163.0	-	-	-	-
Baby Milk Food	-do-	-	-	-	-	-	-	-	-	200.0	-	-	-	-
Canned Fruit and Vegetables	-do-	-	-	-	-	-	-	-	-	272.0	-	-	-	-

Annexure - 9 (contd.)

(tonnes)

Item	Unit	Iron castings	Bars and Rods	Light structurals	Heavy structurals	Plates	CR Sheets and Strips	HR Sheets and Strips	Galvanised Sheets	Tin plates	Castings (steel)	Forgings	Wires	Pipes and Tubes
		GI	MS1	MS2	MS3	MS4	MS5	MS6	MS7	MS8	MS9	MS10	MS11	MS12
Canned Prawn and Fish	1000 Tonnes	-	-	-	-	-	-	-	-	234.0	-	-	-	-
Biscuits (75%)	-do-	-	-	-	-	-	-	-	-	180.0	-	-	-	-
Sugar Confectionary (75%)	-do-	-	-	-	-	-	-	-	-	280	-	-	-	-
Cocoa and Chocolate	-do-	-	-	-	-	-	-	-	-	250.0	-	-	-	-
Dextrose Powder	-do-	-	-	-	-	-	-	-	-	200.0	-	-	-	-
Processed Barley (70%)	-do-		-	-	-	-	-	-	-	250.0	-	-	-	-
Malted Milk Food (70%)	-do-	-	-	-	-	-	-	-	-	180.0	-	-	-	-
Hydrogenated Vegetable Oil	-do-	-	-	-	-	-	-	-	-	75.0	-	-	-	-

Annexure - 10

Iron and Steel Input Requirement in Agriculture and Agro-based Industries

(Alloy and Special Steels)

(tonnes)

Item	Unit	Stainless Steel	High Speed Steel	High Carbon alloy tool & die steel	Carbon Spring Steel	Si-Mn Spring Steel	Spring Steel Vanadium	Constructional Steel (Carbon)	Constructional Steel (Alloy)	Free Cutting Steel	High Carbon Steel	Electric Steel
		A 1	A 2	A 3	A4(C)	A4 (Si-Mn)	A4(V)	A5(C)	A5(A)	A 6	A 7	A 8
Wood Band Saw	1000 Units	-	0.5	0.3	-	-	-	-	-	-	-	-
Cane Crushers	Million $	-	-	-	-	-	-	500.0	-	-	-	-
Power Driven Pumps	1000 Units	1.0	0.01	-	-	-	-	0.1	0.08	2.13	-	-
Tractors (Agricultural)	-do-	-	-	-	-	4.0	-	101.0	250.0	7.0	-	-
Crawler Tractors	Unit	-	-	1.48	-	-	-	1.18	-	-	-	-
Dumper and Scrapers	Unit	-	-	0.32	-	-	-	0.32	-	-	-	-
Deep Freezers	1000 Units	1.5	-	-	-	-	-	-	-	-	-	-
Sewing Machines	-do-	-	-	0.65	-	-	-	0.03	0.16	0.25	-	-

(tonnes)

Item	Unit	Stainless Steel A 1	High Speed Steel A 2	High Carbon alloy tool & die steel A 3	Carbon Spring Steel A4 (C)	Si-Mn Spring Steel A4 (Si-Mn)	Spring Steel Vanadium A4 (V)	Constructional Steel (Carbon) A5 (C)	Constructional Steel (Alloy) A5 (A)	Free Cutting Steel A 6	High Carbon Steel A 7	Electric Steel A 8
Sewing Machine Needles	Tonnes	-	-	-	-	-	-	-	-	-	1.15	-
Dairy Machinery	Million $	50.0	-	0.20	-	-	-	3.3	3.0	5.0	-	-
Steel Files	Million Units	-	-	230.0	-	-	-	-	-	-	-	-
Tool Bits	1000 Units	-	0.15	-	-	-	-	-	-	-	-	-
Arc Welding Electrodes	Million metres	40.4	-	-	-	-	-	-	-	-	-	-
Diesel Engine Stationary	1000 Units	-	-	0.40	-	0.40	-	2.06	7.3	15.0	-	-
Diesel Engine Vehicular	-do-	-	-	-	-	-	-	12.82	5.57	-	-	-

Annexure - 10 (contd.)

(tonnes)

I t e m	Unit	Stain-less Steel	High Speed Steel	High Carbon alloy tool & die steel	Carbon Spring Steel	Si-Mn Spring Steel	Spring Steel Vanadium	Construc-tional Steel (Carbon)	Construc-tional Steel (Alloy)	Free Cutting Steel	High Carbon Steel	Electric Steel
		A 1	A 2	A 3	A4(C)	A4 (Si-Mn)	A4(V)	A5(C)	A5(A)	A 6	A 7	A 8
Valves (Pipe line)	1000 Tonnes	18.40	-	-	-	-	-	-	20.0	-	-	-
Motors (Fraction-al HP)	1000 HP	-	-	-	-	-	-	-	-	-	-	20.22
Motor (1-20 HP)	-do-	-	-	-	-	-	-	-	-	-	-	12.0
Motor Starter	1000 Units	-	-	-	-	-	-	2.0	2.0	-	-	-
Domestic Fan (Ceiling)	-do-	-	-	0.01	-	-	-	-	-	0.14	0.45	9.50
Domestic Fan (Table)	-do-	-	-	0.01	-	-	-	-	-	0.14	0.19	3.40
Domestic Fan (Pedestal)	-do-	-	-	0.01	-	-	-	-	-	0.14	0.19	3.40
Fans and Blowers	-do-	4.0	-	0.01	-	-	-	-	0.80	-	-	-

Annexure - 10 (contd.)

(tonnes)

Item	Unit	Stainless Steel A 1	High Speed Steel A 2	High Carbon alloy tool & die steel A 3	Carbon Spring Steel A4(C)	Si-Mn Spring Steel A4 (Si-Mn)	Spring Steel Vanadium A4(V)	Constructional Steel (Carbon) A5(C)	Constructional Steel (Alloy) A5(A)	Free Cutting Steel A 6	High Carbon Steel A 7	Electric Steel A 8
Switch gear and Control gear	Million $	1.40	-	1.40	-	-	-	-	-	3.6	1.8	3.6
Bicycle (excluding Chains)	1000 Units	-	0.01	0.01	-	1.0	-	-	0.01	3.02	1.20	-
Chains	Million Units	-	-	-	-	-	-	-	-	-	770.0	-

Annexure -11

Typical Models for Development of Iron and Steel Industry in the Developing Countries

Model		Proposed Facilities	Products	Usages
1	(a)	<u>Billet Rolling Mills</u> 50,000 - 100,000 tonnes/year capacity based on imported billets. Reheating with oil/natural gas Mill type - Semi continuous	Rods and Squares 12-50 mm Rebars - 12 - 50 mm Angles - 30x30 - 100x100 Channels - 50 - 100 mm of carbon steel	Building construction
	(b)	<u>Forging Plant</u> Forge Hammers - 2000 kg - 250 kg based on imported semis.	Forged agricultural implements. Shovels, crow bars, picks, beaters etc.	Agricultural hand tools
	(c)	<u>Foundry</u> Cold blast coupola. (Alternative of charcoal blast furnace if forest resource exists)	Simple gray iron castings.	Building, agricultural implements
	(d)	<u>Pipe Plant</u> ERW Pipe Plant based on imported skelp up to 8" OD. Capacity - 30,000 t/year	E R W Pipes	Water transportation for agricultural, domestic and industrial use.

Model		Proposed Facilities	Products	Usages
≠≠ 2	(a)	Mini Steel Plant		
		Mini Mill based on EAF, Scrap/DR Capacity - 200,000 - Two 30 tonnes Electric Arc Furnaces with ladle treatment facility Four strand billet caster and a combined bar and section mill	Rods and Squares - 12 - 50 Angles up to 150x100 Channels - 75 - 200 Rods in coil - 8-25 mm Rebars - 12 - 50 Plane carbon and low alloy steels.	Building and sheds Wire and wire rod based fastner industry
	(b)	Forging Plant		
		Forge Hammers - 2000 kg-250 kg. Forging Presses Hot and Cold Forging of bolts and nuts	Forged agricultural implements like phawras, shovels, crow bars, pick axle, etc. Bolts, nuts, screws	Agricultural hand implements.
	(c)	Foundry		
		Hot and Cold Blast Coupola	General Engg. Castings, maleable and S.G. iron castings	Buildings, agricultural machines, Railways.
	(d)	Pipe Plant		
		ERW Pipe Plant based on imported skelp upto 8" OD. Capacity - 30,000 - 50,000 tonnes/year	E R W Pipe	Water transportation for agricultural, domestic and industrial use.
	(e)	Hot Dip Galvanising Plant		
		Based on imported sheet 30,000 - 50,000 tonnes/year	Galvanised plane/corrugated sheets	Agriculture, industrial and domestic sheds. Agricultural plants.

Model		Proposed Facilities	Products	Usages,
≠≠ 3	(a)	Mini Steel Plant		
		Gas based DR unit or) Coal based DR in 3/4)500,000 t/yr modules)	Rods in coils - 8-25 Rebars 12 - 50 Angles up to 150x100 Channels 75 - 200 Skelp upto 300 mm width Plane carbon and low/micro alloyed steel	Buildings and sheds Wire and wire based fastner industry Pipe industry
		2 Nos. 90 tonne EAF with facilities for ladle treatment.		
		4 strand x 2 billet casters		
		Combined bar - rod and light structural mill.		
		Skelp mill based on imported skelp bar.		
	(b)	Forging Plant		
		Forge Hammers 2000 kg - 250 kg	Forged agricultural implements as in ≠≠2	Agricultural hand implements
		Forging Presses		
		Hot and Cold Forging of fastners	Nuts, bolts and screws	
	(c)	Foundry		
		Hot and Cold blast coupula	General engineering castings of cast iron and steel	Buildings, agricultural machines, Railways.
		Electric furnace 5/10 t for steel casting.		
	(d)	Pipe Plant		
		ERW Pipe plant upto 8" OD partly based on indigenous skelp for smaller sizes - 30,000 t/year	ERW and Spiral Weld pipes up to 64" OD	Water transportation for agriculture, domestic and industrial use
		SW pipes from imported HR coils - 50,000 t/year		

(e) Cold Rolled Strip Plant 4 high cold rolling of strips - 15,000 - 20,000 t/year based on imported hot band.	Cold rolled strips - soft/ tempered, up to 400 mm width.	Pipe plants, cycle and motor cycle industry.
(f) Galvanising Line Hot dip galvanising based on imported hot rolled/cold rolled sheets 30,000 - 50,000 t/year	Galvanised plane/corrugated sheets	Agriculture, industrial and domestic sheds. Agricultural plants.
(g) Electrolytic Tinning Line Based on imported black tin plates - 30,000 - 50,000 t/year	Tinplates	Packaging of agriculture and processed food products.

Annexure -12

List of Skill Needed for Operating Steel Plants

(A) Mechanical Trades

Fitting	- General, hydraulic, lubrication etc.
Rigging	- Heavy and light jobs
Welding	- Gas and electric
Turners	- Lathes - all types
Machinists	- Machine tool operation
Carpentry	
Moulding	
Forging	
Marking	
Template Making	
Metal	
Casting and moulding	- Iron, steel and non-ferrous
Fettling	
Heat treatment	
Assembly fitters	- Major equipment
Pipeline fitters	- High pressure, low pressure and gasline jobs

(B) Electrical Trades

Wireman

Electrician

Cable jointers

Sub-station attendants

Coil makers

Switch board attendants

Load despatchers

Boiler attendants

Turbine attendants

Instrument technicians

Electronics technicians

Testing and trouble shooting personnel

Annexure - 12 (contd.)

(C) Metallurgical Trades

Melters	- Different types
Process technicians	
Operators	- for various process units
Gas and Gas safety personnel	

(D) Transport & Mobile Equipment operator for dumpers, excavators, tractors, tipper trucks and other road haulage equipment

Locomotive engineers

(E) Lab. and Process Control

Process control technicians

Inspection personnel

Metallurgical, chemical and mechanical testing personnel

(F) General Categories

Safety and accident prevention

Planning and Statistics

Marketing and technical service

COMPENDIUM OF ABBREVIATIONS

ACCAR	-	Allis - Chalmers Controlled Atmospheric Reduction
Al_2O_3	-	Alumina
BF	-	Blast Furnace
BOF	-	Basic Oxygen Furnace
BOP	-	Basic Oxygen Process
bbl	-	Barrels
CC	-	Continuous Casting
CI	-	Cast Iron
Cft	-	Cubic feet
CR	-	Cold rolled
DR	-	Direct Reduction
DRI	-	Directly reduced iron
DRC	-	Direct Reduction Corporation
EAF	-	Electric Arc Furnace
ERW pipes	-	Electric resistance welded pipes
Fe	-	Iron
FIOR	-	Fluidised Iron Ore Reduction
GI	-	Galvanised Iron
GJ	-	Gega Joules (10^9 Joules)
GNP	-	Gross National Products
GDP	-	Gross Domestic Products
HP	-	High pressure
HR	-	Hot rolled
HYL	-	Hojalata-Y-Lamina

Kg	-	Kilo-grams
Kg/m	-	Kilogram per metre
KVA	-	Kilo-Volt ampere
KWH	-	Kilo-Wall-hour
lb/yd	-	Pounds per yard
LW pipes	-	Longitudinally welded pipes
MT	-	Million tonnes
Mbbl	-	Million barrels
NSC	-	Nippon Steel Corporation
NKK	-	Nippon Kokkan
OD	-	Outer diameter
P	-	Phosphorous
S	-	Sulphur
SiO_2	-	Silica
SL/RN	-	Stelco-Lurgi/Republic Steel-National Lead Corporation
SW pipes	-	Spirally welded pipes
Tonnes	-	Metric tons (1000 kg)
TDR	-	TISCO-Direct-Reduction
TiO_2	-	Titanium dioxide
t	-	Tonnes
tpa	-	tonnes per annum
UHP	-	Ultra high power
