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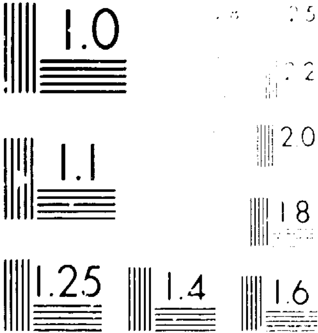
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org



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MINI-STEEL INDUSTRY*

by

Shree N. Acharya**

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I. INTRODUCTION:-

1.0 During the last three decades or so, a revolutionary change has taken place in the mode of steelmaking - a change brought about by technological and economic developments. This change involves development of an alternative route for steelmaking - alternative to the conventional route characterized by the smelting of iron ore and coal in the blast furnace with subsequent steel melting in an acid Bessemer or in Basic Thomas convertor or in the OH or BOF furnace.

1.1 This alternative is the widespread introduction of the so-called "mini-steel mill" concept, involving use of electric arc furnaces. The concept is not something new and in fact has been known for a long time and has been in use in various countries, for production of steel of different qualities.

1.2 In its essentials it has involved using electrical energy for melting scrap in furnaces and converting it into steel. Changes in technology have opened up exciting vistas making it economically feasible to produce different types of steel and converting it into long and flat products. Development of direct reduction processes has ensured production of sponge iron for supplementing scrap in the furnaces. New type of UHP electric arc furnace coupled with ladle refining technologies and continuous casting have made it possible to not only melt the raw materials but also remove the impurities to a considerable extent, thereby improving the quality of final product.

II. DEFINITION OF 'MINI-STEEL' PLANT:-

2.0 A mini-steel plant defies any precise definition;

It may be just a simple reroller using purchased billets and rolling it into different products;

Or it may be a simple small-sized electric arc furnace (5-10 tons capacity) using scrap and producing pencil-sized ingots; - with the scrap supply being sometimes supplemented by sponge iron produced in a direct reduction unit;

Or the electric arc furnace could also be sophisticated high capacity one with downstream facilities like continuous casting machine, rolling mills, etc.

2.1 Mini-steel plants in the developed countries, generally, are having capacities of 100,000 tons per annum and above. For developing countries, sizes are much smaller (for example, India has electric arc furnaces as mini-steel plants with capacities of only 10000 tons to 20000 tons per annum).

2.2 There are different views on defining a mini-steel plant. Some consider that very small plants - rerollers alone or even with a small electric arc furnace - could be categorized as a mini steel plant. Again others consider that such a plant has to be necessarily an integrated one - with a direct reduction plant, electric arc furnace, continuous caster and rolling mills.

And yet again, some others consider that each of these units could be treated as part of mini-steel plant provided they are all different stages in the establishment of a completely integrated unit.

2.3 Size of the plant may not always be very material, as it would depend entirely on the economics of each case which, in turn, is affected by the market situation, raw material availability, cost of input like coal, gas, iron ore, power, etc.

As essential factor would be the managerial set up for the plant. The hierarchy should not have too many tie rs and should not become so complicated as to render the management too impersonal and consequently ineffective.

2.4 One view is to consider a unit to fall in the category of mini-steel plant if the following important conditions are satisfied:

(i) Technology:- A modular and if necessary step-wise construction involving a DR plant, electric arc furnace shop, continuous caster and rolling mill.

(ii) Capacity:- Normally between 100000 and 1 million tons per year.

(iii) Product-mix:- Normally produces only two or three product groups - principally rebar and light/medium structurals. A recent addition to this mix is flat products.

(iv) Management philosophy:- To be run as a profit centre characterized by simple organizational structure allowing short cuts from decision-making to realisation. Nearly all successful mini-steel plants have small compact organizations with three or less than three decision-making levels.

In other words, the special features of the mini-steel plant are its high productivity per capita, narrow product-mix and small compact sizes ensuring flexibility and quick decision-making.

2.5 Mini steelworks - Definition:-

(i) Production capacity - From 100,000 tons per year to 1 million tons per year

(ii) Technology (process route):

(a) DR-plant - EAF meltshop - Continuous casting - Rolling mill.

(b) EAF meltshop - Continuous casting - Rolling mill.

(iii) Products:

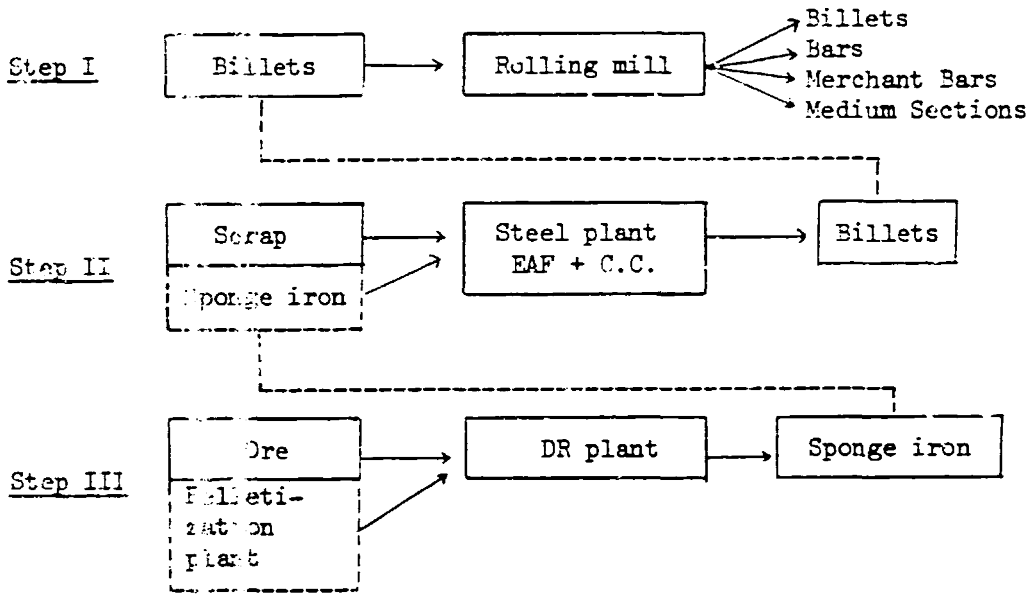
(a) Product groups - Maximum 3

(b) Quality and sizes - Selected ranges

(iv) Company philosophy:
- Small hierarchy
- Fast decision-making
- Profit centre

(Courtsey - KORF Zentrale Technik)

2.6 The overall layout of a modern mini-steel plant could be as follows:-



III. WHY MINI-STEEL PLANTS ?

3.0 Development of mini-steel industry has been particularly rapid in the last 10 years, and this route of steelmaking has taken an increasingly larger share of the market from the conventional techniques involving BF and LD process. In 1980, electric steel production already accounted for over 20% of world crude steel production or almost 150 million tons. Expectations are that by 1990 this volume may double to almost 300 million tons i e., about 30% of total world steel capacity.

3.1 An analysis of the development reveals the following:-

- The total capital investment on a mini-steel plant is much lower than on a conventional route plant. For the latter, it may range from $1500 to $3000 per ton of annual capacity, while the comparable figures for a mini-steel unit could be only 40% for a plant using scrap and 60% for one using D.R.I. In the present world of capital scarcity, this becomes a very vital factor in decision-making;

- Shorter construction period - For mini-steel plant it may be only two years or so as compared to 4 years to 12 years for a conventional plant. The advantage is obvious where the plant starts yielding returns on investment from a very early stage;

- Lower requirements of trained manpower and high managerial expertise - For countries where there is scarcity of such personnel, preference for mini-steel route is obvious. Even highly industrialized countries like the USA have found this advantageous;

- Lower specific labour costs due to the concise product range and simple process route - This enables the mini-steel plant to match the economy of scale advantage of large conventional plants;

- Size capability can be matched with the exact market requirements and, when necessary, modular expansion can be resorted to for meeting the increase in demand;

- Enables production of finished products at close proximity to the market;
- Possesses adequate flexibility in meeting market demand;
- The technological developments have made it possible now to achieve high output, with reduced energy costs, thereby enabling it to compete favourably with other steel melting processes;
- Enables regional dispersal thus encouraging investments that help to remove disparities between different areas of a country;
- Easy in operations because they do not require expensive infrastructure as in case of an integrated conventional plant; e.g., sintering facility, coking coal plant and extensive transportation equipment;
- Per capita output of a modern mini-steel plant can sometimes be two to three times higher than that of conventional plant;
- Can be built on a modular pattern (particularly in the case of D.R. plants), ranging from an annual capacity of 40,000 to 400,000 tons per annum. Thus the plant can adapt its growth to the market situation without being forced to sell large quantities of its products suddenly;
- The concept of 'big is economical', which is applicable to conventional integrated plants is not free from disadvantages, particularly for the developing countries. The economy of scale advantage of such plants can easily get nullified by unexpected problems in the working of the plant or in the marketing of the products. With mini-steel technology proving that small can also be economical, its appeal to the developing countries is obvious.

IV. TRENDS IN WORLD STEEL PRODUCTION:-

4.0 Impact of these developments in steelmaking processes has been getting duly reflected in the trends in world steel production with the mini-steel production gradually increasing its share in the total. Growth rate of world crude steel production for the period 1969 to 1979 was about 1.8%, while the corresponding rate for mini-steel was as much as 5.3%. This increase has taken place in both the developed and developing countries.

In the USA, during the last six years about 15 million tons of crude steel capacity via mini-steel route was added or are in final construction stages. By 1990, another 28 million tons may get installed.

In Italy (particularly the well-known Brescia in the north) about 120 mini-steel plants are operating and they account for more than half of the country's total crude steel production.

Among the developing countries, India already has about 2.5 million tons of installed capacity in mini-steel plants. Other countries like Venezuela, Mexico, Trinidad, Argentina, Nigeria, Qatar, etc. are all going in for DR based mini-steel pants. By 1990, Mexico may be adding another 10 million tons to its existing mini-steel capacity, followed by Venezuela with 6 million tons and Brazil with 4 million tons.

4.1 The following figures present an interesting picture of production in 1980 by major steel processes in different parts of the world.

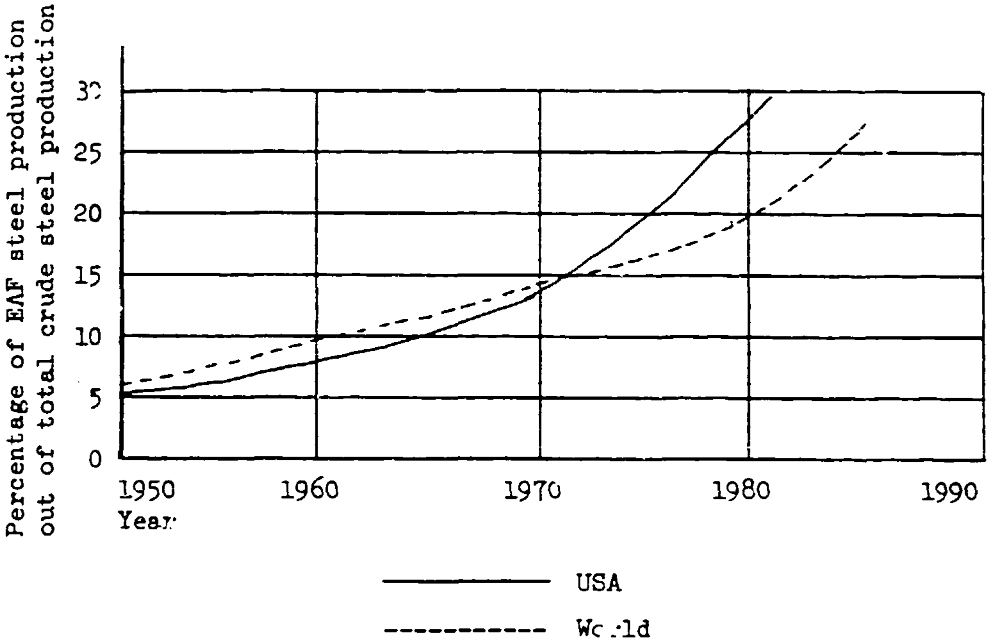
(in percentage)

	Basic oxygen/open hearth	Mini-steel
USA	73%	27%
Japan	77%	23%
S. Korea	71%	29%
Italy	45%	55%
Spain	54%	46%
U.K.	68%	32%
Total EEC	74%	26%

(Source: British Steelmakers, July 1981)

Fig. 1

4.2 One of the studies has shown that production from mini-steel industry will continue to rise and may reach about 30% of total world crude steel production by 1990 (figure below):



(Source: Metallurgical Plant and Technology 4/1981)

Fig. 2

4.3 A recent market demand analysis made by one of the major D.R. Technology Suppliers has brought out following picture of steel production by process:

(Million tons per year)

Process	1980	%	1985	%	1990	%	Growth rate
EAF	155	22	209	25	288	31	6.4%
BOF	373	52	442	54	515	55	3.3%
OH	189	26	172	21	130	14	(3.8)%
Total	717	100	823	100	933	100	2.7%

The share of developing countries in this increase in production by EAF process is expected to be more than 50 million tons.

V. IMPACT OF RESTRUCTURING OF STEEL INDUSTRY IN INDUSTRIALIZED COUNTRIES:-

5.0 The canvas of steel industry in the west presents a rather mixed picture - both in terms of supply and demand. Notionally large capacities exist, but in reality, the operating capacities are lower; number of plants, particularly in the U.K., have become inefficient and uneconomic; enormous subsidies are being given by the Governments to bail out the industry; save working jobs; and modernise the plants. In this process capacities may even be getting reduced, with the producers concentrating on production of high quality steel. Trend appears to be that ordinary steel will continue to be produced, but it may be mostly for meeting internal demand.

5.1 The message of this development in the west, from the point of view of developing countries, is clear. They can now, helped by their cheap labour, and taking advantage of the technological advances in mini-steel processes, enter into the field of production of steel, particularly ordinary steel for which mini-steel plant is well suited, without seriously endangering or damaging the interest of the industrialized countries.

5.2 Establishment of mini-steel plants in the developing countries should also be welcomed by the equipment manufacturers and technology owners of the west, who would have a rapidly expanding market in the developing countries for their goods and services.

5.3 There is thus a certain 'mutuality of interest' inherent in this development which could benefit to both the developing and developed countries.

VI. RAW MATERIALS AND ENERGY:-

6.0 The two essential inputs for mini-steel plants are cheap and adequate availability of (i) electric power and (ii) scrap. The charges for these plus natural gas/coal and electrode may account for about 25% of the final billet cost estimate. As compared to this, in the BF-BOF process, coke plus oxygen and electricity represents approximately 35% of the final billet cost.

6.1 (i) Electric power:- Bulk of this requirement is for melting of scrap/sponge in the electric arc furnace. For melting one ton of scrap power needed is about 560 KWH. For a 500,000 tons per annum capacity steel plant using EAF, the captive power requirement may be of the order of 40 MW. This would cover the following:

- Energy required to melt steel (0.15%C) and slag and heat to 1600°C.
- Heat lost in gas evolution
- Heat gained due to oxidation of electrodes
- Heat gained in slag constituent formation
- Compensation for furnace losses.

Finishing facilities, depending upon their sizes and complexity would require additional amount of electric power.

Total requirement of electric power for a 500,000 tons plant may range between 700 KWH to 750 KWH for which the generating capacity could amount to about 120 MW.

Besides consuming large amount of electrical energy, the electric arc furnace also tends to introduce fluctuations in the power system - a problem that necessitates use of a bank of reactive capacitors to cope with the high surges during melting.

The other important consideration is the cost of supply of this power to the mini-steel plant, for this would have a marked bearing on the economics of the unit.

The developing countries in particular, which are interested in adopting the mini-steel route for steelmaking will have to analyse the above two factors carefully before taking an investment decision.

6.2 (ii) Scrap/sponge iron:- The metallics used in steelmaking can be classified under three general headings: pig iron, scrap and DRI (directly reduced iron). The outlook for these three is given below (in millions of tons):

	Capacity in 1980	%	Capacity in 1990	%
Pig iron	529	60	737	59
Scrap	331	37	457	37
DRI	25	3	48	4

(Source: SEAISI Quarterly, July 1980)

Fig. 3

With the open hearth furnaces slowly getting phased out, there would be corresponding increase in scrap availability. But at the same time technological developments in BOF are encouraging use of more industrial scrap as cooling medium. Also with greater use of continuous casting facility, there is likely to be a fall in the availability of revert scrap. Increased efficiency in fabrication methods will further lead to a reduction in the rate of generation of industrial scrap.

6.3 Taking all these into consideration, the overall net increase in demand of scrap by 1990 may be about 126 million tons. To what extent it would be possible for this demand to be met would depend upon the ability of the scrap collection industry (which is an un-regulated one) to tackle the problem. It is not easy to make any clear forecast if adequate quantity of good scrap would continue to be available for meeting the increasing demand. Neither can one say with exactitude the price at which scrap would be obtainable - a factor which has a direct impact on the cost of steel produced in the furnace.

6.4 Industrialized countries like Italy, Japan, etc. have to resort to import of large quantities of scrap. Several developing countries which have set up steel industry, and others which are in the process of doing so, are depending on import of scrap from surplus areas, e.g. USA and Europe for use in their steel plants.

6.5 As in the case of electric power, for scrap also, the cost factor assumes great importance particularly when it has to be imported from distant outside regions for feeding the electric arc furnaces. Thus, evenif sufficient supplies of scrap are assured, it needs to be of requisite quality - without too much impurity - and its price should be such as to enable the final product to compete in the market.

6.6 (iii) Direct reduction:- Fortunately the technological developments have now made it possible to produce directly reduced iron - or sponge iron - which becomes an excellent material to supplement the scrap supply. An analysis made by IISS (August-September 1979) has revealed that by 1990, there might be only a very small scrap surplus, and with some countries like the USA considering scrap export control, electric steelmakers may find sponge iron or DRI a cheaper and welcome source of iron units. (Ironmaking and Steelmaking 1979, No.6).

6.7 Production capacity of directly reduced iron in 1980 was about 25 million tons, constituting about 3 per cent of total metallic supply. Forecast for future envisages a total production capacity of about 48 million tons by 1990. This would then form about 4 per cent of total metallic supply.

6.8 Advantages of using DRI or sponge iron:

Use of this material offers the steelmakers several potential advantages:

(1) As a metallic source, it has uniform chemical properties and is void of metallic impurities. This enables the steelmaker -

- to predict his end point analysis better;
- helps in improving the quality of steel enabling meeting the stringent quality requirements of the market.

(2) Uniform sizing of sponge iron lends itself to conveyor transport and continuous charging which can help to increase the production by 10% to 20% relative to scrap use.

(3) Raw material cost represents nearly 60% to 70% of total cost. Use of sponge iron, therefore, allows better cost control because of the price of iron ore being more predictable than that of scrap.

(4) Present economic situation makes a decision to instal ironmaking or teelmaking capacity in increments of 2-3 millions of tons as in conventional route, hard to justify. Markets do not grow in such large steps and, therefore, new capacities will be only partially utilized during the first several years of its life. On the other hand, a DR-EAF unit can be built, economically and technically, in modules of 400,000 tons or less, with considerably lower capital investment, thereby reducing capital risks.

(5) Sponge iron is a better material in comparison to scrap for handling and control with possibilities of long-term reliable supply contracts.

(6) Though use of sponge iron increases power requirements in the furnace, the technology of continuous changing of this material in the furnace enables a higher yield of 10% to 14% in useful power input to the furnace. Other benefits are in the shape of less power off time, lower heat loss, improved bath heat transfer, faster metallurgical reaction, reduction in acoustical noise during meltdown and permits combining melting and refining. All these help to increase further the productivity and reduce both electrode and power consumption relative to batch charge level.

6.9 (iv) <u>Direct reduction technologies:-</u> DRI is a highly beneficiated iron ore that can be regarded as a prereduced material ready for further processing to iron or steel. The oxygen in the ore is removed without a melting step with the transformation being affected as a result of a reaction when the oxygen is made to combine with a gas (hydrogen or carbon monoxide) or with solid carbon. The process is termed as gaseous D.R. a solid D.R. depending upon the state of the reductant.

6.10 The level of prereduction is measured by the ratio of the product's content of the metallic iron to its total iron content - the ratio expressed as a percentage and called the degree of metallization.

6.11 Temperature of about 1100°C used in DR processes excludes the possibility of liquid phase occuring during reduction. Consequently the sponge iron from the DR units still has the outer form of the lump ores or pellets and contains the gangue components also in the same form mainly as SiO_2, Al_2O_3, Mgo., a small amount of CaO etc.

6.12 Numerous processes are now available for the direct reduction of ore, using gas or solid reductant like non-coking coal, with the reaction being carried out in shaft furnace, or a rotary kiln or a fluidized bed furnace, etc.

The best known gaseous reduction processes are MIDREX and HYL. They employ a gaseous reductant produced from reformed natural gas that flows counter currently through iron ore in a cylindrical retort or shaft furnace.

Other gaseous processes employing fluidized bed techniques are FIOR, HIB (high iron briquettes), etc.

6.13 An interesting development in the D.R. field is the successful use of solid reductant like non-coking coal. The SL/RN process has been adopted for use in a semi-commercial-cum-demonstration plant in India (Kothagudam). The performance of the plant and process has shown excellent results. It has now become possible for the developing countries, which are not fortunate enough to possess natural gas but have non-coking coal, to adopt solid reductant D.R. technology for producing sponge iron.

Kinglor Metor (KM) process, like the SL/RN process also make use of solid reductant, except that the kiln used is not a rot one but is a vertical shaft kiln. It claims that economic pro[illegible] is possible in modular units of small capacity of about 20,000 tons - 40,000 tons per year.

6.14 Enormous quantities of gas available in the middle East is being just flared. Assessment is that this gas, if utilized, could help to produce at least 250 - 300 million tons of DRI. Some of the developing countries have large deposits of non-coking coal which could be used now for producing DRI based on solid reductant process.

6.15 In the ultimate analysis, of course, any successful increase in production of DRI will be closely dependent upon the reasonableness of cost and availability of scrap.

VII. RESEARCH AND TECHNOLOGY:-

7.0 The technological development in the mini-steel sector in the past decade have been remarkable and have opened out new vistas for adoption of this route by small countries.

7.1 (a) Direct reduction:- The developments outlined in earlier paragraphs have made it possible for developing countries to produce sponge iron of desired quality for use in electric arc furnaces.

Several new processes are at different stages of development:

- PLASMARED process using a plasma arc heater for heating the recirculating gas claims that it is adaptable to almost all gaseous reduction processes and can produce sponge iron with lowest fuel consumption - can use LPG, Heavy fuel oil and coal powder as fuel;
- HYL III - a continuous process for sponge making;
- LS-RIOR process (Lummus-Sumitomo Resid Iron Reduction) - using iron ore fines, low grade (high sulphur) petroleum resid as binder, low grade (high sulphur) petroleum coke as reductant and dolomite - claims metallization about 95% and sulphur content below 0.03%.
- MIDREX EDR process (Electro-thermal Direct Reduction) - claims high energy efficiency allowing production of high quality top gas that can be recycled into the process or exported as fuel gas - energy consumption varies from 2.00 G cal/t to 2.43 G cal/t.
- Direct rolling of sponge iron pellets - may enable manufacture of steel strips and reinforcing bars directly from sponge iron without melting and refining in EAF - work being done at University of Wales and University College of Swansea and in South America (Source:- I and S International, December 1979).
- Other processes that are worth mentioning are Krupps CoDIR, Kawasaki, SPM, SDR, Allis Chalmers, Armco, Höganäs, etc.

7.2 (b) Electric arc furnaces:- These furnaces in the sixties mainly comprised a heavy plate shell with refractory lining, where larger refractory formed parts like dolomite blocks were installed on the walls to shorten the relining procedure. Today furnace shells are of split design and are equipped, wherever possible, with external water-cooled wall panels. This increases the useful furnace volume and allows feeding of material of specified top weight of two bucket loads even when processing light weight scraps.

Improvements in metallurgy regarding slag control were achieved so that the remaining refratctory wall section of scrap melting furnaces needs to be relined only after approximately every 400 heats.

7.3 Other improvements in the electrical design, using water-cooled wall and roof panels, use of better quality electrodes, oxy-fuel burners, agitation of the melt, ladle metallurgy etc. have helped to increase the productivity of the furnace. Tap to tap time has been reduced to less than $1\frac{1}{2}$ hours. During most of the meltdown period, the furnace can be operated with full active power and a power factor > 0.8.

Since consumption of melting current and graphite electrodes constitute over 40% of the processing cost of electric steelmaking, technological developments have concentrated successfully in lowering these costs.

7.4 An interesting development in the field of furnaces is that of the Electro Slag heating process (ESW). Currently scrap or high grade sponge iron, that is a highly metallized material with low gangue faction is being used in electric steelmaking. In view of the higher costs and poorer availability of rich raw materials, future developments have to be towards enabling use of materials with high gangue factions. This process claims that a melting unit can be used with a slag bath higher than normal and a continuous removal of slag can be achieved permitting a higher CO throughput. Such a melting unit has

- a standing rather than a tilting furnace;
- has fully continuous charging;
- has continuous slag removal:
- tapping based on demand;
- coupling with a waste heat boiler helps to recover waste gas heat from the furnace waste gas.

Continuous charging of the furnace is bringing benefits like less power off time, lower heat loss, higher power input, lower electrical losses, improved bath heat transfer and faster metallurgical reactions.

Secondary refining techniques are enabling production of steel of higher qualities.

7.5 (c) Rolling mills:- These constitute the largest element of capital investment in a mini-steel plant. Being the key to the profitability of the plant, they have to be tailored to the plant's needs must be flexible and have a high utilization factor.

Together with its electrical and ancillary equipment, a 150,000 tons per annum rolling mill could account for over 50% of the total capital investment in a mini-steel works. A typical breakdown of this cost could be:

Melting	12%
Casting	14%
Rolling	52%
Building	12%
Services	10%

Even in the case of a mill that produces rebars, the cost may amount to 50% of the total.

7.6 Modern bar and rod mills are highly sophisticated with finishing stands - sometimes intermediate stands - with alternate access angled at 90° so as to avoid twisting of the pieces between the stands, thus improving surface quality. They have controlled cooling equipment at the run out to improve metallurgical properties and advanced control systems giving much greater dimensional accuracy as compared to the smaller and older mills.

Mills with capacity of about 10,000 tons per annum, or more, have separate roughing group with mill sizes ranging from 250 mm to 450 mm and finishing group with a number of stands (150/250 mm) arranged in a single line driven by either one or two motors.

Smaller mills have 5 to 7 150/250 mm stands driven by one motor and work as roughing as well finishing mill.

7.7 Major improvements have been in rolling speed, temperature and guage control, reliability, coil weight, etc. contributing to better production quality and higher productivity. The ingenuity of mill builders has been devoted towards finding ways of improving plant availability, yields, output rates, physical and metallurgical properties, dimensional accuracy and surface quality, while at the same time trying to reduce operating and maintenance costs.

7.8 Some other technological developments are listed below:

- Development of a rolling mill which would be able to slit economically the continuously cast slabs; and which can take slit slabs or large continuous cast blooms and roll them into wide range of intermediate sizes;

- Development of single strand ultra high speed rod mills, employing cantilever type pre-finishing stands ahead of the no-tiwst blocks in place of conventional intermediate stands, with an operating efficiency of 80-85% of the theoretical maximum figure. Such rod mills with a capacity of 500,000 tons per year would be ideally suited for mini steel industry;

- Development of high-reduction mills, employing zoom-rolling;

- Using improved automation techniques coupled with mechanized design improvements which would enable old mills to gain, at a much lower capital cost, most of the advantages claimed for jumbo mills;

- Development of smaller capacity (500.000 tons per year) strip mill (e.g. GSK mill), medium section mills and large rebar mills that would be economically viable and would therefore be ideally suited for mini-steel industry.

7.9 For a relatively low initial stage of output, it may be economic to instal a slow speed continuous cold-strip mill as a first step and then double the power and speed at the second stage. Thus a situation could arise when even small developing countries with a relatively low initial demand for CR strip may be able to invest in continuous rolling equipment.

VIII. ECONOMICS OF MINI-STEEL PLANTS:-

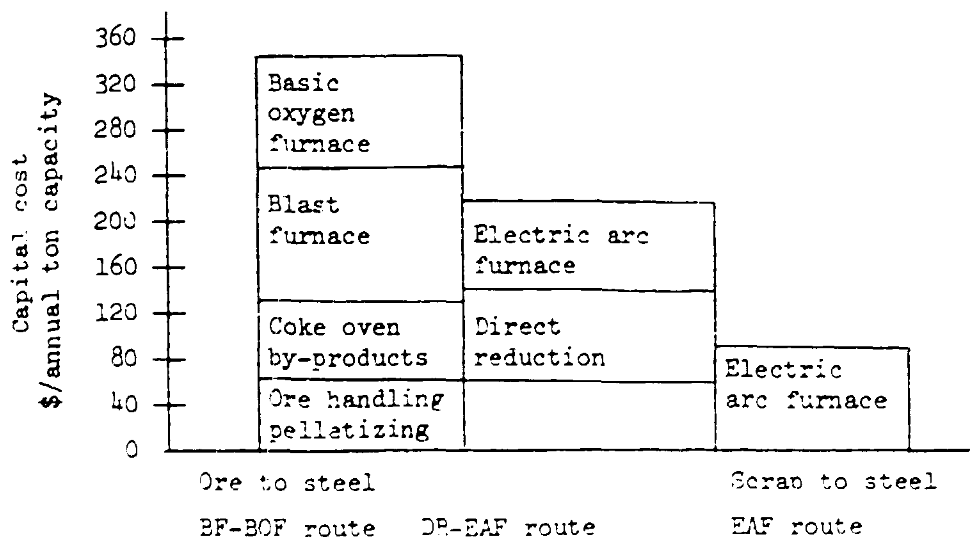
8.0 The mini-steel plants have some distinct advantages over the conventional integrated steelworks, e.g.,

- Lower investment costs; and
- Easier operations as a result of fewer, simpler production units.

8.1 The investment cost will, of course, vary from project to project and it would not, therefore, be easy to indicate any specific figures for it. Generally, however, one could say that the costs in the case of an integrated mini-steel plant having an electric arc furnace using scrap on a combination of scrap and sponge iron with continuous casting and a bar mill could be as low as \$350 to \$450 per ton of annual capacity. In specific cases it can be even lower. ((For example, SIDBEC of Canada - capacity 1.5 million tons per annum - investment cost per ton US\$252.3 for semi finished products as compared to US\$454.4 for a comparable coke oven, BF, BOF and CC works*/. In other cases, costs could be much higher.

As a general observation one could perhaps say that the investment cost per ton of installed capacity of a mini-steel plant is about 40% of BF/BOF cost when only scrap is charged - and 60% if a direct reduction unit is included.

8.2 One analysis of capital cost comparison of different routes to produce steel showed the picture to be as below:



(Source: Ironmaking and Steelmaking 1979 No.1) Fig. 4

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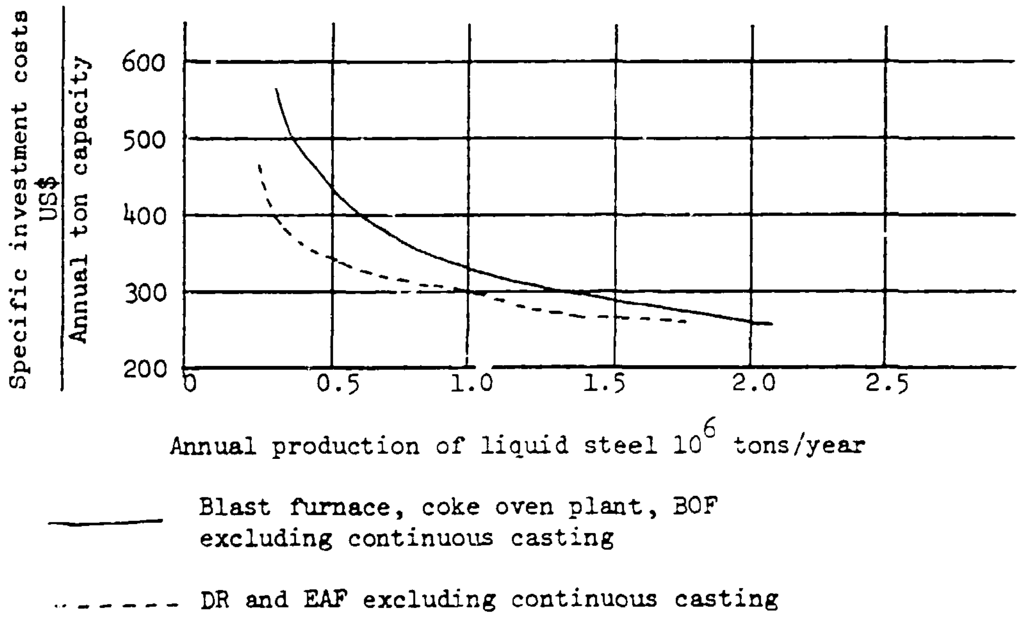
*/ Source: I and S International, February 1981

The above has been determined on the estimated capital costs for a plant of 2 million tons per year capacity, based on battery limits only. The difference reflects the cost of the coke oven and the fact that a DR plant costs about 80% of that of a blast furnace.

8.3 A note of caution could be added here. The capital cost associated with the DR process can vary widely, depending upon the process and the installation size. Presently this figure varies from $85 to $125 per annual tonne of sponge capacity.

8.4 Following figure gives the specific investment costs for both routes of steel production. These data only consider installations upstream of the tapping of liquid metal from the steelmaking facilities. It is obvious that for smaller metallurgical plants, i.e. plants with capacities less than 1.5 million tons per year, the investment costs are more favourable for the mini-steel route comprising DR and EAF. The difference to a large extent, is because of installation of a coking plant in the case of BF route, if coal from domestic sources is to be used.



(Source: MPT 4/1978) Fig. 5

8.5 Analysis of other financial and economic factors like capital output ratio, distribution costs, inventory costs, entrepreneur cost construction time and costs, etc. also suggest that the overall advantage lies with the mini-steel plant.

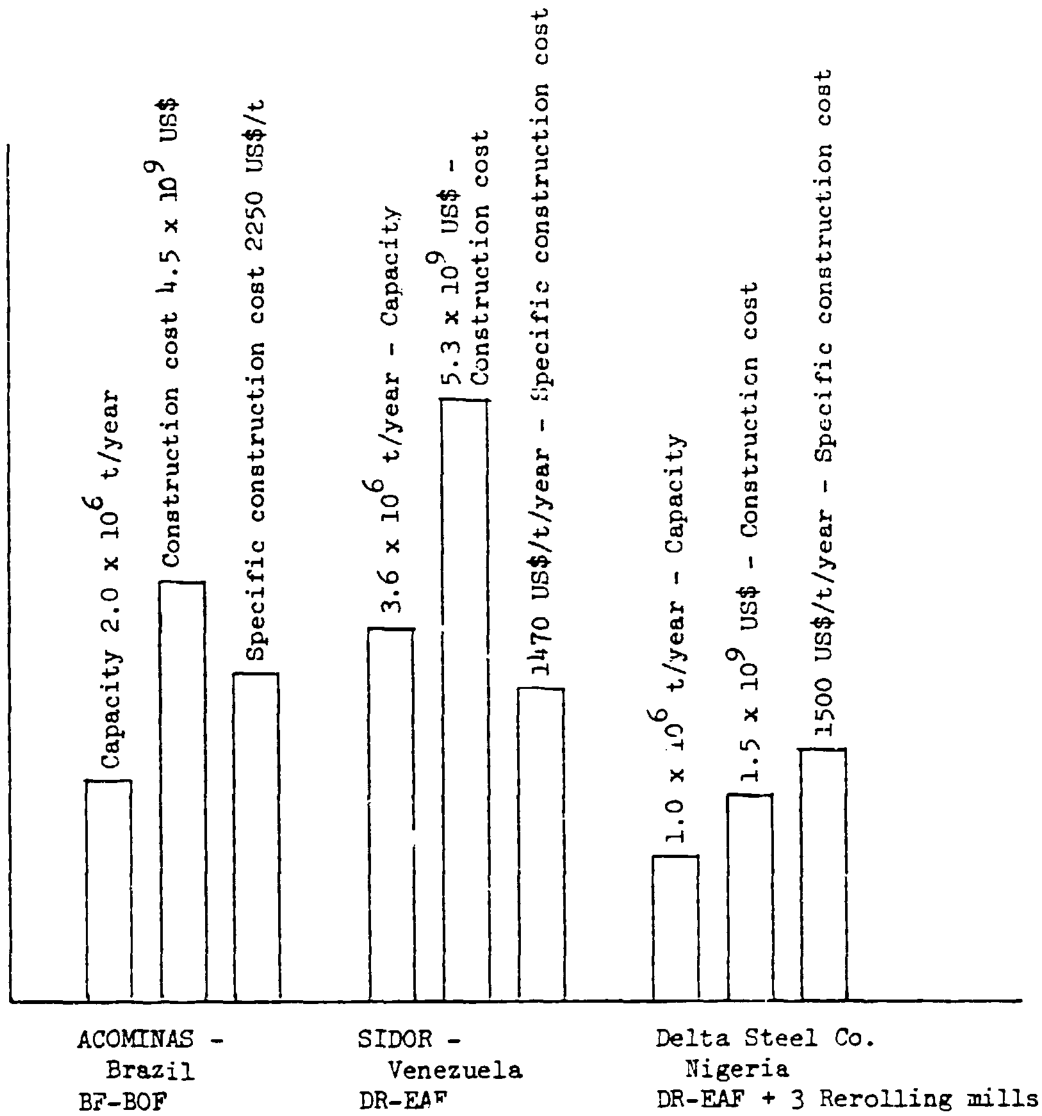
8.6 An interesting example is that of the steel plant set up at Matanzas in Venezuela. Extensive analysis carried out before investment decision had shown that given the available conditions a DR/EAF combination was more advantageous in comparison to a conventional BF/BOF plant. This was also supported by the study carried out in 1975 by a World Bank group of experts which had shown that the

- quality of steel produced by two routes would be about the same;
- estimated capital costs of facilities for pelletizing, ironmaking, steelmaking and continuous slab casting of 3-4 million tons per year favoured a DR/EAF plant by nearly 40% over a comparable BF/BOF installation;
- production costs, excluding fixed charges and taxes, for a tonne of carbon steel slabs are approximately 20% lower when produced by a DR/EAF operation than when made by BF/BOF route;
- average return on investment was from 2.5 to 3 times as great for the DR/EAF facility as for the BF/BOF plant*/.

8.7 Another interesting example is the comparative study of the absolute and the specific direct construction costs for the

- ACOMINAS Steelworks in Brazil (conventional BF/BOF route);
- Plan IV of SIDOR in Venezuela (DR/EAF route); and
- Warri Steelworks in Nigeria (DR/EAF route)

*/ (Source: Iron and Steelmaking 1977, No.5)



(Source: MPT 4/1981) Fig. 6

8.8 There are several studies available which tend to establish that the mini-steel plant would be preferrable to the conventional plant particularly from the point of view of smaller capital investment, better manageability and easier marketing of the product. Of course, for any specific case, the validity of comparison will depend on important factors like the values assumed for the inputs, product configuration, etc.

8.9 The estimated prices and specific inputs are judgement values which will apply differently to different plants at different locations; and they will be strongly responsive to changes in the availability and price level of the main raw materials that are consumed.

8.10 Comparison of certain characteristic data for mini-steel plant and a conventional BF-BOF plant brings out the picture to be as below:

	Mini-steel	BF/BOF plant
Specific investment cost (US$/ton)	700 - 900 with DR 500 - 700 without DR	1500 - 1800
Realization time (years)	2 - 4	6.5 - 8
Productivity (t/year/man)	500 - 1500	300 - 1000
Typical length of material flow (metres)	1500	6000
Primary energy consumption (GJ/t)	20 (EAF with 50% sponge)	25 (Waste heat utilization is presently much better in this process)

IX. CONSTRAINTS TO STEEL DEVELOPMENT IN DEVELOPING COUNTRIES:-

9.0 Two major problems that the developing countries face are:

(a) Cost and financing; and

(b) Labour and development of human resources.

9.1 (a) Cost and financing:- Forecasts of future steel development suggests an increase in world electric steel capacity by 150 million tons by 1990. UNIDO's normative scenario indicates an increase by 117.5 million tons in steel production capacity in the developing countries. Presuming that at least 50 million tons of this gets established via mini-steel route and taking the specific investment cost at $500 per ton of annual capacity, the finance needed would amount to nearly $25 billion.

9.2 (i) Cost:- Total investment cost on the project would get particularly influenced by the following factors:-

- Sophistication of technology to be used;
- Quality of steel required to be produced and product mix;
- Cost of imported plant and equipment;
- Lack of adequate infrastructure - to fill this lacunae, more investment would be needed;
- Non-availability of indigenous trained and skilled labour necessitating importing them from other countries and paying high wages and other expenses.

All these factors tend to increase the cost of total investment in an underdeveloped country by 25% to 30% more than in an industrialized one.

9.3 A developing country embarking on steel production via mini-steel route could consider a step-wise installation of the facilities -- a move that would be in harmony with availability of trained manpower, market demand, national priority and, of course, finance.

- A rolling mill could be set up with investment ranging from $30 million to $50 million;
- The mill could later be integrated upstream with steelworks comprising EAF with continuous casting. Investment for one 50 ton furnace with one 3-strand continuous caster may be around $30 million to $40 million producing about 150,000 tons per year;

- For supplementing supply of scrap, a direct reduction unit could be set up involving an investment of around $25 million.

9.4 Above figures are only indicative and would vary widely depending on the choice of equipment and technology.

Since the general profitability of the plant would be affected not only by the investment cost but also the operating cost, the developing country will have to make a very careful assessment of both these costs.

9.5 (ii) Financing:- Basically, financing comes from following sources:-

1. Internal generation of funds by the company setting up the plant;
2. Sale of equity shares;
3. Borrowings through sale of Bonds or through long-term loans;
4. Government aid.

Closely linked to these is the overall position of the country in terms of its gross domestic savings, total indebtedness, credit worthiness and trade balance.

9.6 For the oil rich countries, financing the steel plant may not pose a serious constraint. But other countries, particularly the small and least developed countries, may find financing a serious hurdle to corss. They will have to lean heavily on outside sources for assistance in the shape of governmental aid and concessional financing by international financing agencies.

9.7 An interesting example is that of India which has recently decided to establish a 3 million tons per annum conventional integrated steel plant, finance for which would be raised entirely from outside sources - external aid, commercial credit and Euro market loans.

9.8 (b) Labour and development of human resources:- Lack of adequate skilled labour is the other major constraint that confronts the developing countries. Because of increasing use of sophisticated technology, the manpower requirements to operate modern steel plant includes now a high proportion of skilled labour. Here again the advantage of adopting mini-steel route is obvious. Manpower needs would be only in hundreds and not in thousands as in the case of conventional BF/BOF route.

9.9 To meet the manpower requirement, the developing countries concerned will need to have a proper manpower forecasting with regular updating, based on which it would be possible to initiate programmes that would ensure that there is a sufficient intake of competent people to meet estimated future personnel requirements, both in quantity and in quality. This would also cover the outflow of trained personnel to other industries and to other countries -- a problem that often assumes serious proportions in the developing countries.

9.10 Adoption of a rolling plan concept would encourage and assist in establishment of training centres that would provide and develop a systematic and continuous training for all categories of workers -- a training which would not only give him the technical skills needed but would also lead to an effective and all-round development of the individual.

9.11 Examples are available of the way in which some developing countries like India, Algeria, Nigeria, Brazil, Venezuela, etc. launched highly successful training programmes for their steel industry. Recent interesting case is that of Qatar Steel Plant and the way in which it arranged for advanced training for its construction/ operating personnel.

X. OPTIONS FOR THE DEVELOPING COUNTRIES:-

10.0 Expansion of steel industry in the developing countries will have to be achieved in the coming years through installation of various types and sizes of plants. Basically these could be reduced to three types:-

- Construction of a greenfield plant with BF/BOF route;
- Expansion of existing steel production facilities;
- Construction of new small mini-steel plants.

10.1 For most of the developing countries, adoption of the mini-steel route both for expansion and for new facilities appears to be the only practical choice.

10.2 But having determined the process route, what does the developing countries do?

- What size of installation does it go in for?
- Does it set up a DR plant or depend on domestic and imported scrap for feeding the EAF?
- Does it go in for a high degree of automation and sophisticated equipment or does it opt for simpler labour intensive technologies?
- Does it only set up a rolling mill to start with and then in due course expand it further with upstream units like EAF and DR plants?

Answers to the above will vary from country to country and no single solution can be suggested. Depending upon the technical and financial resources and market demand, each developing country will have to determine the manner in which its steel industry will develop.

10.3 One may, however, venture to suggest that since this development will be heavily dependent on import of technology, the following important compatibility requirements will have to be kept in view by the developing countries.

(a) Monetary compatibility:-

Technology in the west is usually capital intensive, but what many developing countries may want is labour intensive technology. This may not be so easy. The industrialized countries as a donor country may even cover through aid the initial cost of the technology. But later the expensive operating and maintenance cost may make the technology incompatible in monetary terms.

(b) Material compatibility:-

Developing countries would like to emphasise on use of local raw materials. This may necessitate considerable R and D efforts. In the alternative, even if imported material has to be used for any reason, it should be compatible with local skills and other facilities. Further, it may have to be linked with a gradual programme of import substitution.

(c) Production level compatibility:-

Because of their high cost of labour, industrialized countries have concentrated their efforts on developing a technology which is automated and is suited to mass production. Such a technology may not always be ideal for developing countries who are often faced with problems relating to unemployment, regional imbalances, social justice, etc.

(d) Infrastructure compatibility:-

This involves a simultaneous development of local expertise so as to avoid continued dependence on foreign experts. Concept of such a compatibility has, therefore, to be inbuilt into whatever arrangements the developing countries enter into with the industrialized countries for establishment of the steel plant and import of technology

(e) Social and political compatibility:-

Since technological development of a country is the direct consequence of its social and political philosophy, it is imperative that any import of technology in connection with setting up a project is socially acceptable to the developing countries concerned.

(f) Ecological compatibility:-

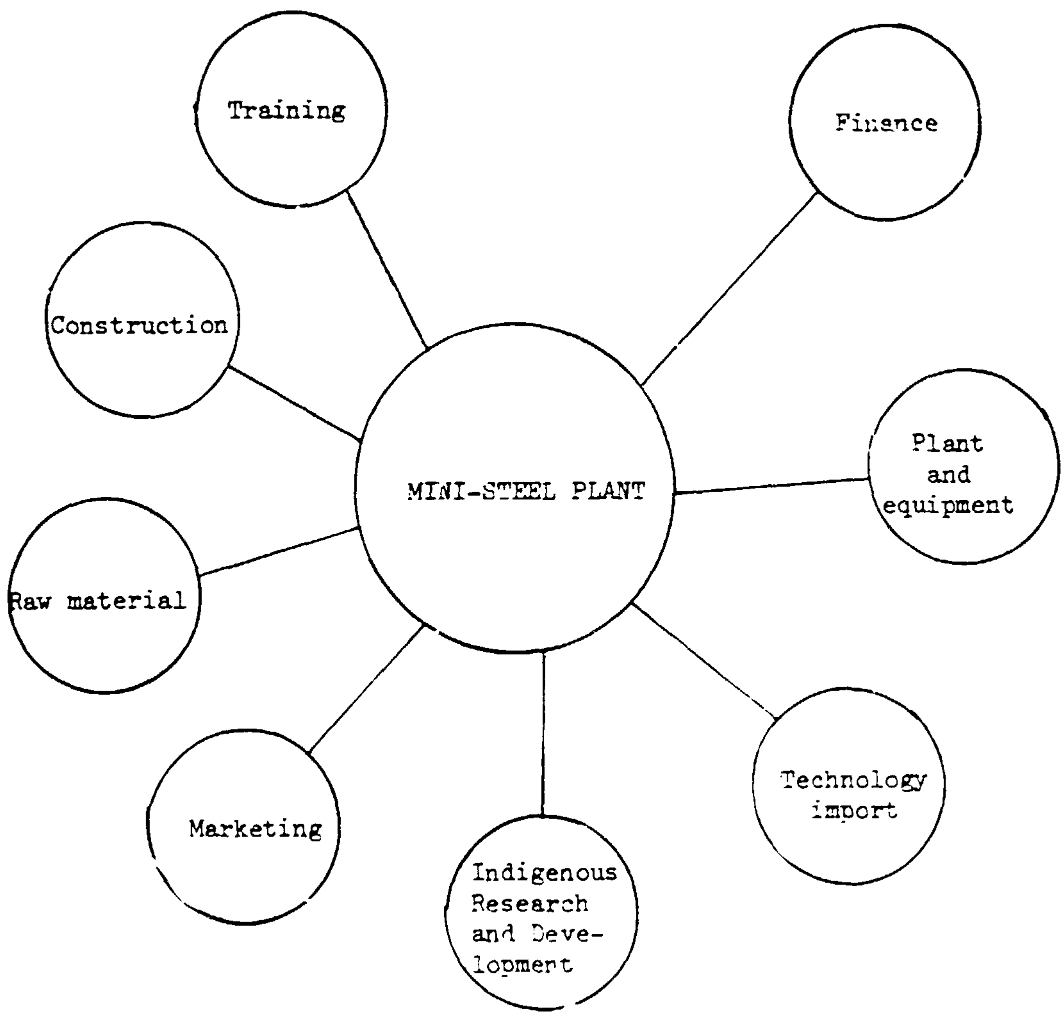
Any imported technology has to operate in harmony with nature. This suggests that the developing countries do not ignore the ecological effects of industrialization and import of technology.

10.4 Option for the developing country is clear. It can no longer delay establishment of a basic industry like iron and steel, without which no industrialization is possible. Considering the advantage of mini-steel route, it must now opt for it. Whether its entry into the sector would be step-wise and through stages or for the integrated plant as a whole, would, of course, depend upon its own national priorities and financial and technological capabilities.

XI. NEW INDUSTRIAL ARRANGEMENTS:-

11.0 Role of international co-operation in industrialization of a developing country is well-known and hardly needs much emphasis. Such a co-operation could encompass both North-South as well South-South partnership. Over the years such co-operation has moved away from a simple bilateral one to a multiple one where every aspect of the project is covered through a variety of form and type of relationship with more than one partner.

11.1 Take the case of a developing country wanting to set up a mini-steel plant. Some of the important areas that it would need to cover through international co-operation are highlighted in the figure below:



11.2 What types of industrial arrangement can the developing countries enter into?

(a) Financing:-

Obtain participation from a foreign partner through equity and/or loan and link repayment through sale of the product from the plant or other products from the country.

(b) Training:-

Utilize external assistance under aid programme for establishing training institutions in the country or have agreement with foreign partner or collaborator who would arrange for training with payment being linked with trade.

(c) Plant and equipment:-

Obtain it by making extensive use of suppliers credit or credit from export-import banks, with payment being linked with general financing and trade arrangements.

If the developing countries have some capacities available for manufacturing part of the equipment or other equipment, this could be utilized for meeting other requirements of the plant supplier.

(d) Raw material:-

This could cover the materials both for construction of the plant as well as for operating it. Cement, for example, is imported and in return supplies made of steel products or other products.

If iron ore is to be imported, it could be repaid through supply of sponge iron or steel.

Similar arrangement could be entered into for other raw material like coal, limestone, dolomite, etc.

(e) Marketing:-

Since the profitability of the project will depend wholly on its ability to market its products, advance arrangements for it would be absolutely essential.

Sponge iron produced in excess to plant's own requirements could be exported to adjoining states which might require it for its electric arc furnaces.

If the rolling mill installed has large capacity (for example, strip mill) most of its products will need to be exported. Prior arrangements for such marketing with linkages with import of essential raw materials would be necessary - perhaps with more than one partner.

(f) Technology import and indigenous R and D:-

This calls for establishment of indigenous research and development establishments which would help in the assimilation and further development of imported technology. For this, help may have to be obtained not only from the various donor countries both from North and South, but also the suppliers of technology. One could also consider an arrangement by which further developments in the field of technology could be continuously shared between the various parties.

11.3 Regional/Sub-regional cooperation:- This type of co-operation can play a truly dynamic role in giving impetus to steel development in developing countries. For example, if 'A' country has excess electric power available and 'B', a neighbouring country, has raw materials like iron ore or natural gas or coal, they could enter into an industrial arrangement on bilateral or sub-regional basis that would enable them to share these facilities. A co-operation of this type would also help to open out a large market for the steel plant products.

11.4 The above is mentioned only as an example and cannot possibly cover the innumerable ways in which industrial arrangement can be entered into - between countries of North and South as well as between South and South. Purpose is to emphasise the importance of such new types of industrial arrangement which would cover every aspect of the project so that, based on the concept of mutuality of co-operation and interdependence, the developing countries would be able to move faster along the path of self-reliance towards the goal of economic and industrial development.