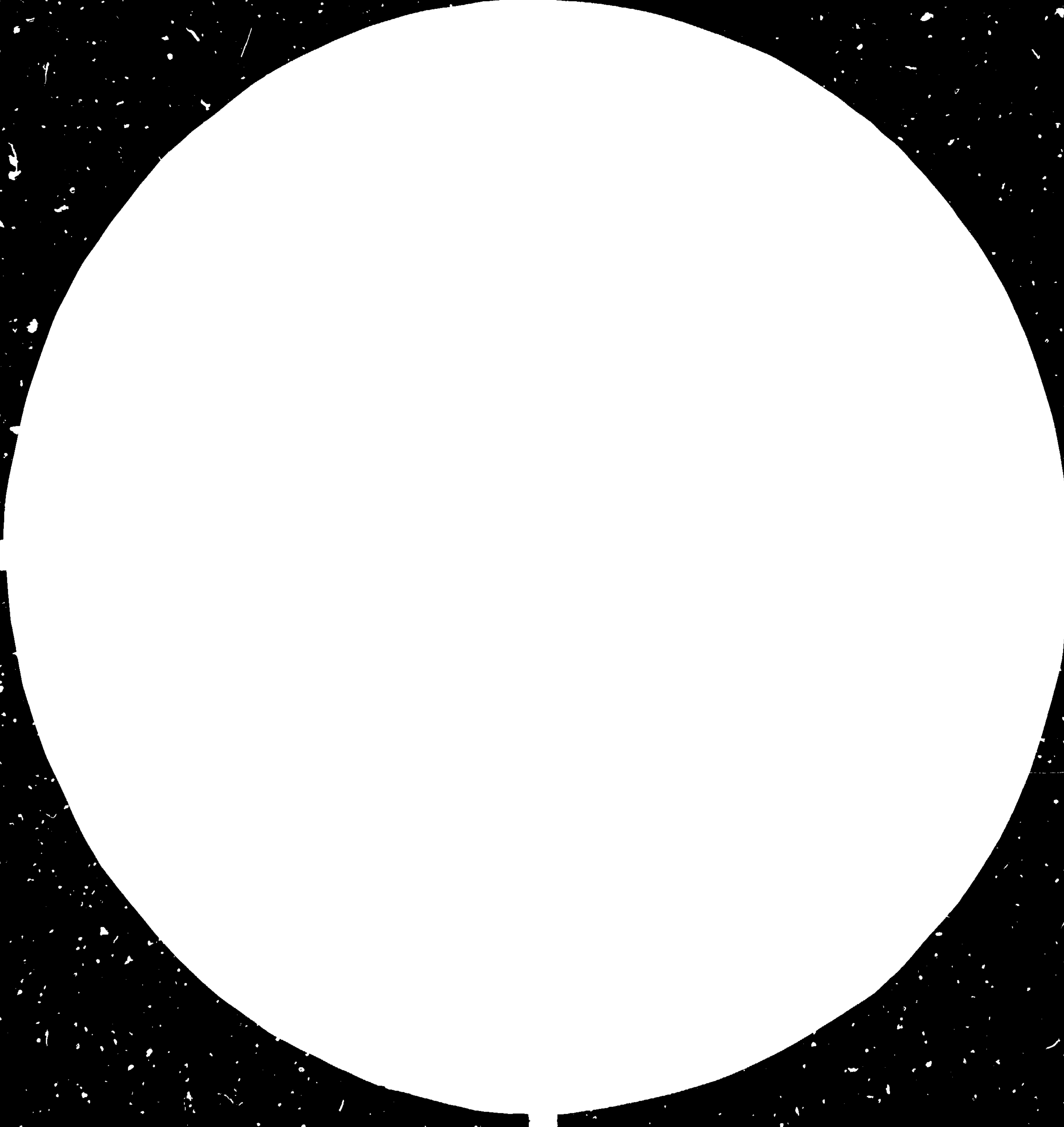
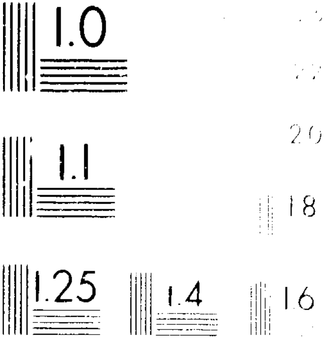
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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5 BIS, RUE DE MADRID 75379 PARIS CEDEX 08
TEL: 522 63 00 TELEX: 650392 SISYNDI PARIS

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IMPORTANCE and POSSIBILITIES of INFRASTRUCTURE and PERSONNEL TRAINING in the IRON and STEEL PROJECTS

E.

Jacques ASTIER

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SUMMARY AND TABLE OF CONTENTS

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INTRODUCTION

The costs of Iron and Steel plants are, usually, high and even for relatively small plants raise, often, difficult problems to finance them. Further more, the costs of Iron and Steel plants seems to vary very much, even for a given size of plant and for a given product mix. We think a large part of these discrepancies come from the fact there is a lot confusion about what is an Iron and Steel plant ?

This is, of course, associated with the cost : what covers, exactly, the various costs quoted in many places about investment for an Iron and Steel plant ?

To help to clarify these confusion, we propose :

1 - to describe, briefly, what are Iron and Steel plants,

2 - to show the importance of infrastructure or, more exactly, of the various types of infrastructures which are needed for an Iron and Steel plant, specially, in Develcpping Areas,

3 - to stress the importance of the personnel i.e. Technical Assistance and, specially, the Training of the personnel needed by an Iron and Steel plant

4 - and, to give some comments about the way such expenses could be financed in a way separate from the cost of the Iron and Steel plant itself.

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I - THE IRON and STEEL PLANTS

Without coming to much details, it must be reminded that there are, in fact, several types of iron and Steel plants which vary depending of the mill (see para. I.1) and the routes to produce steel (see para. I.2). Let us remind first, on figure 1, how is designed an Iron and Steel plant : we shall, already, see there, the importance of :

- infrastructure object of our Chapter II
- and human aspects object of our Chapter III

I - 1) The Rolling mills

Any Iron and Steel plant has to be designed to produce a given mix, what is called a "product mix" of various rolled bars, wire rod, beams, sheets, etc... Figure 2 shows that the capacities of the various mills able to produce each kind of product are quite different and we can, thus, imagine, it will lead to quite different plants.(1)

I - 2) The Routes to produce steel

There are, in fact, as shows figure 3 only two routes i.e. :

- either to produce (or to use) a solid primary metal which can be scrap or DRI (Directly Reduced Iron). It can be melted, usually in Electric Arc Furnace to produce liquid metal
- or to produce a primary liquid hot metal and to use it in an oxygen converter to produce liquid steel. In that case, production of the liquid hot metal (or pig iron) can be made by blast furnaces but new methods are becoming available to do it without coke : they are the new "Smelting Reduction" processes.

I - 3) The pratical possibilities

If we examine, first, the case of industrialized countries, figure 4 show that there, practically, only two possibilities :

a) the so-called "classical" plants i.e. based on blast furnaces and oxygen converters ; due to the high capital cost of such plants and their complexity (which lead to a number of well qualified specialists) the laws of productivity of manpower and the economy of scale lead to build such plants only to feed semi-products to high capacity mills. They are, for that reason, the large flat products plants (and, sometimes, for heavy products, plates, beams, rails...)

.../...

b) and the other hand, for light products, smaller mills are the only possibilities and it is cheaper and easier to feed them with billets from Electric Arc Furnace plants using scrap ; let us remind that, in industrialized countries, scrap, specially "capital scrap" or "obsolete scrap" is abundant and has to be reused.

If we turn to developing areas, there are a number of differences :

- first, the market is usually smaller and it is difficult to build such large specialized plants as in the industrialized areas (see figure 5)
- then, scrap is only available in small amounts, compared to industrialized countries
- but, finally, availability of various energy resources (oil or gas, hydroelectric power, coal, charcoal...) may open new possibilities.

In this situation, figure 5 indicates what are the three main types of plants which are developing in such areas :

- the "classical" plants, usually smaller than in the industrialized areas sometimes based on charcoal
- the "classical mini-steel plant" based on scrap but, again quite smaller than in the industrialized areas, say 50 000 t/year instead of 500 000 t/year
- and the plant based on Direct Reduction : this could be considered as evolution of the mini-steel plant where scrap is not available (see figure 5).

II - DEFINITION and COST of INFRASTRUCTURE

The first thing to do, to be as clear as possible, is to define exactly what is infrastructure or, more precisely, as we shall se in detail, what are the various types of infrastructure in an Iron and Steel plant.

II - 1) Description of the various infrastructures supporting an Iron and Steel plant

As it is probably, one of the most important type of Iron and Steel plant in the future, we shall use as an example, to describe this plant and the supporting infrastructures, a mediumsize plant varying, in possible configurations (see Figure 6) :

- a rolling mill for non-flat product, in fact, bars, wire rod, small and medium size beams

- a semi integration with electric arc furnace (operating, thus, on scrap) and continuous casting of billet).

- a complete integration with a gas-based direct reduction plant..

From such a brief description of this typical plant, what could be called infrastructure ?

- the first one is what is needed for these various metallurgical units : we shall call it "internal infrastructure" and they are only what is added to the equipment (metallurgical, mechanical, electrical, etc ...) to be operational ; this is mainly :

  . civil work
  . building
  . and erection of the equipment

  Some estimates of such costs are in TABLE I.

- next, we have various types of infrastructure which we can classify between :

  - those which are necessary practically anywhere (we call it the "first order")

  - those which are needed but could exist in some places or have to be built in other places ("second order")

  - and finally, those which are needed in underdeveloped areas and are always existing in industrialized countries ("third order")

.../...

To make comparisons, let us give some investment costs for the various configurations of our reference plant in TABLE Ibis.

II - 2) Description and cost of infrastructure of the first order

From our definition, this is always needed irrespective of the context of the plant, let it be in and advanced industrial area or, at the opposite, in an underdevel[illegible]d area. We can list there (Figure 6) :

- main offices of the plant
- laboratories
- maintenance facilities, including machine shops (mechanical, electrical, etc ...) and warehouses for spare parts.

It has, however, to be emphasized that in an industrial area, maintenance facilities can be reduced to the minimum size as much of this work can be subcontracted to existing enterprises.

Anyhow, we can give some datas about the possible cost of such infrastructures ; TABLE II show they add quite an important investment to the cost of the plant. If we want, in an underdeveloped area, to be quite sure about maintenance, it could be necessary to add further facilities :

- either to repair, on the spot, most of the equipment which can lead to heavier machine tools, foundry, etc...

- and/or to have larger spare parts stockpiles and corresponding warehouse

II - 3) Description and cost of infrastructure of the second order

When we come to that point (Figure 7), we reach a number of facilities which are necessary but are not usually taken care of (at least for their full extent) in industrialized areas. They are :

- housing with supporting facilities constituting a whole city ; in industrialized areas, this problem is existing but can usually, be solved in a not too difficult and not too expensive way. As examples, we can say that the city often exists, houses can sometimes be rented and such costs, either for renting or, even, for building new houses are usually, not supported by the Steel Company

- facilities for energy supply specially natural gas, oil or electrical energy. We mean the facilities to transport them but not to produce it ; production will be considered in the infrastructure of the third order.

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Again, in an industrialized area, the plant will, usually, be very near all these facilities and the cost to connect it to :

- energy distribution (natural gas or electrical energy)

- energy transportation (system such as road or railway for coal or fuel oil)

- water system (input and output) etc ...

is limited.

On the other hand, in developing area, many of these have to be built and, for example, for the medium sized integrated plant (400 000t/y) we have mentionned, those facilities could be (TABLE III)

Housing	up to 50 M$
Energy and water supply with road and railway	from 10 to 30 M$

II - 4) Description and cost of infrastructure of the third order

Coming to the end of our list, we arrive to more expensive infrastructures such as those connected :

a) upstream, in providing raw materials such as iron ores, coal natural gas which are not to be bought but produced in new mines or gas fields which have to be specially developed for the Iron and Steel Project. Costs can be quite high and TABLE IV gives some ideas of their importance ... Let us emphasize the fact that in an industrialized countries, it is less and less frequent that such facilities are associated with an Iron and Steel project. The philosophy of the modern seaborne plants is, as an exemple, always related to a "shopping around" (sometimes associated with medium or long term contracts) of the raw materials such as iron ore, coal, fuel-oil etc ...

If we have to include a "captive" iron ore mine for such a plant, it is an important item. For our reference plant which needs around 600 000t/year of high grade ore, the mine could be estimated between :

- 15$/annual ton or 10 M$ for simple open pit mining of high grade ores

.../...

- to 75$/annual ton or 50 M$ for open pit mining of lower grade iron ores which requires mining of a larger tonnage and the concentration plant

To these investment costs, must be added the corresponding costs for transportation which could be quite low for short distance and, for example, pipeline transportation of pellet feed but could increase very much if the distance is large and if, for example, a special railway line has to be constructed.

Some similar calculation can be made if we have to include in the project :

- a coal mine
- a natural gas production facility
- or an electrical power plant. In that case, it must be reminded that costs are of the order of 0,5 to 1$ per kW.

b) downstream in providing utilization of the products. In fact, this has to be considered as another industry or, even, a series of different industries. This is, of course, important and, even, essential in planning any Iron and Steel project but it can never be considered as infrastructure, in any sense, of the Iron and Steel Industry.

On the other hand, the utilization of the by-products of the Iron and Steel Industry can be considered as possible infrastructures. In this field, we can list :

- utilization of slags, either from Ironmaking (Blast furnace slag) or Steelmaking
- utilization of excess gases (such as blast furnace gas, coke oven gas, oxygen converter gas) etc ...

II - 5) Summary of the importance of infrastructure

To summarize this subject of infrastructures in the Iron and Steel Industry we can say (see TABLE V) that :

a) the cost of a plant with associated internal and what we call the necessary infrastructure of the first order, is about twice the cost of equipment

.../...

b) the infrastructures of the second and third orders can, again, increase the cost of the project so that the cost of a plant can vary very much in the following ranges :

- from 250 to more 1 100$/t for a ministeel plant, integrated or not with direct reduction, with a simple program (only bars) or a more diversified one (bars-wire rods and merchant irons)

- from 1 000 to 3 000$/t for classical integrated Iron and Steel

III - DEFINITION and COST of TRAINING

When we come to this second subject of the present study, we have to remember what are the needs of personnel (of trained qualified personnel, of course), of a modern Iron and Steel plant. Thus, this will be the object of our first paragraph before coming to the situation of developing areas in this field and, at last, the various possible ways, with corresponding costs for solving this problem ; let us remember that the problem is : "how to operate efficiently a modern Iron and Steel plant ?"

III - 1) Requirements in personnel of a modern Iron and Steel plant

In this respect, we must emphasize the trends, in the recent years (those we have briefly described in part I of the present study) with :

- a very limited number of people
- but, of a high level of qualification

Figures 8 and 9 from a recent published work (2) illustrates this trend and the corresponding datas have to be used as a yardstick for any evaluation of the personnel needs, everywhere around the world.

TABLE VI gives such "yardsticks" as expressed as best performances of typical plants which are :

- the classical miniplant of an industrial area specialized in one product
- a larger miniplant with a slightly enlarged product mix
- the same plant (400 000t/year) integrated with a direct reduction plant

As a comparison, this TABLE VI gives also some possible performances, regarding productivity, of a classical large integrated Iron and Steel plants.

Two remarks have to be made :

- firstly, for all the plants, if the product mix is larger, the needs for total manpower and hours per ton of product are, of course, growing
- then, if the infrastructure (as defined in the preceding chapter) has to be larger and larger, the corresponding needs, in number of people, are growing. In this way, we have growing requirements which increase both :

.../...

. cost of infrastructures
. needs of manpower and training facilities

III - 2) The problems of developing areas

This problem (again "How to operate efficiently a modern Iron and Steel plant ?) has three facets which are, often, not very well understood :

a) the first one is to consider the usually low cost of manpover in developing areas to minimize the problems. In fact, if we compare a miniplant in industrialized area, say USA with 2 hours/t of product and manpower averaging 20 US dollars/hour the cost, per ton of product, will be, of course :

2 x 20 = 40 US dollars/t of product

If, in a developing area, cost of manpower is 2 US dollars/hour but if production of one ton needs 20 hours, the result appears the same :

20 x 2 = 40 US dollars/t of product

In fact, it is very misleading as, in the second case, the large number of people will :

1/ require additional facilities both inside the plant and outside which means additional infrastructures

2/ complicate the problems of training, which are essential

b) the second one is to consider both solution of technical assistance and training as simple ways of solving this problem. In fact, it is far more complicated ! :

1/ if we were operating the plant only with competent expatriates, we should get the same results as in an industrialized area with the same cost i.e. the 40 US $/t of product in our examples. Unfortunately, this is not true as :

. expatriates will be more expensive than the same people in their usual surroundings ; so our 40 could become 60 US $/t of product or even more ...

. the problem of training of local people and of the transfer of know how is, of course, not solved ...

.../...

2/ so, even if we consider use of expatriates in technical assistance as a part of the solution, the main emphasis has to be made on training. As we shall see, this is a complicated process we shall try, now, to describe and figure it.

c) the third one is, again, concerned with infrastructures. Outside of the plant itself (see Figure 7), there are a number of facilities and the managing of such departments is quite important and, often, underestimated. As an example, TABLE VII gives comparisons between :

- classical optimum figures (such as those of table VI)

- and typical case where we have to include :

  . direct reduction
  . large facilities (detailed in TABLE VIII) for various services, training etc ...

III - 3) Various solutions to operate efficiently an Iron and Steel plant in developing areas

Again, as for infrastructure we shall use the example of a medium size integrated plant, the same as in our second part of the present study. What are the personnel needs of such a plant ?

a) as a first answer, to have our yardstick, we shall remember that such plant, in industrialized areas, could operate on scrap i.e. with a compact "semi-integrated" configuration very efficient in manpower. We figure it will be (see TABLE VII) around 3 hours/t of product.

b) unfortunately, in a developing area, there will be additional needs which can be divided between :

- the need of a direct reduction plant due to the lack of scrap

- the need of a far larger infrastructures which means more people

- the need of a training program and, probably, of a training center to increase the productivity of all the people.

This is figured out, as an example, in TABLE VIII.

c) then, leaving aside the solution (which can be and, in some cases, will have to be a way of initiating the operations) of a large number of expatriates running the plant, we have to consider what could be the best training program.

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The problem of training concerns, in fact :

a) either the 1 380 people if we consider the total number

b) or, if we try to make breakdown by "jobs" :

around 100 in managerial positions

around 850 in production and control but we have to remind that many of them will be associated with supplies and maintenance

around 200 in general maintenance and various supplies and stores

around 130 associated with technical services

and 100 in the training center

c) or, at last, by "grades" :

around 50 engineers or equivalent

around 80 foreman
and 250 technicians

and 1 000 workers.

Let us emphasize the fact that, only a limited number of them will be closely associated with specific Iron and Steel training, probably no more than 150 out of 1 380 ! There will be far more people associated with :

- managerial qualification (we guessed 150 !)
- maintenance problem (probably 300 !)
- and various general trades such as mechanics, electrics, etc ...

III - 4) Cost of Technical Assistance and Personnel Training

It is, of course, impossible to give any precise figures as all the cases are different but some datas can be useful to remind, as references :

a) for such a plant in industrialized areas i.e. with 650 people cost, with average cost of 10 to 20 $/hour (Western Europe, Japan or USA), are :

30 to 60 $/t of product

or

12 to 24 M$/year of wages

b) if we were operating this plant, in a developing area, only with expatriates and training slowly the local people to have say 100 of them entering the plant each year, the cost would be :

- first the same 650 expatriates but it is probably not enough in a developing area : 900 are probably more realistic with extra cost in the range of 15 to 20 $/hour which means :

61 to 81 $/t of product

or

24,3 to 32,4 M$/year of wages

- and the cost, growing each year, of local people entering the plant which could mean, if we want to train the 1 380 people in 10 people about 150 people per year (maybe more if the turnover is not negligible) :

150 x 1 800 x 5 = 1,35 M$/year of wages

if average cost is 5$/hour.

In other words, this adds about 1,5 M$/year every year, plus the cost of training in a training center for general education say 1 M$/year or 2,5 M$/year for the total wages + training for about 150 people

c) if the plant was operating with its 1 380 people, without problem, at average cost of manpower from 1 to 5 $/hour, the result is :

6,2 to 33 $/t of product

or

2,5 to 12,4 M$/year of wages

With such values in mind, we can give some ideas of the corresponding costs of training. We do think two different cases have to be considered :

1/ Specialized training in an area where education has been improved, both for general and industrial levels. In other words, before building the plant and, even, before deciding to enter the field of Iron and Steel Industry, the area or the country could, as soon as possible, start to specialize and train people :

- either in the field of Iron and Steel Industry (say one or two engineers per year)

- or in the general fields associated with such project ranging from management to maintenance, mechanics electrics, electronics etc, from the level of managers to technicians and specialized workers.

.../...

In this way, the area could have a number of people useful for such an Iron and Steel project as well as any other industrial development. If such a training program had been achieved when the Iron and Steel project is decided, the need of specialized people, for such a project, could be easily fulfilled as it is, as we mentionned before, only 150 people.

To train these 150 people for, say, one year abroad could mean including everything (cost of this personnel, trips and expenses abroad, cost of training) between 5 and 10 M$ which is small compared to the cost of the project.

2/ Training of everybody ; in that case, it is estimated that practically all the people, the 1 380 people we figured will be necessary in such a plant, have to be trained :

- either in the specialized training for Iron and Steel Industry (as in case 1/)
- or, even, in the general trades and the general "atmosphere" of the industrial environment.

There, the problem could be serious and, as we mentionned for infrastructure we could go very far ! The limits between the general education system of the country and the specialized training for the project are specially difficult to trace and to recognize. Two important conclusions have to be drawn :

- the first one is that, if the Iron and Steel project is started and built very fast, the general education and training program will, certainly, be lagging and, as it was seen in many cases, a lot of difficulty will occur. Need of technical assistance from expatriates will be high ...
- the second one is that the cost of this training which is, in fact, a remedy to a lach of general and specialized industrialized education could be very high : compared with the figures mentionned in 1/ costs could go up to 50 M$ or more but, again, where is the limit between the general education system of this area and the training program of the project ?

III - 5) Summary of the importance of training

As a summary, TABLE IX gives the various costs associated with the human aspects of an Iron and Steel project which, let us remind it :

.../...

- needs around 1380 people (see Table VII) in a developing area

- could cost, as investments (capital costs) between 340 M$ up to 440 M$ or even more ... (see Table V).

These costs, associated with human aspects are :

- the cost of personnel per ton of product or per year

- the cost of technical assistance

- the various costs of training for the various alternatives

1) in the first two columns , the wages to be paid, either per ton of product (column 1) .or per year (column 2) to people working in the plant for various assumption

2) in the second column at the third line, a possible cost of technical assistance if the plant was operated with expatriates for some time : it means about 32 to 34 M$ wages per year for such an expatriate manpower

3) in the third and last column, the cost of training for various alternatives :

   a - if we have only, as in an industrialized area, to make a specific training of the 150 people associated directly with Iron and Steel making, it is only about one year of training and a cost of

   5 to 10 M$ for training

   b - if we start the plant with expatriate and train gradually, in plant, the local people, the cost could be

   25 M$ for training

   and the time needed could be around 10 years

   c - if we have to train everybody, we mean to "adapt" the whole 1380 people not only to Iron and Steelmaking but to all the trades of an industrialized environment, from management to maintenance with all the corresponding skilled specialization, several years would be needed and cost could be :

   50 M$ or even more

IV - PRACTICAL CONSIDERATION ABOUT the ROLE of INFRASTRUCTURE and PERSONNEL TRAINING in a STEEL PROJECT

The two preceding chapters and, specially, TABLES V and IX which summarizes the cost-aspects of infrastructures and human considerations, notably training in the IRON and STEEL Industry lead to a number of important considerations related to :

- the problems associated with an Iron and Steel project in a developing area
- the financing of infrastructure
- the financing of training.

These will be the three points of this last chapter of the present study.

IV - 1) Problems associated with an Iron and Steel Project in a developing area

The present study raises, in fact, the essence of underdevelopment or, to be precise, of developing area. If, indeed, we want to create a new Iron and Steel plant in a given area the main differences between developed and developing surroundings are :

- first, the lack of infrastructures
- and, second, the lack of trained human resources.

If these problems are not existing, as in the industrialized areas, we can come to the usual problems of (see Figure 1) :

- selecting the products to manufacture and, thus, the type of rolling mills which are connected with the market and the product mix
- selecting the processes and the "route" to produce steel which are connected with the availability of raw materials and the size of the plant.

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From there, usual calculations lead to the economic feasability and typical datas about operations costs and capital costs are given in TABLES X, XI and XII and Figure 10 from the excellent work, already quoted, of Barnett and Schorsch (2).

If we turn to a developing area, the same problems for markets product mixes, raw materials and processes are raised but, in addition we have the two main characteristics of such an area, already mentionned, which are arising :

infrastructures
trained personnel

These two problems (see again Figure 1) raise important economic and financial issues which we are now summarizing.

IV - 2) Cost and financing of infrastructure

As we were just expressing it, the lack of infrastructures or, to be very precise, what we call infrastructures of the second and third orders, is a characteristic of a developing country. To add this infrastructure in an Iron and Steel project has much importance : if, indeed, we use our figures from TABLE V and the datas of Barnett and Schosch (2), specially those of TABLES XI and XII, we come to the conclusions on TABLE XIII regarding the capital costs of plants. We see that :

- if we compare what is produced in scrap based miniplants, in industrial areas, and in integrated miniplants in developing areas, total capital costs per ton can increase from 250/300 $/t to 1 000 $/t or even more!

- if we compare similar plants, the difference is still important, from 850/900 to 1 000/ 1 100 $/t

The effect on the cost, per ton of product (see again TABLES X and XII and specially TABLE XIV) are quite important :

- from average values for the depreciation and interest charges of around 37 to 48 $/t for new plants (compared to averages of 18 to 21 $/t if we take account of existing plants)

- we jump to 145 and even 170 $/t

This means that such costs would prevent any profitability of this project and any possible competition on the market. The conclusion seems that the infrastructures needed to develop such a project should be financed by different ways and, specially, by softer loans than the plant itself.

.../...

It is of course impossible, in the limited scope of this paper to identify the possible sources of financing or the possible terms of such loans (rate of interest, length of grace and reimbursement periods ...) but we tried, at least, to give datas to formulate this issue.

IV - 3) Cost and financing of trainong

The problem of financing for training is different of the one we raised for infrastructures. It is different for four reasons :

- the first one is that the order of magnitude is smaller : 5 to 50 M$
- the second one is that the effect on the cost of the product is small, As an example, if we assume 20 M$ for training and if we amortize it on 5 years of production at full capacity (i.e. 5 x 400 000 = 2 Mt), it means only 10 $/t. If the cost of the manpower in the considered area is not too high, it can be incorporated in the personnel cost and leave possible competition with other producers. If, indeed, we come back to our figures (TABLE IX) or those from Barnett and Schorsch (2) (TABLES X and XII), we see that labor cost, per metric ton of product can vary from a very low 6$/t to usual figures between 30 and 80 $/t!
- the third one is that the cost of the specific training is relatively small, say between 5 to 10 M$ for an Iron and Steel project in the range of 500 M$ say 1 to 2 % of complete cost of the project
- the last one is that the main cost is related to general education and not to the specific training for the Iron and Steel Industry.

This analysis lead to the conclusion that :

- specific training could be financed, maybe on shorter term, as the Iron and Steel project ; this is not an important amount of money but it is essential
- the general training or, let us call it, the general education is a deeper problem which, for us, has not to be related to a single industrial project such as the Iron and Steel project we mentionned. It is, in fact, the main road to develop a given area and should get special attention and special financing.

CONCLUSIONS

The limited scope of the present study cannot, of course, solve all the problems connected with infrastructure and training of personnel in the Iron and Steel Industry. It can, however, lead quite clearly to two conclusions :

- *first, the lack of infrastructure in a developing area can lead to a large increase in the capital cost of an Iron and Steel project ranging from + 20 % to more than 100 % depending the way the comparison is made. This means additional charges of depreciation and interest which, according to the usual rules of financing the Iron and Steel plants and their equipment, would very often prevents any profitability to the project. It seems special financing systems are required to take care of this situation*

- *the second, the lack of trained personnel in a developing area is another drawback to the smooth starting up and operations of an Iron and Steel plant in such a place. The problem is not so much the specialized training of the limited number of people closely associated with Ironmaking, Steelmaking and Rolling processes but the general education and the level in various managerial and industrial trades and attitudes of the whole personnel of the plant. Something has to be made associating this specialized training with an important effort to upgrade the general level of everybody and, specially all those concerned by such a project.*

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Table I

INVESTMENT COSTS for the VARIOUS CONFIGURATIONS
of the REFERENCE PLANT in MILLIONS U.S. DOLLARS (1984)

	Cost of equipment M$	Cost of internal infrastructure Civil, erection, building work M$	Total Cost (See Table II) M$
Simple bar rolling mill 100 000 t/year	25	15	40
Combination mill for bars, wire rod and medium profiles 400 000 t/year	60	40	100
Same as above semi integrated with EAF and billet CC 400 000 t/year	+ 45 = 105	+ 55 = 95	200
Same as above inte-grated with natural gas D.R. Plant 400 000 t/year	+ 50 = 155	+ 50 = 145	300

TABLE Ibis

INVESTMENT COSTS for the VARIOUS CONFIGURATIONS

of the REFERENCE PLANT in US DOLLARS (1984)

	Cost equipment and internal infrastructure		Total cost in $ per annual ton without any external infrastructure
	Total cost M$	Cost in $ per annual M$	
Rolling mill alone : 100 000 t/year 400 000 t/year	 40 100	 400 250	 400 250
Rolling mill semi-integrated with EAF and billet CC (420 000 t/year billet) (400 000 t/year product)	200	500	500
Same as above integrated with gas D.R.	300	750	750

TABLE II

COST of the INFRASTRUCTURE

of the FIRST ORDER

(everything is related to a 400 000t of product/year plant)

item	order of magnitude of cost M$
Main offices	10
Laboratories	3 to 5
Maintenance facilities :	
Workshops	10
Warehouses	5
General transp rt and handling systems	5
TOTAL	33 to 35

TABLE III

COST of SOME INFRASTRUCTURES of tne SECOND ORDER

(everything is related to a 400 000t of product/year plant)

item	order of magnitude of cost M$
housing for families of 1380 people + associated facilities	30 M$
energy supply we mean only, here, the connections to existing systems of : Natural gas Fuel oil Coal Electrical energy Water etc ...	40 to 60 M$

TABLE IV

ORDER of MAGNITUDE of the COST

of some INFRASTRUCTURES of the THIRD ORDER

(everything is related to a 400 000t of product/year plant)

item	basis	total cost M$
Iron Mine (600 000t/year of high grade lumps or pellets)	from 15 to 75 $/t	10 to 50 M$ * even more if long railroad or pipe line have to be built
gas field (for 150 Mm^3/year)	difficult to give average datas	
Power station (for 400 GWh/year) and 140 MW	from 500$ to 1 000$ per MW	70 to 140 M$
Water intake (for 3 Mm^3/year)		1 to 5 M$ even more if it is far away ...
Port	difficult to give average datas	

* some 25 to 35 M$ could be added if pelletizing plant is needed

TABLE V

VARIOUS COST of IRON and STEEL PLANT with INFRASTRUCTURE

(total cost M$)

	Total cost of plant			Extra infrastructure	
	Equipment	internal infrastructure	1st order	2nd order	3rd order
Rolling mill 100 000t/y	15 to 25	+ 10 to 15 25 to 40	+ 5 to 10 30 to 50	+ 2 to 10 up to 60	?
semi integrated classical minimill 200 000t/y	55	+ 40 = 95	+ 5 = 50	---	---
semi integrated diversified miniplant 400 000t/y	105	+ 95 = 200	= 30 = 230	+ 10 to 50 up to 280	?
integrated steelplant with D.R. 400 000t/y	155 +	145 + = 300	40 = 340	+ 70 to 100 410 to 440	+ ?
Classical integrated Iron and Steel plant 2 Mt/year	total 2 500 to 3 000			——————>	can reach 4 000 to 6 000
Classical integrated Iron and Steel plant 4 Mt/year	total 4 000 to 5 000			——————>	can reach 6 000 to 8 000

TABLE VI

VARIOUS MANPOWER of MINIMILLS

and MEDIUM SIZE IRON and STEEL PLANTS

CATEGORY	PERSONNEL	PRODUCTION	RATIOS
minimill 200 000t/year	230 people (200 × 1 800 hours)	one product such as bars in a limited range of diameters	about 900t/man or 2 hours/t
medium size plant 400 000t/year	650 people (650 × 1800 hours)	various product bars, wire rod merchant iron	about 600t/man or 3 hours/t
idem + Direct Reduction 400 000t/year	750 people (750 × 1800 hours)	idem	about 500t/man or about 3,4 hours/t
As comparison : large scale classical integrated plant 3 Mt/year	6600 to 8300 people	one product hot rolled coil	about 360 to 450t/man or about 4 to 5 hours/t

TABLE VII

MANPOWER REQUIREMENTS for a MEDIUM SIZE PLANT

(400 000t/year)

	a optimum operations	b typical case see TABLE VIII	additional requirements from a to b
production facilities :			
Steelmaking shop	150	260	+ 110
Rolling mill	150	200	+ 50
Direct Reduction plant	-----	140	+ 140
1sr order infrastructures			
Main offices laboratories maintenance (workshop, stores, etc ...)	265	550	+ 285
2nd order infrastructures			
Energy supply (gas, water, electricity, etc ...)	85	130	+ 45
Housing	0	?	?
3rd order infrastructures	0	difficult to appreciate : vary from case to case	?
Technical center		100	+ 100
TOTAL	650 people corresponding to 600t/man and 3hours/t of products	1 380	+ 730 but varies from cases to cases

BREAKDOWN of TECHNICAL, MANAGERIAL and ADMINISTRATIVE SERVICES

(medium size plant, 400 000t/year)

designation	total number in the typical case b of TABLE VII	probable number in an industrialized area
General management for production sales and administration	100	70
Laboratories	50	30
Central workshop	150	50
Stores of spare parts and various supplies	50	30
Handling and transportation	140	55
Safety	60	30
Technical services :		
Management	15	85
Natural gas supply	21	
Electrical energy supply	22	
Water supply	21	
Oxygen supply	30	
Compressed air supply	21	
Production of :		
Natural gas Electrical energy Water	?	0

Iron mine, ore preparation and pelletizing	(could be of the order of 300)	0
Training center etc ...	100	0
TOTAL	780	350

TABLE IX

COST of MAPOWER and COSTS of TECHNICAL ASSISTANCE

and TRAINING

(everything is related to our reference
400 000t/t of product/year plant)

	cost per ton of product, in $	cost per year, M$ (assuming operation at full capacity)	total cost of training
1) reference : Classical ministeelplant for bars	2h/t x 15$/hour = 30$/t	12 M$	----
2) reference : Diversified ministeelplant for bars wire rod and merchant iron	3h/t x 15$/hour = 45$/t	18 M$	----
3) operation of plant reference 2) in developing area with expatriate and gradual training of local manpower	4,05h/t x 20$/hour = 81$/t	32,4 M$ + around 2,5 M$ each year for the training of local manpower	on 10 years about 25 M$ *
3b) operation only with local people (if sufficiently trained)	6,2h/t x 1$/hour = 6,2$/t or 6,2h/t x 5$/hour = 31$/t	2,5 M$ or 12,4 M$	
A) cost of specific training	------	------	5 to 10 M$ *
B) cost of general training of the whole personnel	------	------	50 M$ or even more... *

* plus, of course, the cost of the trained personnel

TABLE X

COMPARATIVE PRODUCTION COSTS, in 1981, for WIRE RODS

from Barnett and Schorsch (2)

(in 1981 US dollars (a) per net ton of 907 kg at normal operating rates (b))

	Integrated			Mini-Mill		
	U.S.	W. Germany	Japan	U.S.	W. Germany	Japan
Labor	131	84	51	60	45	37
Iron ore	62	50	49	—	—	—
Purchased scrap[c]	15	5	3	93	96	96
Coal or coke	52	75	59	—	—	—
Other energy	46	37	40	45	52	51
Other costs[d]	60	61	64	65	69	68
Operating costs	372	312	266	263	262	252
Depreciation	12	14	16	11	12	11
Interest	5	8	18	7	8	10
Miscellaneous taxes	5	2	4	3	1	2
TOTAL COSTS[e]	393	336	304	284	283	275

a. Exchange rates in 1981, at 2.26 DM/$ and 230 Y/$, were somewhat out of line with historic relationships. As a result, U.S. production costs, especially relative to those estimated for Europe, may be slightly overstated.

b. For integrated plants, average 1977 to 1981 capacity utilization rates were used to avoid single-year abnormalities. For the United States, capacity utilization averaged 80 percent, for West Germany and Japan, 65 percent. For mini-mills, 85 percent capacity utilization was assumed throughout, and this is close to their average over the last five years.

c. Average 1980–81 scrap prices were used, since these are more typical of long-term relationships than 1981 scrap prices alone.

d. Includes alloying agents, fluxes, refractories, rolls, and so on.

e. Excluding any return on equity.

Sources: Estimated by authors from data contained in annual reports (e.g., Korfstahl, Tokyo Steel, Florida Steel, etc.), Metal Bulletin, World Steel Dynamics, *Core Report Q* (New York: Paine Webber Mitchell Hutchins, 1982), and so on.

TABLE XI

COMPARATIVE CAPITAL COSTS in 1981,
for WIRE RODS PLANTS from Barnett and Schorsch (2)
(in 1981 US dollars per net ton of 907 kg of wire rods (a) and per year at 90 % operating rate)

		Process	Input/Output	Cumulative
A. *Integrated Plants*				
Sintering		89		
Coke ovens		305		
Sinter/HM			0.15	
Coke/HM			0.45	
Blast furnaces		200		351
HM/CS			0.80	
BOF:				
Melt	90			
Billet cast	48	138		419
Billet/Rod			1.065	
Rod mill		179		625
Total				625
B. *Mini-mills*				
Electric furnace				
Melt	98			
Billet cast	38	136		136
Billet/Rod			1.05	
Rod mill		157		300
Total				300

a. Overhead (e.g., office buildings) and infrastructure (e.g., plumbing, electrical, etc.) allocated to all facilities. Ore and coal handling allocated to using facilities (sinter, coke ovens, and blast furnaces). Site preparation and financing costs during construction not included. Both plants have 750,000 tons of wire rod capacity. Mini-mill plant capacity 750,000 tons, integrated plant capacity 4 million tons.

TABLE XII

COMPARATIVE TOTAL PRODUCTION COSTS,

in 1981 from Barnett and Schosch (2)

For C R S (Cold Rolled Sheet) and wire rod

For integrated plant and minimills

and for current plants or new plants

In 1981 US dollars per net ton at 90 % operating rate

	Current Plants			*New Plants*		
	Integrated		*Mini-mill*	*Integrated*		*Mini-mill*
	CRS	*Wire Rod*	*Wire Rod*	*CRS*[a]	*Wire Rod*[b]	*Wire Rod*[c]
Labor	139	127	59	86	73	35
Iron ore	62	61	–	62	60	–
Scrap	15	14	93	15	14	92
Coal or coke	53	51	–	42	39	–
Other energy	53	45	45	41	35	40
Other costs	82	65	65	70	55	58
Operating costs	404	363	262	316	276	255
Depreciation[d]	16	10	10	92	48	21
Interest[e]	6	4	7	72	38	18
Taxes	6	4	3	12	8	4
Total costs[f]	432	381	282	492	370	268
List prices	486	419	419	486	419	419

a: 4-million-ton plant.
b. 4-million-ton plant, producing bar, rod and light structural 0.75 million tons wire rod.
c. 0.75 million ton plant, all wire rod.
d. New plant capital costs ( ) amortized over fifteen years. Depreciation also includes amortized construction interest—$12 a ton CRS, $6 a ton WR integrated, $1 a ton wire rod mini-mill. This reflects 5-year construction period integrated, 2-year construction period mini-mill.
e. 50 percent debt at 12 percent interest assumed, 50 percent equity.
f. Excluding any return on equity. For the same return on equity, new plants must earn more absolutely than current plants, and new integrated plants must earn more than new mini-mills.
Sources: Authors' estimates, based upon data from: World Steel Dynamics, *Core Reports I & Q* (New York: Paine Webber, 1979 and 1982); *Tex Reports* (Tokyo: various years); *TPM Cost Manual* (Washington, D.C.: U.S. Department of Commerce, various issues); and data supplied by various steel firms and equipment suppliers.

TABLE XIII

COMPARISON of CAPITAL COSTS of IRON and STEEL PROJECTS
in DEVELOPED and DEVELOPING AREAS
(from TABLE V and TABLE XI ; in US dollar per metric ton)

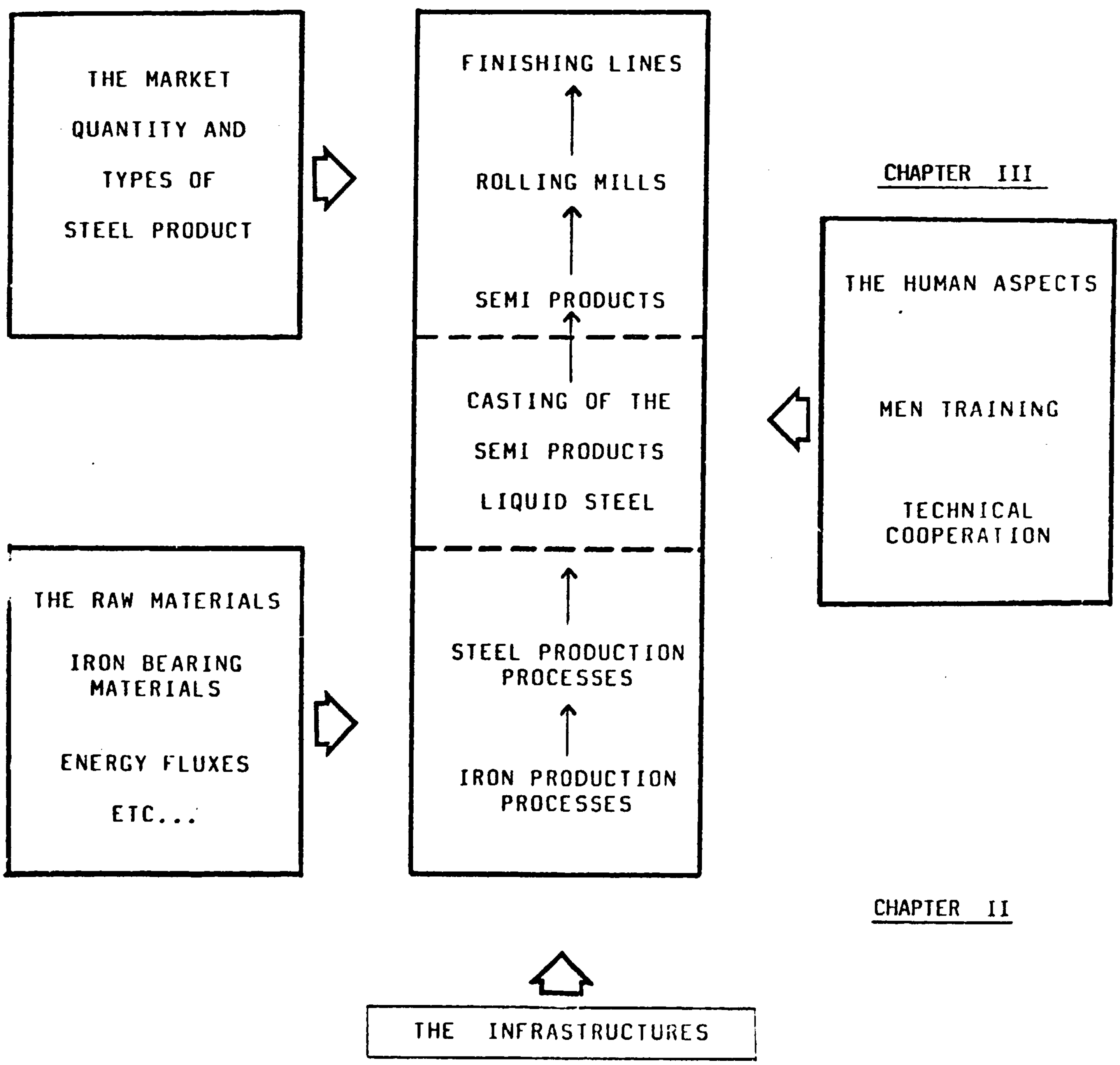
	Developed areas		Developing areas	
	Total cost M $	$ per annual ton	Total cost M $	$ per annual ton
Classical minimills :				
for bar 200 000t/year	50	250	---	---
for wire rod 750 000t/year	247,5	330	---	---
Integrated minimill with D R :				
bars, wire rods and merchant iron 400 000t/year	340 to 360	850 to 900	400 to 440 or more	1 000 to 1 100 or more

COMPARISON of DEPRECIATION and INTEREST CHARGES in US dollars per metric ton of product

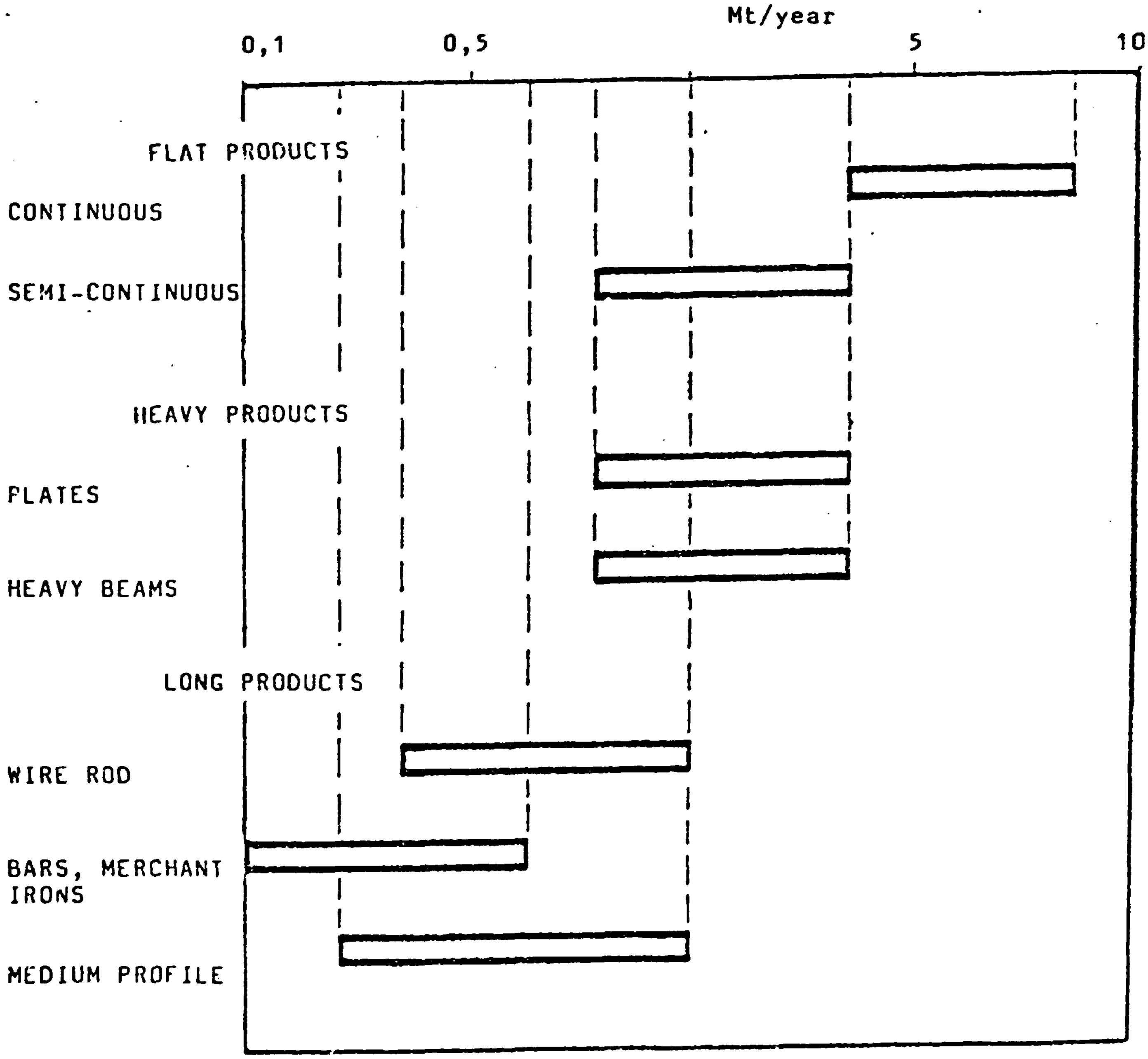
	Developed areas (see TABLES X and XIII)	Developing areas (see TABLE XIII at an average 1000$/t)	
		1	2
depreciation in 15 years	$\frac{330}{15} = 22$ + 1 23 (for bars around 18)	$\frac{1\,000}{15} = 67$ + 3 70	
interest with 50 % debt	$165 \times \frac{15}{100} = 24{,}75$ (for bars 18,75)	$500 \times \frac{15}{100} = 75$	---
66 % debt	---	---	$666 \times \frac{15}{100} = 100$
total for one ton wire rod	47,75	145	170
total for one ton bar	36,75		

Figure 1

THE DESIGN OF AN IRON AND STEEL PLANT



AVERAGE CAPACITY OF MODERN ROLLING MILLS



THE VARIOUS ROUTES AND PROCESSES TO PRODUCE LIQUID STEEL

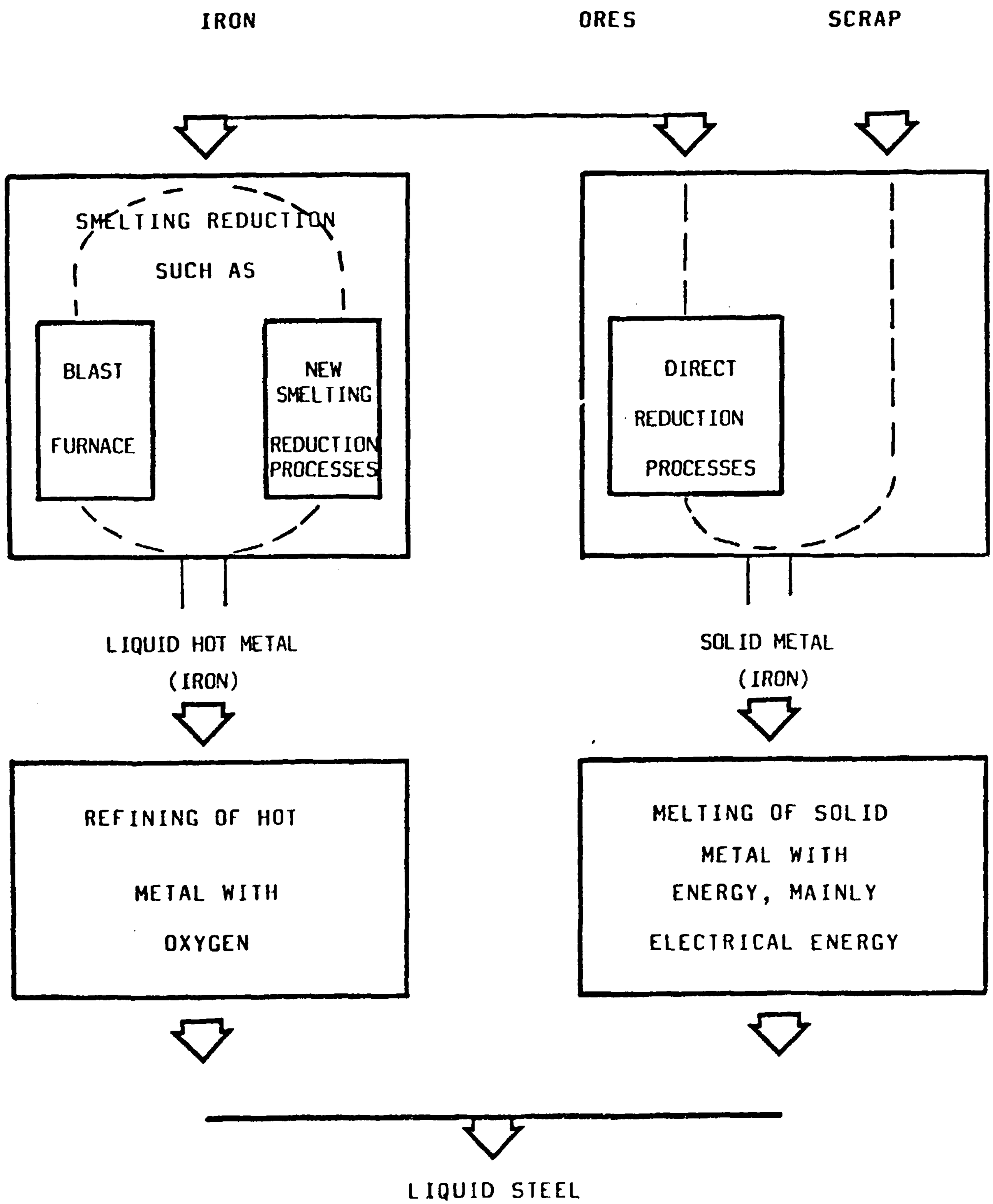


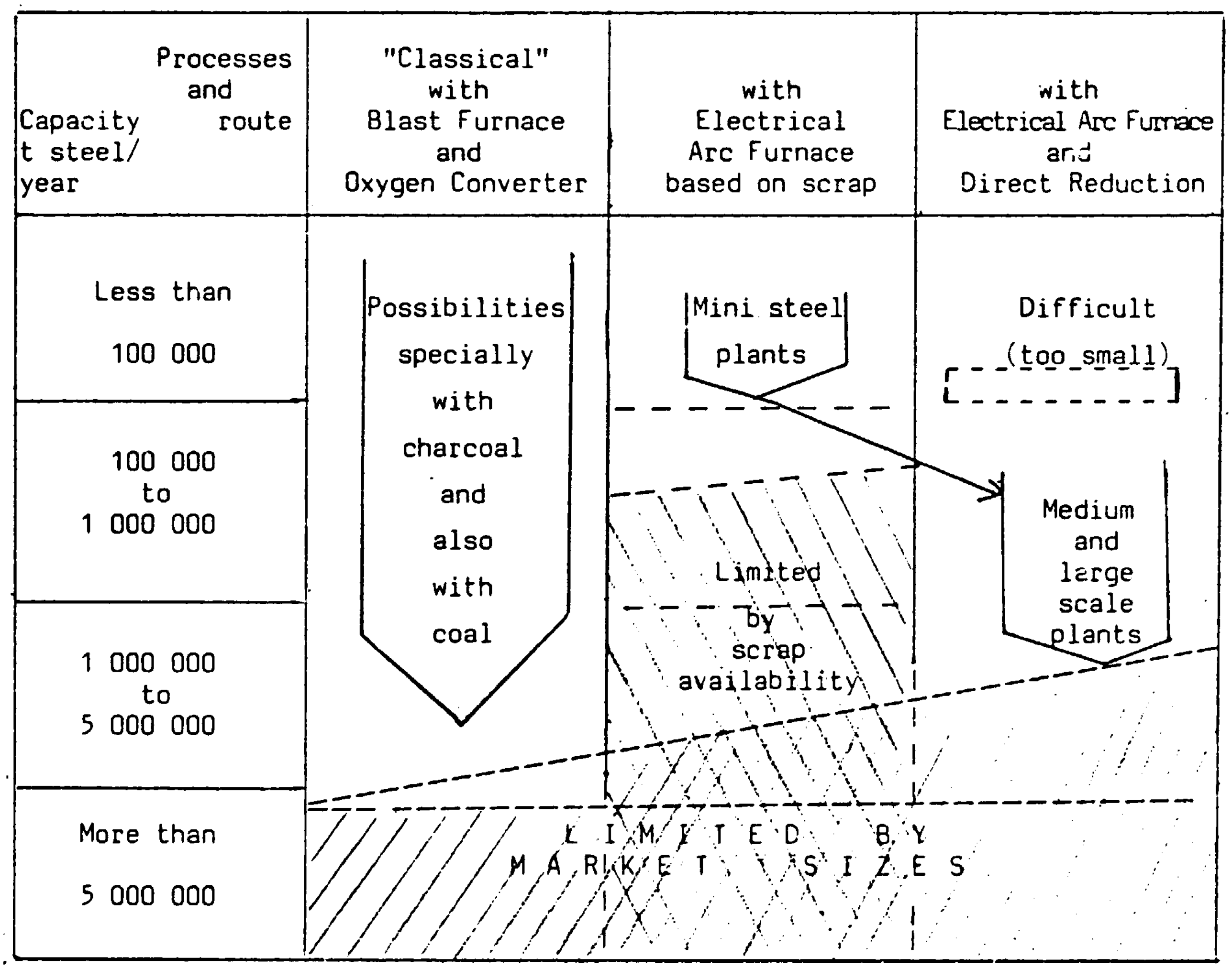
Figure 4

THE TWO TYPES of IRON and STEEL PLANTS in INDUSTRIALIZED AREAS

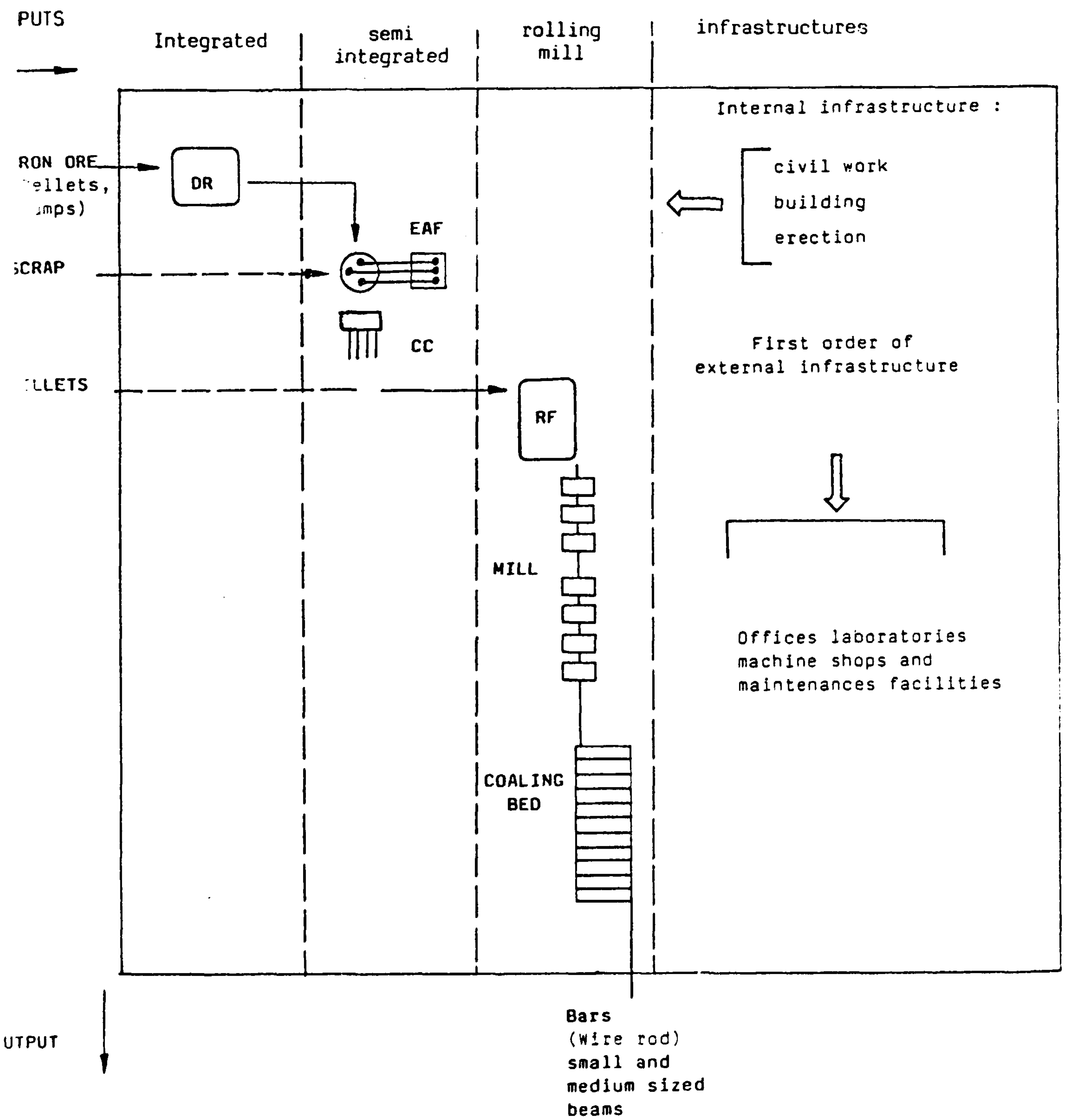
<table>
<tr><th>Processes and route
capacity t steel/year</th><th>"Classical" with Blast Furnace and Oxygen Converter</th><th>with Electrical Arc Furnace based on scrap</th><th>with Electrical Arc Furnace and Direct Reduction</th></tr>
<tr><td>Less than 100 000</td><td rowspan="2">Such plants are disappearing</td><td rowspan="2">Evolution of the mini steel plants for long products</td><td>(Difficult too small)</td></tr>
<tr><td>100 000 to 1 000 000</td><td>Difficult for economical reasons</td></tr>
<tr><td>1 000 000 to 5 000 000</td><td rowspan="2">Evolution of the large flat products integrated plant</td><td rowspan="2"></td><td rowspan="2">Difficult
(too large)</td></tr>
<tr><td>More than 5 000 000</td></tr>
</table>

Figure 5

THE TWO TYPES of IRON and STEEL PLANTS in DEVELOPING AREAS



SCHEMATIC CONFIGURATIONS of a MEDIUM SIZED IRON & STEEL PLANT



VARIOUS INFRASTRUCTURES NEEDED for a MEDIUM SIZED IRON & STEEL PLANT

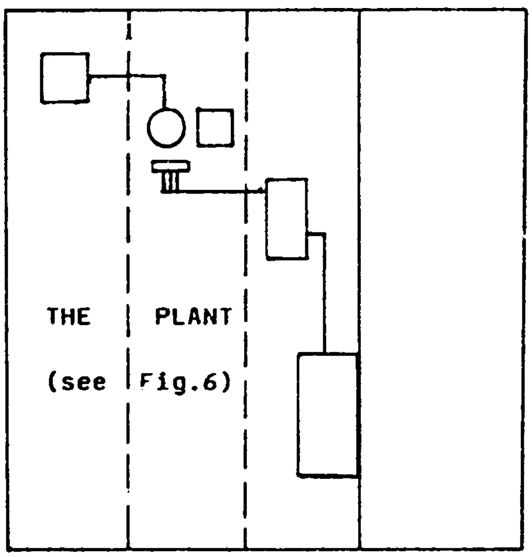
First order of infrastructure	Second order of infrastructure	Third ordre of infrastructure
	Facilities for : - water - gas - electricity	Production of : - gas ? - electricity - coal ?
	Facilities for : - transport	- Iron ore mines
	Housing (City and related facilities)	- Quarries for fluxes
		- Refractories

Figure 8

EVOLUTION of PRODUCTIVITY (MHPT i.e. Man Hour Per Net Ton) by PROCESS in INTEGRATED MILLS from Barnett and Schorsch (2)

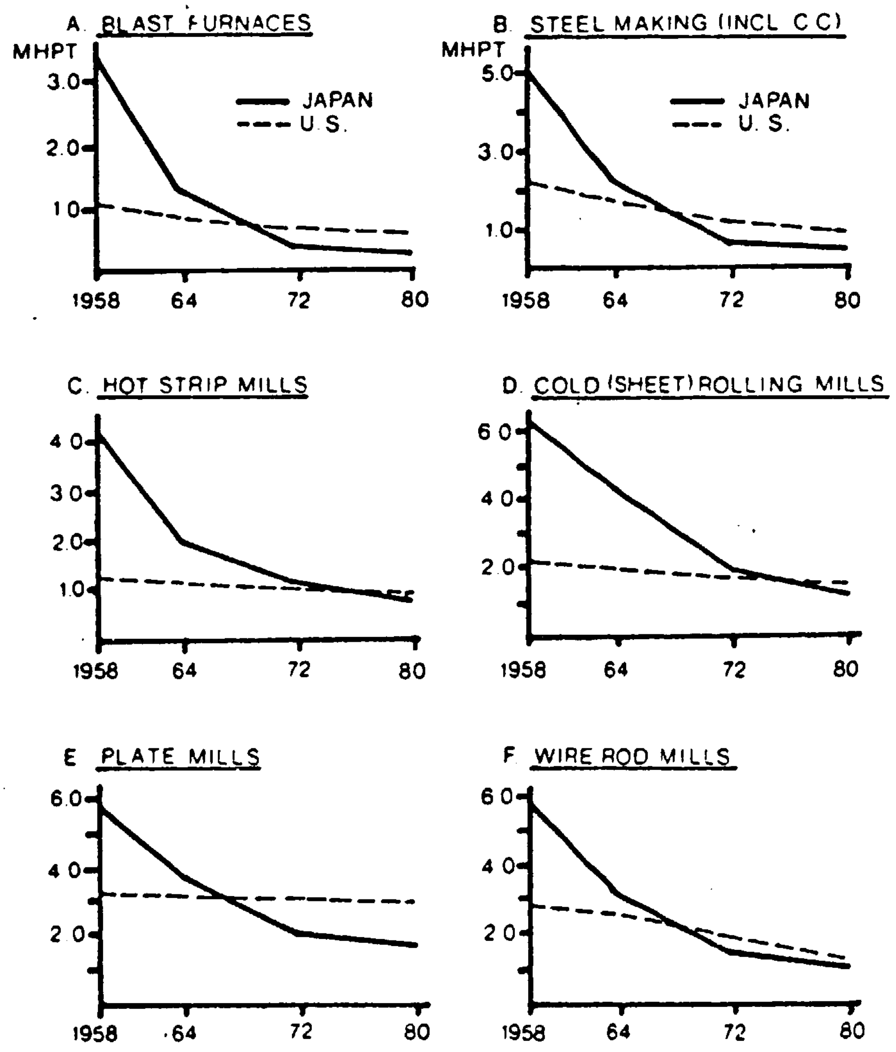
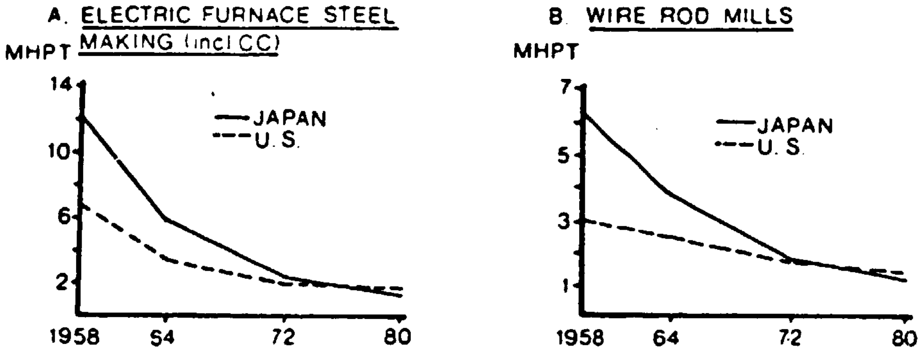


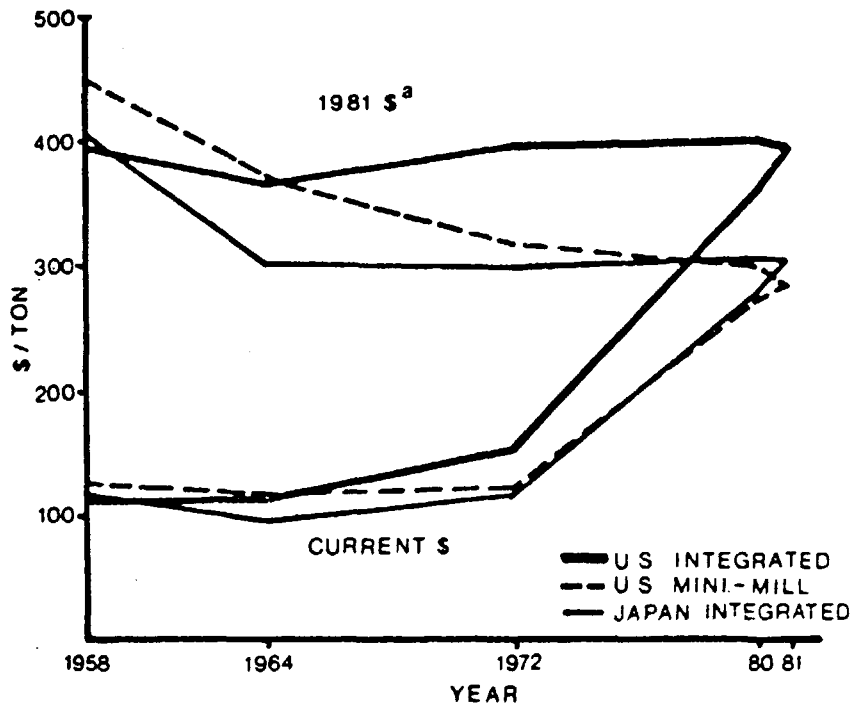
Figure 9

EVOLUTION of PRODUCTIVITY (MHPT i.e. Man Hour Per Net Ton)
by PROCESS in MINIMILLS from Barnett and Schorsch (2)



EVOLUTION of PRODUCTION COSTS for WIRE RODS

from Barnett and Schorsch (2)
(in 1981 US dollars (a) per net ton of 907 kg)



a. Converted from current to 1981 dollars using the Producer Price Index for Industrial Products of the U.S. Department of Labor, Bureau of Labor Statistics.