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PLANT LOCATION AND COST ASPECTS OF INTEGRATED STEEL PLANTS IN DEVELOPING COUNTRIES[1]

by

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SUMMARY

The consumption of enormous amounts of raw material and energy as well as the large scale of production facilities is the feature of the steel industry. For this reason we have to take into consideration various factors in deciding a plant location of the steel industry. It is quite obvious that plant location affects the economy of steel mills.

First, the availability of land affects the total construction cost of a steel mill. In general, the unit site cost of a steel mill in a developed region is higher than that in an undeveloped region because the unit price of land is lower in an undeveloped region. The ground conditions such as load-bearing force and its distribution put great influence on a site-work cost.

Secondly, the access to industrial water sources is an important factor. Sometimes, the construction of a dam and a pipe-line is required, leading to higher water cost. Thirdly, integrated steel plants have to be located near a powerful distribution system of electricity, otherwise a power-grid need to be newly constructed.

Fourthly, in order to ensure lower maintainance cost, it is

preferable to locate a plant at a site near industrial regions. A location in an industrial complex, where power stations, refineries, and petro-chemical factories are in operation, is the best. Fifthly, the port condition has to be checked from the viewpoint of ensuring low transportation costs.

Raw material condition is the most crucial factor for a site planning. Generally, it is advised to locate a plant near a rich domestic ore source. Other problems arise when the combined use of imported and domestic raw material is required. In this case, checking on the price advantage and the operation result is of great importance. Finally, it has to be remembered that sometimes the products transportation cost has a decisive influence on the competitiveness of a plant.

The consumption of enormous amounts of raw material and energy as well as the large scale of production facilities are typical features of the steel industry. For this reason we have to take into consideration various factors in deciding a plant location of the steel industry. It is quite obvious that the plant location affects the economy of steel mills. However, we can not find easily the general rule which explains the quantitative relationship between economy and plant location. In this paper I have tried to analyze such problems with some data from Japan and a few developing countries with which Japan has established technical co-operation.

1. Availability of Land

It is well known that an integrated steel mill needs a vast area of land, and the first step for a site planning is to secure a necessary land. Recent technological progress has reduced necessary space per unit annual crude steel production, and now it is around 0.8 M^2/T compared with 3 M^2/T in previous days. Table 1 shows some examples in Japan. M^2/T varies with such factors as product-mix and sizes of production facilities. Larger blast furnaces and rolling mills as well as the specialization for flat rolled products lead to smaller space.

In estimating necessary space, land for waste disposal, satellite industries, and social facilities such as houses should not be overlooked. Integrated steel mills produce a great deal of waste such as slag (Table 2) and land for its disposal has to be secured beforehand. In Japan slag is

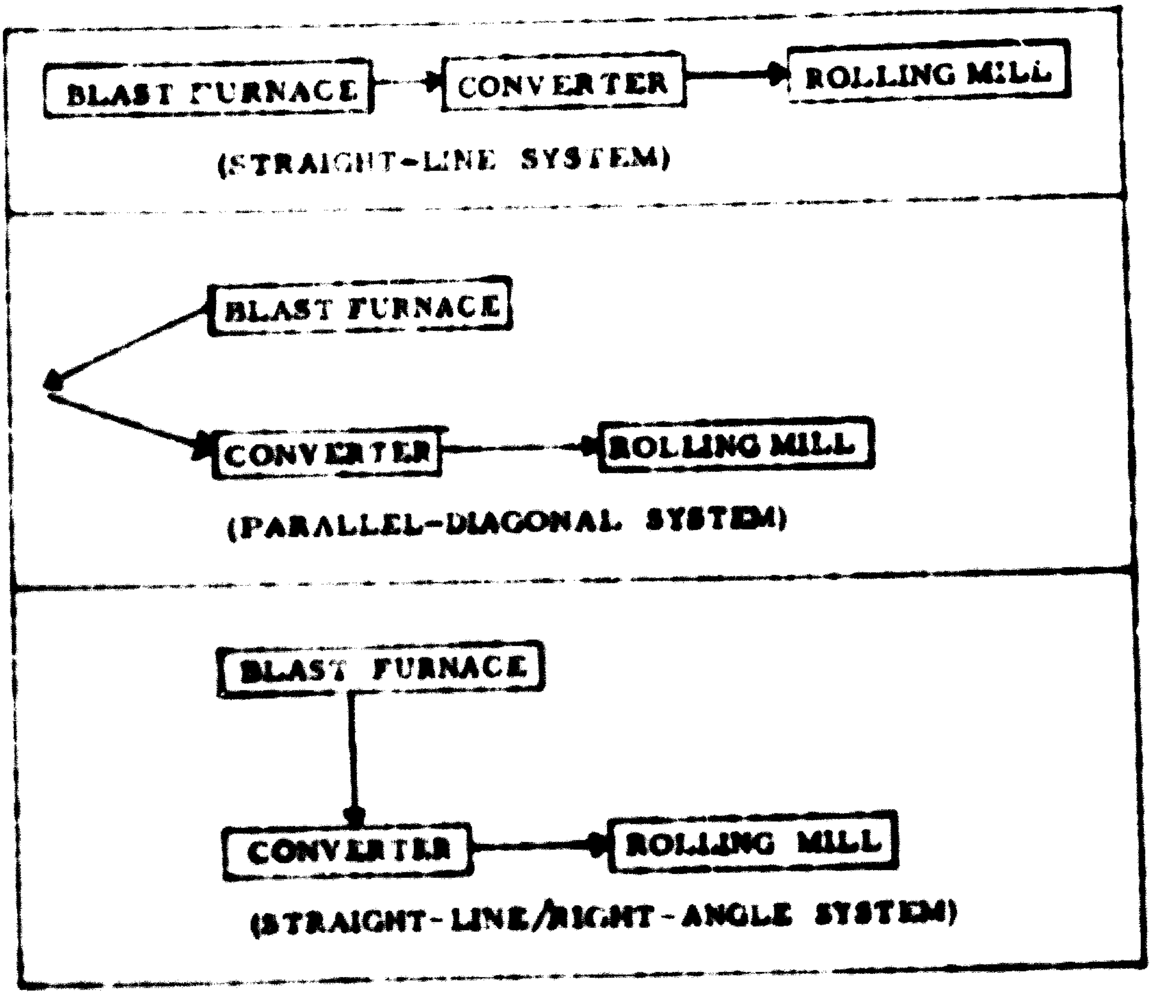
Table 1. Site Space of Steel Plants in Japan.

Site	Crude Steel production 1000 t/year	Area 1000 m^2	Area/production m^2/ton
A	3,653	8,464	2.32
B	1,084	3,509	3.24
C	4,326	5,009	1.16
D	7,489	7,138	0.95
E	4,517	2,554	0.57
F	11,120	8,142	0.73
G	5,716	4,146	0.73
H	7,629	8,086	1.06
I	5,895	4,904	0.83

Table 2. Solid Wastes from a Steel Plant

type of waste	waste production (ton/ton product)	total waste production (10^6 tons/year)	volume (10^3 m^3/year)
blast-furnace slag	0.4	pig iron 2.3 x 10^6 tons x 0.4 = 0.92	660
waste from coal	0.1	pig iron 2.3 x 10^6 x 0.1 = 0.23	230
steel-making slag	0.07	steel 2.5 x 10^6 x 0.06 = 0.15	120
other slag		0.30	210
total		1.60	1220

Figure 1. Layouts of Integrated Steel Plants



widely used in reclamation and future expansion of a plant is made on reclaimed land. However, reclamation is being restricted gradually from the view-point of pollution prevention in the sea. Accordingly the utilization of slag(e.g. as a substitute for construction material) is becoming a urgent problem because of the shortage of land for its disposal. We have to take into consideration land for satellite industries or houses, etc.,when a plant is located in an undeveloped region distant from an urban and industrial area. For example, land for satellite industries reached about 60% of the total area of a steel mill in an Asian country.

As for physical conditions (Fig. 1), not only area but also shape and load-bearing force of ground are the important factors. The shape of the land controls layouts of a plant There are several types of layouts of a steel mill and,in any case,extremely oblong or round land is not suitable. Large load-bearing force is needed for blast furnaces and hot stoves. In case of a deep load-bearing sub-surface, the very heavy foundation necessitates large load-bearing force. In excavations of 20 to 30 M in depth a load-bearing force need to be over 50 T/M^2 (Table 3) to support the vertical load of a blast furnace and its foundation. In addition the biased pressure caused by the horizontal load such as from winds or an earthquake has to be added,leading to total load-bearing force of more than 100 T/M^2. Normally a blast furnace is enlarged at a time of relining, and this should be taken into account beforehand.

Table 3. Load-Bearing Force in a Site of a Steel Plant

Type of Equipment	Load-Bearing Force (T/M^2)
Blast Furnace & Hot Stove	100 ~ 120
Oxygen Converter	30 ~ 60
Rolling Mill	20 ~ 40
Raw Material Yard	15 ~ 20
Products Yard	15 ~ 20
Others	5 ~ 10

Table 4. Water Consumption in a Steel Plant with the Capacity of 2.5 Million Tons per Year

Equipments	Sea Water (M^3/D)	River Water (M^3/D)	Recycling Ratio (%)	Net Input of River Water (M^3/D)
Blast Furnace	235,000	19,500	80	3,900
Coke	26,000	2,500	-	2,500
Sintering	-	5,800	-	5,800
Converter	-	23,500	75	5,900
Blooming	-	62,500	80	12,500
Hot Rolling	62,500	155,000	80	31,000
Cold Rolling	-	69,000	60	27,500
Others	-	5,300	-	5,300
Loss	26,500	5,600	-	5,600
Total	350,000	348,700	71	100,000

As mentioned above, site conditions in the steel industry are affected by various factors such as land space and other physical elements. Therefore, in some cases, a total land cost occupies a considerable part of the total construction cost of a plant. In an undeveloped region the unit price of a land is comparatively low, whereas the unit site work cost is high and more land space is required for satellite industries. However, the unit land cost in a developed area is in some cases higher than that in an undeveloped area as the unit price of a land is remarkably high. In Japan the total land cost occupies 4 to 7% in the total construction cost of a plant. On the other hand, the corresponding figure in a South American country was under 1%.

It is common that a coast-located plant is constructed on reclaimed land. In that case, reclamation cost is affected by depth of water, cost of dredging, and cost of earth (mainly transportation cost) etc. The reclamation cost in the past was about 5 to 10 dollars per M^2 in Japan. In relation to site construction it has to be remembered that ground condition affects site work cost considerably. It is desirable that a large load-bearing force is ensured for a particular facility and a load bearing sub-surface with the strength of 30 to 50 T/M^2 exists over a wide area at a shallow depth. If a silt layer with fine sand particles is thick, it will take longer until it becomes stable, thus causing a longer construction period and a higher cost. Further, a less stable ground necessitates a larger number of piles for foundations. For example, about 8000 steel pipe piles and 25000 concrete piles were used in a steel plant in Asia. Factors such as a climate, snow, flood, and ice etc. also affect a construction cost. A longer rainy season tends to cause a longer construction period.

2. Industrial Water

It is well known that an integrated steel plant uses a great deal of water. The unit consumption of water in a plant differs according to scales of facilities, types of mills and percentages of recycling water, etc. The quantity of water for 2.5 million tons of crude steel production is shown in Table 4 as an example. In general 50 to 60% of water is supplied from the sea and the rest from rivers. However, inland steel plants are forced to use river water only. In this example, the percentage of the recycling water is 71%, but recent practice in Japan is more than 90%.

The measures for a dry season have to be planned. It is advisable to check whether water flow is enough or not in a dry season by investigating the past statistics on flow of rivers and underground water. In order to meet 5 million tons of crude steel production, a minimum water flow of 1 M^3/sec is required. Further, considerable load fluctuation in a steel mill is observed, leading to the necessary water flow of 1.2 to 1.3 M^3/sec. At the same time, water for irrigation should be taken into account. Therefore, taking these factors into consideration, flow of more than 2 M^3/sec is often required, even in a dry season.

If such amount of water flow is not available, it will be necessary to build a dam. The scale of a dam can be estimated by necessary quantity of water flow for industries and irrigation, as well as the duration of a dry season. Therefore, in selecting a site of a steel mill, the flow of rivers and the feasibility of a dam construction has to be considered.

The cost of the industrial water varies with the construction costs of a pipe-line and a dam. In Japan the industrial water supplied by newly constructed facilities costs more than 3 cents/M^3, whereas in an Asian country about 1.5 cents is achieved through government grants for the construction of pipe-lines and dams. Thus, the government expenditure on construction of water supply facilities in line with the investment policy for infrastructures is often indispensable, otherwise the cost of the industrial water becomes a heavy burden on a steel plant.

As for dam construction cost, scale as well as geographical and geological condition are the important elements. A pipe-line construction cost varies with the distance from a water source and a route condition. Table 5 shows an example in an Asian country.

3. Power Supply

Electricity consumption per ton crude steel has increased from the past level of 200 to 300 kWH up to around 400 kWH. In an integrated steel plant about 50% of necessary electricity can be supplied by the works power station which makes use of the by-product gas, and the rest from a power-grid. Taking load fluctuations into consideration, on an average, an integrated steel plant with a crude steel production capacity of 2.5 million tons per year has to be equipped with a works

Table 5. An Example of the Construction Cost of Industrial Water Supply Facilities

Item	Specification	Cost ($ 1000)
Dam	capacity: 130 thousands tons/day type: earth dam	4350
Pipe-Line	length: 17 KM	1500
Pump	500 HP x 4 300 HP x 3	600
Design Fee		12
Total		6462

power station of 100 MW and the supply of 100 MW from a power-grid

Therefore, integrated steel mills should be located near powerful distribution systems of electricity, otherwise a power-grid of long distance has to be newly constructed The construction cost of a power-grid is influenced by such factors as the distance, the capacity, the voltage and the route condition. Table 6 shows an example in Japan. In developing countries, these routes are often forced to pass through forests and mountainous areas, causing a comparatively high construction cost

4. Access to Industrial and Urban Regions

As mentioned above, an integrated steel plant needs huge amounts of raw material and energy like iron ore, coal, electric power and oil, etc , and produces various types of by-products Accordingly if an integrated steel plant is located in an industrial complex where power plants, oil refineries, and chemical factories are in operation, economies in a power transmission and oil transportation can be achieved and coke-oven gas can be valued as a raw material, not as a fuel. For instance, as an integrated steel plant with a capacity of 2 5 million tons per year uses roughly 0 3 million tons of fuel oil in a year, the cost saving can be around 1 million dollars assuming that the transportation cost of fuel oil is 3 dollars per ton. Figure 2 illustrates an example of an ideal industrial complex.

The access to industrial regions also ensures a lower maintainance cost whereas stellite industries have to be newly established in an undeveloped

Figure 2 An Example of Industrial Complex with a Steel Plant

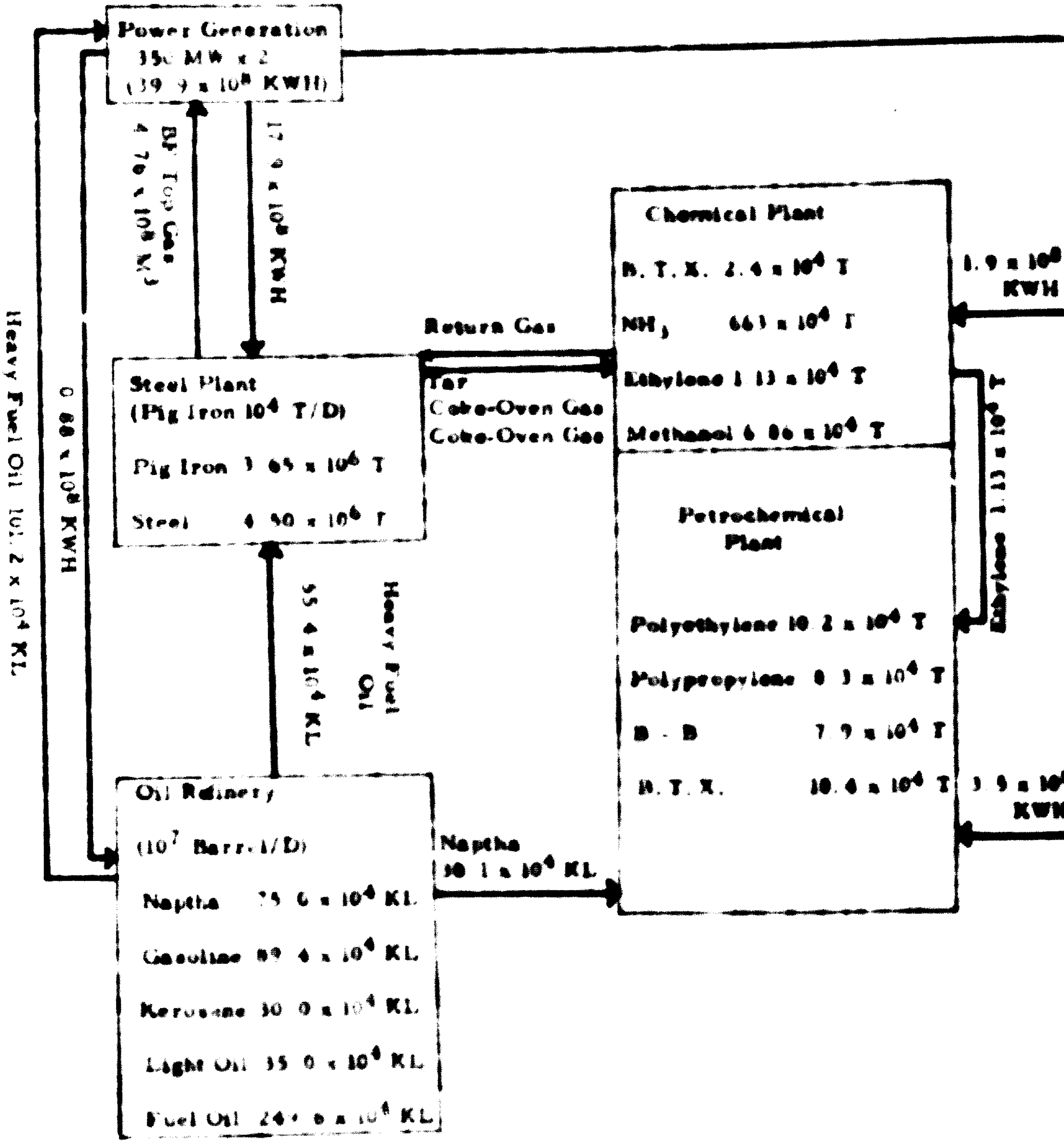


Table 6 Construction Costs of Power Grids in Japan

Case Item	A	B	C
Voltage (KV)	154	220	275
Distance (KM)	48	61	64
Average Span (M)	297	300	360
Construction Cost ($ million)	4.2	7.3	14.8
Unit Construction Cost ($/KM)	87	132	231

Table 7 An Example of the Construction Cost of a Port for a Steel Plant

Item	Specification	Cost ($ million)
Facilities	Berth 2400 M (-14.5M) Break-water 3300 M	23.5
Dredging	Earth Volume 17 million M^3	34.5
Total		58.0

region, leading to a higher maintenance cost. The maintenance cost per ton of products in Japan is now in the neighbourhood of 10 dollars. The construction of social facilities such as houses, schools, and hospitals is another problem. About 6 to 7000 employees are required in a steel plant with a capacity of 2.5 million tons per year and about the same number of employees are required in its satellite industries. This means that a town of 30 to 40 thousands people has to be created at the same time as a steel plant is constructed in an undeveloped region. For example, a company in a South American country paid about 10% of the total construction cost for the town planning for which a government is responsible in most cases.

5. Port Condition

It is known that the port condition affects the sea transportation cost of raw material because the more distant a raw material source is located, the bigger advantage is obtainable by a large vessel (Fig. 3). Harbour size and depth are significant factors in deciding location.

As for size, corresponding to a production plan, the optimum unloading capacity can be decided, from which the sum of unloading costs and waiting costs of ships is optimized. The load handling capacity per meter of a berth is roughly 6000 tons for raw material and 3000 tons for products. Size of harbour is affected by not only load handling capacity but such factors as tide, wind, wave and sand drift etc.

Harbour construction cost varies with geological condition and

Figure 3. Relation between Freight and Types of Ore Carriers

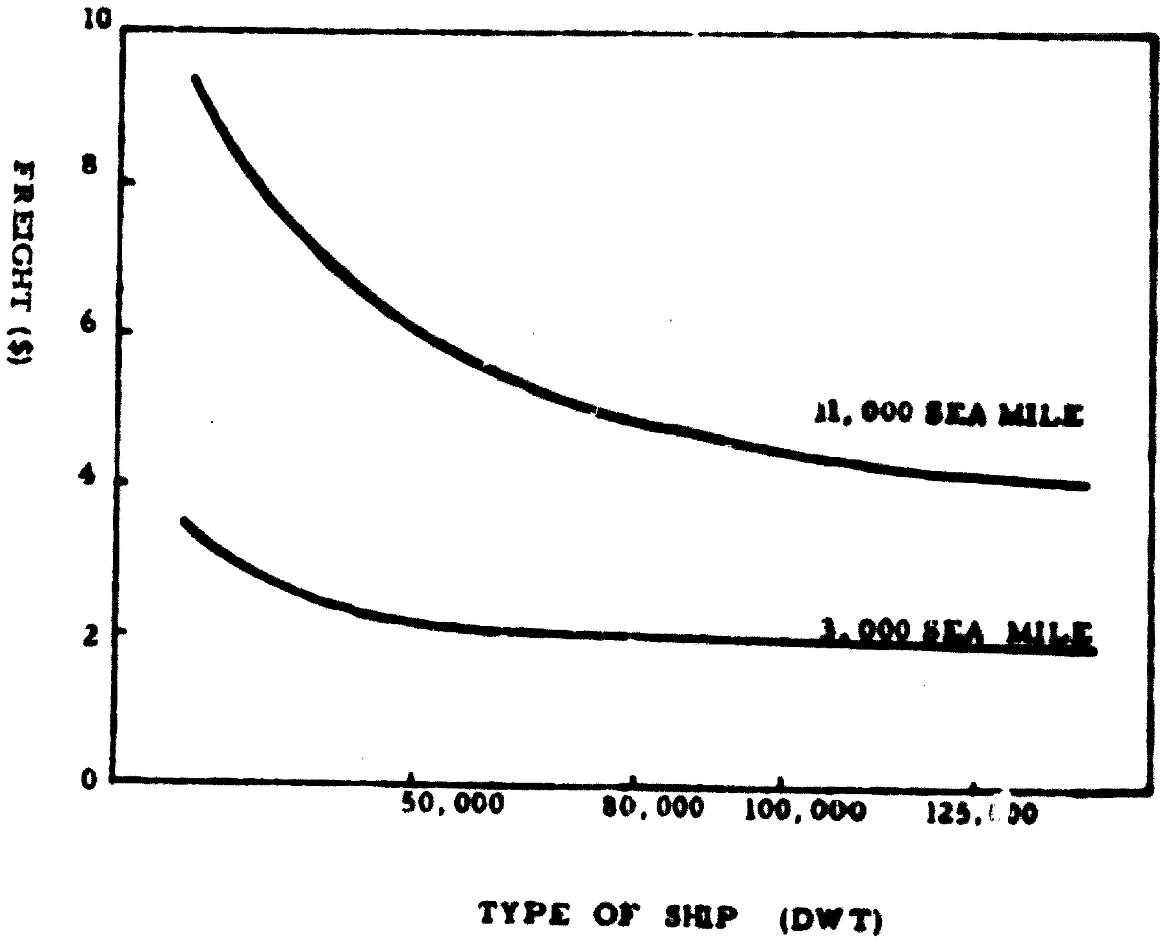


Table 8 Comparison of Pig Iron Production Cost

Country	Pig Iron Cost (Mark/ton)
An African country	67
Australia	75
Brazil	91
Liberia*	109
Europe	130
Japan	130

Source Schmalen Bache Zeitschrift für
Betriebswirtschaftliche Vorschung
(Apr 1969)

* Theoretical [UNIDO note]

Table 9 Types of Products Transportation in Japanese Steel Industry

(unit: %)

Ship					Railway	Truck
Sub-total	Large steel ship	Small steel ship	Wooden ship	Barge		
18.5	3.1	12.2	1.4	1.8	3.0	78.5

a volume of dredging which is proportional to size and a depth. The use of large dredgers and special construction methods such as under water blasting is necessary in constructing a deep harbour because hard rocks tend to be found at a depth. Table 7 shows an example of a construction cost of a harbour in an Asian country.

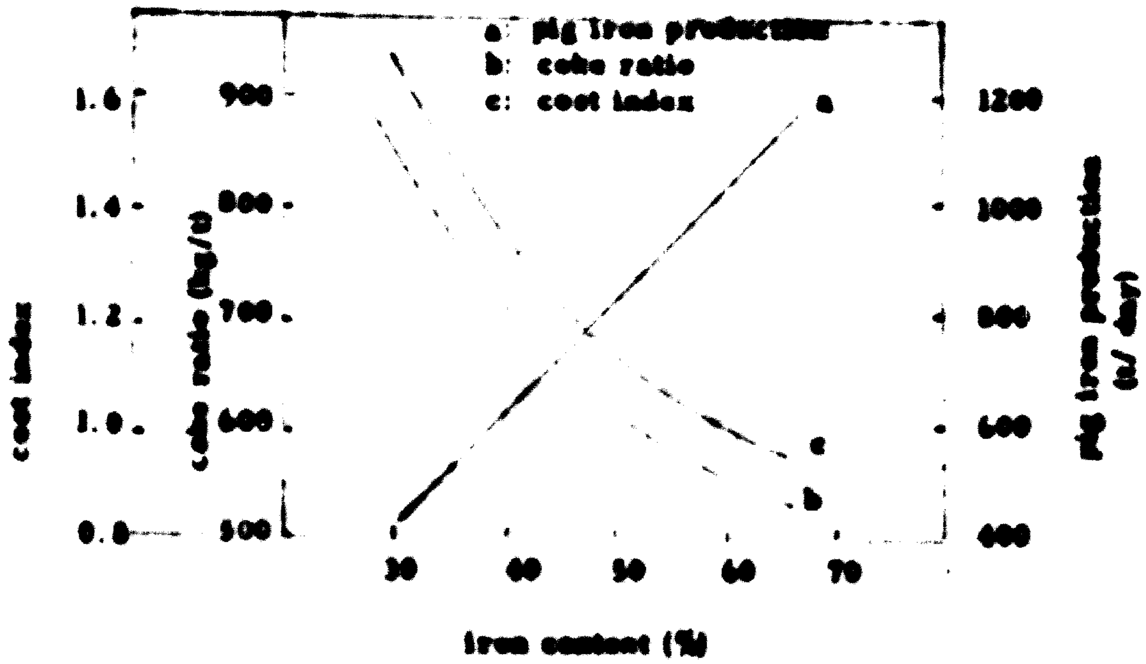
6 Raw Material Condition

Raw material condition is the most essential factor for site planning. In the past most steel plants were located near raw-materials sources in main steel-producing countries including Japan. However, the technological innovation in the ship building industry in 1960s has renewed the idea of site planning in the steel industry.

Generally there are few cases that iron ore and coal both of a good quality are produced in the same region, or even in the same country. Accordingly it is normal practice that steel plants are located in the neighbourhood of a region producing raw material of one kind and raw material of another kind is imported. Recently most steel plants in developing countries have been located near regions producing iron ore of a good quality. It can be noticed that in countries with rich iron ore resources the low production cost of pig iron is achieved through the advantage of cheap iron ore, which offsets various disadvantages in other conditions. This tendency is illustrated in Table 8.

A problem is raised in using poor domestic iron ore. The cost comparison between imported iron ore of a good quality and domestic

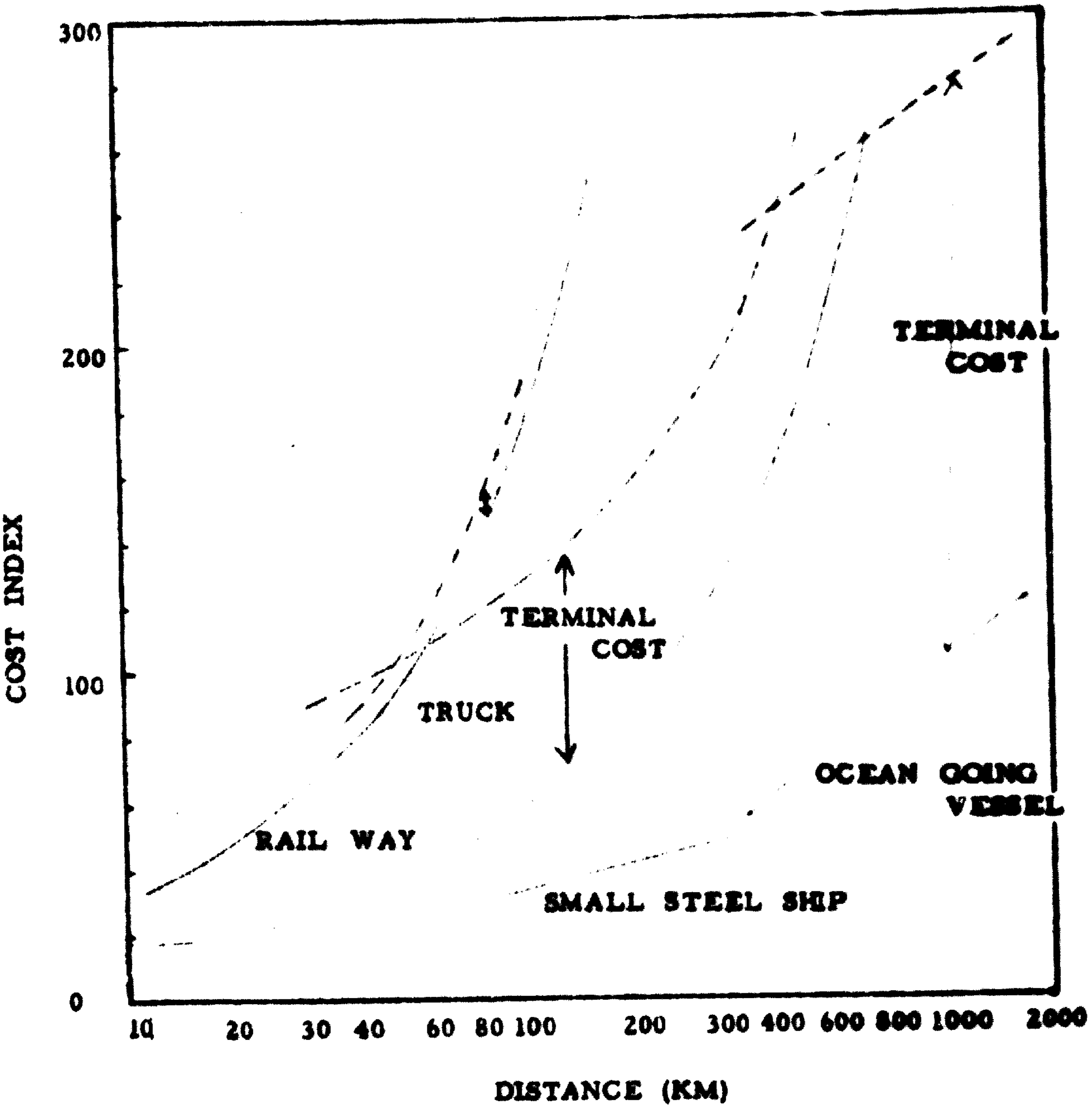
Figure 4. The Relation between Iron Content and Pig Iron Cost



ore is a basic factor for a choice. Use of poor iron ore causes an increase in slag volume and coke consumption, thus leading to a decrease in productivities of blast furnaces and a higher energy cost. It is a question whether such disadvantage can be offset by an advantage of a price of unit Fe content. Figure 4 shows a model of such relationship based on Japanese conditions. Generally coke price, depreciation cost, and wages affect the relationship. The same can be applied for a coal. As coke consumption changes with ash content, a comparison between cheap but poor domestic coal and expensive but good foreign coal has to be made. Assuming that ash contents of 15% and 10% corresponds to coke consumptions of 700 kg and 500 kg per ton pig iron respectively and standard coke cost is $35/ton, the difference in pig iron cost is $7, which can be assessed by the price difference between domestic and imported coal. The strength and the content of volatile material have similar effects. It is noteworthy that sometimes the blending of imported and domestic coal produces better results than the use of one kind only. For instance, a steel plant in a South American country, which was originally designed to use domestic coal mainly, has remarkably improved its operating results through the blending of more coal from the United States.

Finally, it has to be admitted that the cost aspect mentioned above is only a part of the problem and the aspect of the balance of international payments should be checked on the stand-point of a national

Figure 5. Product Transportation Cost by Types of Facilities



economy. There can be cases where the use of domestic resources of comparatively high cost bring about a better performance of a national economy from the view point of long term and dynamic effect. In any case, if the combined use of domestic and imported raw material is necessary, plant location will be influenced by such elements as the cost benefit of domestic raw material, the percentages of imported raw material, and the internal transportation cost.

7. Products Transportation

Heavy weight is a feature of steel products and transportation costs of products play a major role in market competition. In fact it was noticed in an Asian country that the internal transportation cost is so high that the products of a steel mill planned to be located in an undeveloped region was considered not to be competitive with imported products. This was because the infrastructure such as ports and railways was not well established.

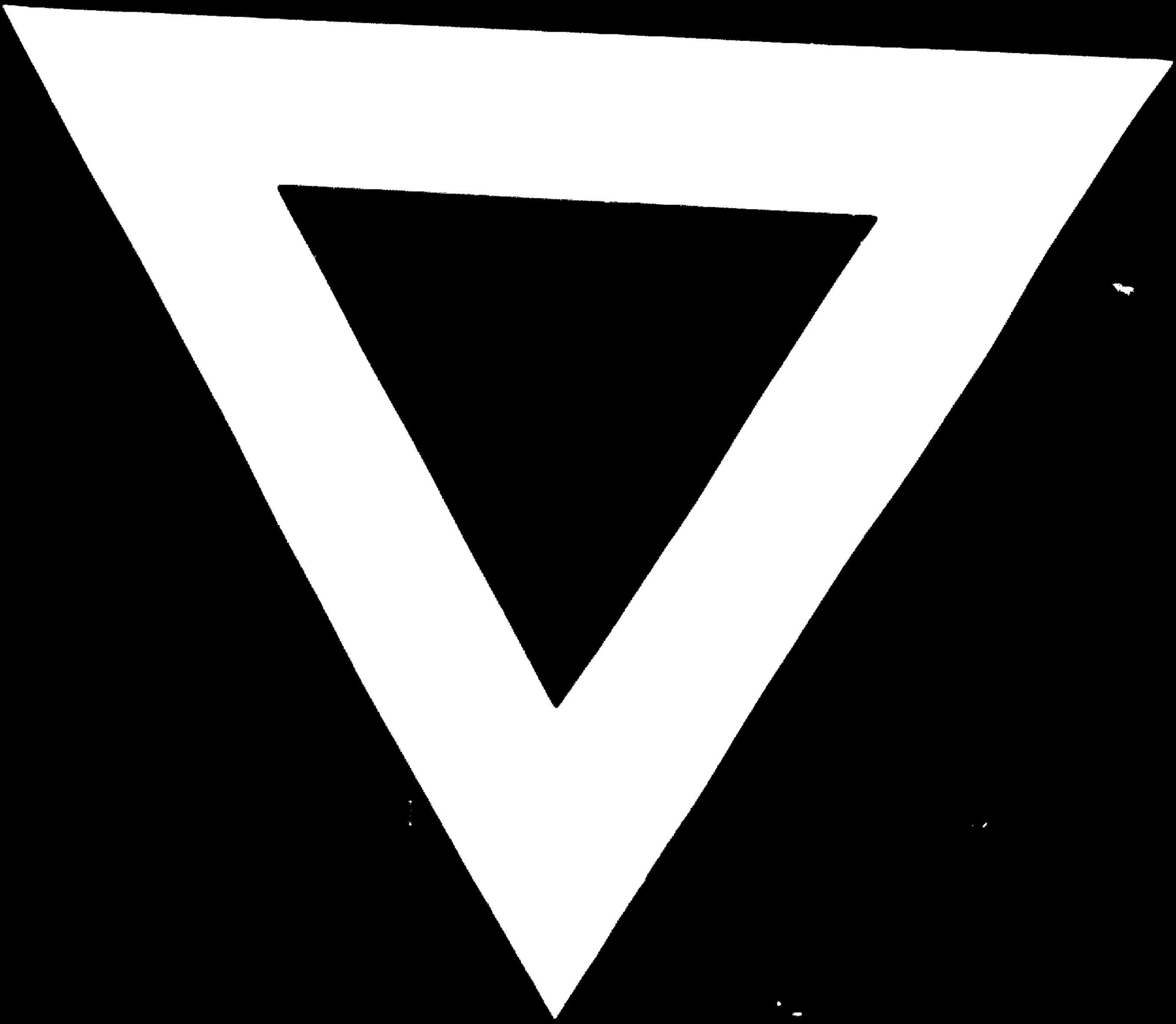
As for the most suitable type of transportation, it differs according to plant location. Table 3 illustrates the different types of transportation used in Japan. Generally railways are of great advantage for long distances and vehicles are preferable for short distances. In any case, terminal costs account for a large portion of total transportation cost, so that it is advised to minimize the times of unloading and loading. For this reason pusher barge systems or lighter aboard ships are being in widespread use.

Finally it has to be remembered that sometimes transportation costs of products have a decisive effect on the competitiveness of a plant.

8. Summary

As mentioned above, the factor of plant location exercises a large influence on construction and running costs of a steel mill. However, the factors which affect such a problem are so complicated that it is not easy to make a simplified model to illustrate this relationship quantitatively. Therefore it is normal practice that several locations which meet the physical requirements are selected as a first step and the cost comparison is applied to them to choose the best location.

Finally, it must be borne in mind that the geographical distribution of steel plants in a country should be planned from the point of view of the national economy. For example, whether one plant with the capacity of 10 million tons per year is more preferable than four each with 2.5 million tons is not a simple problem. Such elements as the size of a country, geographical distributions of raw material, transportation facilities, and even social problems exert a major influence on it.



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