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STATIC AND DYNAMIC METHODS FOR THE STUDY OF FACTORS INFLUENCING THE CHOICE OF LOCATION[1]

by

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SUMMARY

As a result of competition in the iron and steel industry, production capacity in recent years has been outrunning steel consumption by about 100 million tonnes a year. This has led to a considerable disturbance in the balance between supply and demand. The European steel industry has adopted the following strategies to counter the resulting decline in their profits :

a. Changes in production techniques;
b. Amalgamations;
c. Relocation.

The purpose of this study is to formulate the most important input data for the choice of an optimum location from the commercial point of view, independently of national economic policy objectives.

Only essential and quantifiable factors have been taken into account. Many other factors, such as manpower requirements, climate, nature of ground, infrastructure, etc., have been ignored.

Among the quantifiable factors to be considered is the question of the market outlet, including the place of consumption, the volume of finished products required there, and the distance from the market outlet to the point of production. When the market analysis has been completed, the data obtained are used to draw up a possible marketing programme. When this programme has been worked out, a hypothetical production programme is drawn up based upon it. This in turn serves as a starting point for determining what installations will be needed.

The next step is to obtain the capital needed to equip the plant. This includes not only machinery, services, etc., but also the whole investment programme that must be carried out in order to make production possible.

In order to establish the difference in cost between two locations, the cost of each must be calculated separately. This means building up volume charts, calculated separately for each stage of production, which are then costed on the basis of current prices to obtain the production costs applicable to a given location.

Finally, in order to determine the most favourable location, the cost of transporting the products to the market outlet must also be taken into consideration.

In the first step of this procedure, it is assumed that economic conditions at the alternative locations remain constant : the calculation involved is purely static.

In order to determine the optimum long-term location, however, the factors liable to vary in the course of time and their different behaviour at various locations must be quantifiable. The report therefore goes on to give a brief description of a calculation model which makes it possible, using dynamic methods of calculation, to quantify the long-term advantages to be derived from a given location.

This type of operation is extremely laborious, and is therefore only used when there is a reasonable certainty that essential changes in the various location factors can be expected over the years.

These theoretical considerations regarding location comparisons are followed by a model global analysis of the comparative advantages of Venezuela, Brasil, Liberia, South Africa, and Australia as alternative locations in relation to the western part of the Ruhr (Federal Republic of Germany).

1. Introduction

During the last ten years, the question of optimal location for a fully integrated iron and steel plant has increasingly been raised and discussed in the iron and steel industry. The discussion of the problems involved was not merely confined to the European countries because, owing to the rapid spread of know-how in bulk steel production, steel has become a product which can be and is being made all over the world. The reasons leading to new thinking on the problem of where to establish plant are various. Some of these can be explained in micro-economic terms, as is done in the following.

The post-war period saw an unusually rapid increase in world steel consumption, which could not be met by the existing production capacity at first. This great steel consumption was due to an above-average pent-up demand and, later, to continuing industralisation, Naturally, this great unsatisfied demand led to a typical seller's market, thus inducing the sellers to extend their plant and to adapt them to the level of demand. In this context, it is worth noting that it was not only the traditional steel-producing countries which expanded their production capacities, but that further countries established steel production. Thus, we can nowadays see some 2o countries producing approximately 9o per cent of the world's crude steel, whereas, 5o years ago, this percentage was produced by only five countries.

All industrial nations, of course, base their planning on the desire first to supply their home markets and secondly to gain a high share in the export market for meeting world demand.

This competition led to the increase in crude-steel capacity running ahead of steel consumption by some 1oo million tons of crude steel per year, thus disturbing the balance between production capacity and consumption. This change in the market situation and, with it, the change from a seller's to a buyer's market exacerbated competition between those offering steel in all world steel markets. The result of this competition were substantially lower revenues for all sellers and, consequently, lower profits.

Along with this worsening of the steel market position we can note a development which narrowed the steel market from another angle. The research findings of other industries and their expansion (see Fig. 1), e. g. the chemical industries, made it possible for steel to be expelled from traditional areas of consumption by substituting it with more and more improved products. 3o years ago, reinforced-concrete bridges were rare, whilst nowadays it is difficult for steel to struggle against this competitive product. Figure 2 shows that the process of steel being substituted by such competitive products has by no means been completed, which means that we must certainly make some mental efforts to meet this competition.

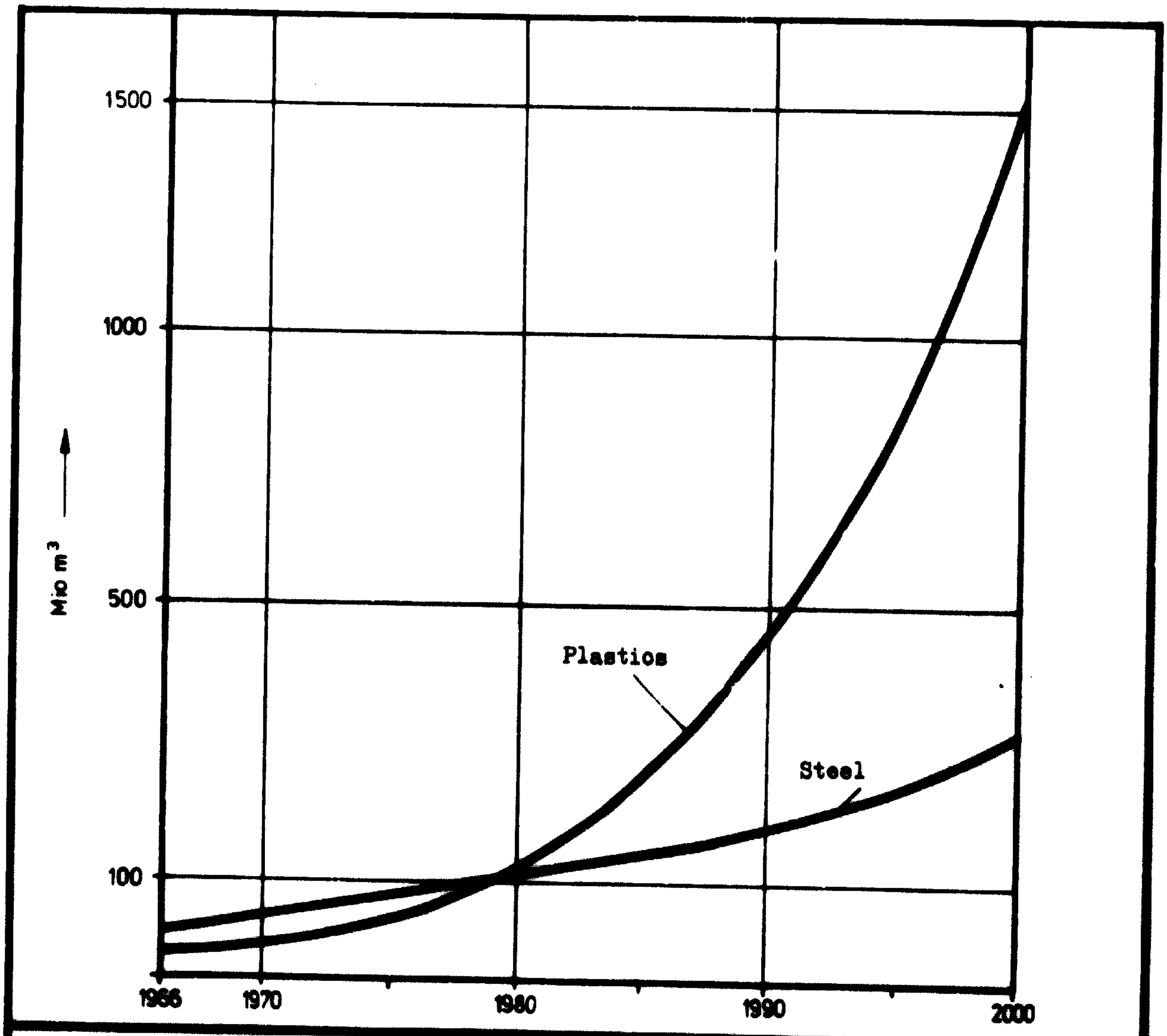
If we look at the reactions of the European steel industries to the above developments and tendencies, we can see certain strategies, which are described in the following in a somewhat simplified way.

1.1. Changes in the production process

In order to bridge the widening gap between costs and revenue, every effort is being made to increase the efficiency of existing plant in order to reduce costs. For a simple example, we refer briefly to the blast-furnace sector, where, as a result of fully prepared ore, by means of injecting O_2, reformed gas, oil etc., as well as by using high pressure at the top, costs have successfully been lowered.

Another, even more revolutionary improvement can be noted in the steel-production sector, which has seen the introduction of the oxygen blast process. Figure 3a shows how the oxygen blast process overtook the traditional steel-making methods in the sixties. Whereas, in 1957, one LD converter, with a tap weight of

Fig. 1 Probable development of world consumption of plastics and steel, 1966-2000



Rate of growth of steel consumption 1965-1980 in per cent per year.

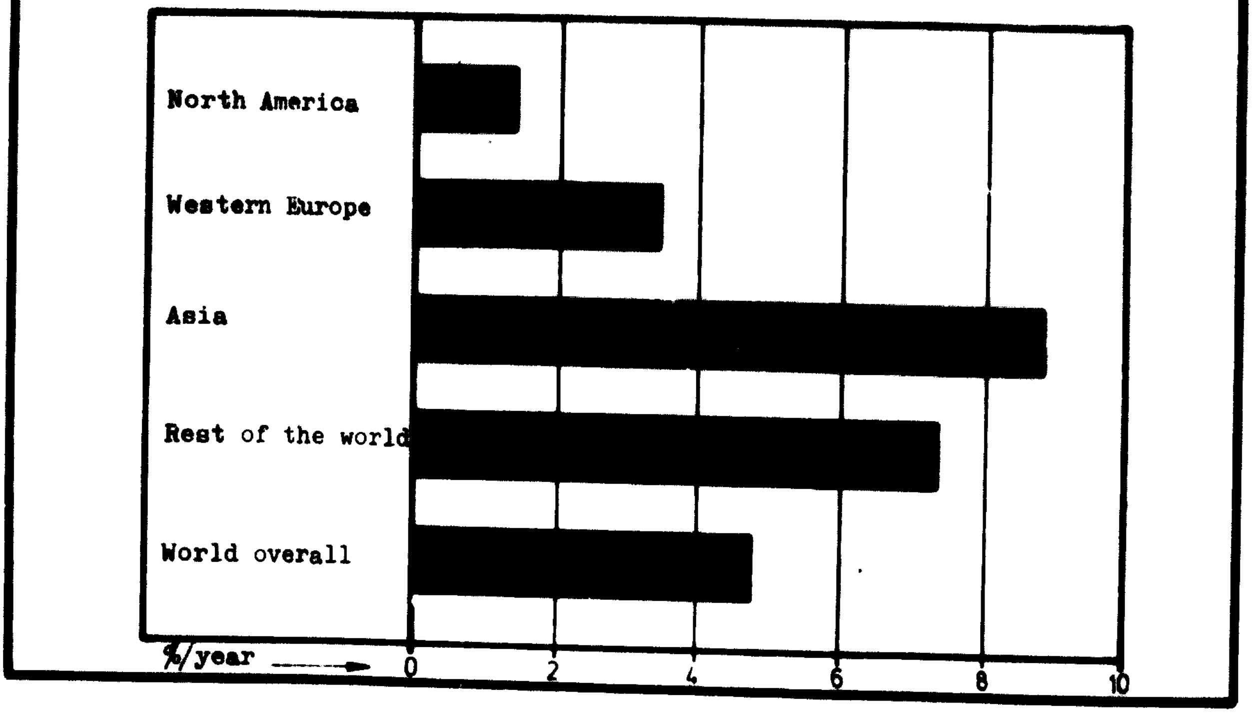
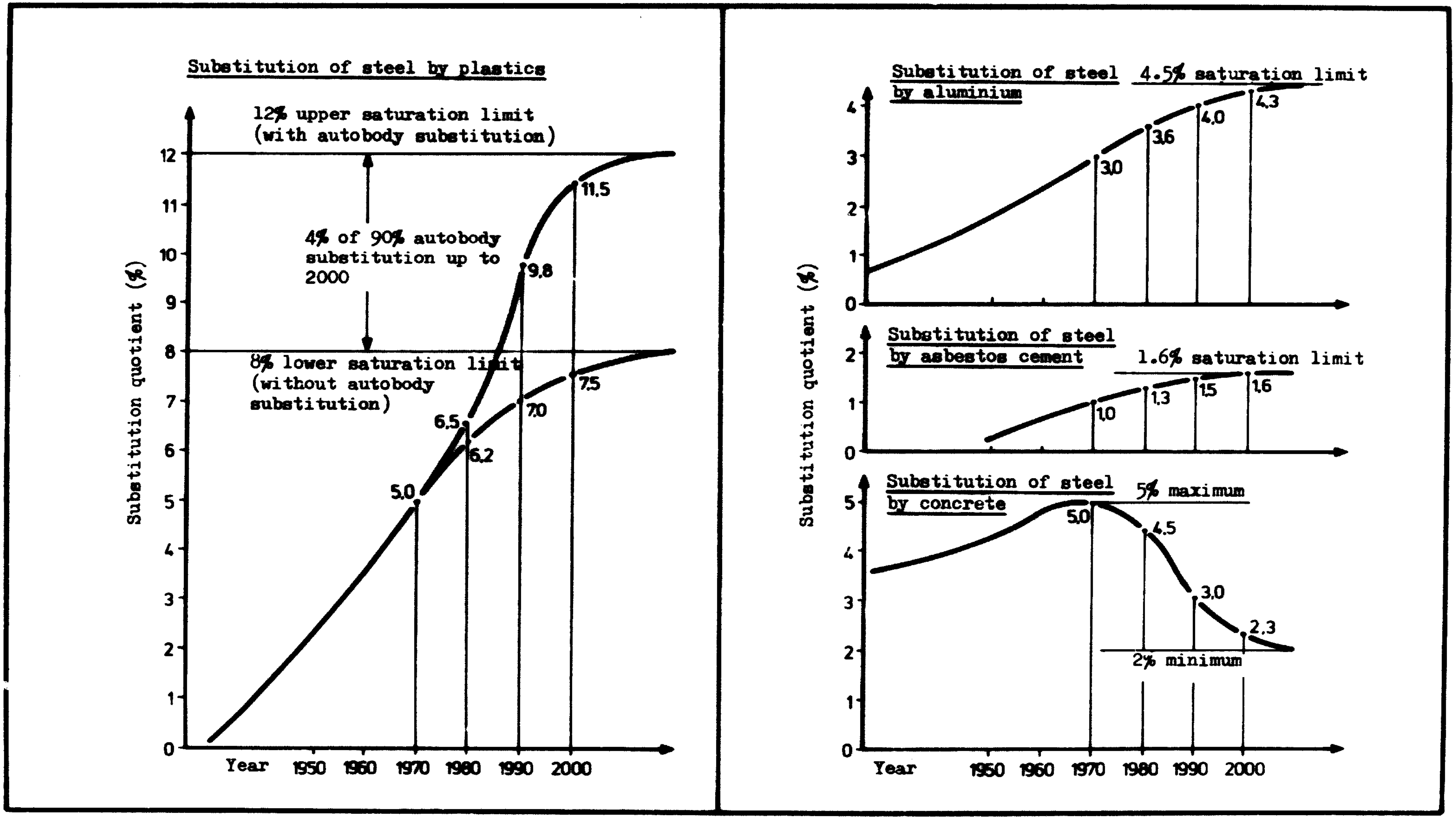


Fig. 2 - Substitution of steel by plastics, aluminium, asbestos cement, and concrete



4o tons, was erected in the Federal Republic of Germany for the first time, the tap weight of the largest converter has increased to 4oo tons today. The difference in productivity can best be illustrated by pointing out that a 25o ton converter in action produces the same amount of crude steel as 8 open-hearth furnaces with a tap weight of 3oo tons.

The increasing introduction of the continous casting process to avoid the production stages of casting bay, soaking pits, blooming or slabbing mill, as well as the efforts to achieve direct reduction, are only briefly mentioned in this context.

1.2. Mergers to form large production units

The increased output was largely due to technological progress in the fields of processing, which provided us with blast furnaces with hearth diameters of 14 metres, LD converters with a tap weight of 4oo tons, blooming mills with an annual throughput of 5 million tons of crude steel. The investment required for such plant and the necessity of making full use of them in order to utilize the advantage of fixed costs degression frequently exceeded the scope of existing enterprises. It was, therefore, a logical consequence for some firms to merge in order to form larger enterprises.

1.3. Changes in location

In the past it was most advantageous for smelting plants to be established on a coal or ore basis, where the transport costs of coal or ore were minimal. In Western Europe there are still numerous examples of such plants, although there have been closures. In the Ruhr and Saar districts, several such plants were established in the immediate vicinity of coal mines, whereas in Lorraine several plants were built in an iron-ore district. Later, after the discovery and development of overseas coal and iron-ore deposits - the latter proved to have a higher Fe content than the European ore used so far - and after a substantial reduction in sea transport costs due to bigger ships, other locations became more favourable than the traditional ones. A site on the coastline of one of the world's oceans was preferred, provided big ships could reach it. In the past decades, this obvious "move to the coast" is a characteristic feature of new iron and steel plants in Western Europe. 1)

2. Theoretical approaches to the siting problem

Against the background of growing industralisation and increasing competition on common sales markets the problem of optimally siting its plants is becoming more and more important for every enterprise. Scientific research on the problem is being refined all the time and is being developed in detail in order to clarify the as yet unclarified relationships from a micro-economic point of view. The aim is to provide each enterprise with the framework within which it is able to decide on sites of interest.

The first attempt of major scientific relevance to clarify general siting problems was made by Johann Heinrich von Thünen. This thesis was first published in 1826.

Further investigations into the location theory by Roscher, Schäffle, and Launhardt were followed in 1909 by Alfred Weber's book "On the Location of Industries".

After Thünen's theory, which was exclusively based on agriculture, Weber's theory of location was the first to be systema-

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1) Brühling, U. W.: Neuere Entwicklungen im Lagerungsbild der europäischen Eisen- und Stahlindustrie, Hamburg 1969

tically drawn up on the realities of on industrial economy. In his thesis, he introduced the term "location factor", which he explains as "a sharply defined specific advantage, which becomes relevant for an economic activity if the latter takes place at a specific locstion or even generally at locations of a specific kind".

According to Weber's thesis, location factors are such features of a geographical location which render it attractive for industrial production. However, Weber restricts his definition in so far as to see production cost advantages only, while excluding from the beginning all influences which plant location may have on the sales area.

In the course of his work, Weber investigates the various types of costs in industrial plant, in order to state the degree of dependence of each type of cost on the spatial characteristics of the place of production. He reaches the conclusion that only the costs of materials, labour, and transport are to be considered as location factors. By converting differences in the price of input materials into transport cost differences he succeeds in reducing the dependence of location choice, for an isolated production, merely to the two factors of labour and transport costs.

Weber aimed at determining the optimal location and at defining it as the place where the sum of the labour and transport costs of a production considered in isolation is lowest.

The pioneering work of Thünen and Weber were followed by extensive investigations which aimed at refining location theory, and made a less isolated approach possible.
All these publications, however, agree on the realisation that the choice of location depends on a number of factors of influence, which must first be investigated with regard to their importance for the establishment of industrial

production, before a decision in favour of a specific site can be made. Accordingly, some of the following criteria of location choice may be relevant:

1.) Sales market
2.) Production programme
3.) Transport costs to sales market
4.) Cost of land
5.) Legal requirements (Dust, noise etc.)
6.) Cost of materials, cost of energy
7.) Labour market (qualitative, quantitative, prices)
8.) Cost of capital goods
9.) Infrastructure of surrounding area
1o.) Capital market situation
11.) Fiscal preferences

In order to find the optimal location for an enterprise while taking into account these factors of influence, it is an essential requirement that the mutual influences of all these factors should also be determined in quantitative terms. However, these locationally relevant factors affect one another in very different ways, some of the influences varying with time. From this it can be concluded that permanently optimal locations do not exist, but vary according to the relevance of the above factors. For the problem of location choice this means that it must invariably be made with a view to future developments instead of being solely based on current requirements.

3. Changing location patterns in the European steel industries

If we look at the development of the European iron and steel industry, we will find that, in Central Europe, this branch of industry has invariably been sited according to where its major raw materials - iron ore and coal - were found. As late as in 1961, some 55 per cent of crude-steel production within the European Coal and Steel Community were located on a coal basis, as compared to 35 per cent on an iron-ore basis.

Moreover, the continuous increase in the production of crude iron and crude steel, especially in the Ruhr district, attracted manufacturers using steel into its vicinity, which in return stabilised the location of the iron and steel-producing industry. Nevertheless, the concentration of European iron and steel industries in the Ruhr and Saar districts, as well as in Belgium, is clearly due to the existing coal deposits. This concentration is still to be found today. The compound economy between coal and steel, i. e. between mines and smelting plant, furnishes clear evidence of this.

Since the beginning of the construction of smelting plants in the Ruhr, the expansion of buying and sales markets, together with the progress made in production technology and an improvement in transport systems, has brought about a certain shift in location patterns in so far as the iron and steel industries of the Ruhr have been concentrated on its western and eastern border areas. The decisive factors in this respect were the inland waterways: the Rhine accounts for concentration in the west, while the extension of the Dortmund-Ems Canal accounts for concentration in the east.

By the end of World War II, a major "Coastal Steel Works" had only been established in the Netherlands. This plant developed well as a result of its seaport position with favourable possibilities for obtaining raw materials directly by sea, but also because of its closed national home market.

After World War II, some other countries also saw a distinct shift of location when new smelting plants were established. The latter were all built on the coast. However, Brühling's 1969 investigation shows that there has been a very diversified "move to the coast" in Europe. In all these locational shifts to the coast, crude iron production has the greatest share, followed by the production of crude steel. On the other hand, the expansion of rolled-steel capacity is by no means so distinctive a feature of coastal plants as compared with inland plants.

On the contrary, Brühling's investigation reveals that it may be quite advantageous for, say, rolling mills of the second heat stage to be close to their sales markets. The different migration patterns of crude iron, crude steel, and finished rolled steel production allow the first conclusion that each stage of production should be investigated separately in location analysis.

However, let us first look at the most important new establishments of steel plants in Europe. The reasons determining choice of location can be briefly outlined as follows:

a) Taranto

The choice of Taranto is probably chiefly due to the idea that such an undertaking was a means of changing the unilaterally agricultural economic structure of Southern Italy. Thus, this steel plant was regarded as a first step which, it was hoped, would spark off further industrialisation in the area. The plant was planned for export production - some 30 to 40 per cent of its production was to be exported to the Middle East and Africa. The site, being on a deep-sea port, was to make both shipment of the products and reception of the raw materials (iron ore and coal) easy and favourable in terms of costs, since the raw-material requirements are almost exclusively met by overseas countries.

b) Bremen

An expansion of crude-steel production on the part of the enterprise concerned made a search for a new site necessary, because the existing plants were incapable of expansion either for lack of land or for economic reasons. Since most of the iron ore had to be imported from overseas countries, to which a major share of production was likewise exported, the management decided to choose a coastal site on a deep-sea port. At the same time, inland waterways are used for carrying the required inland raw materials as well as those finished products which are to be sold in the home market.

c) Dunkirk

One criterion for siting a steel plant here was its proximity to the sales market, i.e. supplying the national shipbuilding industry with sheet steel. At the same time, however, French ore was dispensed with in favour of iron ore imported from overseas countries.

d) Fos-sur-mer

The reasons for establishing this steel plant in southern France were the same as those leading to the Taranto plant.

e) Maasvlakte

This new plant, still in the planning stage, was to be a mere primary production plant for the exclusive production of semi-finished products. The plant provided for 5o % of the semi-finished products to be finished in inland rolling mills and the other half in a coastal mill nearby.

The smelting plant was exclusively designed for the use of overseas raw materials. A realisation of this project would likewise make an analysis of modified changes in plant location necessary.

If we look at only these five new steel plants in Europe, we could note two basic reasons for the choice of their sites:

a) On account of the aims of economic policy of a state the site was chosen so as to fit into the framework of overall economic planning. The choice of location is merely a means to achieve further objectives, its purpose being to initiate further economic development of the area. The primary reasons for such a choice of location, then, are the economic aims of the state. If the state grants the enterprise subsidies, finance or tax relief, micro-economic reasons, too, might favour such a choice as secondary factors.

b) The site is chosen for micro-economic reasons, these being orientation on the sales market, the supply market or the labour market.

Irrespective of the two reasons listed above for location choice, it must be remembered that new plants are established by firms or groups of firms which already have smelting plants elsewhere. As the first set of reasons is largely characterised by objectives of national economic policy-objectives, whose significance the outsider can hardly gauge accurately since economy, infrastructure, and national prestige can hardly be assessed in economic terms, I should like to confine my paper to the second set of reasons. However, even this approach can only provide information on the tendency, as well as on the procedure and implementation of planning, but it will not be able to offer ready-made solutions.

Micro-economic reasons for changing plant location

In accordance with the criteria listed above for plant location, the first European iron and steel plants can be said to have been optimally located. For these establishments in Central Europe were orientated on the deposits of the major raw materials for the production process, i. e. iron ore and coking coal. Once crude-iron and crude-steel plants were established, other steel-using industries were set up there, too. The mutual relationship between these two industries in return stabilised the location of existing iron and steel plants. As it is, the concentration patterns in the European iron and steel industries in clearly attributable to the distribution of coal deposits, and has largely remained so until today. This fact becomes even more obvious if one looks at the economic integration of coal and steel, i. e. between coal-mining and smelting plants.

However, if we look at the increasing migration of European iron and steel industries to the coasts, we must ask what reasons were decisive in this respect. Which of the location factors, then, have changed so drastically that locations on the European inland iron-ore and coal deposits are no longer optimal?

The progress made in production processes brought about better and better outputs both in the production and subsequent treatment of crude iron. The prerequisite of higher blast-furnace outputs, however, is an improvement in the physical and chemical preparation of the ore. But central European ore, with its low Fe content, made it impossible to achieve these outputs. This is why European smelting plants imported more and more rich iron ore from overseas. This ore was unloaded in coastal ports.

The reduced significance of inland ore can be seen most clearly from the relative increases in iron-ore mining and crude-steel production within the European Coal and Steel Community. Thus, the increase in iron-ore mining between 1938 and 197o was from 1oo per cent to 138 per cent, whereas crude-iron production rose, in the same period, from 1oo per cent to 28o per cent. 1)

The contrast between these two rates of increase should show quite clearly the great extent to which the European iron and steel industries have used imported iron ore with a high Fe content. However, we ought to mention in this context that iron ores imported from overseas have, in addition to their high Fe content, the advantage of low prices. Their deposits are bigger and, unlike most inland iron-ore mines, are largely accessible through open-cast mining.

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1) Stahleisenkalender 1973, Düsseldorf, S. 172 und 175

Coal-mining lost its importance in the same way in the European Coal and Steel Community (ECSC). The supply of cheaply priced coking coal of good and, partly, better quality was great so that inland coking coal no longer accounted for micro-economic determinations of location advantages.

With this, however, the two major location factors had decreased in importance, whilst the coast had gained a location advantage because overseas raw materials could be used directly on being unloaded. This location advantage of the coast over inland sites resulted chiefly from the cost of transporting the two raw materials inland from the coast.

Those steel users which are established near steel producers continue to stabilise the latter's location, but they are not capable of absorbing the entire crude-steel production of the expanding smelting plants. The inland steel producers are, therefore, compelled to dispose of their products in other markets, mostly in overseas markets. This fact accounts for a deterioration of inland against coastal sites, because there are additional costs for transporting finished products from the inland site to the coastal port of shipment.

The locational disadvantage accruing to inland smelting plants as compared to coastal plants, taking the same sources of supply into account, amounted, in 1967, in the eastern Ruhr district of the Federal Republic of Germany, for instance, to approximately DM 8,-- to DM 1o,-- per ton of finished product made of crude oxygen steel. This differential is merely the increased cost of iron-ore transport. 1)

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1) W. H. Mieth u. H. Schenck, StE(9o/197o), S. 5o4, Tafel 5

The secondary freight rates for transporting overseas coking coal to the inland plants would be a little lower if the German iron and steel plants were allowed to freely choose their sources of supply. Since there are no freight costs for transporting finished products to ports for export purposes, the coastal plant gains another advantage of approximately DM 7,--/ton on the basis of 1967 prices. Against all these advantages, the cost of transporting semifinished products from the coast to inland plants for further processing only amount to about DM 1o,--/ton.

In my opinion, these three facts allow the conclusion that the traditional location factors have decreased in importance as a result of fundamental structural changes which have taken place and are still taking place in Europe, and as a result of world-wide trade, the opening-up of new supplies of raw materials, and the possibilities of low-cost shipping from overseas countries. This is the reason why all steel companies tend to opt for the coast when considering new plants, in order not to be subject to any restraints of supply or sales. If we exclude all other factors determining the choice of location from our considerations for a moment, we can see the shift in optimal location solely attributable to the aim of minimizing transport costs.

One objective in the establishment of new plants, irrespective of the country in which they are to be set up, is, therefore, quite apart from the effects of other locational factors, to minimize the cost of transporting raw materials to and finished products from the plant.

5. Method of determining location

The preceding chapter contained a brief summary of those reasons which led to locational changes in central Europe. Of these reasons, that of minimizing transport costs was the most important, if all other factors are considered as being of the same importance at every other location. These factors, which apply specifically to the central European area, are not of equal weigh for all other sites under consideration. However, this means that, principally, all locational factors relating to this decision must be taken into account for achieving a correct result. Now, while it may be the sole aim of this discussion to make suggestions on how to draw up locational analysis, it is, however, quite impossible to give concrete information on good or bad sites. It would require a period of at least one year for every single locational analysis to be made in depth.

In order to demonstrate the way in which locational analysis can be drawn up, the approach is to be described in theoretical terms in the following. Only the major locational factors will be considered in this. However, many other factors, which may be of major importance to a locational analysis, but are often not quantifiable, will not be dealt with. In this context I am thinking of the labour problem, for example. The availability of human labour of the required quantity and quality is one of the essential prerequisites for establishing a smelting plant. This, of course, also includes a potential of welltrained executives, who are willing to give their best and to take on responsibilities. Moreover, it includes managers who cannot only supervise but also inspire their staff. These problems, although relevant in practice, are assumed to be solved in this paper.

In addition, we do not take into account any locationally typical special factors and their effect on the balance, such as the effect of climate, soil condition, the market, infrastructure, etc., though the latter factor is of very specific importance. Thus, it is quite possible that a decision is made on account of the proximity of schools or other training institutes, residential areas, and hospitals, or a well-developed road and railway system. In this context we must also consider the proximity of manufacturing industries, repair shops, and supplier's factories, because these provide the possibility of rapidly making use of these firms in the event of breakdowns, thus increasing the availability of plants.

5.1 Sales market

Sales markets are very important locational factors. In this context, this term is to be understood as including both the place of consumption and the quantity of finished products supplied to this place. We must, therefore, begin by raising the question of the quantity of finished products which can or are to be sold in which sales market.

In order to be able to answer this question, we must first examine the total demand of the markets, which are to be supplied by the new smelting plant. The possible behaviour of competitors must likewise be taken into account in the analysis. In addition, market analyses must be made in order to determine the quantitative extent to which the markets under consideration will grow. From this, deductions must be made on how much the new plant can participate in meeting the overall market demand, and how much its sales will grow altogether. At the end of these analyses there will be a possible sales programme, as is shown by Table 1.

Table 1
Possible sales according to markets in 1.000 tons per year

	Product 1				Product 2	Product n
	1975	1980	1985	1990		
Market A	5	10	12	16		
Market B	12	18	25	28		
Market C	2	4	6	6		

Market X	-	5	15	17		
Market Σ	120	150	185	230		

This sales programme, however, only shows possible sales. Figures 1 to 5 may serve as examples of what information must be arrived at for drawing up such a sales programme.

Figure 1 shows the expected development in the consumption of crude steel as well as that of its competitor, plastics. In order to arrive at an approximate comparability, the dimension "m^3" was chosen instead of the weight unit "t". The diagram, however, shows how much greater the rates of growth are for plastics as compared with steel. In accordance with this trend, the growth rates for world steel consumption, shown in the lower part of the diagram, can be seen to be modest, too, having an approximate growth rate of 4.8 per cent p. a. between 1965 and 198o. The highest growth rate, with about 8.8 per cent p. a., is to be expected in the Asian markets, whilst the lowest, about 1.5 per cent p. a., is anticipated in the U.S.A.. Naturally, all these data must be considered as overall figures. They do not suggest any specific growth rates for each product.

This again requires an analysis of each consumer, i. e. we must determine the extent to which the output of industries using steel and, with it, their steel consumption will rise and to what extent steel and its competitors can be substituted in the process. On this, Figure 2 shows an example of the degree to which steel products are expected to be substituted, by the year 2ooo, by plastics, aluminium, asbestos cement, and concrete. At the same time, in accordance with the level of knowledge today, the upper saturation limit of substitution is shown.

Figure 3, then, shows the anticipated development of crude-steel production and the resulting rates of increase until 198o. For planning new plants, however, these figures would be incomplete without the contrast offered by Figure 4. This shows the development of crude-steel capacities and their exploitation since 196o, as well as their estimated development until 198o. From this we can see that, on average, only about 85 per cent of the existing crude-steel capacities are used, i. e. by 198o a crude-steel production capacity of some 15o million tons per year will not be utilized. This, however, means that any further crude-steel capacity is bound to compete with the not fully utilized existing capacities. It is the aim of this account to warn against over-optimistic expectations on the basis of previous growth rates.

Fig. 3a - Development of world crude steel production (by process)

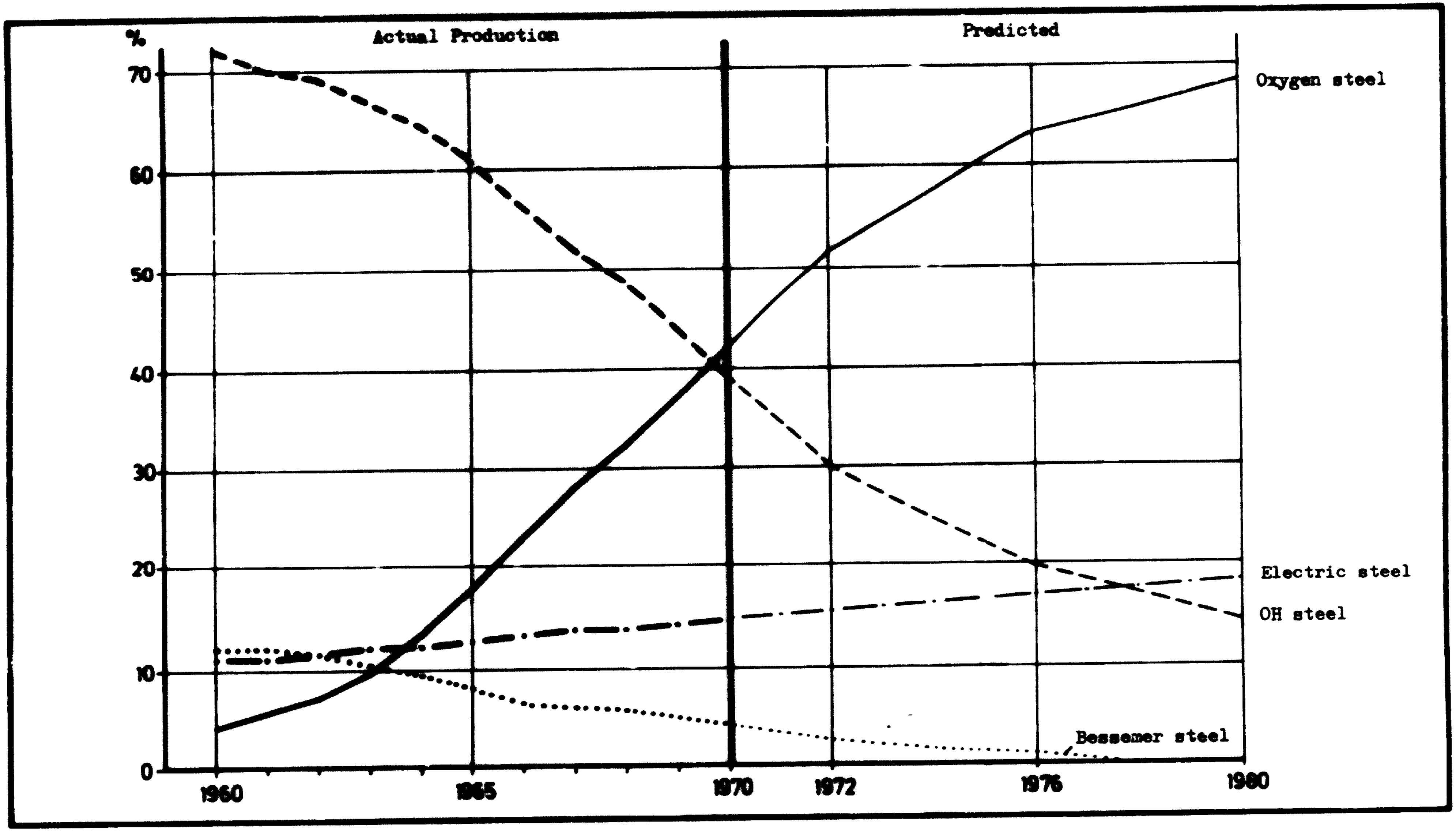

Fig. 3b - Development of crude steel production

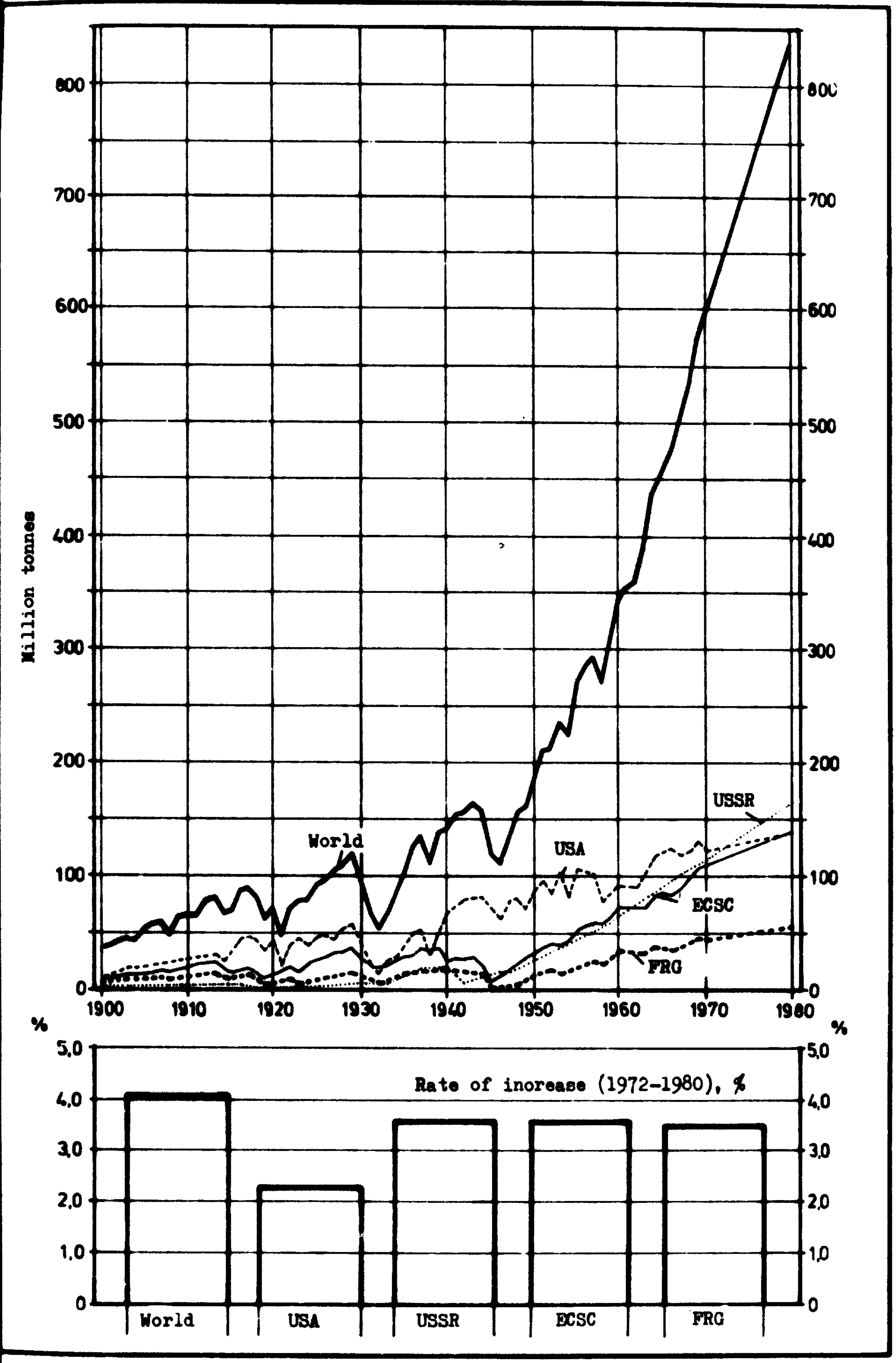

Fig. 4 - Calculation of crude steel production and capacity

	1960			1970			1980			Variation 1961-1971				Variation 1972-1980			
	Prod.	Cap.	Util.	Prod.	Cap.	Util.	Prod.	Cap.	Util.	Production		Capacity		Production		Capacity	
	Mio t	Mio t	%	Mio t	Mio t	%	Mio t	Mio t	%	Mio t	% p. a.	Mio t	% p. a.	Mio t	% p. a.	Mio t	% p. a.
ECSC	73,1	74,2	98,5	103,3	137,0	75,4	142	179	79,3	30,2	3,2	62,8	5,7	38,7	3,6	42,0	3,0
FRG	34,1	35,4	96,3	40,3	57,6	70,0	56	71	77,5	6,2	1,5	22,2	4,5	15,7	3,5	13,4	2,3
France	17,3	17,8	97,2	22,8	28,0	81,4	28	34	82,4	5,5	2,5	10,2	4,2	5,2	2,4	6,0	2,2
Italy	8,5	8,7	97,7	17,4	22,6	77,0	27	35	77,1	8,9	6,7	13,9	9,1	9,6	4,9	12,4	5,0
Belgium	7,2	8,0	90,0	12,5	16,5	76,4	18	23	78,3	5,3	5,2	8,5	6,8	5,5	4,3	6,5	3,6
Netherlands	2,0	2,1	95,2	5,1	6,3	81,0	8	8	100,0	3,1	9,8	4,2	10,5	2,9	4,5	1,7	2,6
Luxemburg	4,1	4,2	97,6	5,2	6,1	85,2	6	7	85,7	1,1	2,2	1,9	3,4	0,8	1,3	0,9	1,1
United Kingdom	24,7	26,0	95,0	24,2	30,3	79,9	31	38	81,6	- 0,5	-0,2	4,3	1,4	6,8	2,9	7,7	2,6
USSR	65,3	72,6	89,9	119,9	134,5	89,1	165	183	90,2	54,6	5,7	61,9	5,8	46,1	3,6	48,5	3,5
USA	91,9	138,0	66,6	112,6	159,2	70,7	138	177	78,0	20,7	1,9	21,2	1,3	25,4	2,3	17,8	1,2
Japan	22,1	25,0	88,4	88,6	116,7	75,9	173	197	87,8	66,5	13,4	91,7	15,0	84,4	7,7	80,3	6,0
World	341,2	403,3	84,6	581,5	719,0	80,9	835	980	85,2	240,3	5,0	315,7	5,4	253,5	4,1	261,0	3,5

Finally, we point to Figure 5, which shows the development of the steel market between 197o and 198o according to an IISI prognosis. It is expressed in terms of an anticipated increase in the per-capita increase in steel consumption in various countries, providing a good survey of the extra steel consumption by 1985 as compared to 197o.

The vast amount of available records - of which only five were selected - may show how great an effort of work must be invested in analysing sales markets before a desirable sales programme can be worked out.

After this stage of work, it will next be necessary to determine the markets which should or could be supplied, their distance from the location of the smelting plant, the methods of transporting the finished products to these markets, and the costs accruing in the process. At the same time, it is useful to analyse the prospects of the major competitors in this market in order to determine, for instance, whether or not they are abel to supply the market at more favourable transport rates, or to what extent they have a transport advantage or disadvantage against our own location.

.2 Production programme and layout of plant

Following the development of a possible sales programme on the basis of a sales market analysis, we must now proceed to develop the required production programme for these markets. The production programme itself, then, is the basis for drawing up the layout of plant.

Let us assume that the possible sales programme had shown that cold-rolled products (plate, hot wide strip) could be sold in major quantities on the date the plant has been scheduled to open, and that, in the long run, too, positive growth rates in market demand for these products can be expected, while the analysis predicted sufficient sales for rod and sections

Fig. 5 - Steel market situation, 1970 and 1985

	Steel consumption		Increase in steel consumption, 1985 - 1970	Steel production 1970	Net steel trading 1970
	1970	1985			
	kg per capita		millions of tonnes of crude steel		
China and North Korea	29	80	56,8	19,60	- 2,60
Other SE Asian countries (less India and Japan)	24	39	22,9	1,28	- 6,89
Latin America	64	110	29,7	13,15	- 5,12
Middle East	48	100	11,9	0,56	- 4,42
Africa (less South Africa, AR Egypt, and Libya)	14	15	2,3	0,55	- 3,64
South Africa	242	364	5,9	4,74	- 0,13
Australia and New Zealand	386	571	7,8	6,96	- 0,52
India	11	25	13,8	6,28	+ 0,13
USA	618	751	63,5	119,14	- 7,36
Canada	517	733	8,9	11,20	+ 0,13
USSR	453	749	105,1	115,87	+ 5,98
European Community (Common Market)	510	737	56,5	109,19	+ 12,48
Japan	681	1103	63,2	93,32	+ 22,75

+ = Export surplus

- = Import surplus

only in later years. In this case, the decision is most likely to be for sheet steel production to be established first, together with the necessary supply of stock, while production capacity for sheet products and section steel are to be added at a later stage. How, then, are production programmes determined after this decision?

A start will be made with cold-rolled products. We must examine what layout of plant is best. At the same time, the plants in question must not be too big at the beginning of production, as this would mean bad capacity utilization, but they must also make it possible for the quantities which are expected to be sold in future to be produced through a potential extension of the plant in stages. In the event of plants being under-utilised during the first phase of extension, a correction of the possible sales scheme for the products concerned will have to be made. In this case, following a change in the objectives, a possible sales programme becomes a target-sales programme.

Taking into account the output of the cold-rolling mill, it will then be possible to assess the required amount of hot wide strip for further processing in the cold-rolling mill. Depending on the depth of treatment, the cold-rolling mill output amounts to between 91 and 94 per cent. In this context, it is necessary to add the direct sales of hot wide strip in the shape of coils, as well as the demand for cut hot-rolled wide strip, in order to arrive at the correct figures for hot wide strip production. On this basis, it will then be necessary to draw up a suitable plant layout in the same way as was done for the production of cold-rolled products. If the capacity of the first building stage tallies with demand, the sales scheme need not be modified. However, the case may occur that the first building stage fails to meet the demand for hot wide strip, whilst the second building stage results in too great an increase in capacity. In this situation, a lowering of sales targets, for instance, for hot wide strip, suggests itself.

The required or possible production of hot wide strip calls for approximately 1.03 t of roughed slabs for each ton of hot wide strip. Taking into account the way roughed slabs are produced - slabbing mill or continuous casting - it will then be possible to determine the required crude-steel production of the first building stage of the new plant. The method of producing crude steel is to be determined in accordance with the anticipated crude-steel production when the plant is fully operational, and, on the other hand, according to how raw materials are obtained - iron ore or scrap. If the new plant is mainly based on iron ore, the LD process is to be preferred. If there is a guaranteed and sufficient supply of scrap, electric arc furnaces suggest themselves. However, rolling mill capacities are so great with the above-mentioned range of products - cold-rolled products, hot wide strip, and plate - that only the LD process can be used economically from the point of view of productivity. It is in accordance with these requirements that the appropriate blast-furnace plant must be devised, including ore-preparing plants. As a guide, one can assume a requirement of approximately 850 kg of crude iron for each ton of LD crude steel.

In this way, a detailed production programme is drawn up and mutually balanced with the sales programme. At the same time, the required plant layout is devised inclusive of its long-term extension. The next step is to calculate the investment sum for building these plants. This sum includes not only the investment costs for production plant required but also every other investment required to make production possible. A comparison of sites will already reveal a difference with regard to investment costs. Different infrastructures, difficulties in setting up plant because of different site conditions and land costs, differences in transport to and from the site etc. may be decisive factors in this respect.

There have been a number of publications on the subject of production plant layout, their efficiency, the relationship between investment costs and plant dimensions etc.. This is why these problems will not be given any further attention in this report. The publications listed in the Bibliography provide a good survey of these subjects.

Once investment costs have been assessed roughly on the basis of the planned plant layout, they must be compared and brought into line with the quotations of the suppliers. From this we are already able to calculate, taking into account the service life (useful life) of the plant as well as the necessary interest payment of the capital to be invested, the capital service to be made by the plant, i. e. to calculate write - off and interest for the production planned. When comparing sites, differences of investment costs or capital service costs are first indications of a locational advantage.

5.3 Determination of cost difference

In order to determine a cost difference between two locations, the costs of each location must be calculated separately. For this purpose, it is first necessary to devise, taking into account production programmes and the production plant concerned in each case, a quantitative framework of all those cost items such as ore, lime, energy, labour, repair costs etc. 1) which are necessary to realise production.

Such a framework, which is devised separately for each production stage from crude iron to the finished product, is thereupon assessed on the basis of prices currently charged at the location in question. In this manner, the product costs are arrived at in relation to location.

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1) Mieth W. H.: Bisi 8643-I, p. 3o ff.

Figure 6 shows the manning scheme for a blast-furnace plant as an example of the determination of labour costs in two different locations. This quantitative framework, apart from listing the number of jobs, their functions, and their manning, also gives examples of wages in order to provide information on the monthly wage bill. However, the table does not allow any reserve for sick employees on holiday, this reserve being added to the labour costs in the shape of a percentage figure. Moreover, the table does not include labour employed for repairs, transport, quality control, etc. These employees are listed in the manning plans of their respective departments, and are later charged, according to their work, to the account of, for instance, the blast-furnace plant. In this way the quantitative framework for labour is to be devised and assessed for all departments.

Figure 7 provides an example of how fuel and energy consumption is determined. It shows the types of energy and the amounts necessary for running a smelting plant. This balance sheet was drawn up on the basis of an assumed smelting plant with an annual production of 3.6 million tons of crude iron, 3.0 million tons of oxygen steel, and 1.8 million tons of open-hearth crude steel, together with wide-ranging further processing of the crude steel produced.

Figures 8 and 9 show the quantitative framework, together with an evaluation, for an oxygen steel plant at two different locations. Figures 11 and 12 show such quantitive framework for a universal slabbing mill. The schedule given in Figure 10 is devised to allow an output assessment of the mill, as well as a determination of the costs for each ton of roughed slab in terms of input weight of the crude slab and final dimensions of the roughed slab.

These few examples, which only represent a few selected production stages, serve to illustrate the analytical method. At the end of these analytical procedures we arrive at the final result, the

Fig. 6 - Example of manning schedule and wage determination for blast-furnace plant

	Job		Work A				Work B			
			Working time [hours/month]	No. of jobs	Hourly pay [DM/hours]	Wage costs per job [DM/month]	Working time [hours/month]	No. of jobs	Hourly pay [DM/hours]	Wage costs per job [DM/month]
1	Ore delivery attendants	W	730	4	4,85	14.162,—	730	4	5,63	16.439,60
2	Burden supervisor	W	730	1	5,09	3.715,70	730	1	5,82	4.248,60
3	Hoist attendants	W	730	4	4,99	14.570,80	730	4	5,63	16.439,60
4	Greasers	T	173,3	2	4,85	1.681,01	195	2	5,48	2.137,20
5	Foremansmelters	W	730	2	5,90	8.614,—	730	2	7,03	10.263,80
6	Istsmelters	W	730	4	5,74	16.760,80	730	4	6,14	17.928,80
7	2ndsmelters	W	730	4	5,20	15.184,—	730	4	5,85	17.082,00
8	3rdsmelters	W	730	4	5,09	14.862,80	730	4	5,63	16.439,60
9	4thsmelters	W	730	4	5,00	14.600,—	730	4	5,35	15.622,00
10	5thsmelters	W	730	4	4,95	14.554,—	730	4	5,17	15.096,40
11	Water attendants	W	730	4	5,20	15.184,—	730	4	4,94	14.424,80
12	Instrument attendants	W	730	2	5,20	7.592,—	730	2	5,85	8.541,00
13	Oil attendants	W	730	2	5,09	7.431,40	730	2	5,85	8.541,00
14	Front-side labourers	W	730	3	4,66	10.205,40	730	3	4,43	9.701,70
15	Foreman: water attendants	T	173,3	2	5,90	2.044,94	195	2	5,53	2.156,70
16	Water attendants	T	173,3	13	5,20	11.715,08	195	11	4,94	10.596,30
17	Gas cleaning foreman	T	173,3	1	5,66	980,88	195	1	5,54	1.080,30
18	Gas cleaning Personnel	T	173,3	10	4,99	8.647,67	195	9	5,35	9.389,25
19	Auxiliaries	T	173,3	22	4,66	17.766,72	195	20	4,31	16.809,00
20	Frontside workers (runners)	T	173,3	3	4,85	2.521,52	195	3	4,31	2.521,35
21	Crane drivers	W	730	1	4,85	3.540,50	730	1	5,17	3.774,10
22	Stove attendants	W	730	1	5,20	3.796,—	730	1	4,94	3.606,20
23	Stove attendants	T	173,3	1	5,20	901,16	195	1	4,94	963,30
24	Stove control operators	W	730	1	5,20	3.796,—	730	1	4,94	3.606,20
25	Ladle weighsmen	W	730	1	5,09	3.715,70	730	1	5,48	4.000,40
26	Slag tippers	W	730	4	4,99	14.570,80	730	4	5,03	14.687,60
27	Burden preparation	W	730	5	4,53	16.534,50	730	5	4,31	15.731,50
28	Burden preparation	T	173,3	15	4,53	11.775,74	195	13	4,21	10.672,35
29	Reserves and by-turn workers	W	730	3	5,20	11.388,—	730	2	5,63	8.219,80
30	Reserves and by-turn workers	W	730	2	4,85	7.081,—	730	1	5,17	3.774,10
31	Stacker drivers	W	730	2	4,85	7.081,—	730	2	5,24	7.650,40
32	Stacker drivers	T	173,3	2	4,84	1.677,54	195	2	4,72	1.840,80
33	Auxiliaries: administration	T	173,3	3	4,13	2.147,19	195	3	3,95	2.310,75
34	Reserves and by-turn workers	T	173,3	7	4,69	5.689,44	195	5	4,94	4.816,50
	Wage cost		296.409,— DM/month				301.113,— DM/month			

Fig. 7 - Fuel and energy balance - Works A

		Quantity used per t crude steel		Calorific value or generated heat	Quantity of heat per t crude steel
		Unit	Quantity		
			Unit/t	kcal	Mcal/t
1	**Blast furnace coke**	kg	364,54	7.000,0	2.551,8
2	**Coke breeze**	kg	43,22	5.500,0	237,7
3	**Other solid fuels**	kg	27,83	7.000,0	194,8
4	**Coke oven gas**	Nm^3	74,57	3.850,0	287,1
5	**Fuel oil**	kg	79,70	9.600,0	765,5
6	**Outside electricity**	kWh	258,72	3.500,0	905,5
7	**Gross heat Consumption**	-	-	-	4.942,3
8	**Blast furnace gas supplied for under-firing**	Nm^3	182,3	1.000	182,3
9	**Nett heat consumption**	-	-	-	4.760,0

Fig. 8 - Process costs, Oxygen melting shop (production 250,000 t/month)

		Cost item	Unit	Consumption	Work A			Work B		
					Price per unit DM	Total costs DM/month	Cost per t produced DM	Price per unit DM	Total costs DM/month	Cost per t produced DM
Personnel cost	1	Wages				367.289,—	1,47		416.296,—	1,67
	2	Overtime extra				44.075,—	0,18		28.620,—	0,11
	3	Holiday Payments				50.640,—	0,20		54.535,—	0,22
	4	Expenditure similar to wages				48.262,—	0,19		89.920,—	0,36
	5	Salaries and similar expenditure				58.393,—	0,23		71.120,—	0,28
	6	Statutory social charges				61.380,—	0,25		60.927,—	0,24
	7	Total Personnel cost				630.039,—	2,52		721.418,—	2,88
Fuels	9	Solid fuels	t	0,0001	90,00	2.250,—	0,01	75,50	1.888,—	0,01
	10	Blast furnace gas	10^6kcal	0,0160	12,50	50.000,—	0,20	8,10	32.400,—	0,13
	11	Coke oven/natural gas	10^6kcal	0,0040	12,50	12.500,—	0,04	8,10	8.100,—	0,03
	12	Liquid fuels	10^6kcal		460,00	2.956,—	0,01	410,00	2.634,—	0,01
	13	Total fuels				67.706,—	0,26		45.022,—	0,18
		Steelmaking oxygen	Nm³	52,000	0,065	845.000,—	3,38	0,058	754.000,—	3,02
Power	16	Electricity	kWh	12,000	0,0480	144.000,—	0,58	0,0360	108.000,—	0,43
	17	Steam	t	0,002	15,—	7.500,—	0,03	12,5000	6.250,—	0,03
	18	Drinking/feed water	m³	0,300	0,5750	43.125,—	0,17	0,5220	39.150,—	0,16
	19	Works/brackish water	m³	5,900	0,0580	85.550,—	0,34	0,0154	22.715,—	0,09
	20	Compressed air	Nm³	12,000	0,0105	31.500,—	0,13	0,0094	28.200,—	0,11
	21	Total Power				311.675,—	1,25		204.315,—	0,82
		Ingot mould, accessories, equipm.				1.737.500,—	6,95		1.776.500,—	7,10
Refractories	24	Dolomite bricks, for bonded	t		146,—	1.241,—	0,01	124,00	1.054,—	-
	25	Furnace bricks	t		247,—	1.853,—	0,01	269,60	2.023,—	0,01
	26	Ladle bricks	t	0,0016	396,80	158.720,—	0,63	431,50	172.500,—	0,69
	27	Runner and sleeve bricks	t	0,0025	224,30	140.188,—	0,56	254,00	158.750,—	0,64
	28	Other refractories	t		-	112.500,—	0,45		102.300,—	0,41
	29	Total refractories			-	414.502,—	1,66		436.627,—	1,75
		Equipment tools			-	212.500,—	0,85		222.500,—	0,89
Other operating costs	32	Works Railway				179.973,—	0,72		197.530,—	0,79
	33	Other transport costs				547.535,—	2,19		582.405,—	2,33
	34	Sampling, chemical analyses, testing				112.500,—	0,45		137.500,—	0,55
	35	Small amounts and overheads				5.000,—	0,02		5.000,—	0,02
	36	Collective operating costs				37.500,—	0,15		40.000,—	0,16
	37	Charges for auxiliary units				145.000,—	0,58		152.500,—	0,61
	39	Total other operating costs				1.027.508,—	4,11		1.115.015,—	4,46
Maint. a. repair costs	40	Own repair wages, extras				61.879,—	0,25		72.830,—	0,29
	41	Workshop jobs				585.000,—	2,34		635.000,—	2,54
	42	Outside repairs				25.000,—	0,10		27.000,—	0,11
	43	Replacement and spare parts				215.250,—	0,86		220.000,—	0,88
	44	Maintenance payments				150.000,—	0,60		160.000,—	0,64
	45	Total maintenance and repair costs				1.037.129,—	4,15		1.114.830,—	4,46
		Converter Payments				550.000,—	2,20		575.000,—	2,30
Serv. o. cap.	48	Calculated depreciation				792.650,—	3,17		848.500,—	3,39
	49	Calculated interest (investments)				416.320,—	1,67		451.450,—	1,81
	50	Calculated interest (current assets)				81.000,—	0,32		87.600,—	0,35
	51	Total service of capital				1.289.970,—	5,16		1.387.550,—	5,55
		Plant process costs				8.123.529,—	32,49		8.352.777,—	33,41
		Costs arising outside plant				590.000,—	2,36		617.500,—	2,47
		Process costs				8.715.529,—	34,85		8.970.277,—	35,88

Fig. 9 - Cost source account, oxygen melting shop (production 250,000 t/month)

				Quantity breakdown		Works A		Works B	
				Charged weight t/month	Charged weight kg/t cr st	Utilisation price DM/t	Cost DM/t cr st	Utilisation price DM/t	Cost DM/t cr st
1. Hot metal	LDAC mixed metal			225.000	900	141,34	127,21	128,56	115,70
	Steelmaking iron (liquid)			-	-	-	-	-	-
	Iron substitute			-	-	-	-	-	-
	Total iron			225.000	900	-	127,21	-	115,70
2. Scrap	Scrap			49.000	196	123,50	24,21	126,63	24,82
	Ingot ends and scrap ingots			1.000	4	140,00	0,56	140,—	0,56
	Runner scrap			1.250	5	120,00	0,60	120,—	0,60
	Spillage/skulls			3.250	13	120,—	1,56	120,—	1,56
	Ladle skulls			500	2	120,—	0,24	120,—	0,24
	Total scrap			55.000	220	-	27,17	-	27,78
3. ore: Brazil: 65 % Fe = 49,12 75,57 DM/t Fe				1,750	7	75,57	0,53	66,43	0,47
4. Additions	Silico manganese (69,0 % Mn)			200	0,8	600,00	0,48	550,—	0,44
	Ferro manganese (77,0 % Mn)			1.450	5,8	500,00	2,90	490,—	2,84
	" " (refined) (82,4 % Mn)			25	0,1	1.165,00	0,12	1.044,—	0,10
	Electrolytic manganese			-	-	-	-	-	-
	Ferro-silicon (77,5 % Si)			187,5	0,75	820,00	0,62	677,—	0,51
	Calcium-silicon			-	-	-	-	-	-
	Aluminium			125	0,5	1.980,—	0,99	2.178,—	1,09
	Aluminium shot			-	-	-	-	-	-
	Copper			5	0,02	3.000,—	0,06	3.065,—	0,06
	Ferro-phosphorus			7,5	0,03	379,—	0,01	330,—	0,01
	Total additions			2.000,-	8,0	-	5,18	-	5,05
5. Ancillary charge costs				-	-	-	-	-	-
Total metallic charge (total for 1 - 5)				283.750	1.135,-	-	160,69	-	149,67
6. Fluxes	Lump lime			625	2,5	54,00	0,14	55,50	0,14
	Powdered lime			20.250	81,0	54,00	4,37	55,50	4,50
	Limestone			1.875	7,5	12,70	0,09	15,29	0,11
	Soda			-	-	-	-	-	-
	Rheinsand			-	-	-	-	-	-
	Pitch coke breeze			-	-	-	-	-	-
	Carburising agent			225	0,9	76,50	0,07	78,—	0,07
	Total fluxes			22.975	91,9		4,67		4,82
Total charge (total for 1-6)				306.725	-	-	165,36	-	154,49
7. Credits for residual material (by-products)		Mater. -t	Fe %						
	Ingot ends and scrap ingots	2.000	100	2.000	8	128,50	1,03	128,00	1,02
	Runner scrap	1.750	100	1.250	5	115,00	0,58	115,00	0,58
	Skulls/spillage	8.670	75	6.500	26	107,00	2,78	106,20	2,76
	Converter dust and sludge	3.640	55	2.000	8	40,00	0,32	40,00	0,32
	Fine crushed iron	2.245	78	1.250	5	60,00	0,30	60,00	0,30
	Meltingresidues			20.750	83	-	-	-	-
	Slag credit			37.500	150	35,00	5,25	35,00	5,25
	Total credit for by-products			33.750	135	-	10,26	-	10,23
Materials cost (total for 1-6 less 7)				250,000	1.000		155,10		144,26
Process costs							34,85		35,88
Nett costs				250.000	1.000		189,95		180,14

Fig. 10 - Pass schedule for universal slabbing mill for 32.5t slab to determine output

Pass No.	Type of pass V = vertical H = horizontal	Size: Thickness	Size: Width	Size: Length	Reduction	Reduction	Rolling time: Pure rolling time	Rolling time: Holding time	Rolling time: Cumulated total time
		mm	mm	mm	mm	%	sec	sec	sec
0		1.790	1.040	2.500			0	10,00	0
1	V H	1.790 1.765	1.040 1.040	2.535	0 25	0 1,4	2,64	5,00	17,64
2	H V	1.715 1.715	1.040 1.040	2.610	50 0	2,0 0	2,72	7,00	27,36
3	V H	1.040 975	1.670 1.685	2.833	45 65	2,6 6,2	2,95	5,00	35,31
4	H V	910 910	1.695 1.650	3.005	65 45	6,7 2,6	3,05	5,00	43,36
5	V H	910 850	1.605 1.620	3.231	45 60	2,7 6,6	3,36	5,00	51,73
6	H V	785 785	1.630 1.590	3.497	65 40	7,6 2,5	3,54	5,00	60,28
7	V H	785 720	1.545 1.555	3.811	45 65	2,8 8,3	3,97	5,00	69,25
8	H V	660 660	1.570 1.525	4.221	60 45	8,3 2,9	4,27	5,00	78,52
9	V H	660 595	1.500 1.510	4.711	25 65	1,6 9,8	4,91	5,00	88,43
10	H V	530 530	1.525 1.500	5.319	65 25	10,9 1,6	5,45	5,00	98,89
11	V H	530 470	1.500 1.510	5.990	0 60	0 11,3	6,24	5,00	110,13
12	H V	405 405	1.525 1.500	6.992	65 25	13,8 1,6	7,16	5,00	122,30
13	V H	405 355	1.500 1.500	7.997	0 50	0 12,3	8,33	5,00	135,63
14	H V	300 300	1.500 1.500	9.342	55 0	15,5 0	9,73	5,00	150,37
15	V H	300 265	1.500 1.500	10.609	0 35	0 11,7	11,14	5,00	166,51
16	H V	240 240	1.500 1.500	11.701	25 0	9,4 0	12,19	5,00	183,71
17	V H	240 225	1.500 1.500	12.561	0 15	0 6,3	13,09	0	196,80

Output for Various Slab Weights and Sizes

No	Ingot size [mm]			Slab size [mm]			Charged weigth [t]	Rolling time [sec]	No. of Passes	Theoretical rolling output [t/h]		
	Thickness	Width	Leugth	Thickness	Width	Leugth				100 %	80 %	60 %
1	1.790	1.040	2.500	225	1.500	12.610	32,5	196,80	17	595,0	476,0	357,0
2	1.040	1.790	2.500	225	1.500	12.610	32,5	177,89	15	658,0	526,0	395,0
3	1.438	965	2.500	225	1.110	12.500	24,0	174,02	17	497,0	398,0	298,0
4	965	1.438	2.500	225	1.110	12.500	24,0	154,42	15	559,0	447,0	335,0
5	1.340	890	2.080	160	1.120	11.610	16,0	145,88	17	395,0	316,0	237,0
6	890	1.340	2.080	160	1.120	11.610	16,0	132,52	15	435,0	348,0	261,0
7	2.250	820	2.215	160	2.130	10.680	28,0	195,33	19	516,0	413,0	310,0
8	820	2.250	2.215	160	2.130	10.680	28,0	178,43	17	565,0	452,0	339,0

Fig. [illegible] – Process costs, universal slabbing mill [illegible] t month)

	Cost items	Unit	Consumption [unit per t output]	Works A			Works B		
				Price per unit	Total costs	Cost per t crude steel	Price per unit	Total costs	Cost per t crude steel
				DM	DM / month	DM	DM	DM/month	DM
Personnel costs	Wages				130.416,—	0,57		148.973,—	0,63
	Overtime extra				19.917,—	0,08		5.246,—	0,02
	Holiday Payments				18.808,—	0,08		19.463,—	0,08
	Expenditure similar to wages				17.925,—	0,08		32.092,—	0,14
	Salaries and similar expenditure				28.670,—	0,12		36.360,—	0,15
	Statutory social charges				23.436,—	0,10		21.036,—	0,09
	Total personnel costs				245.172,—	1,03		263.170,—	1,10
Fuels	Blast furnace gas	10^6kcal	0,174	12,50	517.650,—	2,17	8,10	335.440,—	1,41
	coke oven/natural gas	10^6kcal	0,096	12,50	28.560,—	0,12	8,10	18.507,—	0,08
	Total fuels				546.210,—	2,29		353.947,—	1,49
Power	Electricity	kWh	32,00	0,0480	365.568,—	1,54	0,0360	274.176,—	1,15
	Drinking water	m^3	0,25	0,3300	19.635,—	0,08	0,3000	17.850,—	0,07
	Works water	m^3	2,50	0,0580	34.510,—	0,14	0,0154	9.163,—	0,04
	Compressed air	Nm^3	8,00	0,0105	19.992,—	0,08	0,0094	17.898,—	0,08
	Heating				3.800,—	0,02		2.950,—	0,01
	Total Power				443.505,—	1,86		322.037,—	1,35
Equipment and tools					178.500,—	0,75		188.000,—	0,79
Working materials					130.900,—	0,55		138.000,—	0,58
Other operating costs	Works railway				112.056,—	0,47		124.236,—	0,52
	Other transport costs				53.500,—	0,23		58.450,—	0,24
	Samples, chemical analyses testing				74.100,—	0,31		77.800,—	0,33
	Collective operating costs				51.900,—	0,22		56.000,—	0,24
	Charge for auxiliary plant units				29.250,—	0,12		31.670,—	0,13
	Total other operating costs				320.806,—	1,35		348.156,—	1,46
Maintenance and repair costs	Own repair wages, extras				19.450,—	0,08		21.950,—	0,09
	Workshop jobs				410.000,—	1,72		435.800,—	1,84
	Outside repairs				25.000,—	0,11		25.900,—	0,11
	Replacement and spare parts				239.000,—	1,00		255.000,—	1,07
	Maintenance payments				30.000,—	0,13		31.700,—	0,13
	Total maintenance and repair costs				723.450,—	3,04		770.350,—	3,24
Furnace Payments					207.060,—	0,87		219.240,—	0,92
Service o. capit	Calculated depreciation				580.917,—	2,44		639.083,—	2,68
	Calculated interest (investments)				300.000,—	1,26		330.000,—	1,39
	Calculated interest (current assets)				144.000,—	0,61		156.000,—	0,66
	Total service of capital				1.024.917,—	4,31		1.125.083,—	4,73
Plant process costs					3.820.520,—	16,05		3.727.983,—	15,66
Costs arising outside plant					452.200,—	1,90		487.900,—	2,05
Process costs					4.272.720,—	17,95		4.215.883,—	17,71

Fig. 12 - Net costs, universal slabbing mill (production 238,000 t/month)

		Work A						Work B					
		LDAC steel			OH steel			LDAC steel			OH steel		
		Charge	Utilisation price	Production cost	Charge	Utilisation price	Produktion cost	Charge	Utilisation price	Produktion cost	Charge	Utilisation price	Produktion cost
		kg/t output	DM/1000kg	DM/t output	kg/t output	DM/1000kg	DM/t output	kg/t output	DM/1000 kg	DM/t output	kg/t output	DM/1000 kg	DM/t output
Utilisation cost	LDAC steel (charged quantity = 200,000 t/month)	1176,5	189,95	223,48	-	-	-	1176,5	180,14	211,94	-	-	-
	OH steel (charged quantity = 80,000 t/month)	-	-	-	1176,5	211,73	249,10	-	-	-	1176,5	205,55	241,83
Credit for by-Products	Furnace, mill and deseaming scale (5,655 t/month)	23,8	33,0	0,79	23,8	33,0	0,79	23,8	32,60	0,78	23,8	32,60	0,78
	Deseaming and shearing scrap (36,345 t/month)	152,7	110,75	16,91	152,7	110,75	16,91	152,7	110,--	16,80	152,7	110,--	16,80
Materials cost		1000	-	205,78	1000	-	231,40	1000	-	194,36	1000	-	224,25
Process costs				17,95			17,95			17,71			17,71
Nett costs Prime deseamed slab (DM/t output)		223,73			249,35			212,07			241,96		

product costs, as, for example, shown in Figure 11. This method enables us to follow the development of locational advantages from production stage to production stage. In addition, the products have been divided into those further processed in the same plant and those intended for sale. Thus, on account of packaging etc., the cost of hot widestrip intended for sale is higher than that intended for further processing.

Figure 14 shows the way an analysis of locational advantage can be made, on the example of location "B"; the influence of location factors on the advantage of site "B" is shown for every stage of production. Thus, for instance, the advantage of the product LDAC iron, amounting to DM 12,91 per ton, is attributable to a lower rate of freight for iron ore (DM 7,79 per ton of crude iron), lower blast-furnace fuel costs (DM 4,95 per ton of crude iron) and lower electricity costs. (DM o,78 per ton of crude iron). The lower labour costs and the lower capital service of site "A" account for a slight diminution of the locational advantage of site "B". This calculation, which does not take into account any changes in the choice of cost goods and in the development of their price, makes it now possible for a comparative assessment of locations to be made on the basis of production costs. However, such an assessment will invariably be a "snap" assessment made at the time of analysing the two sites, while plant layout and production programme are invariable units.

5.4 Cost of transport from the plant

In order to be able make any statement on the most favourable site of a smelting plant, it is, however, not sufficient to know the cost advantage of a site. The overall assessment must include an analysis of the sales markets which are to be supplied, of their distance from the alternative sites, of the method of transporting these products to their markets, as well as of the costs of transport. In the end, the most favourable site is that from which the products have the lowest costs until they reach the consumer. The consumer is not interested in the plant location

Fig. 13 - Comparison of net works costs

Product			Output	Work A	Work B	Advantage for work B
				Nett Works costs		
			t/month	DM/t output		DM/t output
Primary products for further processing	Finished sinter for LDAC hot metal		225.500	49,48	44,52	4,96
	Finished sinter for steelmaking iron (OH steel)		75.150	53,51	50,06	3,45
	LDAC hot metal		225.500	139,17	126,26	12,91
	Steelmaking iron		75.150	153,01	140,69	12,32
	Crude oxygen steel		250.000	189,95	180,14	9,81
	Crude OH steel		150.000	211,73	205,55	6,18
	Slab ingots	Ox	170.000	223,73	212,07	11,66
		OH	68.000	249,35	241,96	7,39
	Ingots	Ox	44.000	220,57	209,37	11,20
		OH	6[illegible].600	245,32	238,25	7,07
	Billets	Ox	15.000	246,28	235,68	10,60
		OH	32.320	272,07	265,77	6,30
	Hot wide strip	Ox	115.090	272,84	258,68	14,16
		OH	19.510	299,26	289,50	9,76
Products for sale	Semi finished products	Ox	6.110	247,48	236,97	10,51
		OH	15.270	273,27	267,06	6,21
	Heavy bars and sections	Ox	19.920	362,88	357,73	5,15
		OH	10.870	390,21	389,62	0,59
	Heavy and medium plate	Ox	13.800	355,56	346,02	9,54
		OH	29.734	383,59	378,73	4,86
	Hote wide strip	Ox	18.856	367,25	353,06	14,19
		OH	28.694	398,50	389,52	8,98
	Hot wide strip	Ox	27.500	281,40	268,15	13,25
		OH	12.500	307,82	298,97	8,85
	Cold rolled Products	Ox	107.035	390,46	377,31	13,15
		OH	18.145	418,87	410,44	8,43

Fig. 14 – Analyses of cost advantages for Works B

	Product		Nett works costs			Breakdown of cost advantage						
			Work A	Work B	Advantage for Work B	Ore freight	Fuels b fce	Elec - tricity	Fuels oil OH	Personnel costs *)	Service of capital *)	Scrap
			DM/t output			DM/t output						
Primary products for further processing	Fineshed sinter for LDAC hot metal		49,48	44,52	4,96	5,11	0,42	0,25	-	./.0,09	./.0,30	-
	Finished sinter for steel-making iron (OH steel)		53,51	50,06	3,45	4,02	0,48	0,25	-	./.0,09	./.0,30	-
	LDAC hot metal		139,17	126,26	12,91	7,79	4,95	0,78	-	./.0,13	./.1,02	-
	Steelmaking iron		153,01	140,69	12,32	6,72	6,28	0,78	-	./.0,14	./.1,05	-
	Crude oxygen steel		189,95	180,14	9,81	7,03	4,46	1,34	-	./.0,48	./.1,31	./.0,61
	Crude OH steel		211,73	205,55	6,18	3,36	3,15	1,14	2,15	./.0,64	./.0,97	./.1,06
	Slab ingots	Ox	223,73	212,07	11,66	8,27	5,25	1,96	-	./.0,64	./.1,96	./.0,72
		OH	249,35	231,96	7,39	3,95	3,70	1,74	2,53	./.0,82	./.1,56	./.1,25
	Ingots	Ox	220,57	209,37	11,20	7,99	5,07	1,80	-	./.0,73	./.2,01	./.0,69
		OH	245,32	238,25	7,07	3,82	3,58	1,56	2,44	./.0,91	./.1,62	./.1,20
	Billets	Ox	246,28	235,68	10,60	8,33	5,28	2,14	-	./.1,01	./.2,56	./.0,72
		OH	272,07	265,77	6,30	3,98	3,73	1,89	2,54	./.1,20	./.2,16	./.1,25
	Hot wide strip	Ox	272,84	258,68	14,16	8,53	5,41	3,18	-	./.0,89	./.2,95	./.0,74
		OH	299,26	289,50	9,76	4,07	3,81	2,95	2,61	./.1,08	./.2,54	./.1,29
Products for sale	Semi-finished Products	Ox	247,48	236,97	10,51	8,33	5,28	2,36	-	./.1,01	./.2,56	./.0,72
		OH	273,27	267,06	6,21	3,98	3,73	2,11	2,54	./.1,20	./.2,16	./.1,25
	Heevy bars and sections	Ox	362,88	357,73	5,15	8,82	5,60	2,94	-	./.1,47	./.3,82	./.0,76
		OH	390,21	369,62	0,59	4,22	3,95	2,68	2,69	./.1,66	./.3,39	./.1,33
	Medium bars and sections	Ox	355,56	346,02	9,54	9,05	5,74	3,58	-	./.1,89	./.4,62	./.0,78
		OH	383,59	378,73	4,86	4,33	4,05	3,31	2,76	./.2,09	./.4,19	./.1,36
	Heavy and medium Plate	Ox	367,25	353,06	14,19	10,09	6,40	3,92	-	./.1,95	./.4,73	./.0,88
		OH	398,50	389,52	8,98	4,82	4,51	3,66	3,09	./.2,17	./.4,24	./.1,52
	Hot wide strip	Ox	281,40	268,15	13,25	8,53	5,41	3,40	-	./.0,89	./.2,95	./.0,74
		OH	307,82	298,97	8,85	4,07	3,81	3,17	2,61	./.1,08	./.2,54	./.1,29
	Cold rolled products	Ox	390,46	377,31	13,15	9,17	5,82	5,38	-	./.2,81	./.4,82	./.0,80
		OH	418,87	410,44	8,43	4,38	4,10	5,13	2,81	./.3,01	./.4,38	./.1,39

*) Cost advantages and disadvantages for main cost centres

from which he is supplied. It is the price of products free at his processing plant that matters to him.

Assuming that the production costs are equally great at either site under consideration, and that the products are sold at the same prices, one would note that each location has a closely defined sales area, which can only be supplied from the alternative location at the expense of cuts in revenue.

If we assume further that transport costs are proportionate to the range of transport, we could, in theory, delineate the sales areas by means of a straight vertical line, placed in the middle of the horizontal connection line between the two sites. Figure 15 shows this theoretical solution. Taking into account the above assumptions, the diagram enables us to see that, according to the production cost advantage of site "A", for instance, this central vertical line moves towards site "B". Thus, the sales market which can be supplied at more favourable costs by "A" is being extended.

5.5. Result of assessment

If, after the preceding mathematical analysis, a locational comparison is made, we will arrive at the end result, which shows the location most suitable, out of several locations, for supplying the sales markets. In this context it is, however, necessary to point out that the result is a merely statistical statement, because the calculation was confined to a specific time. Pronouncements on locational advantages in the long run will only be possible after taking into account factors varying with time, like, for example, cost goods prices, cost goods choice etc., as is done in dynamic analysis.

The advantage of comparative statistical analysis lies in the smaller amount of work required. In addition, the information provided by comparative statistical analysis may even be sufficient for long-term considerations, if the factors of influence

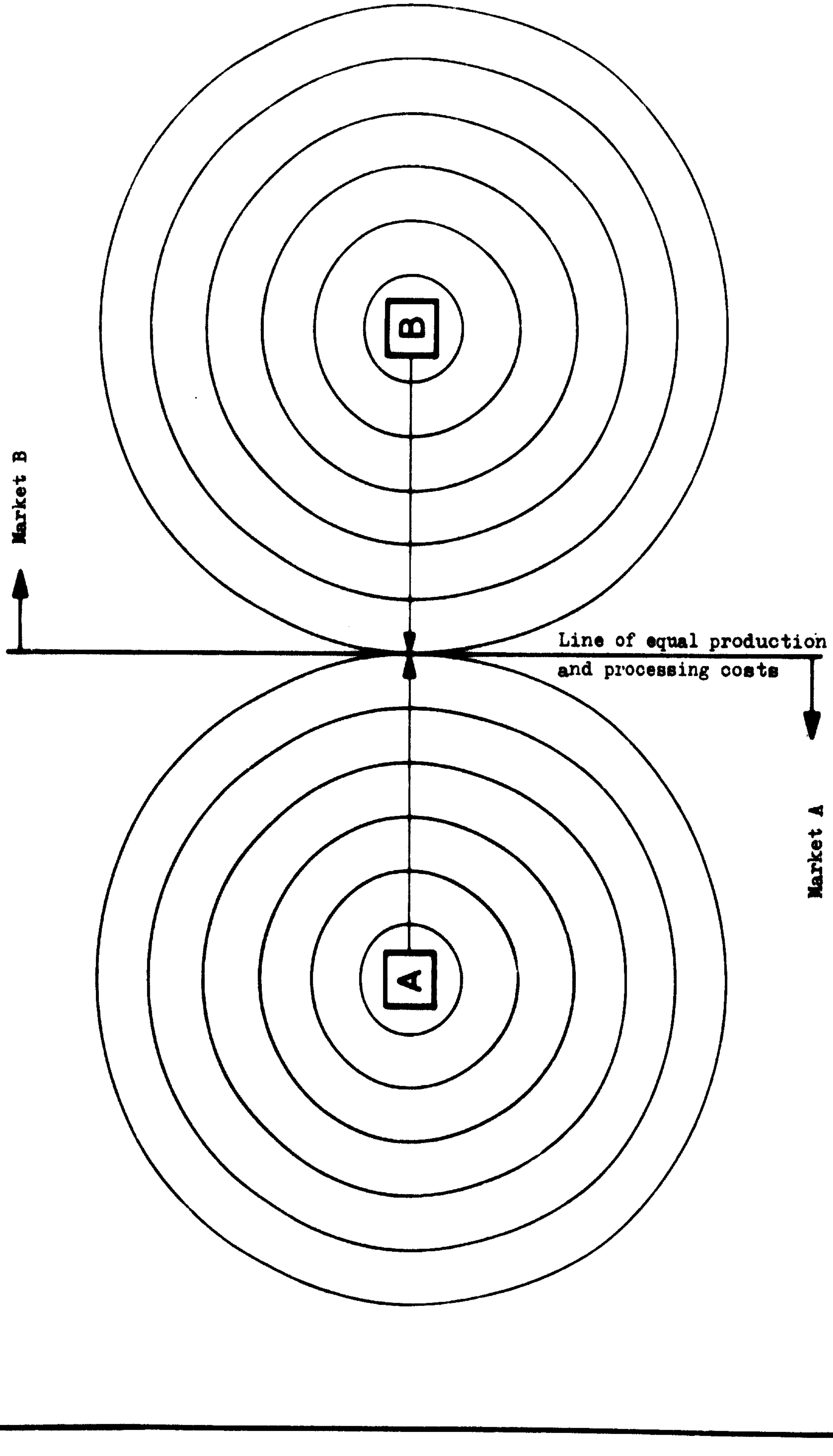

Fig. 15 - Theoretical calculation of markets

accounted for in the analysis are subject to the same trend. This applies, for instance, in the event of both sites under consideration being affected equally by economic policy.

The result of such an analysis must invariably be verified by means of a sensitivity analysis. This, of course, includes a re-assessment of the available information and its degree of precision, the evaluation of purely qualitative factors, as well as all the other premises.

6. Dynamic comparison of sites

Having pointed to the limited information value of statistical site comparisons, we will now try to describe, briefly, the dynamic method of determining a location.

In order to be able to determine the long-term advantage of a newly planned plant, it is necessary to quantify those factors which vary with time, as well as their respective behaviour. Only this enables us to provide positive evidence of an assured long-term locational advantage.

In view of the great number of locational factors, which, moreover, affect each other as well, it is necessary to apply a method which makes it possible to effect locational analysis for the steel industry irrespective of certain geographical regions. A method available for this purpose must enable us to find the most suitable site irrespective of the number of factors of influence and their locational differences. However, the dimensions of such a comparative mathematical analysis no longer allow any manual calculations. For economic reasons, it is, therefore, necessary to devise a mathematical model which can be used for data processing.

Dynamic analytical methods, of course, are based on the same assumptions as statistical ones. They include, for instance, a determination of the sales market and of the sales programme, the development of a sales programme including all the plant and output data as well as sufficient quantitative framework for the consumption of cost goods. In addition, it will be necessary to account for the price of cost goods and their longterm changes at the locations in question. Moreover, a dynamic analysis drawn up in this manner, together with a mathematical model, provides the opportunity of partial optimization, for example through substituting cost goods (e. g. partial decrease of crude-iron input in the LD converter and its replacement with scrap).

A locational analysis of this kind 1), using a mathematical model, was demonstrated at the annual Congress of German Metallurgists at Düsseldorf in 1972. The aim of the analysis demonstrated there was to determine the most favourable method of supplying a familiar market. The model served to assess the lowest locational costs of smelting plant with their own processing plant. At the same time, the model also made it possible to effect a locational separation of smelting plant and processing plant, and to show the result. However, this comparison of sites was based on existing, invariable production programmes and market structures.

In the model, the following items were listed as subject to processional changes or variable according to cost goods input:

- the source of supply of coking coal
- the choice of natural gas or fuel oil for meeting heat requirements (lime-stone or dolomite for the burden)
- the composition of the burden
- the cooling system of the LD steel plant
- the electricity supply of the steel plant
- the locations of processing plant
- the supply of the market from several processing plant.

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1) Weisweiler, Franz-Josef: Modell mit Anwendung für Standarduntersuchungen von Hüttenwerken mit Weiterverarbeitung, Stahl u. Eisen 1973

With the aid of the mathematical model the most favourable alternative was determined for each site, thus obtaining partial optimation.

The question remains as to the cases where this method of locational comparison can be applied. This brief description obviously shows that this method of analysis constitutes another step towards reaching objective results in locational comparisons. However, I believe that, on account of the great amount of work required, it will only be applied if, on the basis of assured indicators, the locational factors can be expected to be subject to substantially different changes in the course of time.

7. Example of global comparative analysis of locations

After an initial demonstration of locational analyses and comparisons by theoretical methods, it is no doubt of some interest to describe the result of such an analysis. For this purpose, however, the description of a more global analysis is more appropriate, because it is more likely to show the essential features in the process. A model example of this was demonstrated by Th. Brandi (1) at the same Annual Congress of German Metallurgists in 1972. The aim of his analysis was to provide an answer to the question of whether a certain site in Western Europe offered any advantages over overseas sites. A global analysis of this kind first required the establishment of certain premises whose validity must be verified by the analysis. Thus the investigation assumed that

1. The geographical situation of the plant with regard to the sales markets and, with it, the cost of transporting finished products from the plant,
2. The geographical situation of the plant with regard to the raw material markets and, with it, the cost of transporting raw materials to the plant, and

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1) Th. Brandi: Stahl und Eisen 1973

3. An energy supply assured with regard to types of energy, quantity, and price, are decisive for determining the optimal site, and that, moreover,
4. Approximately 5o per cent of the total cost is caused by raw-material input and energy consumption.

On the basis of these premises, it is possible to describe the optimal site in terms of its proximity to the sales market, the iron ore and the sources of energy.

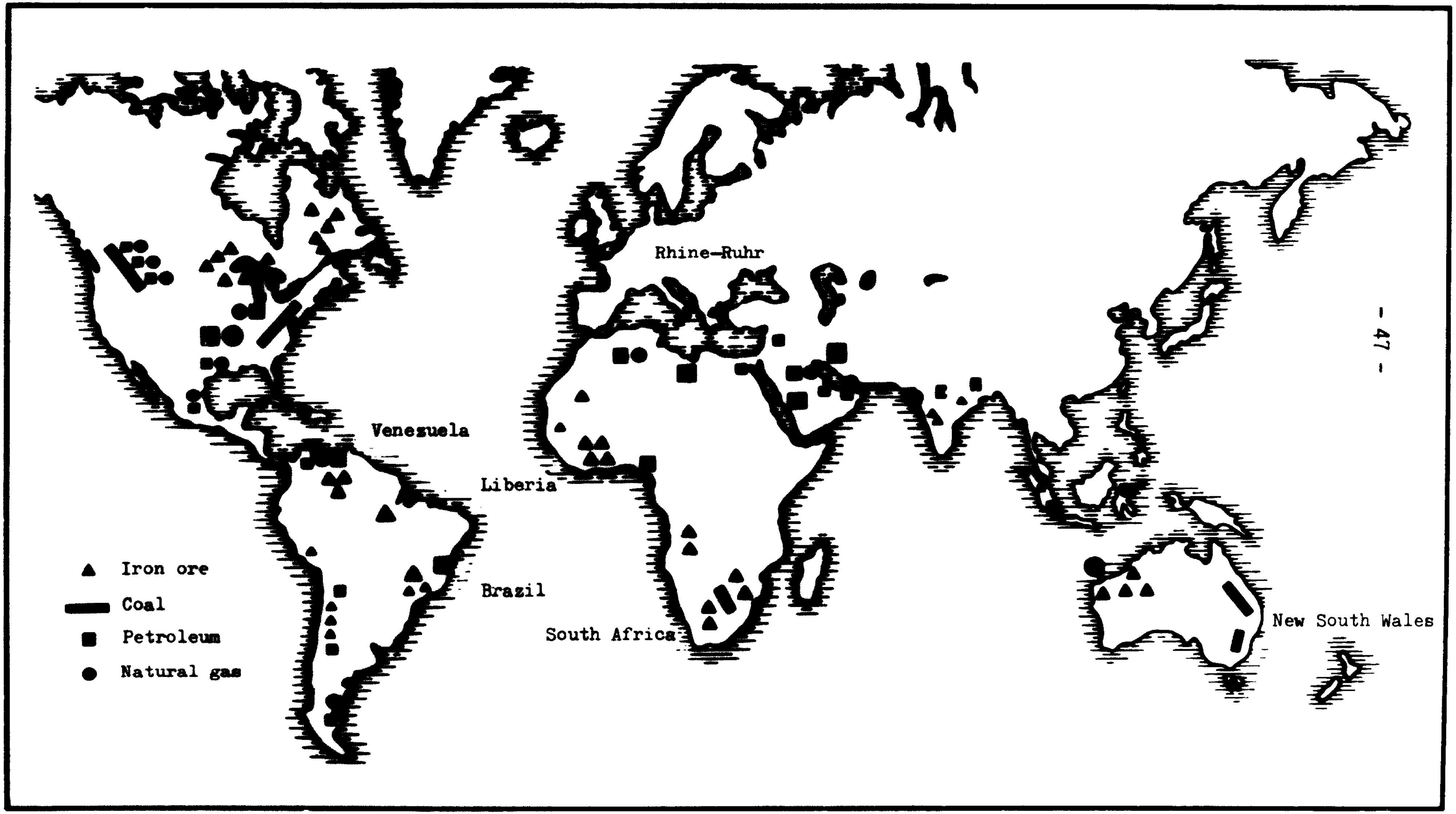
Starting from this, an analysis was made of those regions of the world which have deposits of iron ore and which can supply energy (cf. Figure 16). The result is that iron ore and energy can only be found closely together in the USA, in India, Southern Africa, and Australia. There are large iron-ore deposits in South America and West Africa, but these areas have quantitatively and qualitatively insufficient deposits of coking coal. From this first analysis, only the following countries offer competitive sites:

a) Venezuela
b) Brazil
c) Liberia
d) Southern Africa
e) Australia

At first sight, plants located in these areas seem to offer an advantage over certain plant locations in western European inland areas. Their advantage is due to the fact that the freight rates for carrying iron ore to the plant are comparatively low, and that coking coal is cheaply available from nearby areas or can be bought cheaply in the world market.

If we calculate these cost advantages over a European plant on the raw material and energy supply side in terms of a mixed consignment of semi-finished and finished products, we will arrive at a sales area which - only in terms of the above-mentioned four assumption - could be supplied more favourably from the sites considered.

Fig. 16 - Significant non-European iron-ore and energy resources (excluding the Eastern Bloc) [after Brandi]



A projection of these advantages on a world map (see Figure 17) reveals that, with the aid of lower input material costs, the African coast could be supplied from southern Africa, as could some of South America's east coast (dotted line). In addition, it becomes clear that the coasts of Western Europe could be reached from Venezuela, since the lower cost of input materials roughly balances the cost of transporting finished products from the plant. What is more, almost the entire coast of South and North America as well the West coast of Africa can be supplied more favourably from this location (see full line).

However, Brandi points out in his analysis that two major factors have not been considered in this analysis:

1.) The cost of producing steel has been assessed as being equally great for all locations considered, or, respectively, it has not been taken into account in the analysis. An exact detemination of the steel-producing costs would have required too extensive an analysis of every locationally specific factor.

2.) The cost analysis of the transport of rolled-steel products only includes the cost of loading and transport at sea. The cost of unloading, customs duties, etc. has not been taken into account. On the other hand, possible decreases in transport costs through the use of special ships, on account of its long-term character etc. have not been included in the analysis, either.

However, these locational factors, which were excluded from the analysis, are so important as to justify the claim that competitiveness in the European market is not positively assured by plant sites in Venezuela, either. As we said before, locational advantages consist not only in favourable energy and raw-material costs. 1)

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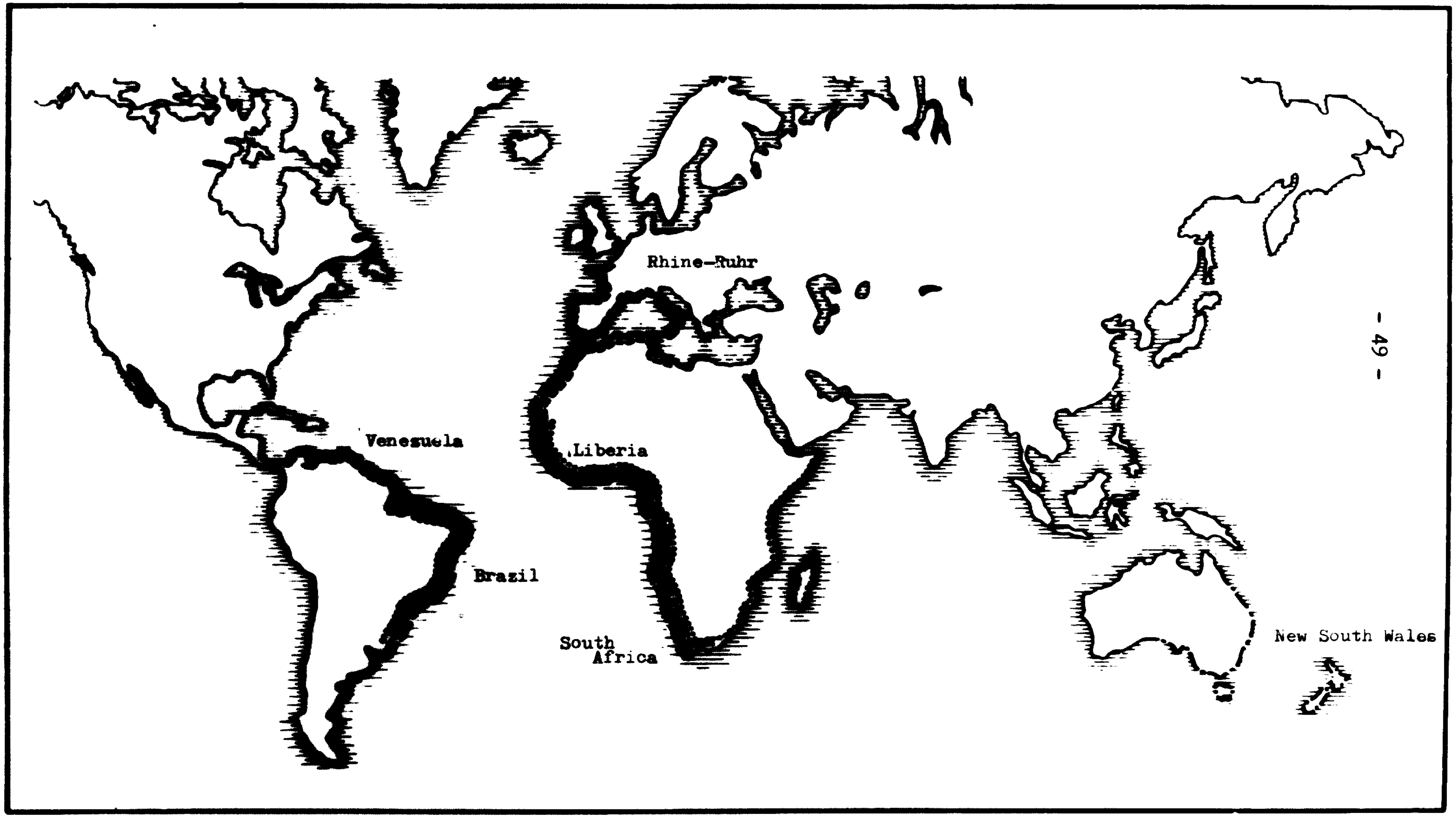
1) v. d. Rijst, v. d. Woestijne: in Stahl und Eisen 9o (197o p. 449

Fig. 17 - Competitiveness of certain locations compared with a location in western Europe



The global analysis of locations described above did not deal with any precisely defined site, but a region or a country as a whole, where a plant may possibly be established. This method of locational analysis makes it possible to exclude those regions which a global analysis proves to be at a disadvantage, before a detailed analysis of the sites under consideration is made. This is why I considered describing the above example to be interesting.

Conclusions

After this brief survey of the possibilities of determining the most favourable site for a smelting plant it is, I think, necessary at this final stage to point out once again some major problems entailed in such investigations.

Thus the description has, I hope, shown how complicated an analysis of locational problems is. I have tried to demonstrate that an exact analysis required sufficient time, as well as experts who possess the necessary amount of knowledge and experience. General considerations are of little assistance in this context. Irrespective of this, one must be aware of the degree of exactness of such analyses. The result of any investigation can never be more exact than the information constituting its data framework! However, the fact that locational factors partly change at different rates means that there is no such thing as a permanently optimal site. 1) For the choice of location, this means that it must be adapted in each case to future developments instead of being solely based on the data valid at the time of analysis.

It may therefore, be taken for granted that, in any discussion on a possible site for a smelting plant, the general requirements for establishing this type of production plant are fulfilled.

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This includes a solution of the problems of raw-material supply, supply of labour, and infra-structure in its long-term development. However, it is just as important to know, as far as is possible, the development of the sales markets and the possible behaviour of the competitors operating in it. For it is nowadays impossible for anybody to make fully isolated decisions in a world-wide economy with its many mutual relationships.

The scope of this description made it impossible for the location problem to be discussed from a macro-economic point of view with its altogether different methods. Objectives of structural or general economic policy may, from a macro-economic point of view, render a location interesting which the enterprise concerned is first bound to reject as unfavourable from a micro-economic viewpoint. However, with the aid of fiscal preferences, taxation policies, tariff policies, state grants etc., the national economy may modify locational factors to the effect that macro- and micro-economic objectives tally. These mutual relationship and their prerequisites could not be discussed within the scope of this paper, although they are certainly of major importance for developing countries building up their own industries.

The above applies, in particular, to national economies with scarce financial resources. This is why every decision of economic policy which calls for state finance must be examined with regard to the alternative investment possibilities for these financial means, in order to invest the money in such untertakings which produce the highest marginal profit for the national economy. For the latter, this may mean that, on account of the above factors, a site regarded as optimal may have to be dispensed with. For such a decision the only standard is a comparison of the product cost of plants in the country, as determined by locational analysis, and a comparison of these figures with world market prices.

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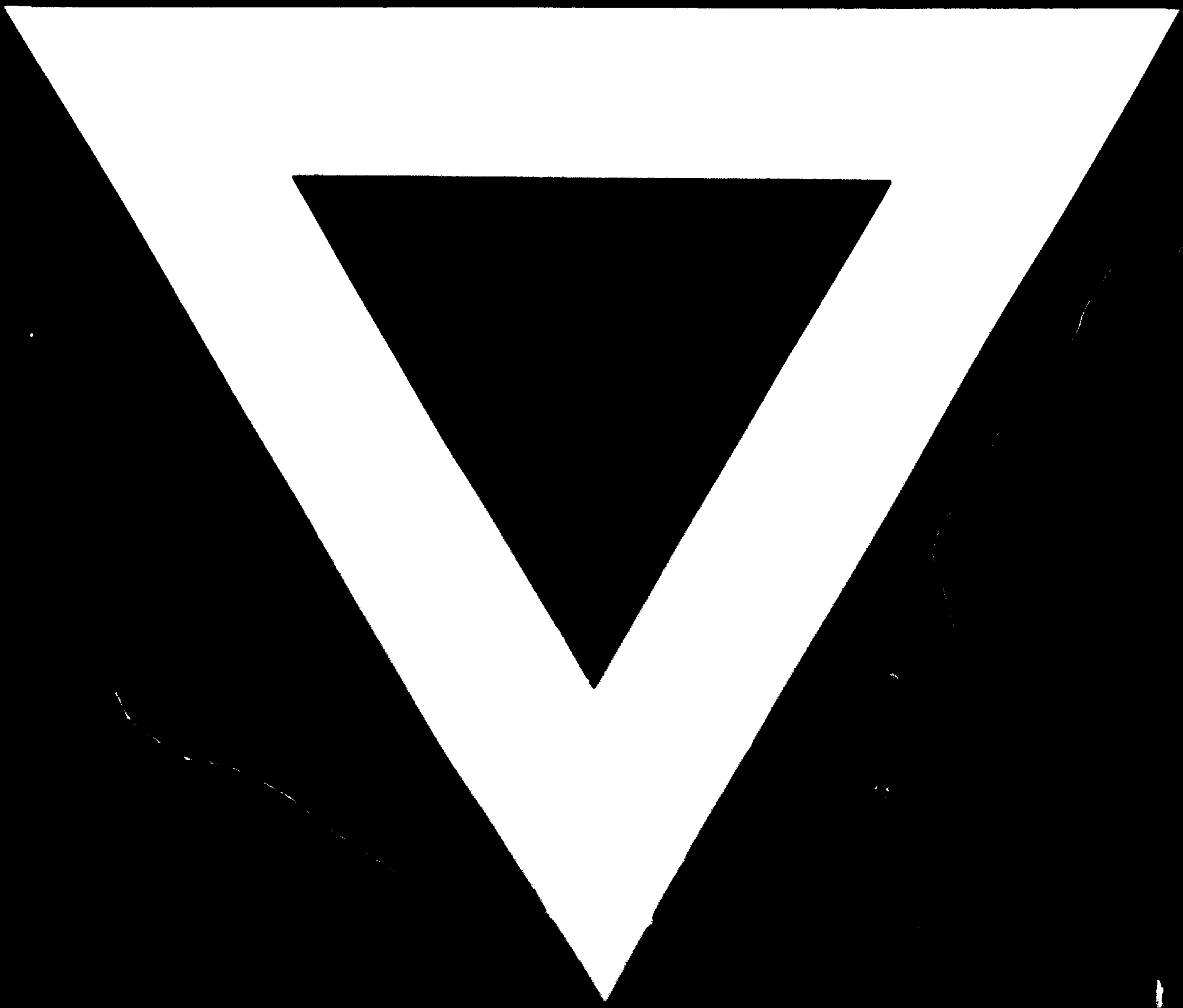

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