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Moscow, USSR, 19 September – 9 October 1968

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STEEL PLANT LOCATION
A GUIDE FOR THE DEVELOPING COUNTRIES [1]

by

Elbert T. Culver and Jai Pearce
United States of America

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SUMMARY

The building of a steel plant in a developing country may be desirable for a number of economic, social or even political reasons. Regardless of objectives, it is invariably necessary to establish a reasonably accurate picture of the economics of the project and be able to demonstrate clearly to potential sources of loan funds how the debt incurred to build the plant will be serviced and repaid.

There is no possibility of calculating the operating economics without studying plant location; it is equally impossible to establish plant location without giving due regard to the economics of all the factors which affect the type, the size and the location of the plant. All these factors are inter-dependent and must constantly be evaluated in terms of one another as data become available.

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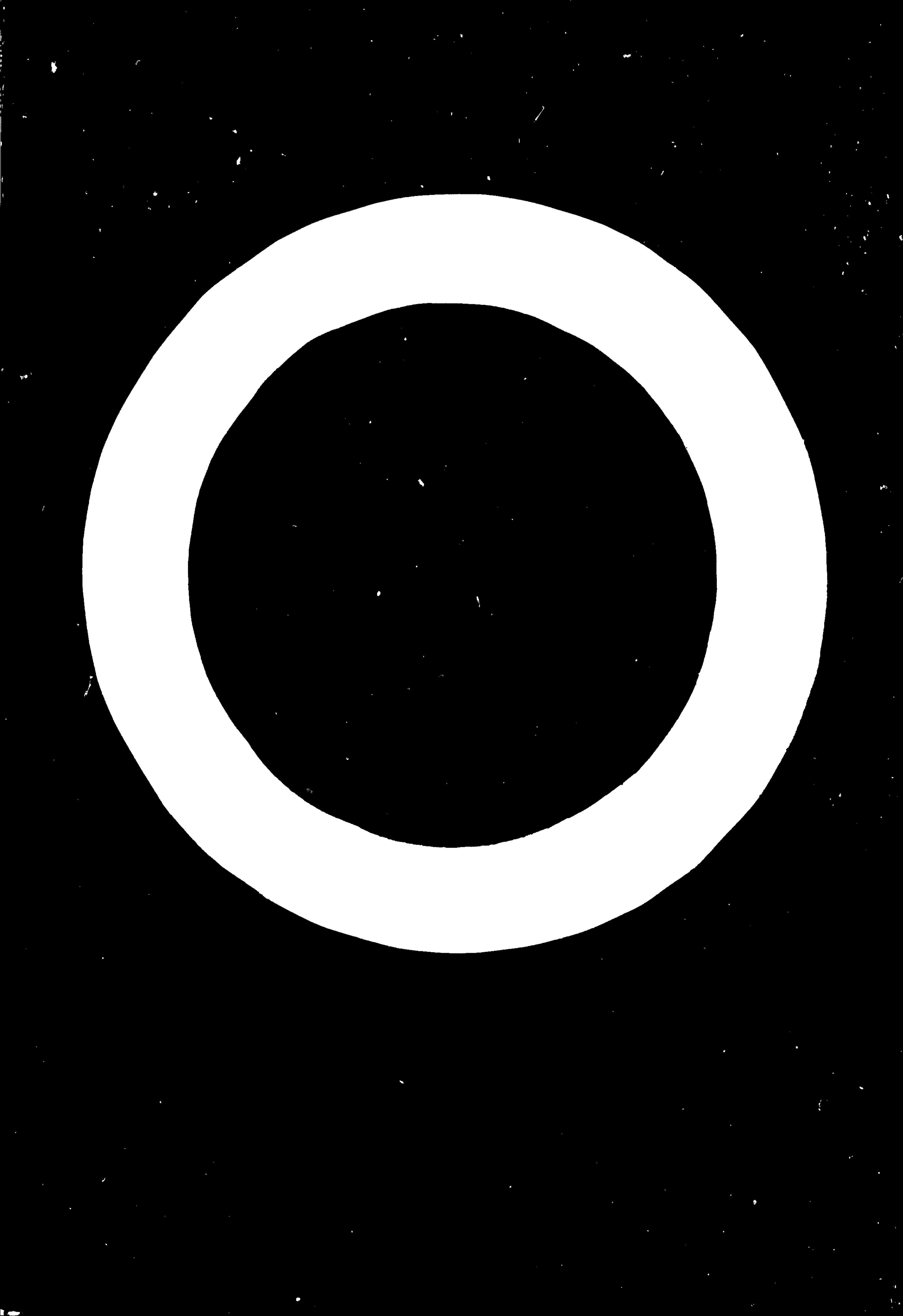


In approaching the problem of establishing a steel plant, the essential factors in the correct sequence of analysis are, first, those which establish over-all project viability and, second, those which apply to selection of a specific geographic site. Those which involve viability include markets, raw material utilities, manpower, socio-economic and financing elements. Those concerned with specific sites are transportation, equipment and materials availability, meteorology, geology, etc.

Market studies must be approached from two directions, the theoretical and the practical. Official statistics, current census, and rate of expansion of population figures are frequently available. Customs or excise department figures on steel and steel equipment imports, and industry survey figures on metal production may be found. Per capita steel consumption figures may be available, or if not they should be estimated. Projecting apparent current steel consumption figures to show existing and near future demands is then a fairly simple matter.

The second, more practical, approach is to go directly to the market place for current requirements and predictions of future sales. Questions are asked of the steel producers and rollers; they are asked of the importers, of the fabricators, of the warehousers and distributors, — of all the consumers. A summation of the data derived from these studies will give the investigator a valuable lead as to what types of steel products are in demand and in what quantities. By interpreting the market place findings in the light of statistical facts, it is possible to establish a practical product mix for the projected plant.

Concurrent with the above studies, a team of experts must undertake a raw material survey. All local sources of iron ore, coal, limestone and other materials must be thoroughly investigated and the materials analysed and tested.

The solid minerals entering the ironmaking process comprise only one classification of raw material. For feasibility study purposes, close attention must also be given to the water and energy requirements of the plant. Under certain conditions the presence of surplus utilities or the absence of others can dictate plant location or metallurgical process or both.

Up to this point in the investigation, no real technical or commercial basis for attempting to fix a site has yet been established. However, once the processes are selected and the plant input and output tentatively set, it is time to look at the map. In the study of steel plant feasibility, and ignoring for the moment all social and political implications, the criterion for logistic study is the ultimate cost of a unit of molten steel, at a particular place, ready to be cast into a semi-finished product. All the input into the plant is appraised with respect to the cost of, for example, one ton of crude steel.

Thus, in the case of iron ore, the cost of mining, delivering and smelting local ore must be compared with the same cost for importing and smelting high grade ore from elsewhere to produce the same tone of steel. In the case of coal the effects of higher ash or sulphur in local coal must be appraised in the light of the ultimate cost of producing steel. Similar analyses must be made on each input item - the limestone, the cooling water, the labour requirements - all must be appraised in terms of cost per ton of crude steel.

A plant site, ideal from most other viewpoints, may be in a location completely remote from any source of labour supply. In this case the cost of an entire town including transportation, utilities and other infrastructure must be considered along with (but not part of) the cost of the steel plant. Obviously, availability of manpower can become a critical, or even the controlling factor in site location.

Experience and common sense will have limited the potential locations within a given country to a relatively few areas. In addition to studying each of these from the standpoint of logistics, it is now also necessary to investigate such matters as land availability, site and soil conditions, geology, meteorology, special construction problems, nuisance abatement, etc. All this data, reduced to cost figures where possible, is tabulated and a tentative selection made, normally involving two, or at the most three, alternate sites.

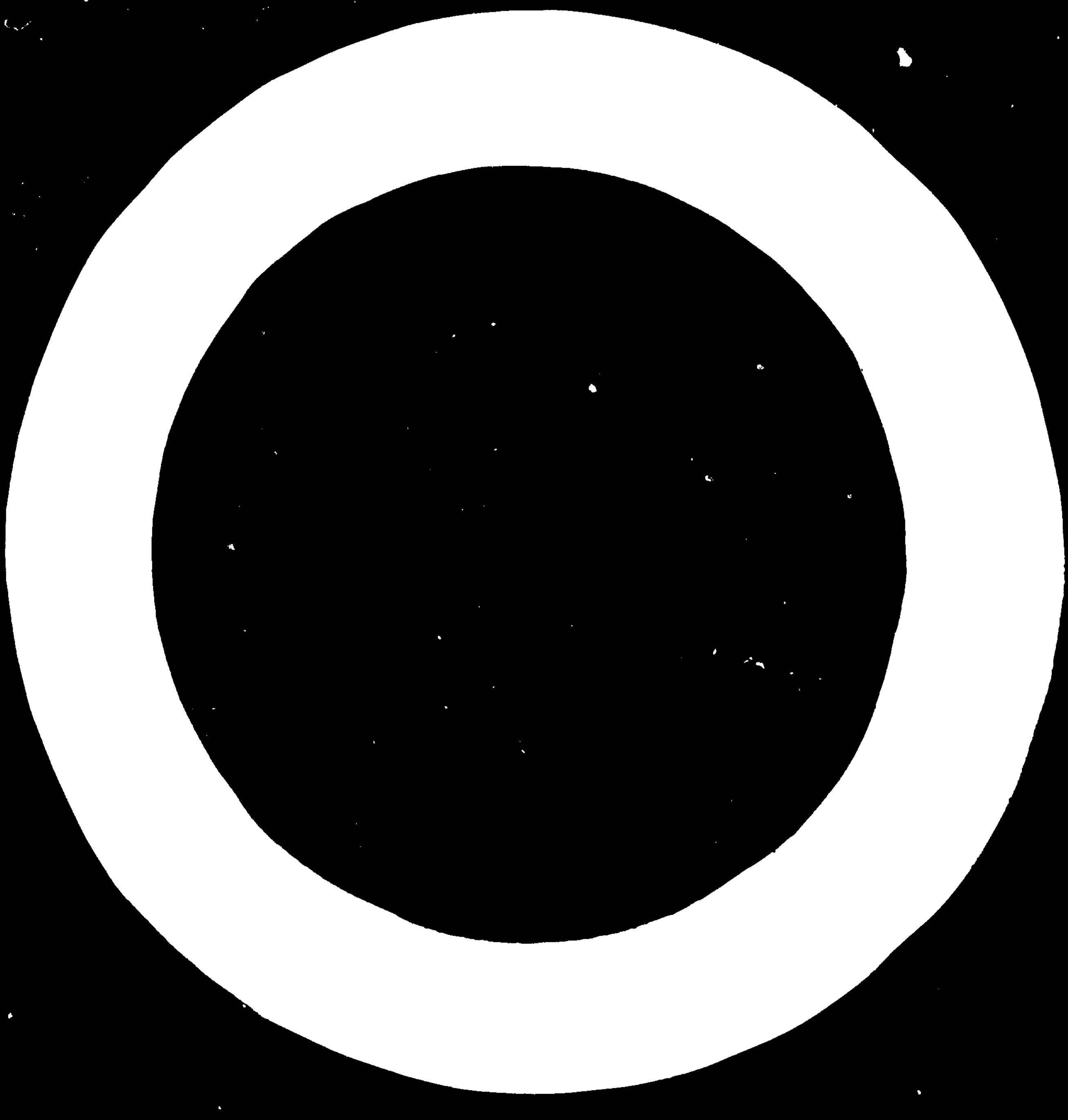
The discussion so far has been concerned only with the factual, the technical, the pragmatic aspects of plant location. Two other very important factors have not yet been explored. These two will invariably have a most profound effect on the location of a steelmaking plant.

The first is concerned with the socio-economic aspects of the undertaking. While a steel plant by itself creates relatively few jobs compared to the vast sums of money spent, the ultimate new employment record may well show an increase equal to ten times or more that of the mill itself. A guaranteed local supply of semi-finished, competitively prices steel will encourage new enterprises which will in their turn provide additional jobs and reduce imports. Many service-type businesses will be started to provide transportation, retail stores, restaurants, maintenance shops, communications and similar facilities required by a growing industrial community. Thus the tremendous investment in the basic plant has, in fact, spawned an entirely new community and raised the standard of living of perhaps thousands of people. It is obviously a matter of serious concern to any government to guide such growth carefully and in accordance with an over-all master plan for national development.

The second factor is financing. Financing, as the term is used here, is concerned with obtaining the foreign and local capital to pay for the plant. All countries large or small are more than a little concerned with their national budgets and accounts. A steel plant may be a country's largest single investment. Suppliers and their parent countries must, therefore, recognize their obligation to assist clients in the developing countries in the avoidance of high cost, overdesigned, or poorly located plants.

By strict attention to finances, that is to say, by minimizing plant capital and operating costs through effective market analysis and plant sizing, by accurate raw material investigations, through thoughtful logistics studies, and scientifically approached site selection, the financing of the project should not pose money difficulties in the years to come, and the plant itself can make a major contribution to the nation's financial strength.

To illustrate the points developed in the paper, a comparative analysis of three hypothetical steel plant developments in different parts of the world will be presented. This will be followed by a tabulated illustration of the details of specific site selection which applies basic principles to four potential areas in a single country. Each of the major factors affecting plant location will be investigated and a tentative conclusion drawn based on the facts presented.



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The building of a steel plant in a developing country may be desirable for a number of reasons. For instance, saving or earning foreign exchange, improving the supply of finished or semi-finished products, increasing earnings through the sale of manufactured products abroad rather than raw commodities, the establishment of additional jobs for an expanding population, or even the social and economic growth of an entire region brought about in part through the development and expansion of dependent satellite industries.

The capital investment in a new steel plant is never small and can indeed be a very large sum of money. Therefore, regardless of the aims, it is invariably necessary, as a pre-requisite to actual construction, to establish a reasonably precise picture of the prospective economics of the project. Only thus will it be possible to demonstrate clearly to potential sources of loan and equity funds how the debt about to be incurred to build the plant will be serviced and repaid.

Furthermore, experience has time and time again indicated that because a new steel plant represents a major investment of scarce resources of a nation, it needs to be first analyzed on a fundamentally economic basis. Project economics thus becomes a matter of prime importance.

There is, however, no possibility of calculating the project economics (including the effects of both capital and operating costs) without studying plant location. It is equally impossible to establish plant location without giving due regard to the economic impact of all those factors which affect the type, the size, and the location of the plant. All such factors are interdependent; all must be evaluated in terms of each other. Certain conditions are fixed by the geo-physical or political background. Others are variable, and these must be analyzed, evaluated, sifted and blended with the fixed conditions to assure a commercially, technically and financially sound project.

In the course of investigations leading to establishment of a new steel plant, experience has indicated that the self same factors requiring evaluation for plant location proper, have a major impact on other areas of the project as a whole. Accordingly, frustrating losses of time and effort may be avoided by isolating the common denominator factors, determine what is needed in each case, and then evaluate them in relation to plant location in two sequential parts: First, the establishment of general project viability; second, the selection of a specific geographic plant site.

While these two steps are complementary, in that work on the second step cannot be carried further without use of information collected and analyzed for the first, this procedure permits control on the time and effort involved. The first step of viability approaches the plant location problem based on a general site area selected by experienced judgement. This could be either from sites provided by previous studies within the country or through prior survey of influencing factors based on published or unpublished information. The viability step thus establishes a preliminary economic basis that justifies or rejects further work and expenditure on the project, including the second step of actual site selection.

This paper emphasizes the use of techno-economic and engineering analysis techniques for evaluation of factors affecting steel plant location. It first provides an overview of the various influencing factors requiring attention to establish both general project viability and the selection of a specific plant site. It then takes each variable factor and analyses it in terms of the type of survey required, what information is needed, and what use is made of the results obtained. It discusses the use of techno-economic techniques to establish general project viability, and illustrates through practical application the use of methods established to three hypothetical situations with widely varying social, geographic, supply and market conditions. This is followed by an illustration of how practical results from survey data are supplemented by local site factors, and used for selection of a specific plant site; using as an example, four possible plant locations in a specific country or region. It concludes by highlighting the influence of political, social, and financial considerations which, in many instances, provide the compelling and final basis of steel plant location.

FACTORS INFLUENCING PLANT LOCATION

As indicated earlier, the viability step established preliminary economic justification of the project as a whole. It is also observed that in any given situation, the geo-physical factors representing the nature and geographic location of natural resources, the climate and physical features of an area, are fixed. The political environment is also fixed. Accordingly, it is the logistical aspects of the variable factors which when weighed with the fixed that provide a means to determine project viability and/or the selection of a specific site in a given area. In making this logistical evaluation, it is important to note that accessibility is the most significant consideration. This is because both the viability and site location steps are essentially relating in a logical manner, via the most accessible routes, the key factors influencing steel plant location - markets, raw materials, utilities, manpower, transportation, infrastructure, financing and other related factors which have to be evaluated through experienced judgement.

However, before applying such a concept to the plant location problem, the first consideration is to obtain the data necessary to start the study. This must be done through field surveys in each key area by experienced specialists, since the validity of the study depends to a great degree on the accuracy and the comprehensiveness of the data collected. The main questions that arise at this point are - What is it that is required from each survey? How will the results be used? How is the survey to be approached? Obviously, if basic guidelines are to be established, these can become the most critical in terms of the costs, time and effort required. Let us examine what is required and analyze each influencing factor and its related survey in terms of approach, needs and uses.

MARKET SURVEYS

Market studies can be approached from several directions, including: (1) projections from past trends of steel consumption, (2) correlations of steel requirements with planned economic growth, (3) analogies with experience in similar countries when they were at an equivalent stage of development, and (4) expectations of major steel consuming elements within the country obtained through field visits.

Successful studies generally use a synthesis of all these methods, tempered with independent judgment of a given country's potential based on underdeveloped natural, human, and financial resources. The nature and stability of the political and social framework under which the study is made must also be given strong consideration.

The need for combining several approaches in developing valid estimates of future market requirements results from the possible weaknesses inherent in any single method depending on the prevailing conditions. Experienced judgment from years of marketing work and market research, however, provide the solution to the most appropriate combination of methods to be employed.

Notwithstanding, the most appropriate market study technique, which is outside the scope of this paper, the major results from a market study should, for any meaningful plant location study, provide the (1) size of market, (2) consumption pattern of major industries and specific types of products consumed together with projected potential, (3) current and probable future product prices, tariff and import duties and related government policies, (4) present and future availability of scrap, including quality and price, (5) anticipated present and future product shortfalls after accounting for existing capacity and (6) indication of shortfalls by specific product size range for projected plant design.

Once such data is available, the determination of plant size, product-mix and projection of potential sales carefully analyzed in terms of specific type of steel products is a relatively simple task. However, in such an analysis the limitations of mill equipment and operating economics must be carefully considered. It is not unusual for such studies to disclose a need for a wide range of products. This need must accordingly be tempered by experienced consideration of plant capacities and costs in relation to steel plant equipment capabilities, particularly with respect to the rolling mills. It is usually impractical to meet a country's needs in a single plant at the outset of a project. Furthermore, it is not practical, contrary to common belief, to vary rolling mill production over an excessively wide range of sizes and products without seriously impairing plant efficiency. Therefore, some importing will continue until increased demand makes further installations economically attractive.

RAW MATERIAL SURVEY

Concurrent with the above market studies and the preliminary delineation of the plant product mix, a team of metallurgical experts must undertake a general raw material survey. Since iron constitutes a major portion of the earth's crust, it is an unusual situation where iron ore of some variety is not available. The overriding factors are quantity, quality and availability. All three must show considerable promise to make local supply attractive.

Concerning quantity, there should obviously be sufficient proved reserves to supply the plant, not only as built, but also considering future expansions, for at least 25 years. Qualitywise, the presence of gangue materials is harmful, and can have significant impact on process selection, production techniques and costs. High gangue content means excess material must be mined; excess weight must be shipped - excess energy must be supplied for each unit of production from the smelting process. The vast quantities of high grade materials available today in the world at competitive prices taken together with the emergence of high capacity bulk carriers for ore transport, make unusual, as a general rule, the consideration of ores analyzing less than 60% Fe. The subject of availability should therefore need little comment. Mining cost and accessibility can, however, become a predominant factor in source selection. Ore bodies in inaccessible hinterlands can be considered only under special circumstances.

Coal and/or coke is a far different story. There are relatively few deposits of high grade, non-sulfurous, low ash coals in the world, Since with the exception of one commercially operating ironmaking process employing gas as a reductant, some form of solid carbonaceous material will be required, serious consideration may well have to be given to imported coal or coke. This latter commodity is generally in short world supply and establishing a price for delivery some years in the future is an uncertain business. It is probable that any sizeable, long-term coke contract would be met only by erecting additional facilities at an existing installation. Coal on the other hand is much more readily available than coke and the survey team's job will be confined to evaluating sources, qualities, prices, and shipping costs.

Limestone, the fluxing ingredient in the process, is like iron ore, found almost everywhere. It may, however, involve considerable exploration and testing to find grades suitable for iron and steel making which are so located that transportation is not prohibitively costly.

Finally, there is a sizeable number of small tonnage material requirements -- silica, fluorspar dolomite, ferroalloy and other additives, all of which must be priced in the country under study. Such information is not difficult to assemble if sufficient time and expertise is available.

For purposes of techno-economic evaluation, the raw material survey should provide the (1) quantity, quality and availability of iron ores and/or agglomerates, coal and/or coke, limestone and indicated miscellaneous materials, (2) the mine-head or source costs of each, (3) applicable price quality and quantity differentials, (4) applicable tariff and duties for importatron and related governmental policies, (5) the prevailing transportation situation relative to each raw material and its source, (6) applicable transport tariff and related future policy and (7) estimated developmental cost and timing for new raw material mines and transport facilities.

The result of the raw material survey taken together with the market studies provides a logical basis to establish the preliminary plant metallurgical process, and in turn permits the development of necessary plant material requirements. Based on these, a preliminary economic analysis provides guidelines for determing the most suitable basis for establishing the extent of local raw materials and required impor s. The size of imports in turn would have a significant effect on the decision for a seaboard location.

UTILITY SURVEY

The solid minerals entering the iron and steelmaking process comprise only one classification of raw material. Even for preliminary feasibility study purposes, close attention must be given to the water and energy requirements of the plant. A number of areas of the world have totally inadequate supplies of fresh water in quantities to meet steel plant requirements. Partial substitution of salt water is feasible, but fresh water is always required and must also be brought to the plant at a reasonable cost. Energy may be in the form of steam, gas, coal, electric power, etc. The potential sources of each must be evaluated, and the necessity of meeting emergency situations cannot be ignored.

These and all the other investigations of physical resources for the projected plant must be carefully considered together for the selection of the most advantageous process. Conventional and well proven processes should be given prime consideration. However, if abundant electrical energy at low cost is available together with high grade ore, this may well suggest an electric smelting operation. An unused source of natural gas may provide such a cheap form of reductant that this single consideration may appear compelling over all others in dictating the process. It should therefore be obvious that the utility survey must be considered together with raw material and market studies to establish the "best process" and in turn the optimum plant size.

Thus, for any meaningful analysis, the utility survey must provide the (1) overall situation in various areas with respect to location, capacity and characteristics of water power and natural gas (2) the quality, and potential availability in each area to meet both the needs of the plant and infrastructure (3) the estimated planned developmental costs to make adequate sources available (4) cost and pricing policies for utilities (5) the stability of utility systems, limitations and emergency provisions (6) long range development plans and related policies. This data integrated with the raw material and market data permits evaluation in some detail of the advantages and disadvantages of not only plant process and size, but the suitability of a specific location.

MANPOWER SURVEY

A plant site, ideal from most other viewpoints, may be in a location far too remote from any source of acceptable labor supply. In this case the cost of an entire town, its utilities, its transportation system, and all other such infrastructure must be considered along with the cost of the steel plant. Obviously, availability of manpower can become a critical, or even the controlling factor in site location.

Physical proximity may prove to be the lesser of two problems, the other being the quality and state of training of the personnel available. Developing countries will normally not have a pool of experienced steel workers from which to draw. They may even have to depend on people who have had little or no schooling of any sort to fill key positions in the new steel plant organization.

The task of transforming uneducated, agrarian people into semi-skilled technical workers is extremely difficult, but certainly not impossible. This point has been proven over and over again in many types of industrial enterprises in some of the more remote areas of the world.

The big danger lies in underestimating the time and money involved. Although professional assistance should be sought once the viability of a project is fairly well established, still even preliminary studies must anticipate this potentially major expense. A manpower survey should, therefore, provide (1) prevailing concentration of manpower (2) prevalent and potential manpower skills and capabilities (3) manpower aptitude and attitudes to training and relocation (4) existing manpower costs and related policies by disciplines and skills and (5) estimated future costs and related labor policies.

This data considered by regions may provide a major influence in plant location. It is not unusual to find concentration of skills, and relocation expense must be considered in final selection of a site.

TRANSPORTATION SURVEY

The accessibility of a given raw material source and/or market to a plant site considered favorable in relation to other factors, may well be offset by the lack of adequate transportation facilities. Depending upon the available modes of transportation, a techno-economic evaluation in terms of raw material assembly costs to a proposed plant siting area, and the delivery costs from the plant to market areas, may either independently, or taken together, dictate the need for a specific plant location.

A transportation survey must provide (1) the available modes, their prevailing capacity and limitations; and future potential (2) developmental costs for transport links to markets and raw material sources (3) the availability of chartering and/or leasing services (4) the prevailing tariff structure and related governmental policies (5) the limitations on handling of heavy loads and lifts for plant construction (6) location of deepwater ports, existing and future, depth of water, tidal range and other limitations (7) harbor dues and taxes, customs procedures and related policies (8) harbor equipment and developmental plans (9) stevedoring costs and their availability (10) prevailing vessel waiting times and flag restrictions and (11) prevailing market distribution patterns and future possibilities.

The resulting data used in conjunction with the raw material and market studies will provide a means to systematically evaluate the advantages and/or disadvantages of specific areas for plant location and develop relative cost comparisons in terms of assembly and delivery of raw materials, men, equipment and products. It will also permit development of marketing and distribution plans to meet both steel plant and local needs.

INFRA-STRUCTURE SURVEY

The term infra-structure refers to all related facilities outside the plant site under study. It provides a measure of the ancillary services that would be available to an industrial complex in the area. This would include such items as housing, hospitals, schools, shopping and recreational facilities, available industrial opportunities, transportation facilities, available utilities and power for plant construction and services, etc.

It is obvious, that in establishing a new steelworks, a major investment on infra-structure may be avoided if such facilities were already present. The availability of service and maintenance shops would reduce capital requirements for such purposes during plant construction and operations. The prevailing social and industrial policies in a given area become important, particularly in terms of financing of infra-structure and the overall responsibility involved. The available communications, power characteristics, and waterworks, etc., all play a very important cost role in plant location. Whereas, the overall impact of infra-structure may not play a predominant role in the first step of establishing project viability, it would be a significant factor in selecting a specific site in the area under consideration.

An infra-structure survey needs to provide data pertaining to both local and expatriate needs. In any new steel plant established in a remote location of a developing country that lacks necessary skilled manpower for plant construction and operations, the local transfer of population and expatriate requirement can be high. One of the main factors required to attract such skilled personnel to the area is the availability of reasonably adequate infra-structure. The infra-structure survey data should therefore account for both local and expatriate needs in terms of (1) size of local population and number of resident expatriates (2) available housing and types (3) hospital facilities (4) schools (5) available utilities for construction and operation (6) shopping, market, and recreational facilities (7) transportation facilities (8) communication facilities (9) available service and maintenance industries (10) prevailing policies on social and industrial planning, method of financing infra-structure and government agency responsibilities.

ESTABLISHMENT OF PLANT VIABILITY

Up to this point in the investigation, no real technical or commercial basis for determination of plant viability or an attempt to fix a site has yet been established. However, during the various surveys discussed earlier, a reasonably good opportunity has been available to check out the general site areas that were initially provided either by the contracting agency or through a paper survey. It is now possible to review the specific survey data collected and inspect the map more carefully to make a reasoned guess as to the likely plant site on which to make the plant viability analysis. For this step of the investigation experienced judgment coupled with preliminary techno-economic analysis are considered the best guide lines. It is the authors considered opinion that until viability is established on this basis, there is little point in making precise, detailed and expensive studies on individual sites. These are discussed later in this paper.

The field data that needs initial evaluation is the market survey - the first and perhaps the most important single factor affecting the entire project. It provides the means to establish the plant size, the product-mix and the projection of potential sales. Plant size and product-mix together may by themselves, or perhaps in conjunction with raw material and utility studies, fix the major metallurgical pro cesses to be employed. With the plant sized, and the product-mix and process selected, it is then possible to tabulate the estimated raw material, utility, manpower, transportation and essential infra-structure needs. Once these well considered figures are available for analysis, it is now finally possible to go back to the question of logistics and accessibility and examine the projected steel plant from the standpoint of the many factors affecting the actual cost of supply, production and delivery.

The term logistics, formerly used only in a military sense, is the art and science of supplying the correct quantities of men and materials to a given place at the lowest cost and with predictable regularity in order to bring about a desired result. In the study of steel plant viability, and ignoring for the moment all social and political implications and the effects of distribution to various markets, the criterion for logistic study is the ultimate cost of a unit of molten steel ready to be cast into a semi-finished product. All the input into the plant, both in terms of capital and operating requirements, needs to to appraised with respect to the cost of, for example, a ton of crude steel.

Thus, in the case of iron ore, the cost of mine development and the cost of mining, processing, delivering and smelting local ore must be compared with the same cost for importing, stockpiling, and smelting high grade ore or pellets from elsewhere. In the case of coal the adverse effects of higher ash or sulfur in local coal must be appraised in the light of the ultimate cost of producing steel. High ash content means more slag and wasted energy. High sulfur coals usually produce high sulfur coke. This in turn introduces a contaminant into the iron which is costly to remove. A high silica content in limestone results in a higher slag volume which is also wasteful in terms of the total energy requirements. The appraisal of such conflicting aspects of raw material supply requires a high degree of technical knowledge and experience for correct and meaningful evaluation.

As noted, salt water can be used for many cooling requirements, but relatively expensive equipment may have to be used to guard against corrosion. Some considerable quantity of fresh water is invariably needed and this can prove to be a very serious problem, involving at times prohibitively high costs in dams, reservoirs, pipe lines, etc. The expense of developing water source must then be compared with the cost of a complex in-plant recirculation and reuse system -- obviously a job for experts.

However, having evaluated the effects of various influencing factors, and established an appropriate input basis that provides an optimum cost for a ton of crude steel, the analysis is taken further into estimation of product costs. These are based on the steel casting and rolling facilities adopted for the study, and take into account the cost contribution in terms of labor, materials and services in the manufacturing process. Based on these estimates a preliminary estimate of steel plant cost of sales is made. This includes estimates of plant inventories and capital and financing charges. In specific cases, it may be appropriate to include product delivery costs to the market in which case this would provide cost of sales in the market place. The capital charges are determined through order-of magnitude estimates of the production and service facilities adopted for the study. Since no detailed plant specifications or final plant site have been established at this stage all estimates are closely controlled and influenced by experienced judgement on similar projects related to the tentative site in the area under study. Estimated financing charges are similarily handled from experience applied to available data.

The estimated cost of sales related to the sales revenue established through market survey price data, provides a basis to determine project profitability. The additional use of break-even techniques permits a further means of evaluating the impact of varying production, capacity and price situations. By this procedure a reasonably good economic basis for project viability is established and a go-ahead or reject decision can be taken on the next step of selecting a specific plant site or for further work on the project.

In all this, in addition to the logistically oriented evaluation approach so far discussed, another major techno-economic analytical technique was being applied in the process of judgement and evaluation of the data acquired from the foregoing key factor surveys.

It is worthwhile to stress this technique at this point.

This is the technique of progressive modification of conclusions as new information comes to light in the time-sequence of the study, until a final conclusion or prediction is arrived at on the basis of the total picture developed. This method is not new and is actually widely used in all types of technical, scientific and analytical work - so we use it here. While the actual use of this approach may not be obvious in the discussion to this point, it is inherent in the analytical approach.

One way to demonstrate the use of this technique is to highlight the areas in which it comes into play. This is done now through practical illustration in case studies representing three hypothetical potential steel plant situations under very different geographic, political and geological conditions. Specific place names and/or quantitative details are purposely omitted for obvious reasons and are, in fact, unnecessary since the objective is to exemplify and emphasize the principle involved for clearer understanding, and perhaps stimulate the imagination of the reader.

ILLUSTRATION - PLANT VIABILITY CASE STUDIES

For example, let us consider a case study in a semi-industrialized country located in a generally affluent and developed region. Here, the final conclusions from the various studies provide three major changes or amendments in the conclusive process, until a final decision was arrived at incorporating all facts and after applying the procedures enumerated earlier. Let us examine the analytical process:

> "The market survey indicated sufficient short-falls to justify new plant capacity of 500,000 annual tons of crude steel. Initial product-mix was to be limited to billets, merchant shapes and light structurals. However, a strong growth rate anticipated for flat products together with the export potential indicated a plant expandable to 2,000,000 annual tons with the first expansion to meet sheet and plate demands.
>
> The magnitude of initial and future operations indicated the need to consider conventional process techniques. Accordingly the plant as so far envisaged, will consist of one blast furnace, two basic oxygen steel vessels, continuous billet and bloom casting and a semi-automated, heavy-duty merchant mill capable of rolling reinforcing rod, small flats, assorted round and shaped rods, and light structurals up to a maximum of 100 mm dimensions.

The Raw Material Survey generally indicated that locally available iron ores are of low quality, and beneficiation and sintering have not provided satisfactory results. Furthermore, high grade lump ore can be delivered at a cost equal to or less than the delivered cost of local ore. Imported fines are extremely promising, and all techno-economic evaluations tend to indicate the advantages of a sinter plant for part of the blast furnace burden. This would not only recover iron values from flue dust, scale and generated ore fines, but provide necessary flexibility to draw on world sources on a competitive basis to optimize costs.

Coke produced from local coals is found unsuitable for the blast furnace. Careful pilot plant tests indicate that a coal blend with 25% local coal and 75% imported coal provides an adequate coke. A techno-economic analysis indicates the need for a captive coke plant rather than coke purchase. Limestone of acceptable quality is mined locally and is readily available at competitive prices. Minor additives would require imports.

The Utility Survey has generally indicated that no problem of fresh water supply exists, however, the use of salt water would be looked at again after a specific site is selected. Power in substantial quantities is available, the cost of transmission could become a factor if plant location was remote from existing population centers.

The Raw Material and Utility Surveys generally accept the process equipment tentatively selected on the basis of market alone, but supplement the following:

1) A definite need for a seaboard location to permit import of iron ores, 75% of the coal needs and other supplies.
2) A sinter plant must be installed.
3) A coke plant must be added to the plant facilities.

The Transportation Survey indicates two areas where water depth, tidal range and potential of new harbor development exist. An existing port is also a possibility that could be considered. Transport and utility connection costs could have a significant impact depending on final location.

The Manpower Survey indicates that no major manpower availability problem exists. However, sufficient funds must be budgeted for an adequate training program.

Analysis of additional available data provides a tentative location for viability analysis. Final conclusions may be summarized as follows:

1. The market seems assured as indicated, with only modest government protection from import dumping.
2. The plant must be located on a seaboard site providing dredged depths to handle 50,000 ton vessels, preferably 100,000 tons. Port development costs should not be included in plant capital costs, but must be justified as part of a national development plan.
3. Plant size and facilities are as indicated earlier. Production costs will be considerably lower than in any of the existing plants by virtue of using the most modern iron and steelmaking techniques and higher grade raw materials.

4. Infra-structure costs are expected to be minimal since virtually the entire coast is developed to some degree.
5. A cadre of technically trained manpower is available but some training will be necessary.
6. Capital costs will be comparable to those reported as average for the industry.

The viability study indicates that the project will be feasible. The estimation of accurate capital and operating costs should be taken up to provide sufficient data to attract and develop plant financing. This is particularily necessary to attract a potential group of private investors whose participation will make the proposition more attractive and improve overall plant economics. At the same time, the study to select the best realestate on which to locate the plant should be undertaken."

Again, in another part of the world - let us consider a very different situation of a small emerging nation where the viability study indicated that the project on its own was judged not viable. However, consideration as part of a larger scheme of export mining and power development provide the means for attractive project economics. Here is how this one evolved:

"The Market Survey indicated a very limited demand of something less than 50,000 annual tons of a rather wide range of rod, bar and merchant products, largely to meet the needs of a developing construction program.

On the basis of market this is considered an uneconomical proposition. This conclusion was based principally on experience and the result of numerous studies of very small plant situations.

A review of the Raw Material Survey, however, calls for a possible reassessment of the situation. Substantial deposits of high grade (65 +%) iron ore are available. Indications of an export market are good. Under national planning, development of this mining area in collaboration with major foreign mining interests, is under active consideration to open up an export market to generate much needed foreign exchange. Significant deposits of non-coking coal of fair quality are found in an adjoining area. The ore bodies are located near a sizeable river navigable to the coast.

The Utility Survey indicates that further up the river an excellent potential for hydro-electric power development exists. Plans to open up this aspect are well in hand, particularly due to a major power demand in an adjoining country where development of non-ferrous resources are under active consideration.

In view of this potential raw material base and active consideration of a large power development program, a small electric smelting unit together with steelmaking and continuous billet casting may make sense as part of a larger scheme of economic development. The possibilities of a sponge iron facility and electric arc refining operation also need comparative evaluation. The lack of infra-structure and manpower would have to be carefully considered in determining the location of a second-hand rod and bar mill considered suitable to meet immediate market demands.

A Manpower Survey indicates the complete lack of local talent familiar with steel plant operations. Combining the needs of the proposed iron ore mining and power development programs, the task of transforming a labor force accustomed to an agrarian existence to an industrial one is a very difficult one. A management and technical service contract is essentially indicated to provide expatriate personnel to fill practically all key supervisory and operating positions in the plant. Each foreigner from the acting president down through the ranks of foremen, operators and even some skilled laborers will each have a local counter-part working alongside and learning on the job through day-to-day performance. The training and schooling costs, time and effort will be high and must be accounted for in the overall budget. In short it will be a course of adapting to an industrial environment, men and women completely unaccustomed to an ordered way of life in terms of action, attitude and responsibilities imposed by an industrial society.

The Infra-structure Survey and costs point to the need to locate the rolling mill in a major population center near the coast and supply the billet feed down from the up country location of the primary facilities. The mill would be operated on a one-shift basis to meet local needs. Its location would however readily permit increased production to meet any available export market needs. This however cannot be counted on due to the extremely competitive situation in world steel.

The Transportation Survey backs up this conclusion due to the complete lack of rail and road facilities to the coast. River transport seems a logical starting point till a national transport development program can justify the high costs of developing other means of transportation. Ore would be conveyed to a river collecting station. The location of primary iron and steel facilities at this assembly point would be a logical site for a viability analysis.

Analysis of all factors indicates that economically the plant cannot stand by itself. It may however be economically justified as part of a larger scheme of iron ore mining and power development. Since this in turn depends on low cost development funds and grants from developed nations, as well as on public and private funds, a well documented feasibility study on the entire total program needs to be undertaken and submitted to the local government for their use in seeking aid and support abroad.

The general site location has been fixed by geological, topographic and infrastructure considerations. Specific site studies should await the outcome of the larger investigation."

So far the case studies have dealt with two essentially opposing situations in terms of the general level of prevailing industrial development. It is of interest however to consider as an example a third case - a situation involving a coalition of nations seeking regional development of an iron and steel industry. Here we have a situation where past attempts to economically justify a national steel plant in each country did not turn up viable conditions for various reasons. There are however sufficient indicators to believe that such viability would emerge at some time or other in the future as population needs coupled with industrial development demand more iron and steel.

A United Nations industrial development group, studying individual needs and efforts to establish a basic iron and steel industry, has after preliminary canvass with each government of the neighboring, but autonomous, nations, made the suggestion that a steel plant development program designed to fit the needs of the region rather than individual nations may be feasible. A preliminary study is required to indicate the practicability of the suggestion. Let us follow the manner in which such a study developed:

> "The Market Study indicates that every country involved has some sort of steel producing or steel rolling facility. Both new plants and expansions of existing plants are under active consideration. Further facts that characterize the entire area are as follows:

1) Almost complete dependence on outside sources of crude steel and/or semi-finished feed materials.

2) No known, large, indigenous source of high grade iron ore or coal.

3) In spite of size, the geography of the region is such that no one country can justify an economically sized pig iron plant for strictly local use.

4) The economics of the region are those characteristic of developing countries everywhere: a general shortage of available investment capital combined with a real need and a strong desire to industrialize.

5) A nearly complete absence of technical know-how as well as an overall shortage of technically trained labor and management.

6) Development of a regional program is made difficult by a normal and healthy divergence of national goals and strong nationalistic tendencies.

The term "per capita consumption" has little meaning in this region, since at least 90% of the population is rural and does not "consume" any measurable quantity of steel. Urban areas, however, are expanding rapidly, and substantial tonnages of steel products are being used. Moreover, industrialization generally is being promoted, indicating a sizeable demand in the not-too-distant future. Obviously, this market will cover an extremely wide range of products, more than would normally be considered for a new, integrated steel plant. Thus, the concept of regional development takes on more meaning in that each contributing country might conceivably install a single facility of reasonable size to supply the entire region with one finished product in a range of types and sizes. Initially the basic semi-finished input to each area would be supplied in the form of billets, blooms or slabs from a single centralized facility located near the hub of the region.

In the absence of detailed market data, which this stage of the study does not warrant gathering, a potential need for 1,000,000 annual tons of crude steel is assumed as the starting point for the viability study. This capacity would indicate a blast furnace, basic oxygen steel plant, and a continuous billet and slab casting complex erected at a centrally located deep water port. A merchant mill, a sheet mill, a structural mill and a pipe mill (as an initial supposition) would be erected (or may already exist in part) in each of the other four co-operating countries. All plant locations would be selected on the premise that eventual complete integration and/or expansion is the goal, which should be accomplished at minimum cost.

The Raw Material Survey indicates that no ore or coal deposits of sufficient magnitude exist in the countries under consideration. Moreover, both these raw materials can be obtained in quantity from a nearby country with reasonable advance notice and planning. The non-availability of sufficient purchased coke indicates the need to add a coke plant.

The Utility Survey emphasizes the general adequacy of power in the countries in question, but that transmission costs may become a factor depending on location. Assuming a coke plant is included, the basic plant (confined to primary facilities only) would be a net producer of energy rather than a consumer. The installation of a large power plant using available by-product gases supplemented by coke breeze and imported oil or coal could provide additional power to supplement local sources. The economics of this needs to be evaluated. Fresh water will probably not be available year-round in sufficient quantities regardless of location. Provisions will have to be made to cool, clarify and recirculate limited supplies of fresh water and also to use salt water for specific cooling applications.

The Transportation Survey indicates that there is a severe limitation on the number of ports capable of servicing the super iron ore and coal carriers that are being introduced. Only two or three potential deepwater sites are readily indicated where general locational consideration can be readily evaluated. An analysis of available survey data further indicates that:

1) There is only one major port with existing dock facilities capable of handling the plant requirements. For viability and preliminary planning this is considered an obvious and logical plant site. The two other ports in the area could be expanded and deepened, but at considerable cost.

2) It is also fairly certain that the finishing plants dispersed in the several countries will undoubtedly be located in or near large population centers,

therefore, there is no need at this early stage to attempt to pinpoint sites. For the purposes of this study it will be sufficient to tentatively allocate specific facilities to specific countries after giving due regard to existing installations. The location may be assumed to be the present major industrial city.

3) Thus Country A, which is expanding at a rather more rapid rate, might undertake the much more expensive sheet rolling plant. Country B, which has a burgeoning oil industry, might logically install a pipe mill. Country C, which has the largest population and is most in need of housing, would be assigned the merchant mill. Country D, although consuming only a small portion of its product, would be offered the opportunity to roll structural steel items for export to the partners and other users in that part of the world. This limitation is largely imposed by the capabilities of mill equipment to obtain an economic scale of operations.

Manpower and Infra-structure Surveys of the areas tentatively established for viability analysis, indicate specific limitations that would need to be accounted for in the analysis. There is a limited pool of manpower trained in steel plant technology in the region, but the prevailing type of infra-structure in specific areas has the necessary basic essentials to provide the necessary incentive to attract such personnel and even expatriates who may consider permanent settlement. Some modification of infra-structure would be obviously required. Extensive training programs will however be required together with technical service contracts to provide start-up and operating assistance in the initial years of operation. This must be taken into account in the overall budget. On an overall basis the actual recruitment of sufficient personnel both trained and untrained, should not however be difficult.

Based on an overall viability analysis on the lines indicated earlier, final conclusions based on data provided by the various surveys indicate the following:

1) While past attempts to establish a large regional integrated iron and steel industry have not been successful, this is not sufficient reason to believe that this concept is doomed to failure.

2) Facts and figures so far disclosed by the case study reveal that the program is economically feasible.

3) A centrally located primary iron and steelmaking complex will be located at a deepwater port. This

facility using imported raw materials will export, at pre-determined prices, semi-finished steel feed material to four partner countries.

4) The four partner countries will install rolling mills to produce finished steel product for consumption in the region. Each country will import its needs only from its participating neighbor at prices set by mutual agreement which will permit a reasonable profit to all.

5) Location of each plant facility will need to be carefully chosen since market indications provide sufficient assurance that each could be expanded to provide an economic basis to justify an integrated facility sometime in the future.

No short-term conclusion is, however, in sight for such a scheme. It is basically a pioneering effort that will require months and perhaps even years of painstaking investigation and negotiation before it can bear fruit, be accepted and be supported as a practical and economical plan by the participating countries.

SELECTION OF A SPECIFIC PLANT SITE

So far, the influencing factors affecting plant location have been isolated and examined, the fundamental principles and analytical techniques of establishing plant viability have been discussed and illustrated. Now it is time to narrow down the study to select a specific plant site. In this phase of plant location, all the factors and techniques discussed previously are used. This exercise is required to determine the exact location that will maximize project profitability.

Up to this point the field surveys and viability step have isolated generally promising areas, but no definitive investigation to pinpoint specific geographical sites and analyze the effects of local site factors has been attempted. This aspect will now be discussed and will include definitive investigation of such matters as specific distances to markets; trucks, railroad and shipping costs; actual site conditions and installation of infra-structure; the relative impact of area, utility and transport development costs and other factors related to the final choice of the actual piece of ground on which the plant is to be erected. A second case study is presented to illustrate the practical application of the previously discussed techno-economic and engineering principles to this phase of the study.

The illustration offered here is based on a comparative analysis of four sites in a hypothetical country. Each is investigated in sufficient detail to permit a final selection to be based on logical reasoning and economic fact. It should be noted that although the four sites compared here do not refer to any of the three areas considered earlier, they do represent actual experience and realistic data adjusted only slightly for presentation.

In most cases, the raw material base, applicable process and various operating requirements established through the viability study are relatively well defined, and the site selection investigation can proceed in an orderly manner. In some instances, however, it is possible that unusual variations in production technology are introduced which require an intermediate step of rigorous process selection evaluation and analysis. This intermediate step rejects or accepts a particular site on the basis of the economics of special technology required to provide the plant capacity and product mix desired. For instance, the conditions at one site might indicate the use of local ore beneficiated in special equipment, pre-reduced, and smelted in an electric smelting furnace. At an alternate site, imported ore would be smelted in a blast furnace.

The economic comparison of these two sets of conditions is not a simple matter and will involve considerable time and expertise. Although discussion of such problems is outside the scope of this paper, the possibility of their arising is emphasized and must be considered in any final recommendation.

The site evaluation exercise that follows here is based on four final locations, systematically isolated as a result of the overall analysis. In each case prior market surveys required to establish plant viability have been made, the need for a steel plant established, and the size and product mix have been determined. In this specific case study, process analysis indicates that the major production processes applicable to each site are identical, namely the blast furnace for ironmaking, basic oxygen steelmaking, and casting and rolling facilities to produce similar product mixes. For each site, however, estimates of actual raw materials, utilities and power are separately made on the basis of preliminary material and fuel balances to suit each site condition. This permits adjustments to be made in the quantity of various raw materials to accommodate variation in quality from sources best suited to each site. Plant detailed manpower needs are determined through estimates made principally from experience.

Having established the source costs and the quantities of raw materials, utilities, power and manpower needed at each location, the major advantages or disadvantages of each location are then analyzed. This is done in part with the originally discussed survey factors and additionally in terms of local site factors developed through additional field investigations of each individual site. The total information collected, is collated into specific categories for systematic analysis to obtain the best site. The factors used and the illustration of results obtained now follow.

1. General Site Factors

These are factors related to the physical location of the site, namely an inland or deep water location, and its relation to raw materials sources and markets; the general availability of land in the area, the nature of soil and terrain, and needs in terms of cash outlay for site preparation; the transportation environment; the availability of infra-structure and skilled labor, climate conditions, etc.

2. Raw Materials, Power and Water

These refer basically to investigations of local or foreign sources. In many cases, a comparative evaluation of several imported raw material sources will have to be made. The uninterrupted availability of an adequate quantity of raw materials of the required quality must be assured. A minimum of 25 years' supply should be assumed for planning purposes. The direct availability and cost of power, fuel, and water, or the development of adequate sources, are obviously vital to the success of the enterprise.

3. Factors Affecting Operating Costs

The profitability or non-profitability of the steel enterprise depends on the cost of products at the market place. The two major factors affecting cost of products at the market are the cost of assembling raw material at the plant site and the cost of distributing the products to various markets. These cost factors, along with variation in power costs, are included in the final analysis sheets which assist in the selection of a site. In this particular case study, no significant variation in water, manpower, and indirect material costs were indicated. This holds in-plant operating cost parameters constant in relation to these items. Under other situations with different circumstances, the effects of such factors may have to be included and reflected in the site selection analysis.

4. Factors Affecting Capital Costs

The cost of roads, railroads, power lines, power stations, dams, harbors, docks, town sites, pumping stations, and a host of similar auxiliary installations can be equal to a substantial portion of the actual cost of the steel plant itself. Certainly the net income from even a fairly sizeable steel producing operation cannot and should not be expected to carry the huge financial burden of the investment in infra-structure. Still, the cost must be considered in the overall economy of the country and should be a major consideration in the minds of the planners. A strong recommendation made to cover such a situation and perhaps avoid months of fruitless work is for the engineers making the plant viability and location study to maintain close and continuing communications with the national government involved. In this way, the survey group or consultants can gain foresight on the likelihood of obtaining official approval on recommendations that they will eventually make.

If the steel plant program is advertised as a social development project, it can be assumed that the government is prepared to absorb costs well above and beyond those for the plant itself. In such a case, it is worthwhile and necessary to fix these additional costs as precisely as possible. This is an undertaking of no small magnitude which will very possibly involve experts from many other disciplines.

On the other hand, in a profit-oriented situation, such as one where private investment is to be backed by foreign government loan guarantees, an investigator would do well to inform himself as early and as completely as possible on the extent to which local governments can and will underwrite infra-structure costs, and be guided thereby in consideration of a final recommendation on site location.

Next in line for study after settling these somewhat indirect or non-specific questions, is the matter of choosing the actual piece of real estate by developing the capital cost factors that would directly affect the eventual erection of plant equipment. Investigations in this area have to do with such things as cost of land, geological formation of the ground, water tables, rainfall, tides, temperature variations, air and water pollution problems -- in short all the strictly local factors, any one of which can have major effects on the capital and/or operating costs of the plant. Here circumstances may indicate the need for detailed site investigations in terms of topographic surveys, soil borings and other similar studies before any meaningful techno-economic evaluation can be made.

The dock which will accommodate large ships in spite of high tides will invariably cost far more than a normal dock. Excavation in rock is not to be compared with similar work in loamy soil. Piling can be a very large item of cost. Thus, it should be quite obvious that, in addition to the commercial questions of plant input and output, there must also be a serious and in-depth investigation made of the purely physical factors associated with the specific locale under consideration.

Illustration - Comparative Site Selection Analysis

Once the magnitude, cost and individual content of each factor affecting site selection have been evaluated, it is then time to use comparative techno-economic analysis techniques to effect a final site recommendation. Figure I illustrates such a comparison based on factual data. It provides a means to appraise each item individually, yet also assists final selection through direct examination of the data as a whole. In such an analysis past experience and expertise in the building and operating of integrated steel plants plays a very significant role in assessing the influence of a particular factor. The tabulation demonstrates such an analysis and the methods used to reach a final conclusion on site selection.

Figure 1

COMPARATIVE ANALYSIS OF GENERAL, OPERATING COST

AND CAPITAL COST FACTORS AFFECTING SITE SELECTION

FACTORS	SITE A	SITE B	SITE C	SITF D
I. General Factors				
1. Location	Inland Site located at source of vast deposit of high grade iron ores. Area is newly developed and site is located at railhead for ore export.	Coastal Site at Estuary of river network connecting to numerous and varied iron ore mines. Site is in close proximity of a possible deep water harbor.	Inland Site located adjacent to major dam, catchment reservoir and hydro-electric generating station. Large iron ore deposits also found in the vicinity.	Independent Deep water Site adjacent to major port and harbor facility of large industrialized town. Market oriented site. Serviced by main trunk railroad lines to all major raw materials and other markets. Port currently used for iron ore export.
2. Availability of land	Adequate area available. All Government property. Only cost would be transfer of local residents to new location.	Availability of adequate Sites limited. Special layout considerations would be required. Cost of non-agrarian acreage $40-80 per hectare. Land largely privately owned.	Adequate area available on land owned by Government. Only cost would be transfer of limited number of local residents to new location.	Adequate area available. Larger portion of site already Government property. Cost of transfer of few residents involved.
3. Soil Conditions	Seems excellant with good bearing qualities based on general examination of ravines in vicinity and general geological information.	Largely silted loam with clay. Rock base would be at considerable depth. Pile foundations generally indicated.	Decomposed laterite for first 2 meters depth followed by 3 meters of weathered rock and below lies good rock. Should be excellent.	Hard well compacted soil. Examination of wells in area indicate silty loam with weathered rock for two meters followed by weathered rock below.
4. Site Level	The area would require extensive site leveling with high and low contour differential of 60 meters.	Fairly level with exception of a few hillocks. One particularly large hill may be avoided by judicious layout work.	Fairly level. Tree covering would have to be removed. The site near the plant lies between contours R.L. 245 to 275 meters.	Fairly level open area. Minimal site preparation.
5. Heavy equipment transportation problems	Lifts exceeding 50 tons through major port approx. 2000 Km distance. Railroad tunnels and curves place limitation on equipment design.	Seaboard location. Port modification necessary. Special highway to plant required.	Shipment via two major ports approx. 1000 Kms distant. Major port modifications required at one port. Lifts up to 150 ton possible at the other. Some railroad bridges require strengthening.	Seaboard location. Present port capable of lifts up to 50 tons. Lifts exceeding 50 tons at two ports approx. 2000 and 1000 Km away. Some heavy duty high-way improvement necessary. Investment of $100,000 will permit all tonnage to be handled through existing port.

Figure 1 (continued)

FACTORS	SITE A	SITE B	SITE C	SITE D
6. General transportation	Broad gauge only. Already heavily committed to iron ore traffic. General transport accessibility poor & expansion costs will be high. Roads require extensive work.	Limited to only meter guage. Major investments for transport improvements necessary to meet steelworks needs.	Has advantage of service of both broad and meter guage railways. Located on major national highway.	Has advantage of being on main trunk line between two major industrial and commercial centers. Also located on national highway between the two centers.
7. Labor	Poor local source.	Skilled labor available but shortage exists.	Skilled labor available. Some shortage exists.	Good source of skilled labor.
8. Climate & Meteorology	No specific problems	No specific problem. Rainfall is high up to 3000 mm (120 in.) as a mean annual average.	No specific problem. Has more equitable climate compared to all other sites.	No specific problem. High winds up to 110 Km/hr. (70 mph) have to be designed for.
II. Raw Materials				
1. Iron Ore				
(a) Source	Large reserves of high grade deposits capable of supporting the plant for 80 years is available in mines in the vicinity. Some mine development work will be required.	Distributed reserves of high grade ores throughout the area are capable of meeting plant needs for approx. 70 years. Blending would be critical. Major mine development will be required.	Large reserves of high grade iron ore in vicinity of plant site can sustain production for approx. 100 years. Some new mine development needed.	Large reserves of high grade iron ore at mines approx. 400 Kms distant. Sufficient to sustain plant for 90 years. Low cost ore fines available at export railhead screening station.
(b) Transport	Ore can be conveyed by belts direct to the plant.	Barges from river based mine shipping stations to a main unloading center. Belt conveyor to plant.	Belt conveyor or aerial ropeway from mine to the plant. Distance would require comparative study of the two transportation modes.	Direct transhipment on existing railroad from iron ore mines to port. Belt conveyors from railhead to plant site are indicated.
2. Coal				
(a) Source	Indigenous sources are ample but deposits located approx. 1200 Km from site. Imported coals would require transhipment at port 400 Km distant.	Indigenous sources are ample but deposits far from site. Imported coals can be handled at port in vicinity. Farthest from indigenous coal sources of any site.	Indigenous sources available though distant from site. Two ports approx. 1000 Km distant may be used for imported coal.	Indigenous sources available though distant from site. This site is closest to indigenous coal of all sites. Imports can be readily made through port adjacent to site.
(b) Transport	Difficult due to overload on existing single rail track. Could however be possible. Imported coal costs would be high due to transhipment at port	Difficult due to site being served by meter guage alone necessitating transhipment as coal sources on broad guage. Imported coal could be handled at plant dock	By broad guage track direct to plant, distance may become critical. Imported coal costs would be high due to transhipment at port for transfer to inland location.	By broad guage track to plant. Imported coal can be directly handled at port.

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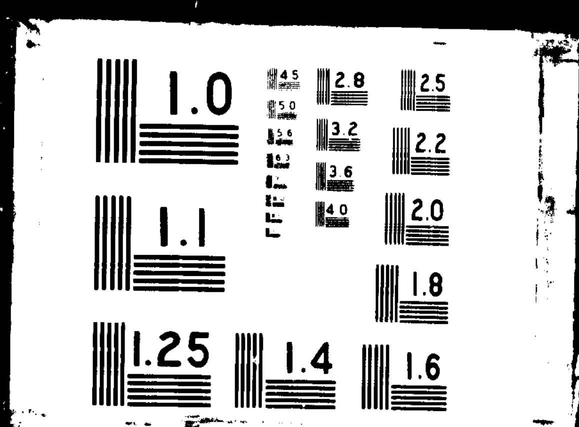

FACTORS	SITE A	SITE B	SITE C	SITE D
3. Limestone & Other Materials	Available from local sources. Cost at site would be highest of all sites, due to relative in-accessability	Available from local sources. Best delivered costs of all sites.	Available from local sources. Cost at site higher than all except site A.	Available from local sources.
III. Power & Water				
1. Power	Ample power available if schemes scheduled in national planning are completed. Cost for additional transmission lines to the site would be required.	Power supply dependent on plans of adjacent state government where power schemes are to be implemented. Could become a serious cost item.	Good power situation. Expansion plans scheduled are well advanced.	Availability of power seems assured based on current status of power development in area. A high voltage feeder line needs to be installed at an estimated cost of $1,600,000.
2. Water Supply	Sources available. Need dam and reservoir costing an estimated $3,000,000.	Ample sources from rivers and sea. Need dam and reservoir for potable water supply costing an estimated $450,000.	Available dam and catchment reservoir has ample capacity.	Local supply inadequate. Need dam and reservoir costing an estimated $10,000,000. Sea water available for use.
IV. Factors Effecting Plant Operating Costs				
1. Total annual cost of indigenous raw materials delivered at site.	$ 42,500,000	$ 58,000,000	$ 44,000,000	$ 51,000,000
2. Ton-Kilometers of transport required for raw materials to site.	2,900,000,000	5,250,000,000	4,625,000,000	3,750,000,000
3. Annual cost of Power	$ 5,500,000	$ 7,900,000	$ 4,500,000	$ 4,950,000
4. Annual cost for Distribution of finished product (based on market distribution established by Market Survey)	$ 20,600,000	$ 17,450,000	$ 16,500,000	$ 7,500,000
5. Ton-Kilometers of transport required for product distribution	1,555,000,000	1,388,000,000	1,129,000,000	569,000,000
Total Annual cost (with all indigenous materials)	$ 68,600,000	$ 83,350,000	$ 65,000,000	$ 63,450,000

[illegible]

FACTORS	SITE A	SITE B	SITE C	SITE D
6. For comparative analysis:				
(a) Delivered cost of imported coal at each site.	$ 33,000,000	$ 25,100,000	$ 33,500,000	$ 27,200,000
(b) Increase or (decrease) Over indigenous coal delivered costs	($ 200,000)	($ 9,750,000)	($ 8,800,000)	($ 5,600,000)
Total Annual Cost (adjusted for imported coal)	$ 68,400,000	$ 73,600,000	$ 56,200,000	$ 57,850,000
V. Factors Effecting Investment Costs				
1. Area				
(a) Land Acquisition for site	Cost is expected to be reasonable since it is all Government property.	Cost would be highest of all four sites investigated. Though site area is notified, negotiation with private parties not complete.	Cost is expected to be reasonable since all land is Government owned.	Cost is expected to be reasonable private owned parts notified and compensation fixed. Cost would however be higher than site A and C.
2. Area Development Costs				
(a) Transportation Facilities	$ 32,900,000	$ 124,000,000	$ 42,500,000	$ 7,200,000
(b) Water Supply	$ 3,000,000	$ 500,000	$	$ 10,000,000
(c) Power Transmission	$ 6,000,000	$ 1,000,000	$ 400,000	$ 1,600,000
(d) Mining	$ 10,000,000	$ 22,600,000	$ 7,400,000	$ 7,000,000
Total Area Development Costs	$ 51,900,000	$ 148,100,000	$ 50,300,000	$ 25,800,000
3. Infra-structure	Expected to be highest of all four sites	Expected to be high. No local facilities that could be used for steelworks	Expected to be lower than sites A and B, but higher than site D.	Major town with local industry a major asset in vicinity. Costs would be lowest of all four sites investigated.

Figure 1 (continued)

FACTORS	SITE A	SITE B	SITE C	SITE D
4. Construction Materials	The site is favorably located with respect to building materials except sand.	The site is favorably located with respect to building materials, but costs would be higher than sites C and D.	The site is favorably located with respect to building materials.	The site is favorably located with respect to building materials. Cement plant in vicinity a major advantage.
VI. <u>Conclusions</u>	Apart from having the lowest cost for delivered iron ore, [illegible] disadvantages over the other three. The area is generally inaccessible and under developed. Skilled labor would be a major difficulty. Being an inland site, no particular advantage is offered by import of high grade coal as compared to use of somewhat inferior indigenous coals. Though a steel works may be built here after the area develops, this site is not recommended for this project.	Advantages of a seaboard location provides significant advantages of importing high grade coals. This is offset by major disadvantages in area development costs and iron ore delivery costs. Both disadvantages are expected to be removed as modern mining techniques and rationalization of mines, and planned development in transport networks are implemented in the future. This site is not recommended for this project, but could be one that should be considered in the future for additional steel development.	An excellent inland site with major advantages in most respects. Higher area development costs over Site D offset the operating cost advantages of this site. The excellent location with respect to iron ore gives this site one of the lowest cost of delivered iron ore of the four sites investigated. The advantages of being served by both broad and meter guage railroads permits use of two major ports and facilitates delivery of raw materials and marketing of product. If an inland site is required, this is to be recommended. Initial investment costs it would however be higher than Site D. Inadequacy of infra-structure would also be a disadvantage over Site D.	An excellent sea-board site with deepwater harbor and excellent markets. The operating cost factors are lowest based on indigenous materials. With imported coal, the costs are somewhat higher than Site C due to market oriented nature of this site. This disadvantage is more than offset by the low area development costs and excellent infrastructure. The area is already an industrialized sector and along with availability of skilled labor would pose least problems for establishment of a steelplant considering all factors. Apart from this, the essential deepwater location would [illegible] considerable strategic importance and flexibility to obtain best raw materials and consideration of export markets. **From all four sites investigated, this is the most recommended.**

VII. <u>Recommendation</u>

Site D is recommended with respect to all factors for establishing a steelplant with maximum flexibility and lowest costs. Site C is recommended as the most suitahle inland site as a second alternative. The significantly downward trend in world raw material prices again point to the advantages in recommending a seaboard location with deepwater facilities.

POLITICAL AND FINANCIAL FACTORS

Consideration so far has been given only to the factual, the technical, the pragmatic aspects of plant location. A market survey has established a desirable product mix and a selling price. Studies of available raw materials, whether local or imported, have been viewed against a background of plant capacity and available utilities and manpower. All these have made possible an evaluation of the technical and commercial feasibility of the plan. Tons, gallons, mandays, kilowatts -- all have been investigated in detail. The per ton cost of the products times estimated tons of production gives an estimated cost of sales. Expected net sales less the cost presents a sound basis for predicting the financial viability. Two very important factors have not yet been explored. These two will invariably have a most profound effect on the outcome of the entire project.

Cooperation with Government

The first is concerned with the socio-economic aspects of the undertaking. As previously noted, the primary purpose of establishing a steel plant will vary from place to place. It might be built strictly in the interests of financial gain as an investment by private enterprise. In this case the plant obviously will be located to maximize profitability. As is more frequently the case with the developing nations, the impetus behind such a sizeable undertaking is an admixture of nationalistic drive and a sincere desire to lessen or overcome imbalance of payment problems. Both are most commendable purposes and worthy of serious consideration. How do they affect site location?

No country in the world is free of the problem of finding jobs for a population which grows at a constantly expanding rate. While a steel plant by itself creates relatively few jobs compared to the vast sums of money spent, the ultimate new employment record may well show an increase equal to ten times or more that of the mill itself. Steel is a basic industry. A guaranteed local supply of semi-finished, high quality sheet, strip or bar at competitive prices will encourage the formation or expansion of numerous fabricating and assembly shops, and other industries based on steel plant by-products. These new enterprises will provide not only more jobs, they will also further reduce imports. Many service-type businesses will be started to provide transportation, retail stores, restaurants, maintenance shops, communications and similar facilities required by a growing industrial community. Thus the tremendous investment in the basic plant has, in fact, spawned an entirely new community and raised the standard of living of perhaps thousands of people. It is obviously a matter of serious concern to any government to guide such growth carefully and in accordance with an overall master plan for national development. Thus it is quite possible that technical excellence and logical commercial planning will have to be revised to accommodate political and national considerations.

Financial Factors

The existence of two overriding factors which profoundly affect steel plant location were mentioned. National planning and policy comprise only one of these elements. The other is financing, and it must be clearly distinguished from the already critically considered subject of finances. Financing is concerned with obtaining the foreign and local capital to pay for the plant. The subject of finances, the cost of goods and services has, of course, been used as a guiding principle throughout the foregoing study stage of the project.

All countries large or small are vitally concerned with national budgets and accounts. In the case of those nations with a newly emerging industrial community, the inclusion of a steel plant in the economic plan for development is an item of major importance. It may be a country's largest single investment. It has happened that governments, in their effort to promote too rapid industrial growth over a period of a few years, have permitted their nation's economy to become burdened with unrealistic debt repayment and service schedules. It is most positively the responsibility of the lending nations to consult with and advise potential borrowers accurately and conservatively on the economics of the plant they propose. It is not enough for a developing nation to merely want a steel plant and then find a country or group of countries willing to supply the financing and technology to bring the plant into being. The suppliers and the parent countries must recognize their obligation to assist their clients in the avoidance of high cost, over-designed, poorly located plants.

By strict attention to finances, that is to say by minimizing plant capital and operating costs through effective market analysis and plant sizing, by accurate raw material investigations, through thoughtful logistics studies, the financing of the project should not pose money difficulties in the years to come, and the plant itself can make a major contribution to the nation's financial strength.

CONCLUSION

In this paper the authors have presented the underlying principles to be used in establishing project viability and in selecting an optimum site for the location of a steelmaking plant. Emphasis has been placed on the application of techno-economic analysis methods which in turn are based on fact and experience, rather than on whim and unrealistic planning. By covering such a vast subject in a single article, some of the extremely complex work frequently required to establish the correct facts may have been inadvertently hidden. Studies such as those illustrated in the case studies included may require a year or more to conduct. The cost of such work can be high. Still this is the only sound approach. One hears of "free" study work. Beware! The cost in time and money and materials will in the long run be much higher.

Accordingly, it is appropriate at this time to stress that during the foregoing discussions what has been said ultimately leads to the realization, that in the process of selecting a proper site for a steel mill there is one single ingredient that has more impact on the decisions and choice than anything else. This one ingredient is the experience, the wisdom, and the competence of the individual or individuals who evaluate the many kinds of information that must be assembled. At each step, for each category, for each sub-division of technical and non-technical facts, it can be observed that evaluation and progressive alteration of conclusions must take place. In the final analysis this inescapably depends upon the human factor which closely guided by specialized knowledge, background and experience, enables the individuals or persons involved to bring to the process the type of competent judgment required.

Therefore, in conclusion, the authors would like to add a word of caution to those persons or nations embarking on, or already involved in, a steel plant development program. Be guided by the principles enumerated here, but leave the actual work to the experts. It cannot be emphasized too strongly; the subjects of project viability and site selection are extremely complex and embrace a wide variety of disciplines. A large number of companies and groups of experts are available in many parts of the world. The developed countries have long expressed a willingness to lend assistance, both monetary and technical, to their emerging neighbors. No amount of after-the-fact effort and expenditure can erase the effects of ineffectual developmental planning or improper site location.

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