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Planning investment programme in the Nigerian iron and steel industry

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PLANNING INVESTMENT PROGRAMME IN THE NIGERIAN IRON AND STEEL INDUSTRY

BY

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DEDICATION

To Awanu Jerome and Hannah Awolumate, both of blessed memory.

ABSTRACT

The iron and steel industry has been acknowledged as the critical pivot on which the industrial and technological development of any nation hinges. Nigeria's quest for the establishment of a metallurgical complex dates back to 1958. Protracted geo-ethnic wrangling and bureaucratic setbacks, however, delayed its take-off for over two decades. It was not until the early 1980s that the steel industry really began to take shape. Despite huge government investment of over U.S. $10 billion, the Nigeria iron and steel industry is yet to make an appreciable impact on the economy. The industry is currently bedevilled by gross inefficiencies in its operations as reflected in very low levels of capacity utilization, high dependence on imported inputs and other consumables, uncompetitive production costs and weak linkages with other sectors of the economy.

Against this background and the need to avoid past inefficiencies, this study evaluates the least cost investment, production and trade strategy for the steel industry over a planning horizon which spans 1993 to 2001. The specific objectives of this study include planning the scale, location, choice of technology, time-phasing and product mix of major investment projects to be undertaken in the Nigerian iron and steel industry between 1993 and 2001; examining the issues of project viability, market efficiency and project profitability in the context of both the domestic and potential export markets; and analyzing the appropriate policy measures and remedial programmes which the government might take in promoting a more efficient iron and steel industry in Nigeria on the basis of the international development experience of a number of countries with structural transition problems and plant vintage similar to those of Nigeria.

The methodology adopted is that of mathematical programming. An intertemporal, multi-process, mixed integer programming model of the steel industry is constructed to evaluate several research policy issues currently confronting the beleaguered industry. This methodology would permit explicit consideration of economies of scale in investment decisions.

The results of the model indicate that the existing steel plants are inefficient. The estimated marginal cost of production of steel during the first planning horizon is greater than the world price of steel by as much as 19.3 per cent for Delta steel company, 41.3 per cent for the inland rolling mills and 47.6 per cent for the already commissioned mills at Ajaokuta steel company. It is sub-optimal to construct any plant during the stipulated planning period. Emphasis should be placed on maximizing the utilization of the commissioned plants, while all the requirements for flat steel should be imported. Ajaokuta steel company, on inception, may turn out to impose extra cost on the economy. This derives largely from the potential increase in cost of imported raw materials and recurrent cost needed to operate this plant. As much as ₦225.3 million could be saved between 1993 and 2001, if Ajaokuta and Delta steel plants should utilize sinter concentrates and super-concentrates respectively produced by the Nigerian Iron ore Mining Project, Itakpe rather than imported iron ore. An aggressive pursuit of exports by the steel plants also turns out to be very profitable.

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TABLE OF CONTENTS

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

CHAPTER SIX

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

1.1. THE PROBLEM

The iron and steel industry is the foundation upon which a self sustaining industrial and technological take-off can be based. The role of steel in national development permeates all sectors of the economy because of its multi-dimensional linkages with other sectors, hence the allusion that for any nation to take off technologically, she must possess the capability for steel manufactures.

The United Nations (1978:1), observed that:

> downstream processing of indigenous iron ore resources represent an attractive possibility for industrialization on the part of a number of developing countries. Besides the conventional developmental benefits, there may be significant linkage effects into other sectors and potentially significant balance of payments benefits on both the export and import replacement sides. Indeed, it is possible that a number of developing countries can generate an internationally competitive advantage in a range of steel manufactures.

Nigeria's quest for the establishment of a metallurgical complex dates back to the colonial era, precisely to 1958. Initially, the government was only interested in establishing rolling mills. With the growing awareness of the availability of iron ore, coal and other relevant raw materials domestically and the quest for rapid technological and industrial take-off, emphasis was shifted to the possibility of establishing an integrated basic steel plant. After independence in 1960, the government also realized that mere political independence is meaningless except it was sufficiently anchored on self reliance. An industrialization policy was thus enunciated with a local iron and steel industry perceived as the centre-piece of Nigeria's technological and industrial development.

Sololski (1966:251), observed that:

> More than prestige seems to be involved. It is a
> matter of self reliance, of self realization on a
> national scale.

However, protracted geo-ethnic wrangling and prolonged bureaucratic setbacks delayed its take-off for over two decades. It was not until the early seventies that real effort was intensified for large scale production of steel in Nigeria.

The stated objectives for the establishment of the steel plants as contained in the nation's steel policy[1] include the following:

> ... The provision of a solid industrial base for Nigeria's technological development;
>
> ... The conservation of the country's foreign exchange through the reduction of the outflow of funds for the importation of iron and steel products;
>
> ... Export promotion in order to optimize the use of the country's total available resources beyond crude petroleum;

... The creation of employment opportunities in the steel plants and related industries; and

... Facilitating a geographical dispersal of the country's economic activities.

The iron and steel industry is yet to make appreciable impact on the economy in spite of the fact that Delta Steel Company, Aladja (then the largest Direct Reduction Plant in Africa)[2] was commissioned as far back as 1982.

The current state of the industry is characterized by epileptic operations as reflected in the very low levels of capacity utilization, high dependence on imported inputs and other consumables, uncompetitive production costs, and weak upstream and downstream linkages with other sectors of the economy. Colossal amounts are being expended on importation of raw materials and other consumables while we are yet to get to grips with the export promotion of steel products as a means of diversifying the revenue base of the economy. Questions are being raised by skeptics on the validity of the assumption that the steel industry is the threshold of Nigeria's industrial and technological development.

Walstedt (1974:157), while reviewing the steel industry of Turkey warned that:

> The production of steel is highly capital intensive, and unless steel mills are designed to an economic size, the market is gauged correctly, and construc-

> tion is phased and implemented with great care and skill, high investment will hurt badly. The effect of any miscalculation in the typical developing country is intensified by the fact that capital there is scarce and expensive.

Without more efficient planning and implementation, we will find to our chagrin that the Nigerian iron and steel industry will continue to absorb scarce foreign exchange while the fulfillment of its stipulated objectives will ever remain elusive especially as political arguments continue to hold sway.

Against this background and the need to avoid inefficiencies, this study intends to evaluate the present structure and development potentials of the industry. Specifically, a dynamic mixed integer programming model of the steel industry is constructed to plan the size, location, choice of technology, capacity, time phasing and product mix of major investment projects to be undertaken in the Nigerian iron and steel industry between 1993 and 2001. This would form the basis of a rational programme that would facilitate a more efficient development of the industry.

1.2. JUSTIFICATION FOR THE STUDY

The past four decades witnessed several attempts at evolving a viable iron and steel industry as a tool for speeding up rapid industrial and technological development in Nigeria. While the steel industry was heralded as a giant step in the creation of a modern economy by some observers, to others, it was condemned as a gross waste of resources.

Available evidence amply demonstrates that the Nigerian iron and steel industry is facing diverse problems created partly by defensive planning hence the recent suggestions by the World Bank (Hatch Report)[3] that steel projects in the country should be scrapped. For example, most of the feasibility studies on the steel plants were only meant to produce ex-post rationalisation of government's decision. Adequate feasibility studies were not conducted on optimal locations, raw material sourcing, markets etc. The result has turned out to fall short of the goals and aspirations embodied in the development plans. Since inception, none of the plants has been able to utilize up to 30 per cent of total installed capacity in any particular year.

However, the Nigerian iron and steel industry belies simple analysis. To simply condemn the steel industry is an exercise in conjecture. The need for a more rigorous empirical work on the industry is apparent in view of the available fragmentary information about this sub-sector.

This study has its roots in certain fundamental questions that are being raised about the Nigerian iron and steel industry.

i) Is the Nigerian steel industry merely a political artifice? Is Nigeria justified in emphasizing iron and steel in her development plans, or is she merely building steel plants because it is considered as a sign of progress?

ii) Is Nigeria expanding her steel mills in the most judicious manner? Are actual and proposed locations for steel mills justified?

iii) Did Nigerian planners correctly adapt the steel industry to resource endowment and to new opportunities in a perpetually changing world economy?

These issues are crucial not necessarily because they will help to clarify whether investment in Nigeria's steel industry is justified or not, but because they are of more general relevance to industrial development in Nigeria as in other developing countries.

The study also intends to formulate a detailed medium-term investment strategy for the Nigerian iron and steel industry. The formulation of an optimal investment plan centres on certain issues: what, how, and how much to produce with the focal point being on when to initiate or increase production (Westphal 1971:2). Using a mixed integer programming approach, it intends to plan the scale, location, timing and choice of technology of major investment projects to be embarked upon in the industry.

1.3. OBJECTIVES

The ultimate objective of this study is to evolve a medium-term investment plan for the Nigerian iron and steel Industry. The more specific objectives of the study would focus on the following:

i) To examine the existing structure and development potentials of the iron and steel industry in Nigeria. The study intends to analyze the existing pattern of production, transportation and importation of steel products in Nigeria with a view to identifying the factors that impede production;

ii) To plan the scale, location, timing and the choice of technology of major investment projects to be undertaken in this sector between 1993 and 2001.

iii) To examine the issues of production viability and market efficiency in the context of both the domestic and potential export markets; and

iv) To examine the impact of various policies and analyze the appropriate policy measures and remedial programmes which the government might take in promoting a more efficient steel industry on the basis of international development experience of a number of countries which have structural transition problems and plant vintage similar to those of Nigeria.

1.4. SCOPE

The steel industry currently consists of about twenty plants with the two integrated plants at Ajaokuta and Aladja and three inland rolling mills at Osogbo, Jos and Katsina owned by the Federal Government. About fifteen mini-plants which are either owned by state governments or the private sector also exist in different parts of the country. The primary emphasis of the study is on the public steelworks comprising the two integrated steel works at Aladja and Ajaokuta and the three rolling mills at Osogbo, Jos and Katsina.

The planning horizon covers the period between 1993 and 2001. This is subdivided into three time intervals, viz. 1993-1995, 1996-1998, and 1999-2001. The choice of three-year time interval is informed by two major considerations. First, the approximate gestation period for the steel industry is three years. Second, the planning period is made to conform to the second, third and fourth rolling plans of Nigeria's first perspective plan. The planning horizon is truncated in 2001 due to the fact that planning decisions may become meaningless if prognosis is made too far into the future considering the uncertainties involved in the global steel industry.

1.5. OUTLINE OF THE STUDY

The remaining part of the thesis is organized as follows: Chapter two reviews the historical development of the Nigerian iron and steel industry. Among the specific issues examined in this chapter are the evolution of steel-making in Nigeria, the structure and performance of Nigerian public steelworks and the product mix of the existing plants in Nigeria. Others are the demand for steel in Nigeria and the problems and prospects of the Nigerian iron and steel industry. Chapter three examines some theoretical and empirical issues on planning investment in the iron and steel industry while chapter four deals with the methodology of the study. This encompasses the planning approach, the planning problem, the structure of the model, the data base and solution procedure. The model solution and its interpretations are reported in chapter five. The major findings, recommendation and conclusion as well as study limitations and indications for further research are the focus of chapter six.

Endnotes

1. See the commissioned study on the Nigerian iron and steel industry by Federal Ministry of Mines, Power and Steel titled 'A Study of the Nigerian Steel Industry', by PAI Associates, 1983, pp. 129.

2. The two other Direct Reduction Plants in Africa are Executive Board iron and steel Company (EBISCO) of Misurata , Libya Arab Jamahiriya with installed capacity of 1.1 million tons per annum and the 704,000 tonne per year Alexandria national iron and steel company, Dikheila, Egypt.

3. Anxious to put the industry back on course, the Federal Government employed a Canadian Consultancy Firm, Hatch Associates in 1988 to examine the sick industry. The report of the study financed by the World Bank on behalf of the Nigerian Government described the steel project as overambitious and advised the Government to cut it down or scrap the industry.

The title of the study is 'Final Report; Steel Sub-sector Study in Nigeria'. Hatch Associates, Federal Ministry of Mines, Power and Steel, Lagos.

CHAPTER TWO

THE NIGERIA IRON AND STEEL INDUSTRY

2.1. THE EVOLUTION OF STEELMAKING IN NIGERIA

In spite of the fact that archeological investigations have confirmed the existence of iron-based cultures dating back to premedieval times in the Nok area of Plateau State, Igbo-Ukwu in Anambra State and Igun street in Benin, Edo State, prime consideration was not accorded to the establishment of a metallurgical complex in Nigeria until the 1950s. Prior to independence and for a considerable time after independence, the nation's limited requirements of iron and steel products were met by imports mostly from Great Britain, Japan, West Germany, Canada and USA.

Soon after independence, the Federal Government adopted an import substitution industrialization strategy. This strategy, coupled with the realization of the role of steel in national development, informed the decision by Government to embark upon the establishment of steel plants.

Specifically, the planning of the Nigerian iron and steel plants dates back to 1958. Initial effort was geared towards the establishment of a rolling mill that would meet the limited requirements of imported steel at that time. Various market studies were thus conducted in 1958 to establish the commercial viability of a steel rolling mill that would utilize imported ingots and scrap to produce structural rolled steel.

As soon as these studies were initiated, it became apparent that the nation would be better-off with an integrated steel plant following the growing awareness of the domestic availability of iron ore, coal and other relevant raw materials for steel making. Furthermore, the planning of Kainji dam guaranteed the ready availability of cheap electricity that could power a moderately-sized electric furnace steel plant.

Between 1960 and 1967, the government initiated and received several proposals from foreign firms including those from the United Kingdom, the United States of America, Germany, the Soviet Union and Canada on the feasibility of establishing steel plants in Nigeria . These studies almost unanimously expressed pessimism about the economic feasibility of an integrated steel plant in Nigeria. Among the several reasons adduced were the small size of the domestic market for steel and its derivatives; the inadequacy of infrastructural support facilities and the prohibitive cost of setting up these facilities; the poor quality of iron ore and coal reserves in the country; and the deficient manpower base for operating and maintaining such a technically sophisticated industry. The subsequent pilot studies conducted on the Agbaje and Udi ore also proved that they were unsuitable for the envisaged direct reduction process.

The Federal Government, despite these reports, pursued its steel ambition culminating in the first encouraging report by Soviet geologists in 1967. In the interim, a small scrap based steel plant with a capacity of 12,000 tonnes per year of structural steel was established at Emene in 1962 by the former Eastern state government in partnership with some private firms. Furthermore, two scrap based mini-steel plants, Continental iron and steel company and Universal steel company were both established at Ikeja in 1970 by private firms.

In 1967, a team of Soviet experts was invited to conduct a feasibility study for establishing an iron and steel plant. They presented a pre-feasibility study which recommended the blast furnace route for iron-making and the need for further geological surveys for exploration of better ores and coal for the proposed industry, since the known reserve were of poor quality. Based on this report, *Teknoexports,* an agency of the Soviet Government and Geological surveys of Nigeria were commissioned and jointly sponsored by the Governments of USSR and Nigeria to carry out aeromagnetic survey of over 22 per cent of Nigeria's total surface for five years.

The result of the survey revealed that abundant raw materials for steel production exist in the country. These include more than 300 million tonnes of iron ore at Itakpe Hills near Okene, 100 million tonnes of coking coal at Lafia in Plateau State, limestone at Mfamosong in Cross River State, marble at Jakara and Ubo in Kwara State, dolomite at Burumu and Osara and refractory Clay at Oshiele and

Onibode. The UNIDO study of 1967 (Vieira :1967) also established a convincing demand pattern for steel in Nigeria. The basis for setting up a steel plant was thus established with these discoveries. The Nigerian Steel Development Authority (NSDA) was inaugurated in April 1971 and charged with the responsibility of planning, constructing and operating steel plants in addition to conducting geological surveys, market studies and metallurgical research.

Messrs Tiajpromexport, a Soviet firm was commissioned to prepare a preliminary project Report (PPR) for the establishment of the first integrated steel plant in Nigeria in 1973. This report, though submitted in 1974, was eventually modified and accepted in 1975. Among the prime recommendations that were subsequently adopted by the Federal Government was the need for the plant to utilize Itakpe ore and a blend of local and imported coal to produce only long products. In 1975, Ajaokuta was selected as the ideal site and a contract for the preparation of the Detailed Project Report (DPR) for Ajaokuta steel company was signed with *Tiajpromexport.* The report was submitted in 1977, examined, modified and accepted in 1978. A contract for the preparation of working drawing, supply and installation of equipment, construction of civil work and training of personnel for Ajaokuta was signed in June 1979 between the Federal Government and V/D Tiajpromexport under deferred payment agreement spread over a period of thirteen years from July 1979 to September 1992.

The Federal Government also proposed in the Third National Development Plan (1975-80) to set up two direct reduction plants at Aladja and Port Harcourt, each with a capacity of 500,000 tonnes per year. Based on several proposals, a tentative decision was taken to site a Midrex Direct Reduction plant at Port-Harcourt and a Hyl plant at Aladja. By the second year of the third plan, the Midrex plant was transferred to Aladja while that of Port Harcourt was shelved and replaced with the Bonny liquified natural gas project.

The contract for the establishment of Delta steel plant, Aladja was signed between the Federal Government and a German-Austrian consortium on turn-key basis. The plant was envisaged to produce one million tonnes of liquid steel per annum using direct reduction and continuous casting technology. It was commissioned in 1982 amidst pomp and pageantry, thus becoming the premier integrated steel plant in Nigeria.

Steel rolling mills were also included in the projects for study under the Third National Development Plan (1975-80). In 1976, proposals were invited by the Federal Government for the establishment of rolling mills at four possible locations, namely: Kano, Jos, Osogbo and Minna/Zungeru. The proposals were expected to cover product mix, material, personnel and infrastructural requirements, plant layout, economic analysis and a time schedule for project execution. On the basis of the proposals, agreements were signed for the establishment of three satellite rolling mills at Jos, Osogbo and Katsina in June 1979. Each of the mills was planned to produce 210,000 tonnes per year of bars, wires and rods with eventual expansion to 720,000 tonnes per year and backward integration to incorporate steel making facilities. The mills were designed to obtain their billets from Delta steel company, Aladja.

The Fourth National Development Plan (1980-85) observed that the cost of billets transportation from Aladja to Katsina would make the Katsina Mill unviable. Accordingly, the Katsina mill was to be redesigned to become an integrated steel plant based on scraps from the immediate neighbourhood. The Fourth National plan also recognised the need to develop a third steel complex which will produce flat steel products. This decision was informed by the realization that about fifty percent of steel imports consist of flats while the existing steelworks produce only long products. *Eisenbau Essen (EBE)* was commissioned to undertake a feasibility study for the establishment of an integrated iron and steel plant to produce flat steel. The study recommended a 1.6 million tonne per year plant expandable to 3 million tonnes. Ikot Abasi was also recommended as the most suitable site of all the coastal locations that were examined. This has however been shelved.

Ajaokuta steel plant is being executed in three phases. The original construction schedule agreed upon in 1981 envisaged the commissioning of the entire first phase in April 1986. By backward integration, the light section and the wire rod mills were commissioned in June and December 1983 respectively and have since been in operation. However, by 1983 the civil work started to slow down eventually affecting erection work. The project's first phase was recently commissioned on December 19, 1992. However, some of the commissioned units are still non- functional.

Analysis of steel development efforts in Nigeria would be incomplete without mentioning the increasingly significant role of mini-mills and the steel fabrication sub-sector that currently complement the activities of the public steel works. They are mostly owned by state governments and private concerns.

Some new projects are likely to come on stream soon. They include the 100,000 tonnes per year LAPEC steel complex at Epe, a joint venture between the Lagos state government and a United States engineering company. However, previously mooted projects such as the high-alloy steel plant at Ogbomoso and the backward integration of the satellite rolling mills are not likely to be implemented before 1995.

Nigeria presently has a crude steel production capacity of 1,236,000 tonnes per year and a rolling capacity of 3,241,000 tonnes per year (see figures 2.1 and 2.2 respectively). The crude steel production capacity is expected to increase to 2,536,000 tonnes per year with the recent commissioning of the first phase of Ajaokuta. Table 2.1 presents the location and crude steel/rolling capacity of existing steelworks in Nigeria.

TABLE: 2.1:

STEEL MILLS IN NIGERIA

COMPANY/LOCATION	CRUDE STEEL CAPACITY (T)	ROLLING CAPACITY (T)
ASCL, Ajaokuta	-	1,090,000
DSC, Aladja	1,000,000	320,000
KSRC, Katsina	-	210,000
JSRM, Jos	-	210,000
OSRC, Oshogbo	-	210,000
SUB TOTAL	1,000,000	2,040,000
ALLIED, Onitsha	-	20,000
ASIATIC MANDARIN, Ikeja	-	60,000
BROLLO, Onitsha	-	65,000
CISCO, Ikeja	60,000	150,000
FEDERATED, Otta	40,000	140,000
GMS, Asaba	14,000	50,000
KEW MERALS, Ikorodu	-	20,000
KWARA COMMERCIAL, Ilorin	-	40,000
MAYOR, Ikorodu	-	228,000
NIGERIAN SPANNISH, Kano	72,000	188,000
ORO STEELS, Oro	-	-
QUA STEEL, Eket	-	60,000
SELLMETALS, Ikeja	-	100,000
UNION STEEL, Oro	-	-
UNIVERSAL, Ikeja	50,000	80,000
SUB-TOTAL	236,000	1,201,000
GRAND TOTAL	1,236,000	3,241,000

Source : Atlas of African Industry, Iron and Steel, UNIDO 1989, pp.16-17.

CRUDE STEEL CAPACITY OF STEEL MILLS IN NIGERIA (TONNES PER ANNUM)

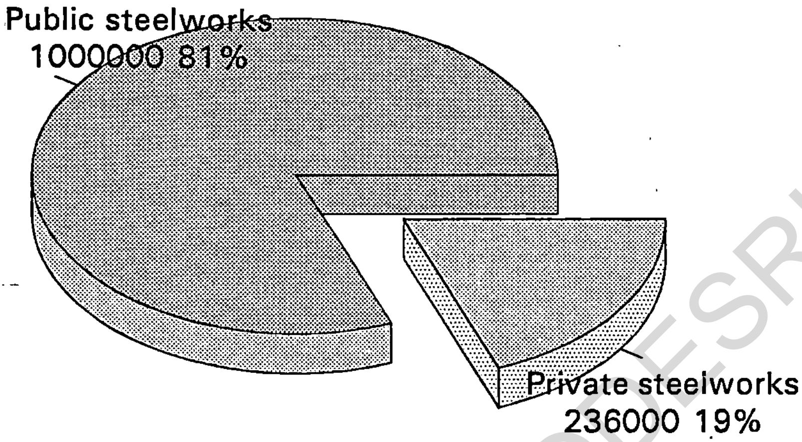


Fig. 2.1

ROLLING CAPACITY OF STEEL MILLS IN NIGERIA (TONNES PER ANNUM)

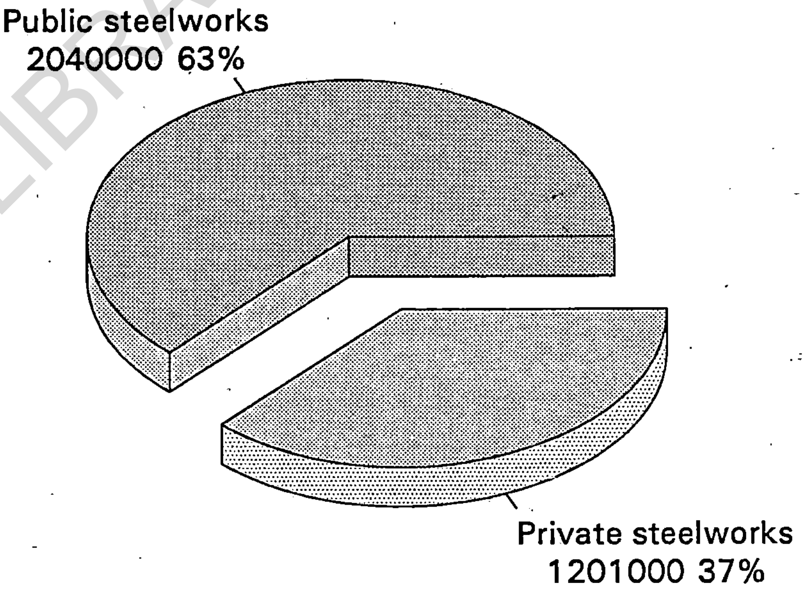


Fig. 2.2

2.2 THE ROLE OF STEEL IN NATIONAL DEVELOPMENT

The iron and steel industry has been perceived as the centre-piece of Nigeria's industrial and technological development. This is predicated on the fact that enhanced levels of domestic production and consumption of steel are necessary preconditions for the transformation of the industrial base of any economy. This subsector has been shown to be a credible index for measuring the pace of a nation's industrial development. It is now accepted as an empirical fact that a nation's industrial and technological development can hardly commence unless annual per capita steel consumption exceeds 50 kilograms.

Steel represents, by far, the most widely used metalic material due primarily to the fact that it can be manufactured relatively cheaply in large quantities and to very precise specification. The industry is a vital instrument for developing intersectoral linkages[1] with all other sectors of the economy. It is linked to the minerals and mining industries, building, construction, energy sector, the chemical industry, engineering, agriculture, transportation and defence. In view of this extensive linkage chain, it has been estimated in the United States that for every worker employed in basic steel production, there are twenty other jobs generated (Igwe: 1989).

Since independence, the development of the steel industry has occupied the centre-stage in government planning because of its perceived role as a major catalyst for rapid industrialization. However, the contribution of iron and steel to the gross domestic product is currently negligible. This can be attributed to Nigeria's current development status and the relatively low contribution of manufacturing to the gross domestic product.

The yearly contribution of manufacturing to the gross domestic product between 1986 and 1991 is shown in Table 2.2. On average, this was about 7.16 per cent of the gross domestic product.

TABLE: 2.2

CONTRIBUTION OF MANUFACTURING TO NIGERIA'S GROSS DOMESTIC PRODUCT AT CURRENT FACTOR COST IN BILLION NAIRA.

YEAR	AMOUNT	% CONTRIBUTION
1986	6.30	8.73
1987	7.22	6.76
1988	10.73	7.52
1989	11.77	6.08
1990	15.40	6.64
1991	20.46	7.29

Source:- Ministry of Budget and Planning, Economic and Statistical Review, 1991.

Table 2.3 presents steel consumption data for Nigeria between 1978 and 1991. They are either produced locally or imported from abroad. Currently, only SITC Category 673 representing long steel products are produced in Nigeria. All the requirement of flat steel products are imported.

Figure 2.3 attempts to show the proportion of Nigeria's steel imports and domestic production between 1978 and 1991.

TABLE: 2.3

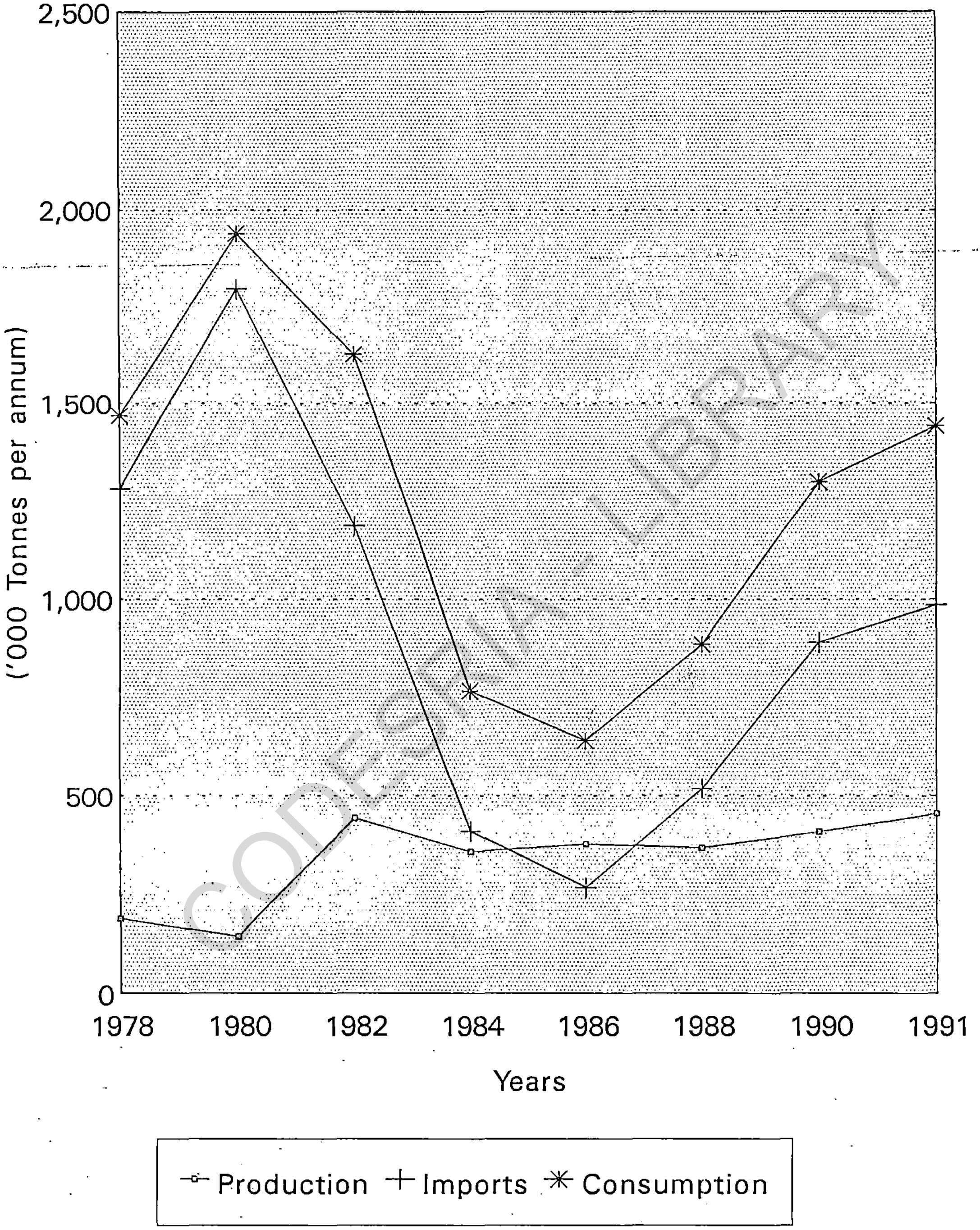
STEEL CONSUMPTION IN NIGERIA (,000 TONNES)

YEAR	TOTAL PRODUCTION	IMPORTS	STEEL CONSUMPTION
1978	186.0	1,282.0	1,468.0
1979	152.6	876.9	1,029.5
1980	141.0	1,798.6	1,939.6
1981	221.8	1,650.3	1,872.1
1982	443.9	1,185.3	1,629.2
1983	308.2	585.1	893.3
1984	357.0	409.9	766.9
1985	488.5	415.9	902.4
1986	377.2	264.1	641.3
1987	305.6	466.7	772.3
1988	367.2	518.8	886.0
1989	383.0	617.0	1,000.0
1990	409.0	891.0	1,300.0
1991	456.0	986.0	1,442.0

Steel production represents SITC 673, Bars, Rods, Angles and Sections. Steel imports represent SITC Category 673-679.

Source:- Figures for 1978-1987 are from steel-sub-sector study in Nigeria, Hatch Report 1989, while 1988-1991 data are from field survey.

Fig. 2.3: Steel Consumption in Nigeria For Selected Years



2.3. OPERATIONAL CHARACTERISTICS AND PERFORMANCE OF STEELWORKS IN NIGERIA

The Nigerian steel industry currently consists of the public steelworks, private mini-mills and a fragmented but active steel fabrication subsector.

2.3.1 The Public Steelworks

With the end of the Civil War in 1970 and the quadrupling of oil prices in 1973 which substantially increased oil revenue, the Federal Government embarked upon the construction of several steelworks in the 1970s. The publicly-owned steelworks at present consist of the two integrated steelworks at Aladja and Ajaokuta and the three satellite inland rolling mills at Osogbo, Jos and Katsina although plans are being made to privatize the inland rolling mills.

i). Delta Steel Company Aladja

This is the foremost (and pivotal) plant of the Federal Government owned steelworks. It was officially commissioned in January 1982 and situated at Ovwian-Aladja, six kilometres South-East of Warri. Delta steel Company is an integrated steel plant utilizing gas-based direct reduction technology for steelmaking. It consists of two midrex DRI modules supplying iron pellets to electric arc furnaces (4 x 110 EAF).

Its installed capacity is 1 million tonnes per year of liquid steel which can be cast into 960,000 tonnes per year of semi-finished 120 x 120 mm billets of which 660,000 tonnes will be used by the three satellite inland rolling mills and the balance used in-house. It has a capacity for rolling 320,000 tonnes of bars and light section. The available facilities at Delta Steel company, Aladja are shown in Table 2.4. The major production units of the plants as indicated in Table 2.4. are Pellet plant, Electric Arc furnace shop, continuous casting plant and rolling mills. It also has a number of ancillary plants and services required to complement iron and steel making. They include lime plant, oxygen plant, harbour, air separation plant, central laboratory and quality control, and foundry. Others are power supply and distribution, repair and maintenance shops, communications and water supply.

TABLE: 2.4

Available Facilities at Delta Steel Company, Aladja

UNIT	FACILITY	INSTALLED CAPACITY
1. Pellet Plant	One Lurgi straight grate machine with drygrinding facilities	1,448 million tpy of pellets
2. Direct Reduction Plant	Two midrex Direct Reduction modules	1.02 million tpy of sponge iron
3. Electric Arc Furnace Shop	Four 100 tonnes EAF with 60 MVA Transformer	1.0 million tpy of liquid steel using 80 : 20 sponge to scrap ratio
4. Continuous Casting Plant	Three 6 stand curve Mould Billet Casters	960,000 tpy of 120 x 120 mm billets
5. Rolling Mills	18 strand Light section mill	300,000 tpy of billets
6. Lime Calcinating Plant	One 200 tpy ported Rotary Klin of Lurgi design	60,000 tpy of Burnt Lime
7. Oxygen Plant	One Air Purification Plant	2300 NM^3/hr of O_2 with liquid oxygen Nitrogen and Argon storing factilities

Source: Delta Steel Company, Aladja. Field Survey.

Since inception in 1982, its highest production figure was recorded in 1985 when 243,000 tonnes of liquid steel and 77,948 tonnes of rolled products were produced respectively, representing about 24.3 percent of capacity utilization.

Delta Steel Company, Aladja is beset by numerous operational problems that have combined to inhibit the attainment of planned production levels. Perhaps the most formidable are shortage of raw materials and other consumables - a manifestation of poor funding, erratic power supply, the learning problem associated with new technology, problems of manpower and unstable management. The end result is high and uncompetitive production costs which are ultimately passed on to the final consumer. Furthermore, Delta Steel Company has been unable to supply billets to the three inland rolling mills adequately. Production figures for the plant between 1985 and 1988 are shown in Table 2.5.

ii) Ajaokuta Steel Company, Ajaokuta

Ajaokuta Steel Company is located in Kogi State on the West Bank of the River Niger (see figure 4.1). The company is perhaps the most ambitious and controversial of the Federal Government steel plants. It was incorporated in September, 1979. It is to be executed in three stages. It has a first phase planned capacity of 1.3 million tonnes per year of cast steel producing long products, a second phase of 2.6 million tonnes per year producing additional 1.3 million tonnes

TABLE 2.5

OPERATIONAL CHARACTERISTICS OF STEELWORKS IN NIGERIA

COMPANY	MAJOR RAW MATERIALS	NO OF FURNACE	CRUDE STEEL CAPACITY (T)		CRUDE STEEL PRODUCTION				ROLLING CAPACITY	ROLLED STEEL PRODUCTION				PRODUCT MIX
					1985	1986	1987	1988		1985	1986	1987	1988	
1. ASC, AJAOKUTA	BlOOMS 100x100mm Billets	1							540,000	43,843	50,000	42,013	-	Rebars, Coils Sections
2. DSC, ALADJA	Iron Ore, Scrap National Gas 120x120mm Billets	EAF 4 x 110	1,000,000		243,000	125,621	136,552	132,552	320,000	77,948	66,943	53,762	58,260	Rebars, Section
3. JSRM, JOS	120x120mm Billets								210,000	65,000	26,000	20,410	17,700	Coils, Rebars
4. KSRM, KATSINA	120x120mm Billets								210,000	70,000	70,000	42,050	35,000	Coils, Rebars
5. OSRC, OSOGBO	120x120mm Billets								210,000	50,000	30,000	33,937	16,500	Coils, Rebars
MINI PLANTS														
1. ALLIED, ONITSHA	Billets, Cross-ends, R50								20,000	8,000	3,500	2,000	2,140	
2. ASIATIC MANDARIN	Billets, Scraps								60,000	2,000	3,000	6,000	5,000	
3. BROLLO, ONITSHA	Sheet, Coils								65,000			4,000	6,000	Sections Shapes
4. CISCO, IKEJA	Scrap, ingot RHO/50 120x 120mm Billets	EAF 1 x 20t	60,000	20,000	10,000	16,000	20,000		150,000	25,000	16,000	20,000	26,000	Rebars, Section
5. FEDERATED, OTTA	Scrap, ingot Billets 100x 100mm, 120x120mm	EAF 1 x 12t	40,000	10,000	15,000	12,000	12,000		140,000	20,000	25,000	12,000	15,000	Rebars, Section
6. GSM, ASABA	Scrap, Billets R40	EAF 1 x 8t	14,000	3,000	1,500	1,000	3,000		50,000	15,000	1,500		3,000	Rebars, Section
7. KEW METALS, IKORODU	Billets, Cross-ends	Fuel Furnace 1 x 5t	9,000						20,000	8,000	1,500	2,500	4,130	Rebars, Sections
8. KWARA COM. ILORIN	Billets, Cross-ends								40,000			2,440	3,000	
9. MAYO, IKORODU	120x120mm Billets, Cross-ends, R40/50								228,000	20,000	20,000	14,000	10,000	
10. NIGERIAN SPANISH, KANO	DRI, Billets R40	EAF 1 x 20t	72,000	36,000	36,000	30,000	3,000		188,000	36,000	24,000	24,000		Rebars, Section
11. ORO STEEL, ORO ILORIN	Coils													Straitening
12. QUA STEEL, IKEJA	120x120mm Billets								100,000	18,000	9,000	5,777	920	Coils, Rebars
13. SELS METAL, IKEJA	Billets 100x 100mm 120x120mm								100,000			5,000	18,000	Rebars
14. UNION STEEL, ORO	Billets, Cross-ends R50											2,500	2,500	Coils, Rebars
15. UNIVERSAL STEEL, IKEJA	Scrap, ingot Billets 100x 100mm 120x120mm	EAF 2 x 840t	50,000	29,000	30,000	40,000	52,000		80,000	30,000	30,000	36,000	60,000	Rebars, Section

Source:- Compiled from

1. Atlas of African Industry, Iron and Steel, UNIDO, Vienna, 1989.
2. Federal Ministry of Mines, Power and Steel of Nigeria Steel Sub-sector Study in Nigeria Final Report, 1989.
3. Ajaokuta Steel Company Ajaokuta, 1990 Calendar.

of flat steel and the third phase of 5.2 million tonnes per year with varying degrees of finished and semi finished steel products including heavy plates and sections. The layout of the plant is such that it can eventually be expanded to 10 million tonnes per year.

Ajaokuta Steel Company is a conventional plant utilizing the blast furnace/oxygen furnace technology. It consists of a conventional mill with coke ovens, blast furnace, continuous casters and rolling mills. The units and capacity of the main plants are shown in Table 2.6.

By backward integration, the 320mm light section and bar mill (400,000 tonnes per year) and the 150mm wire rod mill (130,000 tonnes per year) were commissioned in June and December, 1983 respectively and have been in operation using imported billets. The medium section and structural mill, with an installed capacity of 560,000 tonnes per annum of rails and medium structures has technically been completed but full load testing awaits the importation of blooms.

TABLE: 2.6

AJAOKUTA STEEL COMPANY - UNITS AND CAPACITIES OF THE MAIN PLANTS (PHASE 1)

UNIT	PRODUCT	TONNES/ YEAR
1. Raw material plant		9
2. Sinister plant	bin sinister	2.64m
3. Coke Oven (2) and by product plant	run of coke over	800,000
	tar	48,000
	ammonia	3,000
	light oil	130,000
	hydrogen surphide	4,000
4. Blast furnace 1	hot metal	1.2m
	pig iron	155,000
	slab	675,000
5. Basic Oxygen furnaces (2)	liquid steel	1.4m
6. Bloom caster (3,2 stran)	blooms	1.3m
7. Rolling mills-light section:		
Mill	light section	400,000
Wire Rod Mill	wire rods	130,000
Billet Mill	billets	795,000
Medium section Mill	Medium section	560,000
8. Repair shop		
9. Auxiliary Facilities:		
Lime plant		
Dolomite plant		
Thermal power plant and Turbo-blower section		
Oxygen plant		

Source: Steel subsector study in Nigeria, Final Report, Hatch Associates Appendices p. 1.1.

Construction is still in progress on the steel making plant while several of associated infrastructure and services lag behind plant construction and are likely to hinder plant operation. The entire plant was recently commissioned in December 1992 despite the fact that most of the units are yet to be operational. It is being scheduled to commence operations soon.

Ajaokuta Steel Company , like the other steel ventures, is not isolated from the problems at present confronting the industry as production from the commissioned mills have been abysmally low. This stems largely from the absence of billets which are currently imported. Other problems include lack of infrastructure, non-availability of essential raw materials, energy and transportation problems, and finance. Production figures for the commissioned mills between 1985 and 1988 are shown in Table 2.5. It appears that Ajaokuta, when finally completed will be another white elephant project. The latest projections indicate that Ajaokuta will produce expensive poor quality steel from low grade local quality ore and coal (Balogun 1988).

iii) The Inland Rolling Mills

There are three rolling mills at Osogbo, Jos, and Katsina rolling billets produced by Delta Steel Company, Aladja into finished products. They are designed to produce 210,000 tonnes each of long steel products per annum, ranging from 6 mm wire rods to 40 mm bars with eventual expansion to 420,000 and 720,000 tonnes per year during the second and third phases respectively. However, the timing is yet to be determined. No steelmaking is planned for Osogbo and Katsina while there are plans to install electric furnaces in the Katsina mill to produce steel from scrap. Each of these mills comprises of a single bar and wire rod mill. The main productive units are reheating furnace, rolling stands consisting of roughening stands, intermediate stands and finishing stands for bar and wire rod respectively. Others are cooling system, oil forming machines and a straightening machine. The auxilliary plant facilities include the compressed air supply system, water supply system and oil supply system. The rolling process is similar to that of the bar and wire rod mills of Delta Steel Company.

At the time these mills were being established, it was planned that Aladja would reach its maximum capacity of 1 million tonnes of liquid steel which would then be cast into 960,000 tonnes per year of billets. Thus, the inland rolling mills at Osogbo, Jos and Katsina would each receive 220,000 tonnes of billets as basic raw material. This has not materialized. It appears that the decision to tie these mills to Delta Steel Company as the major source of feedstock was not systematically analyzed. This decision was borne out of political consideration rather than basic economics. The end result is that the nation has to contend with low capacity utilization in these rolling mills as a result of absence of billets and high uncompetitive prices.

2.3.2 The private Mini-mills

About thirteen mini-steel plants and rolling mills operated by the private sector and two other operated by state governments currently exist in Nigeria. Six of them have various scrap based steel making facilities. They have installed crude steel capacities of between 9,000 and 72,000 tonnes per year and rolling capacities of between 20,000 and 228,000 tonnes per annum. At full capacity utilization, they are capable of producing 236,000 tonnes of crude steel and 1,201,000 tonnes of rolled products. They pioneered steelmaking in Nigeria and at present complement the public mills. It must, however, be mentioned that the earliest steel plant in Nigeria, Nigersteel company Emene, is undergoing rehabilitation, while a sixteenth one is under construction in Lagos.

The general economic recession has not spared these mills as capacity utilization averaged only 12 per cent between 1985 and 1988. A list of these mills can be found in Table 2.1, while Table 2.5 presents the production figures and product mix for these mills between 1985 and 1988.

2.3.3 Steel Fabrication Sub-sector

Over 250 private firms are actively engaged in steel fabrication nationwide. They depend largely on imported flat steel and their product mix covers a wide range of products ranging from enamel wares to steel pipes, metal cans, truck bodies and galvanized sheets.

Available data from Hatch Associates (1988) indicate that this sector has been severely constrained by the economic depression ravaging the country as evident from the fact that Nigeria's imports of flat sheets and plates from fifteen major supplying countries declined from a peak of 638,000 tonnes in 1980 to 163,000 tonnes in 1987. Capacity utilization for this subsector was 20 per cent in 1987.

2.4 PRODUCT MIX OF NIGERIAN STEELWORKS

Four categories of steel mill products can be identified. These are:

1. Bar products - These include wire rods, round bars and bar shapes.
2. Structural products - Beams, angles and channels.
3. Flat products - Plates, hot rolled sheets, cold rolled sheets, tinned sheets, galvanized sheets, pickled sheets and other coat sheets.
4. Cast products - Pipes, valves, fittings, etc.

An apparent distortion in the planning of the steel industry is the absence of flat products in the aggregate product mix. All currently operating mills are producing only long products to the exclusion of flat products which are indispensable for the engineering industry. While the inland rolling mills at Osogbo, Jos and Katsina have been producing various sizes of bars, rods and coils, the commissioned mills of Ajaokuta steel plant have been producing wires, rod and light sections since their inception in 1983. The entire first phase is also dedicated to the production of long products. This trend is not significantly different at the mini-mills where all currently operating rolling mills are producing only bars and rebars.

The steel industry was born during the oil euphoria of the 1970s when the construction industry witnessed an unprecedented boom and a consequent upsurge in the demand for long products. Moreover, it was part of the overall import substitution

strategy adopted soon after independence. Its product mix was thus designed to replace imports. This suggests a distortion as estimates of current demand for flat products range between 45 per cent and 62 per cent. Table 2.7 and Figure 2.4 presents the product mix of Nigeria's steel plants.

TABLE: 2.7

PRODUCT MIX DISTRIBUTION PATTERN FOR NIGERIA'S STEEL PLANTS

STEEL PLANT	WIRE ROD IN COILS	OTHER BAR PRODUCTS	STRUCTURAL PRODUCTS	FLAT PRODUCT	CAST PRODUCT	TOTAL
Ajaokuta Steel Company, Ajaokuta	130,000	150,000	250,000	-	-	530,000
Delta Steel Company, Aladja	-	180,000	140,000	-	-	320,000
Jos Steel Rolling Mill, Jos	124,100	85,890	-	-	-	210,000
Katsina Steel Rolling Mill, Katsina	124,100	85,890	-	-	-	210,000
Osogbo Steel Rolling Mill, Osogbo	124,100	85,890	-	-	-	210,000
Private and State Government Mini-Mills	-	1,201,000	-	-	-	1,201,000
TOTAL	502,330	1,788,670	390,000	-	-	2,681,000

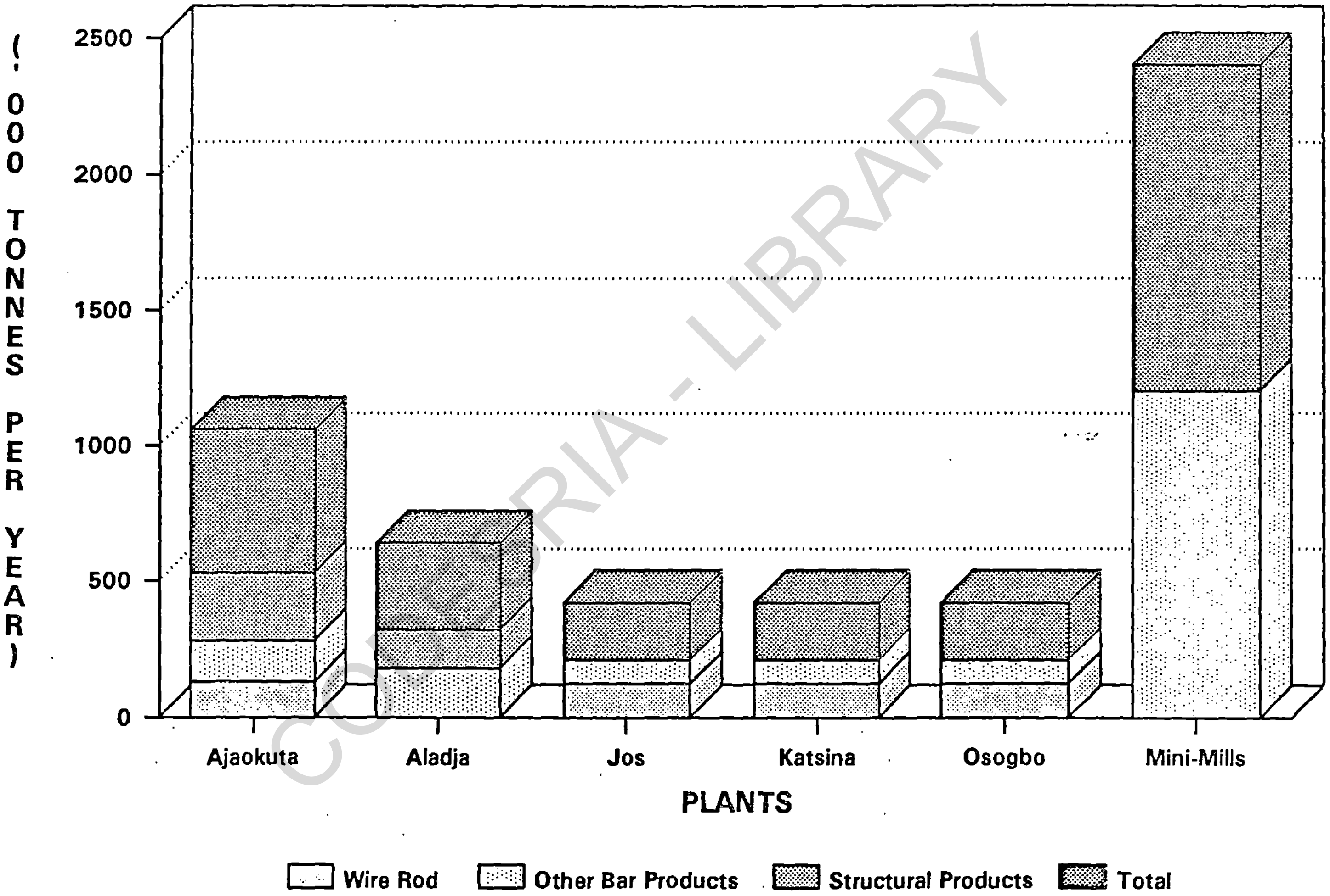
Source:- Field Survey, Delta Steel Company, Aladja.

2.5 THE DEMAND FOR STEEL IN NIGERIA

2.5.1 Historical Steel Demand

With the importance attached to rapid industrialization since the attainment of independence in 1960, steel consumption has been on the increase. It achieved remarkable growth in the 1970s and reached its peak in 1980 when almost two

FIG. 2.4: PRODUCT MIX DISTRIBUTION PATTERN FOR NIGERIAN STEEL PLANTS



billion tonnes of steel was consumed. This phenomenal growth in steel consumption in the 1970s can be attributed to favourable economic conditions informed by surplus revenues generated from the oil sector and the consequent upsurge in the spate of construction projects. Several high steel content projects such as the oil refineries, Delta Steel Company and series of overhead bridges were embarked upon during this period.

However, steel consumption has been on the decline since 1980. The unprecedented economic decline that afflicted Nigeria since the beginning of the 1980s severely affected steel consumption in Nigeria with the result that the 1.9396 million tonnes achieved in 1980 now represents the highest level ever attained in Nigeria. Since 1981, steel consumption has been on the decline as reflected in Table 2.8. It reached its lowest ebb in 1986 when only 641.3 thousand tonnes was consumed. Nevertheless, it has continued to recover since then in line with improvements in the Nigerian economy. A careful examination of Table 2.8 would show that steel consumption is affected by the level of economic activities as reflected by the gross domestic product. Changes in the gross domestic product and steel consumption followed the same trend.

TABLE 2.8

PER CAPITA STEEL CONSUMPTION AND STEEL INTENSITY IN NIGERIA (1981-1991)

STEEL CONSUMPTION IN '000 TONNES		GDP IN N MILLION	% CHANGE IN STEEL CONSUMPTION	% CHANGE IN GDP	POPULATION	PER CAPITA STEEL CONSUMPTION (KILOGRAMS)	STEEL INTENSITY
1981	18721.1	70,396	-	-	89.4	20.9	0.0266
1982	1629.2	70,157	-13.0	-0.3	92.4	17.6	0.0232
1983	893.3	66,390	-45.2	-5.4	95.4	9.4	0.0135
1984	766.9	63,006	-14.1	-5.1	98.6	7.8	0.0122
1985	902.4	68,916	+17.9	+9.4	101.8	8.9	0.0131
1986	641.3	71,076	-29.1	+3.1	105.2	6.1	0.0090
1987	772.3	70,741	+20.4	-0.5	108.6	7.1	0.0109
1988	886.0	77,752	+14.7	+9.9	112.3	7.9	0.0114
1989	1000.0	81,030	+12.9	+4.2	116.0	8.6	0.0123
1990	1300.0	90,800	+30.0	+12.1	119.9	10.8	0.0143
1991	1442.0	94,280	+10.9	+3.8	88.5	12.9	0.0153

Source:
(1) Steel consumption from Hatch Report (1988) and Phoenix Nigeria Limited(1990)
(2) GDP in Million Naira at 1984 factor cost from Central Bank of Nigeria, Statistical Bulletin (1991)
(3) Population figures from Nigeria's Principal Economic and Financial Indictors, Federal Office of Statistics and provisional result of 1991 population census.

It is worthwhile to note that the volume of steel consumption in Nigeria as measured by the per capita steel consumption (a parameter that has traditionally been used as a rough index of a country's level of industrial development) and the steel intensity, the ratio of apparent steel consumption to the gross domestic product or the volume of steel consumed per unit value of total economic activity, is relatively very low. The highest level was achieved in 1980 when the per capita steel consumption was 22.8 kilograms. This is abysmally low compared to that of other countries. The apparent steel consumption for other developing countries like Mexico, Libya and Brazil hovers around 100 kilograms as shown in Table 2.9.

TABLE 2.9

APPARENT STEEL CONSUMPTION PER CAPITA FOR A NUMBER OF COUNTRIES IN 1984

COUNTRY	PER CAPITA STEEL CONSUMPTION IN KILOGRAMS
Czechoslovakia	700
Japan	619
USSR	575
Belgium-Luxemberg	570
U.K	254
Mexico	113
Libya Arab Jamahiriya	100
Brazil	88
Tunisia	81
Egypt	43
Peru	27
India	17
Nigeria.	8

Source: International Steel Institute - 1986.

It is glaring that the per capita steel consumption in Nigeria between 1981 and 1991 listed in Table 2.8 does not compete favourably with the listed figures.

2.5.2 Future Steel Demand

Several studies have been conducted to estimate and project the demand[2] for steel in Nigeria. These studies include PRC (1981), the World Bank (1983), ECA (1985) PAC MECON (1989), Hatch Associates (1988) and Phoenix Investment Services (1990). A common feature of these studies is the fact that they were commissioned by the Ministry of Mines, Power and Steel.

The projected demand for steel made by the earlier studies are shown below.

TABLE 2.10

PROJECTED DOMESTIC DEMAND (000 TONNES)

CATEGORY	PRC (NIG) LTD			WORLD BANK		ECA	
	1985	1990	1995	1985	1990	1990	2000
Long products	1557	2648	4062	1330	1790	948	2156
Flat products	2600	3513	4060	1410	1880	1161	2642
Tubes, etc.,	279	377	495	200	250	764	1738
TOTAL	4436	6538	8617	2940	3920	2873	6536

Source: Compiled from various reports at the Federal Ministry of Power and Steel, Lagos.

Most of these projections were made by extrapolating historical trends during the oil boom era and import statistics computed by the Federal Office of Statistics. Subsequent events have proved that these projections are out of tune with recent situation in the industry. They were informed by optimistic economic growth scenarios triggered off by the oil boom.

Hatch Associates was thus commissioned by the Federal Government in collaboration with the World Bank in 1988 to examine the steel industry in line with recent developments in the economy. Based on the 1982 - 1987 figures and a 6.5 per cent annual growth in steel consumption, assuming 4 per cent annual real GDP growth rate, the projected demand made by this study are as follows:

TABLE 2.11

PROJECTED STEEL DEMAND BY HATCH REPORT (1989)

YEAR	STEEL DEMAND (TONNES)
1989	1,000,000
1990	1,065,000
1995	1,459,000
2000	1,999,000
2003	2,415,000

Source: Steel Sub-Sector Study in Nigeria, Final Report, Hatch Associates, 1988.

These figures are unrealistic. The pessimistic scenario can be attributed to the fact that the period of study (1982-1987) covers years of depression apart from being too short to be the basis on which reasonable projections can be made. Furthermore, important and significant consumers of steel were left out of the study. The population size of 200 where only 43 firms responded was too small as the basis on which meaningful projections can be made.

In spite of the fact that the dynamics of steel consumption in Nigeria cannot be predicted with reasonable accuracy, perhaps the most realistic forecast of the demand for steel products in Nigeria is the study conducted by Phoenix services (1990). It is more realistic in view of the fact that 1,600 end users were surveyed out of which 925 responded. Their projections of steel demand in Nigeria between 1990 and 2005 are shown on Table 2.12. These figures are considerably less than the projections made by the earlier studies conducted by PRC (1981), World Bank (1983) and ECA (1985), while they represent a considerable improvement on the pessimistic scenario of the Hatch report of 1989.

TABLE: 2.12

PROJECTED STEEL DEMAND BY PHOENIX SERVICES (1990)

YEAR	PROJECTED STEEL DEMAND (TONNES PER YEAR)
1990	1,300,000
1991	1,442,000
1992	1,732,800
1993	1,787,930
1994	2,033,100
1995	2,143,930
1996	2,294,005
1999	2,810,254
2005	4,217,435

Source : Federal Ministry of Power and Steel, Lagos, 1991.

2.6 PROBLEMS AND PROSPECTS OF THE NIGERIAN IRON AND STEEL INDUSTRY

The priority accorded to the rapid development of a virile self-sustaining iron and steel industry in Nigeria derives largely from the perception of the industry as the critical pivot on which Nigeria's future technological and industrial development hinges. The nation's huge investment of over U.S. $10 billion towards the realisation of a viable steel industry can be justified not only by the potential role which the industry is expected to play in the country's overall socio-economic transformation, but also by the domestic availability of essential raw materials, the expected employment multiplier effect and the seemingly wide gap between domestic production and consumption of steel products.

However, recent events in the industry have demonstrated that the iron and steel industry was born without adequate preparation. Latent economic and operational problems, some of which are quite excruciating, have continued to plague the industry. Some of these problems are examined below:

2.6.1. <u>Sub-optimal Locations</u>

Four essential inputs for a viable integrated steel plant are good quality iron ore, coking coal of metallurgical quality, good infrastructure with cheap and uninterrupted power supply and a solid technological base. Thus, the best location for an iron and steel plant is a site where all its principal raw materials are found not only in close proximity to one another but also near the major markets for the product. Since the industry's several raw materials are hardly ever found in the same locality, and most iron and steel works in general tend to serve the needs of several geographically separate markets, such an ideal location for the industry does not exist. However, there is the need to be content with low cost sites under an average set of economic and technological conditions throughout the life of the plant (Manners: 1971).

Apart from Delta Steel Company which is strategically located near natural gas fields and a navigable sea channel, these factors were not given adequate consideration in the choice of location for the steelworks in Nigeria. The need for geographical dispersal of the steel mills and political considerations seem to have weighed unduly in favour of most of the historical locational decisions. Right from inception, Ajaokuta Steel Company was known to be suboptimally located. Katsina as a location has turned out to be quite expensive as explicitly stated in the fourth plan.

Due to locational distortions in the spatial configuration of the industry, several problems relating to the sources of raw materials for the plants and the market for the products, have emerged. Billets produced at Delta Steel company are being shipped by road to Osogbo (over 400 kilometres), Jos (over 900 kilometres) and Katsina (1,350 kilometres). The finished products are then transported back to key marketing centres. The implication is that the nation's steel plants are high cost producers partly due to high cost of transportation. In 1985, while imported re-enforced bars landed at a price of ₦380 per tonne in Port Harcourt, domestically produced bars attracted about ₦700 per tonne.

2.6.2. Absence of Critical Raw Materials

The perfunctory planning and implementation of the nation's steel industry has continued to hinder the development of a virile steel industry. Despite huge government investment of over fifty billion Naira on the nation's steel projects, project planners had a clouded view of the raw material component. The issue of domestic sourcing of raw materials was not systematically analysed as can be seen from Tables 2.13 and 2.14 which present the raw material input requirements and sources for both Aladja and Ajaokuta steel companies respectively.

TABLE: 2.13

RAW MATERIAL INPUT REQUIREMENTS FOR DELTA STEEL PLANT AT OPERATING CAPACITY OF ONE MILLION TONNES PER YEAR

Raw Material	Quantity (000 tonnes)	Sources
Iron Ore	1,500	Imported - LAMCO in Liberia and SAMARIO in Brazil
Limestone	130	Mfamasong
Natural Gas	59682×10^6 NMS	Ugheli oil gas fields
Scrap	160	Importation
Coke	5	Importation
Ferro-Alloys	30	Importation
Electrodes	8	Importation
Refractory Bricks	55	Importation

Source: Field Survey, Delta Steel Company, Aladja.

Iron ore and coal that constitute about 85 per cent of the raw material components of Delta steel company are currently being imported, while Ajaokuta steel company may have to perpetually depend on imported coking coal to the tune of one and a half million tonnes per annum on completion due to the non-coking quality of Nigerian coal. In spite of the fact that Associated Ore Mining company had a stockpile of 5.6 million tonnes of iron ore since 1986, neither Aladja nor Ajaokuta can utilize this ore except benefication is carried out. The chemical composition of Itakpe ore is such that it contains only 38 percent iron ore on the average but Aladja

TABLE: 2.14

RAW MATERIAL INPUT REQUIREMENT AND PROPOSED SOURCES FOR AJAOKUTA'S FIRST PHASE OF 1.3 MILLION TONNES PER YEAR

Raw Material	Quantity ('000 tonnes)	Sources
Iron Ore	2,135	Itakpe, Ajabanoko and Choko-Choko
Coking Coal	1,200	Enugu, Lafia - Obi (35%) and Importation (65%)
Limestone	700	Jakura, Ubo and Mfamasong
Dolomite	250	Burum and Osara
Bauxite	13	Importation
Scrap	300	Recycle and Local
Refactory clay	63	Onibode/Osiele
Manganese Ore	85	Importation
Deoxidizers	23	Importation
TOTAL	4,769	

Source: Field Survey, Ajaokuta Steel Company, Aladja.

and Ajaokuta require 64 and 68 percent of iron respectively. Aladja steel company is currently depending on iron ore from Liberia and Brazil. With the present economic recession, Aladja is finding it increasingly difficult to import not only iron ore but refactory materials and other spare parts. With such a total dependence on imports, the nation's steel industry is thus exposed to the caprices of international trade and geopolitics.

The doubtful structural linkages between the integrated plants and the inland rolling mills and mini-mills also constitute a matter for concern. The greatest single factor that has inhibited the operations of the widely dispersed steel rolling mills at Osogbo, Jos and Katsina,is linking them to Delta steel company as their major source of billets, the major raw material. Since its inception in 1982, Delta steel company has been unable to achieve 30 percent capacity utilization for any year and this has adversely affected the performance of these mills. Between June and December 1987, Osogbo steel rolling mill was closed down while Jos did not produce between December 1988 and January 1989 due to absence of billets. The apparent inefficiency of the rolling mills stems from lack of billets.

The incompatibility of billet sizes being produced at Aladja with those to be produced at Ajaokuta also constitute a potential source of problem. Ajaokuta billets have a cross section of 100 x 100mm as against 120 x 120mm being produced at

Aladja. The billet configuration of Ajaokuta is such that they cannot be used by the rolling mills.

Lack of synchronization of all mutually related activities in the steel industry from mining through benefication, infrastructural facilities, logistics planning to plant construction has continued to hinder the development of a viable industry.

2.6.3. Inappropriate Technologies

The problem of inappropriate technological choice can best be levelled against Ajaokuta steel company which utilizes the conventional blast furnace/basic oxygen furnace for steel production. The planned capacity of the first phase of 1.3 million tonnes of liquid steel per annum is too small to justify the huge investment on infrastructure and ancillary facilities. The minimum efficient scale of integrated steelworks utilizing the blast furnace route for steelmaking has advanced considerably from 2 million tonnes per year in the 1950s to between 8 - 10 million tonnes per year in 1980. This is likely to increase to 15 million tonnes per year in 1995. Technological progress is fostering a continuing trend towards the use of large-scale steel plants.

The nation's steel industry was implemented with the package importation of technology on turn-key basis. The principal actors that were involved were firms from diverse countries. They include:

Ajaokuta steel Company	-	USSR/W. Germany/France
Delta steel Company	-	W. Germany/Austria/India
Osogbo Rolling Mill	-	W. Germany/Austria
Jos Rolling Mill	-	West Germany
Katsina Rolling Mill	-	Japan.

Consultants were also employed for all the steel projects to monitor project execution and supervise construction. The consultants for Ajaokuta Steel Company are Pan African Services Nigeria Limited and MECON of India. Hayek Engineering AG of Zurich was in charge of the steel rolling mills at Osogbo, Jos and Katsina while MECON of India handled Delta steel company. Nigeria engineers and consultancy firms were assigned only minimal roles in the overall implementation of the steel projects. The package importation of technology inhibited the proper understanding of its component parts and the subsequent domestic adaptation. Technological transfer was thus not affected as little learning was achieved by Nigerians. Spareparts replacement and services are still being provided by foreign firms.

2.6.4. Undue Delay in the Completion of Ajaokuta Steel Company

Ajaokuta steel company is the most ambitious integrated steelworks in Nigeria. The first phase of the Ajaokuta dream is yet to materialize. The original plan for Ajaokuta envisaged the commissioning of the various units by backward integration leading to the final commissioning of the entire first phase of 1.3 million tonnes per year in 1986.

Construction work started in June 1981 with Tiajpromexport, the major contractor expected to prepare the working drawings, supply the equipment, structures and materials as well as install the process units. However, in October 1980, the civil engineering work was split into three different and identifiable lots and awarded to the following western contractors:

LOT I	-	Messrs Fougerolle and Fougerolle Nigeria Limited. Raw material preparation plant, Coke oven plant and Blast furnace plant.
LOT II	-	Messrs Bilfinger and Berger Nigeria Limited, Rolling Mills and steel making shops.
LOT III	-	Messrs Dumez Nigeria Limited, Auxilliary and Ancillary shops.

The contractors were expected to complete these lots in 54 months with effect from November 1980. The backward integration approach was adopted with the timely commissioning of the light section mill and wire rod mill in June 1983 and

December 1984 respectively.

Due to the general economic recession and the consequent spiralling inflationary trends marked by escalating material and labour costs far beyond what was envisaged in the global contract, funds allocated to the civil engineering contracts were exhausted halfway. The entire first phase was only commissioned in December 1992. According to industrial experts, several productive units such as the medium section mill, coke oven batteries and blast furnace are yet to be ready. It is now twenty five years since the Soviet Union[3] started to grapple with what now appears to be the unenvious task of building an iron and steel complex for Nigeria.

2.6.6 Operational Problems

The steel industry was born without adequate preparation. While the various steel projects were commissioned amidst pomp and pageantry, subsequent events that followed have left a lot to be desired. The steel plants are now havens of corruption, nepotism, tribalism, politics, fraud and unstable management. Other inadequacies that have hindered the attainment of planned production levels are problems of finance, lack of skilled manpower, inadequate and erratic power supply and overpricing of both electricity and natural gas.

It is, however, imperative to note that the fundamental problems confronting the development of a self-sustaining iron and steel industry are quite daunting. With prudent planning and determination, these intractable problems are by no means insurmountable.

Endnotes

1 In view of the strategic importance of steel and its numerous linkages with other sectors of economy, the advertising campaign for the privatisation of British steel reads 'it fries, it flies, it lifts, it shifts, it holds, it makes, it breaks, it swings, it rings, it drills, it mills, it scans, it cans, it cuts, it shuts, it shines,' see Times (London), 17th September, 1988. Also in Alli-Balogun (1988) pp. 623.

2 These studies erroneously assumed that the demand for steel is equivalent to the volume of steel consumed. The data, therefore, excluded the volume of steel kept as inventory. We do however perceive that inventory of steel is likely to be very small.

3. For more exposition on the role of the Soviet Union in the acquisition of steel technology by Nigeria, see 'Soviet Technical Assistance and Nigeria's Steel Complex' by Alli-Balogun (1988). <u>The Journal of Modern African Studies</u>, Vol. 26, No. 4, pp. 623 - 637.

CHAPTER THREE

ISSUES IN PLANNING INVESTMENTS IN THE IRON AND STEEL INDUSTRY

3.1. INTRODUCTION

The need to incorporate interdependences among highly interrelated activities in investment decisions has led to increasing use of planning models incorporating economies of scale. However, few applied increasing returns planning models have been constructed. The art of planning with economies of scale has only recently passed beyond its infancy due to difficulties often encountered in obtaining global optimum to planning models that explicitly specify increasing returns to scale. It is still being treated at the sectoral level due to problems of aggregation.

This chapter examines some theoretical and empirical issues in planning investments under economies of scale. Among the issues examined are the meaning of economies of scale, analytical approaches to planning investments and a review of the literature on the iron and steel industry.

3.2 ECONOMIES OF SCALE IN THE CONTEXT OF INVESTMENT PLANNING.

Economies of scale or increasing returns can broadly be defined as reductions in per unit costs achieved by expanding the scale of production, which is represented by installed production capacity (as opposed to capacity utilization) Lucke (1988). In microeconomic theory, the concept is commonly expressed through a downward sloping, long-run average cost curve relating per-unit costs to changes in capacity. The long-run curve may be thought of as the envelope of an infinite number of short-run, U-shaped average cost curves that relate per unit costs to changes in capacity utilization. It is usually assumed that per unit cost decreases as capacity is expanded by a constant amount (that is, the second derivative of the long-run cost function declines towards zero as capacity increases). At some point termed the minimum efficient scale, cost savings due to further extensions of capacity are assumed to be insignificant and decreasing returns set in.

The degree of increasing returns is generally expressed by the elasticity of total cost with respect to scale. A scale elasticity of less than 1.0 implies falling average costs: the smaller the elasticity, the faster is the fall in average costs arising from scale Westphal (1975:259). Empirical studies of many industries conducted by several economists, including Pratten and Dean (1965), have demonstrated that the elasticity of total plant investment cost with respect to plant capacity is constant over a wide range of capacity, frequently between 0.6 and 0.8. This implies that doubling plant size increases investment costs by approximately 60-80 per cent. Depending on the industry, economies of scale in the use of labour may even be greater.

Economies of scale are sometimes also found in the use of raw materials,although these are generally less important than scale economies associated with capital and labour use.

An example of a constant elasticity cost function having a constant scale elasticity of less than one is shown in figure 3.1. The total investment cost rises with the size of the unit installed but at a decreasing rate so that marginal cost to each increment of output is declining. Unfortunately, it is not possible to specify this non-linear relationship in a solvable mathematical programming model except the true investment cost function can be approximated by piecewise linear functions.

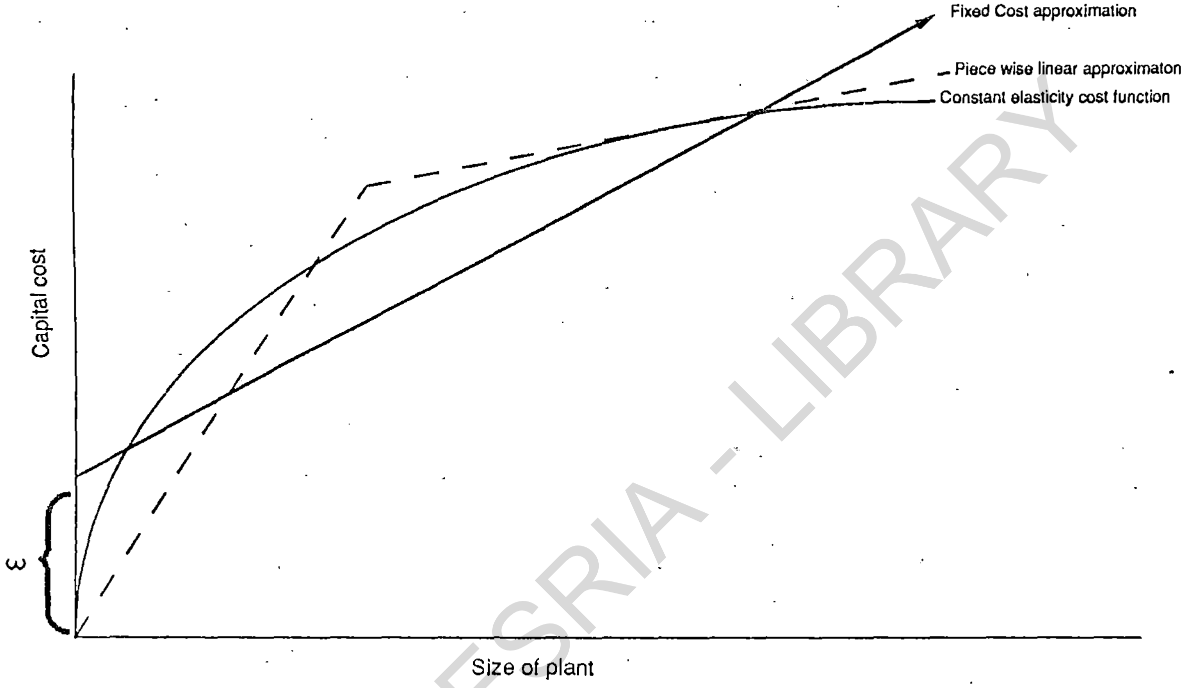
Two classes of piecewise linear approximation to any constant elasticity cost function showing increasing returns are possible. These are:

(1) The fixed charge linear cost function which closely approximates the constant elasticity cost function over a wide range of plant scale; and

(2) The piecewise linear approximation having n-linear segments.

Figure 3.1 illustrates the fixed charge cost function which closely approximates the constant elasticity cost function over a fairly wide range of plant

Fig. 3.1 The investment cost function



scale. This can be formally represented in a programming model as follows:

$\phi_k = wy + vh$ ------------ (1)

$hy - y \geq 0$, and ------- (2)

$y = 0$ or 1, ------ (3)

Where

ϕ_k = Total cost of capacity expansion

w = Fixed charge or fixed cost associated with plant construction.

y = Zero-one variable associated with the fixed charge.

v = Variable cost associated with plant construction; and

h = a positive upper bound placed on the size of the productive unit to be installed.

Equation (1) is the fixed charge cost function. Equations (2) and (3) are required to ensure that the fixed charge is incurred once capacity is installed. In equation (2), if h is greater than zero, then y must also be greater than zero but by equation (3), if y is greater than zero then it must be 1. If the capital cost associated with capacity expansion were to be entered into the objective function without equation (3), the zero-one variable y, the fixed cost would always be incurred whether or not capacity is constructed. This problem is solved by the introduction of the integer variable y into the function. $y = 1$ if capacity expansion takes place so that the fixed charge is incurred and zero if no capacity is installed so that the fixed charge is deleted. A pertinent issue relates to the appropriate value of h to be selected. This can be solved by placing an upper bound on the size of capacity to be installed. This may be informed by a technically defined maximum plant size otherwise, it may indicate the scale at which average capacity cost is at a minimum.

In practice, there are a number of ways to select w and v once the parameters of the constant elasticity cost function are given. They may be chosen to coincide at the plant scale thought a priori to be optimal. Alternatively, they may be estimated through a least square regression over points for a particular interval along the constant elasticity cost function. The latter approach was adopted by Choksi, et. al (1975) for the Egyptian fertilizer industry.

The n-piecewise linear approximation method where n denotes the number of linear segments in the approximation differs from the fixed charge linear approximation approach in that the first linear segment emanates from the origin while the second segment has a smaller slope (i.e. marginal cost) than the first. By choosing the number of linear segments to be included in the approximation, it is thus possible to approximate the constant elasticity cost function to any degree of accuracy. An example of n-piecewise linear approximation having two segments is shown in figure 3.1. The specification of an n-linear piecewise concave cost function requires the use of a number of integer variables equal to the number of linear segments less than one (i.e. n - 1). The fixed charge approximation method is the most widely used by economists dealing with economies of scale in numerical models. Examples are Kendrick (1967), Westphal (1971), Gately (1971), Choksi, et al (1980) etc. The only practical application of n-piecewise linear approximation found in the literature is the study by Kendrick, et. al (1984) having three segments.

3.3 APPROACHES TO PLANNING INVESTMENTS

The development of investment appraisal techniques has a long history - from Bohm Bawerk and Wicksell, through Irving Fishers and Keynes. The postwar period, however, witnessed a remarkable spate of attempts at developing analytical approaches to investment planning. This development has been aided by the growth of quantitative techniques and the introduction of computer hardware and software for dealing with previously intractable problems of risk, uncertainty, economies of scale and interdependence among projects.

The traditional tools of investment analysis are the present value and rate of return criteria. These entail the ranking of projects on the basis of either criterion and selecting those with the highest pay-off until the investment budget is exhausted. The optimal choice of projects would then be those with the highest pay-off which maximizes the society's net benefit. The key assumption required to apply this approach is the absence of interdependence between projects. The ranking of projects according to their rate of returns implies that the outputs of the project are independent of one another and the factors of production used are perfectly mobile and homogeneous. Emphasis, then, is on the substitutability of one project for another rather than complementarity between projects. In spite of its simplicity, there now appears to be a consensus of opinion that this type of cost benefit analysis is not an appropriate procedure for investment planning and that it is subject to several limitations (Heroux and Wallace, 1975; Keown and Martin, 1978).

These approaches would be unsuitable for the process industries where there are widespread interdependences among industrial production activities. The existence of economies of scale in the process industries which are the result of a number of interdependences leads to a number of complications in the design of projects. This has been described in detail by Chenery (1959), Kendrick (1967), Manne (1967) and Westphal (1971). Choksi, et al (1975) have identified the planning problems created by three types of interdependencies. These are problems associated with spatial interdependence which refers to the trade-off that exists between large productive units and high transport costs. Economies of scale tend to favour large productive units over small ones, but the former serves a large market thus giving rise to higher transport cost. In order to evaluate the trade-off between large productive units and cost of carrying excess capacity on one hand and transportation on the other, it becomes necessary to evaluate alternative investment programmes defined over space and time. Temporal interdependence arises from the fact that under conditions of increasing demands in the presence of economies of scale, it may be efficient to build plants with excess capacity in order to take advantage of the declining average cost of production. Thus the trade-offs involve the choice between large productive units with low average cost of production and the cost of carrying excess capacity. Interprocess interdependence results from the input-output relationship between various stages of production. These interdependencies necessitate the determination of the optimal investment programme for the entire set of activities rather than individual projects. Chenery (1959) and Westphal (1983) have demonstrated that interdependence combined with economies of scale make explicit non market co-ordination necessary to achieve optimal allocative decisions.

Other investment criteria that have been suggested by economists range from simple rule of thumb such as those based on capital intensity and balance of payments effect (e.g. Polak 1942; Kahn 1951), to elaborate application of marginal productivity (Chenery 1953), comparative costs (Bohr 1954), and cost benefit analysis using shadow prices (Little and Mirrles, 1974; Squire and Van der Tak, 1975).

For public enterprises which are set up to achieve second best efficiency and equity objectives, social cost benefit analysis has been developed for comparing the likely return on projects. Two variants have been developed in the literature, the method suggested in the UNIDO guidelines (1972) and the approach by Little-Mirrles (1974). They differ partly in their choice of numeraire and in the treatment of shadow prices from non-traded goods. In the little-Mirrles approach, it is the uncommitted social income expressed in the foreign exchange as compared with aggregate consumption expressed in domestic currency in the UNIDO guidelines.

Unfortunately social cost benefit analysis cannot handle effectively problems incorporating economies of scale. The usual methodology is based on marginal economics. A project with significant scale economies is anything but marginal. It has been observed by Taylor (1979:199), that the usual project analysis technique deserves a barely passing grade at dealing with economies of scale. According to Le Squire, et al. (1975:17), the merit of a project characterized by economies of scale cannot be judged without making an estimate of the demand for its output, and this in turn requires placing the product in its sectoral and country context.

In contrast to the logic that underlines the Little-Mirrles and UNIDO approach where the focus is on the appraisal of individual projects, an alternative methodology is the evaluation of projects within an economy-wide framework. This approach was adopted by Goreux and Manne (1973) and Goreux (1977) to investigate the impact of investment projects on Mexico and Ivory Coast respectively within a general equilibrium framework.

Since this study is concerned with achieving efficiency in the steel industry, an investment planning methodology that embodies allocative efficiency while at the same time lending itself to the treatment of economies of scale is chosen. The determination of interregional flows is best achieved using programming techniques. These category of models also lend themselves to the explanation of engineering processes in the different stages of commodity transformation.

There is considerable variety in the type of programming models that have been adopted for similar studies in the literature. The most frequently used are linear, dynamic, integer, and more recently, linear complementary programming. Table 3.1 presents the modelling methodologies that have been employed for different commodities in the literature, the purpose of the methodology, the quantitative methodology used and economic behaviour specified. This study would nevertheless concentrate on a survey of spatial equilibrium and programming models.

The most elementary application of linear programming to planning problems is the transportation problem. Given a set of plants and markets that produce and consume a specific commodity, the transport problem examines which plant should serve which markets if total transport cost are to be minimized without permitting any plant to ship more than its capacity or any market to receive less than it requires.

Table: 3.1

COMMODITY MODELING METHODOLOGIES AND THE MODELING PROCESS

Methodologies	What is the purpose of the methodology?	What quantitative method is used?	What economic behaviour is specified?	Examples of Commodity Application
Market Models	Demand, supply, inventories interest to produce an equilibrium price in competitive or non-competitive markets.	Dynamic micro econometric system composed of different or differential equations.	Interaction between decision makers in reaching market equilibrium based on demand, supply inventories, prices, trade, etc.	Cocoa, Coffee, Jute, Sugar and Tin
Spatial Equilibrium and Programming Models Linear and Quadratic Programming	Spatial flows of demand and supply and equilibrium conditions assigned optimally in equilibrium depending on configuration of transportation network	Activity analysis of a spatial and/or temporal form. Degree of complexity depends on endogeneity and method of incorporating demand and supply functions.	Interaction between decision makers in allocating shipments (exports) and consumption (imports) optimized through maximizing sectoral revenues or minimizing sectoral costs.	Iron and Steel Lead and Zinc
Mixed Integer Programming	Spatial and temporal equilibrium embodying production-process, transportation, and project investment components.	Activity analysis involving spatial and temporal optimization but also including integer (0,1) variables to represent capacity additions.	Interaction between decision makers in finding minimum discounted costs of meeting specific market requirements, i.e., project selection.	Aluminum, Copper, Fertilizers, Iron Ore, Iron and Steel
Optimization Model	Supply and demand analyzed in relation to optimal resource exhaustion over time and cartel behaviour	Dynamic micro econometric system featuring formal cartel-fringe models such as that of monopoly, stackelberg or Nash-Cournot.	Interaction between decision makers in optimizing resource allocation and prices over time in noncompetitive markets involving bargaining activity.	Aluminum, Copper and Crude Oil
System Dynamics Models	Demand, supply, inventories interact to produce an equilibrium price emphasizing role of amplifications and feedback delays.	Dynamic micro economic differential equation system which features lagged feedback relations and variables in rate of change	Interaction between decision makers in adjusting rate of production to maintain a desired level of inventory in relationship to rate of consumption	Aluminum, Broilers, Cattle, Copper Hogs and Orange Juice
Input-output Models	System regarded as process that converts raw materials into intermediate and final products via intermediate processes	Input-output model combined with macro economic framework or disaggregated raw materials balance framework	Interaction between non-fuel and macro markets in reaching materials and energy balance including supply-demand determination.	Minerals, Energy and Agriculture

Source: W.C. Labys, and P.K. Pollak, Commodity Models for Forecasting and Policy Analysis, Croom Helm Ltd., Publishes, London, 1984, pp. 45-57. Also in Walter C. Labys. Recent Developments in Commodity Modeling. A World Bank Focus. October 1988, pp. 10.

The transport problem can be formally stated as follows:

$$\text{Min } Z = \sum_{i \in I} \sum_{j \in J} u_{ij} \; x_{ij} \quad \text{------------------} \quad (4)$$

where

Z = total transport cost.

i = an individual plant in the set of plants I.

J = an individual market in the set markets J.

X_{ij} = the amount of products shipped from plant i to market j.

U_{ij} = the constant unit transport cost of shipment from plant i to market j

and

K_i = capacity of the plant.

The first constraint that no plant can ship more than its capacity can be written as:

$$\Sigma X_{ij} \leq ki \qquad i \in I \quad \text{-----------------------} \quad (5)$$

Equation (5) states that the sum of shipments of products from plant i to all marketing centres j must be less than or equal to the capacity of the plant.

Where

. The symbol $j \in J$ indicates that one should sum over all the indexes contained in the set J.

The symbol $i \epsilon I$ on the right hand side indicates that there must be a constraint of this type for all plants in the set I..

The second constraint of the transport model stipulates that each marketing centre must receive as much products as its specified requirements. Thus if

d_{ij} = the product requirements of market j, the market requirement constraint can be specified as follows;

$$\sum_{i \epsilon I} X_{ij} \geq dj \quad \dots \quad \text{for all } j \epsilon J \qquad \text{----------} \quad (6)$$

The sum of shipments of the product from all plants i to all marketing centres j must be greater than or equal to the product requirements of all marketing centres j. $j \epsilon J$ on the right hand side of equation (6) indicates that there must be a constraint of this type for all marketing centres.

Finally, shipments of the product cannot assume negative values. This is formally stated by a non-negativity constraint.

$$X_{ij} \geq 0 \qquad \text{----------------} \quad (7)$$

The transport model is thus to minimize total transport cost subject to the capacity constraint (2), the market requirements constraint(3) and the non-negativity constraint (4).

The simple transport model can be expanded to include production cost, multiple plants, production processes, intermediate products, interplant shipments, exports and imports. Other equations that can be included are material balance at plants, maximum capacity expansion,limits to economies of scale, tariff cost, capacity charges and operating costs for productive facilities. The spatial processing characteristics can also be dynamised over time. More complex objective functions can also consider the total benefit to consumers and producers within the system, in which case the model would maximize an objective function formulated in terms of net social pay-off i.e a quasi-welfare function theorized by Samuelson (1952).

Linear programming approach has been widely applied to a variety of problems ranging from development planning, industrial location, interregional trade flows and international trade. A recent update of the application of linear programming to planning can be found in Labys, Takayama and Uri (1988) where applications are reported for aluminium, bauxite, coal, electricity and food commodities. With reference to the steel industry, linear programming was applied by Casetti (1966) to determine optimal location of steelmills serving the Quebec and South Ontario steel markets. Zumbrunnen and Osleeb (1986) also applied linear programming to determine the optimal input pattern, output and technological choice facing the Soviet iron and steel industry.

Unfortunately, in spite of its wide scope of application, linear programming is relatively inefficient in handling investment planning problems with economies of scale since it cannot embed production scale economics and hence finesse the linear limitation on the production cost function.

The multiperiod mixed integer programming model represents an alternative methodology for solving optimization problems over time. While it represents an application of linear programming over time, it also introduces an integer character which accommodates combinations of 0-1 variable representing the existence or non-existence of a production facility. The background to mixed integer programming[1] stems from attempts to cope simultaneously with a number of issues including production, transportation and investment for capacity expansion over time. It typically begins with a transport component that resembles the one earlier described. The project selection components are incorporated into the model by introducing investment to augment capacity expansion and economies of scale. Intertemporal dimension is then incorporated in the model to find the minimum discounted cost of meeting specified market requirements over the planning period. The search involves the selection of activity levels for the following variables: increment to capacity, shipments from plants to markets and among plants, imports and exports, and domestic purchase of raw materials, miscellaneous inputs and labour.

The pioneering study on the application of multi-period mixed integer programming to investment planning problems in the process industries can be attributed to Kendrick (1967), (a review of this study can be found in the final part of this chapter). Based on the methodology developed by Kendrick and Stoutjesdijk (1978) to plan and analyze industrial investment projects in developing countries, two large scale application of this approach include Choksi, Meerus and Stoutjesdijk (1983) for the Egyptian fertilizer industry and Kendrick, Meerus and Alatore (1984) for the Mexican steel industry. This approach has also been applied to energy analysis by Iwayemi (1975) for the Nigerian electric power supply industry, Langston (1983), the Iraqi refinery complex, Kwang-Ha (1981) concerning the Korean electric power industry and Jung-Hu (1982) in describing the Korean petrochemical industry.

The mixed integer programming approach is still relatively inefficient in computation when compared to the extensive nature and problem size that linear programming models can solve. In most cases global optimum cannot be guaranteed. However, it is more realistic in solving problems involving economies of scale .

An alternative approach to investment planning with economies of scale is dynamic programming. This has been employed by Manne (1967) to plan the size, location and time-phasing of future manufacturing facilities for four heavy industries in India, Erlenkotter (1972) for the sequencing of interdependent hydroelectric projects and Albouy, et. al (1975) for power supply. While dynamic programming appears to be superior for investment planning problems, where the dominant concern is timing or uncertainty, its applicability is extremely limited since it cannot be applied to obtain optimal solution, except the dimensionality of the problem is extremely limited. Results obtained have generally been under very restrictive conditions. Dynamic programming models are typically applied to smaller scale phenomena.

Though simulation models do not belong to the genre of programming models, they have nevertheless been applied to investment planning problems, especially in the electric sector, Anderson (1972), Takayama and Hashimoto (1984). While it permits the specification of more exact non-linear relationships, the simulation approach considers only a very limited number of alternatives based on informed knowledge or non-rigorous analysis. Its major defect is that it does not allow the full range of alternatives to be considered. Complementary programming can be traced to Hashimoto (1981) in his 'WISE' model of the iron and steel industry. This approach was also adopted by Dammert and Chhabra (1987) to determine the minimum lead and zinc prices that will cover the highest cost projects to meet the demand for lead and zinc.

The need has been emphasized for a re-appraisal of current development planning methodologies to cater for the multi-objective nature of investment decisions since goals are often multiple and conflicting (Taylor et. al (1982), Iwayemi (1983), Soyibo (1985) and Sobodu (1990).Thus, the multidimensionality of the objective function in any solution methodology must be explicitly considered. Several researchers including Kapur (1970), Cohon (1978), provide insight into the various alternative quantitative techniques that can be used given the existence of multiple objectives; although they do not develop any specific application. These alternative techniques include multi-objective linear programming,goal programming, multi-objective mathematical programming with utility functions, preference analysis, etc. Among these techniques, Zeleny (1982) indicates that three of the 'more practical and more technical methodologies' given multiple criteria are linear multi-objective programming, goal programming and compromise planning.

Linear multi-objective programming is similar in many respects to linear programming except that several objective functions are specified and maximized or minimised instead of a single objective function. A thorough presentation of the methodology can be found in Cohon (1978) and Zeleny (1982). While linear multi-objective programming encompasses maximization or minimization of several objective functions, goal programming is directed towards the achievement of predetermined 'targets' or 'goals', Zeleny (1982), Soyibo (1985) and Sobodu (1990). Compromise programming, which is perhaps the most recent among the three, combines many of the features of linear multi-objective programming and goal programming. The methodology entails the determination of ideal sets of objective values after which a compromise is sought between them. Besides being relatively new, it is viewed as being more complex than the other two approaches discussed above.

The concept of establishing 'goals' as tactical devises appears to be more compatible with the decision-making process. The establishment of goals and the ability to prioritize them enable decision makers to reflect a consensus of opinion regarding objectives among the decision makers and the involved participants. A number of researchers including Ignizio (1976), Lee and Lerro (1974), Soyibo (1983) and Sobodu (1990), have already proposed and provided examples of the application of goal programming.The three approaches are however deficient in the planning of investment programmes in the steel industry. Although goal programming can be effectively used to solve the problems created by multiple conflicting goals, it does not compensate for decision variables that are restricted toward integer variables. The more logical approach is thus to combine the techniques of integer and goal programmes. However, computational problems may render this infeasible.

3.4 THE LITERATURE ON THE IRON AND STEEL INDUSTRY.

Several studies have been conducted on the iron and steel industry both in developed and developing economies. The earlier iron and steel studies focus mainly on estimating the demand for iron ore and steel using simple econometric techniques. A review of these studies can be found in Hashimoto (1983).

The pioneering study on planning investment programs in the iron and steel industry can be traced to Kendrick (1967). He designed a medium-term investment program for the Brazilian steel industry with the aid of a multiple-period mixed integer programming model comprising of three steel plants and three regional markets.

The objective is to meet the minimum discounted cost of certain exogenous fixed demand. Based on the then existing structure of the Brazilian iron and steel industry, the choice was among twenty three alternative investment projects of varying sizes, location, metallurgical processes, and dates of initiation and completion. Of the twenty three investment projects, only twelve were selected by the model.

A year later, Wein and Sreedharan (1968) determined the optimal installation timing for individual process elements in the design of an integrated iron and steel mill making semi-finished products for Venezuela. The model is a single, multiperiod dynamic programming model with stochastic demand. There is no choice of technique, and the sequence of process element installation is pre-determined. The model is then operated to permit separate make-buy choices with respect to each product. The major defect of the study perhaps was the pre-specification of installation sequence which imposed severe restrictions on the model.

An economy-wide model was employed by Westphal (1971) to plan the scheduling and scale of two major investment projects namely, a petrochemical complex and a steel mill to be constructed in the Republic of Korea under economies of scale. The rest of the economy was aggregated into a limited number of sectors. The model is a dynamic input-output optimizing model having the mathematical structure of a mixed integer programming model. The model's use is however restrictive as it was only applied to decisions on project timing and scale. Apart from being static, decisions as to optimal plant location, technical design and product mix were not explicitly considered.

The 'WISE model' of the iron and steel industry constructed by Hashimoto (1981) employs a new technique known as linear complementary programming. This permits the treatment of the interrelationship existing between current investment and future market prices. In this model, investment in steel facilities is explained dynamically with price expectations based on forward information. Investment is assumed to be planned rationally. It is thus possible to make comparisons between investment based on rational expectation in relationship to those decisions where industries are assumed to follow predetermined investment plans. Since investment must be made far ahead in the steel industry, this specification provides a more realistic approach to forecasting steel capacities, prices and production responses during swings in overall economic activity.

Perhaps the most comprehensive study on planning investment programs in the iron and steel industry is the study conducted by Kendrick, et. al (1984) to outline a methodology for planning investment programs in the steel industry and illustrated with application to the Mexican steel industry. Three models were constructed to examine different facets of the problems confronting the steel industry. Two static models were solved as linear programming models while the third was solved as a mixed integer program. While the two static models are useful for examining operational problems, the small dynamic mixed integer model permits the focus to shift from operational problems to investment planning. In the illustration, the problem faced by the Mexican iron and steel industry included the declining quality of ore and coal from interior mines and the government policy of operating differential pricing of natural gas and electricity at different locations to encourage decentralization. The results do indicate that $26 million a year could be saved in the

Mexican steel industry by easing restrictions on coke imports and exploiting the possibility of additional interplant shipments of intermediate products. Furthermore, policies for natural gas are crucial to determining the most efficient investment pattern for the industry. If the low domestic price is allowed to rise slowly to the world market price, the choice of technology shifts from direct reduction to blast furnace. The study recommended almost all of the expansion plans of the industry to be done at ports where imported pellets can be obtained at lower prices than domestic ore as domestic ores are being exhausted.

Zumbrunnen and Osceeb (1986) employed a comprehensive time series based multiprocess analytical linear programming model to evolve an optimal plan for the Soviet iron and steel industry. The Soviet iron and steel model (SISEM) investigated the spatial allocation of energy inputs, pig iron and steel outputs and technological choices confronting the Soviet metallurgical industry. Unfortunately, this study could not embed production scale economics into the model due to the linear limitation on the production cost function used. While recognizing the fact that a non-linear dynamic model would have been more appropriate than the linear static model used, they were unaware of any readily available software which could find stable solutions to such a large mathematical problem as formulated by SISEM database.

Recent years have witnessed a sustained interest by researchers as well as policy makers on the iron and steel industry of Nigeria. Such studies include Diejomoah (1983), Ogegbo and Igwe (1984), Igwe (1986 and 1988), and Oyeyinka and Adeloye (1988). Such studies however mainly evaluated one problem or the other confronting the Nigerian iron and steel industry.

In conclusion, one can infer that while several empirical studies have been conducted on the iron and steel industry of several countries, particularly those in latin American countries, very few empirically-based studies, if any, exist on the Nigerian iron and steel industry. The need for an in-depth empirical investigation of the industry is thus imperative.

ENDNOTES

1. A survey of cost benefit analysis can be found in Prest and Turkey (1966).

2. For more exposition on mixed integer programming, see Baulmol 1972 chapter 8, and Westphal 1975 chapter 2.

3. There are no solution algorithms for obtaining the global optimal solution for models in which economies of scale are specified in a non-linear form. However, solution algorithms are available for obtaining local optimum solutions and simulation models may incorporate non linear increasing return functions.

4. See Dantzig (1965), pp. 535, Markowitz and Manne (1952) and Westphal (1975). Tomlin and Erlenkotter (1971) using a computational superior alternative omitted the zero one variable and applied the branch and bound method to the piecewise linear problem.

5. See Iwayemi: (1983) pp. 448.

6. In the late 1970s, developing countries with 62 percent of the world's population accounted for only 9 percent of global manufacturing. The second general conference of UNIDO held in Lima, Peru (12 - 26 March,1975) therefore declared that the share of developing countries in World industrial production should be increased to at least 25 percent by the year 2000. They emphasized the need for particular attention to be given to the development of basic industries - Steel, Chemicals and Engineering which would enable developing countries to consolidate their economic development.

CHAPTER FOUR

THE INVESTMENT PLANNING MODEL OF THE NIGERIAN IRON AND STEEL INDUSTRY

4.1 INTRODUCTION

Several economic issues need urgent redressing regarding the future supply of steel products in Nigeria. Given the increasing domestic demand for steel, what is the most efficient way for Nigeria to meet its future steel demand? Should it produce or import the products? The most formidable problem, perhaps, is the current absence of flat products in the product mix of existing steelworks. Given the seemingly high demand for flat products in Nigeria, what are the imperatives of successful product mix rationalisation in the Nigeria steel industry? Should Nigeria continue to rely on importation from abroad for these steel types or should some or all of the facilities be upgraded to produce flat steel? With Ajaokuta's first phase of 1.3 million tons per year coming on stream in June 1992, is there a possibility of oversupply of bars and wire rods given existing demand levels? What should be done with the inland rolling mills at Osogbo, Jos and Katsina? Should they be integrated backwards to produce billets which is currently their major bottleneck? Given that steel use will continue to increase and existing steelworks cannot meet current demand, what is the optimal scale, timing and location of new capacity expansion? How do we break the near total dependence on imports for critical raw materials and other consumables? The issue of power and natural gas pricing in Nigeria also require urgent examination.

The Nigerian steel industry is essentially oriented towards the domestic market. Given the current expansion of productive facilities, the question of steel exports will arise shortly. Finally, the problem of transportation in the Nigerian iron and steel industry requires some attention. Considerable interest need be attached to the cost minimising transportation mode of raw materials, intermediate and final products given the doubtful structural linkages that exist between the steel plants, market regions and sources of raw materials.

Against this background, this aspect of the study is preoccupied with evaluating the industry with a view to evolving a consistent and coherent framework which would facilitate the determination of possible development strategies for the Nigerian iron and steel industry. A sectoral investment planning model is specified to evaluate the prospects for the industry.

The planning approach being adopted for this study is that of mathematical programming. An intertemporal, mixed integer programming model of the steel industry is constructed to evaluate the industry.

The model consists of a set of mathematically specified relationships that incorporate the essential characteristics of the iron and steel industry and the Nigerian environment. The objective is to evaluate a number of interrelated activities to meet the exogenously specified geographically dispersed demand for steel over a planning horizon which covers the period between 1993 and 2001. The most exhaustive use of the model is to determine the least cost investment, production and trade strategy for the steel industry over the specified planning horizon. The model would facilitate the selection of optimal values of production in existing production facilities, plant size, technology, location and timing of new production facilities, imports and exports of steel products, and interregional shipment of steel products at each plant location and for each time period.

The criterion for project selection among alternatives is based on minimising the present value of discounted cost. It is, however, recognised that cost minimisation is only one of the numerous objectives that may be considered in the development of the steel sector. Other objectives may include income distribution, maximisation of employment benefits, the need for geographical dispersal of industries and other social and political criteria. A mixed integer goal programming model should have been more appropriate since it would have enabled us to consider several multiple, conflicting and sometimes non-commensurable objectives simultaneously rather than the present approach which considers only one objective. Given the computational complexities of mixed integer goal programming, the earlier approach will be adopted. Some of these objectives will however be taken into consideration by the model. It suffices to say that major data problems exist and an improved database is a prerequisite for better understanding of the Nigerian iron and steel industry.

4.2 SPECIFYING THE PLANNING PROBLEM

This section presents the various factors involved in specifying the planning problem. The basic design and characteristics of the model as well as the major features of the planning problem are examined concurrently. They include the following:

4.2.1. Production Processes

Two main technologies are available for steel production. These are the conventional blast furnace and the more recent direct reduction process. For each technique, five distinct production processes can be identified. These are raw material preparation, iron making, steel making, steel casting and rolling. The major differences between both technologies are in the first three areas of raw material preparation, iron making and steel making. Generally, the same techniques are available for casting and rolling regardless of the process for producing liquid steel.

The choice of technology is determined by the technical alternatives of using different inputs. The technological choice available to Nigeria has been presented in terms of activity analysis. An engineering type of production function which indicates the input-output relationship between the various processes is used to present the different input combination required to obtain a given product mix. The optimum choice of inputs and processes is therefore determined by the relative input prices and the investment and operating cost of the plant utilizing the inputs. The model considers six productive units and eight processes from iron making to rolling of products.

4.2.2. <u>Plants</u>

Five separate plants are explicitly included in the study. These are the two integrated plants at Aladja and Ajaokuta and the rerolling mills at Osogbo, Jos and Katsina. In spite of the fact that feasibility studies have been conducted for the establishment of several steel plants such as the high grade steel plant at Osogbo, no new plant is included in the study as it is very unlikely that any new plant would come on stream during the planning horizon.

The production processes in the model have been disaggregated to the plant level so as to permit the explicit specification of the production structures and investment and operating costs for each plant as well as the incorporation of capacity constraints that are plant specific and take into account a maximum capacity utilization factor. It is assumed that a plant cannot exceed its maximum capacity over the period. The capacity utilization rates vary between 30 and 100 percent. These are based on historical information as well as the vintage of the plant.

4.2.3. Marketing Centres

In spite of the fact that Nigeria has a surface area of 924,000 square kilometres, industrial activities are mainly concentrated in few urban centres. Based on a careful examination of import statistics and the current distributional pattern of the existing steelworks as well as the report of a commissioned study on the Nigerian iron and steel industry, three demand regions have been identified for this study. These are Lagos, Onitsha and Kano. They would serve as reference points for computing transport distances between sources of steel products and the demand regions. An estimate of the relative market share of the different cities are presented below:

Lagos	- 40 percent
Onitsha	- 30 ”
Kano	- 30 ”

It is assumed that the market would remain stable, at least in the medium term. Figure 4.1 is a map of Nigeria showing the steel plants, rolling mills and major marketing centres.

4.2.4. Expansion Units

Expansion units are the productive units that are considered in the expansion plans. All expansion in the period under consideration will be accomplished by constructing additional productive units in the old plants since no green-field site is included in the study. The set of expansion units to be considered are blast furnace, basic oxygen furnace, electric arc furnace, and a flat steel facility comprising of a slab caster and rolling mill.

4.2.5. Commodities

Fourteen commodities are included in the study. These commodities are further subdivided into three subsets, viz: raw materials, intermediate products and final products. The commodities include iron ore, coal, limestone, scrap, natural gas, liquid steel coke, pig iron, sponge iron pellets and electricity as raw materials, billets as intermediate product for interplant shipments, and flat and non-flat steel as final products.

4.2.6. **Transportation**

Given the locational distortion of existing mills in Nigeria, the problem of transportation of steel products currently constitutes a major constraint. At present, about 98 percent of raw materials, intermediate and final products are transported by road. The transport problem thus involves not only finding the shortest route but also the least cost mode of transportation among plants, between plants and marketing centres and between importing points, marketing centres and plants.

The transport of raw materials, intermediate inputs and final products from both domestic and foreign sources is explicitly considered in the model. Three feasible transportation modes, namely: road, rail and waterways are considered. The extent of usage of any of the three systems would depend on the location of the plant or mill vis-a-vis the sources of raw materials and marketing centres. For all three modes of transportation, linear cost functions have been derived. Transport cost between two points is assumed to be proportional to the quantity moved and includes

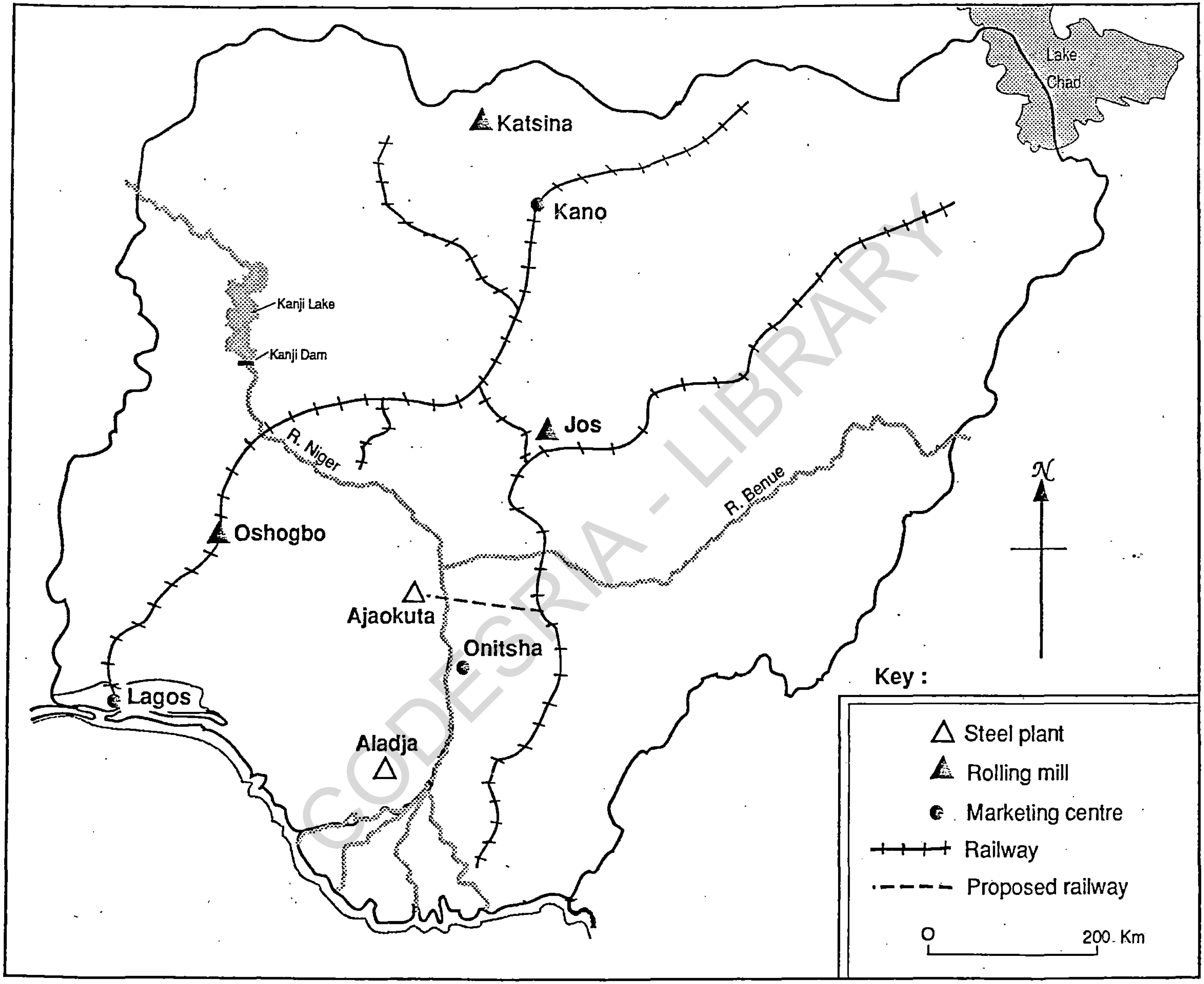


Fig. 4.1: Map of Nigeria showing the steel plants, rolling mills and major marketing centres.

time periods viz: 1993 - 1995, 1996 - 1998 and 1999 - 2001.

By dividing time in a discrete fashion with multiple time periods, the number of variables and parameters are increased by a multiple of the number of time periods. An implicit assumption is made that all activities will remain constant within a given time period but can change from one time period to the other. For example, in our model with three time periods, each with a three-year duration, there are variables Z_{p1}, Z_{p2} and Z_{p3} to represent the annual production of steel in each time period. The variable does not represent the total production in the three-year period but rather the average annual production level. The same treatment holds for other variables except the investment variables which represent the total amount of capacity that come on-stream at the beginning of the time interval, rather than the average amount of capacity that would be added in each year of the time interval.

The introduction of multiple time periods into the model results in two complications, namely; making cost and demand projections, and using time discounting to render costs and benefit streams comparable over time. Kendrick (1967) elaborated on the fact that it may be extremely difficult to make good projections of future cost because it requires anticipation of technological changes and shifts in demand and supply for all the major inputs under consideration, in which case an analyst with a model is no worse than one without a model. It is assumed that one can adequately project the relevant costs data while the demand projection for this study are adapted from a commissioned study by Phoenix Nigeria Ltd. (1990). Since our objective is one of minimising the present value of cost rather than undiscounted cost, it is imperative to multiply each cost unit by a discount factor to render costs and benefit streams comparable over time.

The discounting procedure is straight-forward except that each time period in the investment planning model includes several years. For a model spanning nine years, with annual time periods and a cost $\O_t$ in each year, the discounted cost for the first year would be $(1 + \rho)^{-1} \O_t$; for the second year, $(1 + \rho)^{-2} \O_t$; and for the entire period:

$$\xi = \sum_{\tau=1}^{9} (1 + \rho)^{-\tau} \O_{\tau}' \text{ ------------------ } (4.1)$$

where

ρ = the annual discount rate, and

τ = time index

ξ = discounted cost

This specification implies that all constraints should be specified annually. This would make the model too large.

With the formulation of the current model, it is necessary to respecify the discount factor with three time interval of three years.

The cost charges for each time period would then become

$$k_1 = \phi_\tau' \quad \tau = 1, 2, 3$$

$$k_2 = \phi_\tau' \quad \tau = 4, 5, 6$$

$$k_3 = \phi_\tau' \quad \tau = 7, 8, 9$$

where

k_t = the average annual cost for each year during time period t.

Equation 4.1 can then be rewritten as

$$\xi = K_1 \sum_{\tau=1}^{3} (1 + \rho)^{-T} + k_2 \sum_{\tau=4}^{6} (1 + \rho)^{-T}$$

$$+ \; k_3 \sum_{\tau=7}^{9} (1 + \rho)^{-\tau} \text{ ------------- } (4.2)$$

The first term on the right hand side of the equation 4.2 is the discounted sum of the first three-year period, the second for the next three years and so forth.

Equation (4.2) can be rewritten compactly as

$$\xi = \sum_{\tau=1}^{3} \delta_t \, k_t \text{ --------------------------- } (4.3)$$

where

$$\delta_t = \sum_{\tau=1+(t-1)\Theta}^{3(t-1)+3\Theta} (1+\rho)^{-\tau}$$

$$= \sum_{\tau=1}^{3} (1+\rho)^{-3(t-1)-\tau}$$

The general form of Equation (4.2) can now be written as:

$$\delta_t = \sum_{\tau=1}^{\Theta} (1+\rho)^{-\Theta(t-1)-\tau} \quad \text{---------------------(4.4)}$$

where Θ = the number of years per time period.

4.2.9 The Treatment of Investment Activities

Most investment projects in the steel industry are not perfectly divisible and tend to exhibit significant economies of scale. Such projects present special economic and computational problems because they cannot be solved by the usual methods of optimization which assume that variables must take continuous non-negative values. The method adopted is thus an approximation technique using mixed integer programming where variables representing investment are treated as discrete since the non-linearity of the investment cost function renders it not directly amenable to treatment in a linear programming model. In our model, economies of scale in investment cost are modeled through a linear approximation to a non-linear cost function. Figure 4.2 illustrates how this approximation is carried out. Consider the investment cost function $\varnothing_k = f(h)$ shown in Figure 4.2. The total investment cost rises with size (h) of unit installed, but at a decreasing rate so that the marginal cost of each increment of capacity is declining. The true investment cost fuction f(h) is approximated by the fixed-cost plus linear segment function g(h). Algebraically, this approximation can be written as:

$\varnothing_k = w + vh$ ....(4.5)

$\varnothing_k$ = approximate capital cost for a productive unit of size h;

w = fixed-charge function of investment cost;

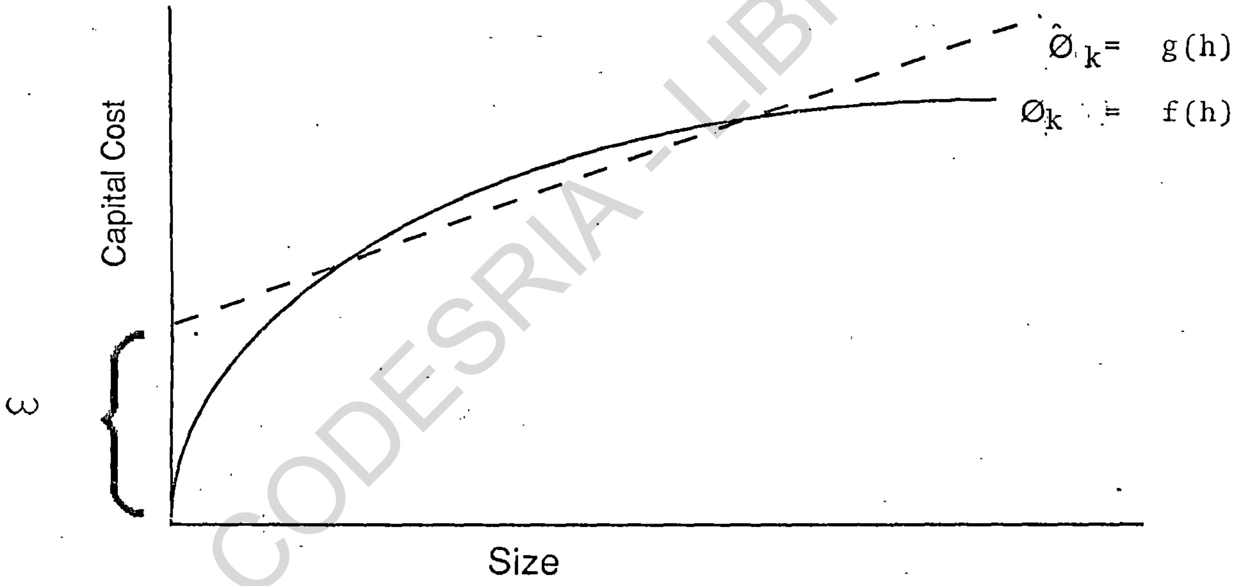
v = slope of linear portion of investment cost;

h = size of productive unit to be installed.

The fixed-charge, w, ensures that economies of scale in construction cost will be realised, in the sense that, the larger the capacity constructed, the smaller the incidence of the fixed charge per unit of capacity.

If the capital cost associated with capacity expansion were to be entered into the objective function in the formulation given in equation 4.5, the fixed charge will always be incured, regardless of whether or not capacity is constructed, because no mechanism is present in the equation that will delete it from total cost. This is in contrast to the variable cost, which is capacity dependent so that $vh = 0$ when h is

Figure 4.2 The investment cost Function



0. This problem is solved by introducing a new variable, y, into the function in the form:

$$\emptyset_k = wy + vh \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.6)$$

y is thus a variable that can assume two values, either 1 or 0, where 1 is selected if capacity expansion takes place so that the fixed charge is incurred, and 0 if no capacity expansion takes place so that the fixed charge is deleted. Hence:

$$y = 0 \text{ or } 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.7)$$

Since the model has a fixed time horizon, one further modification to the treatment of capital cost is necessary to avoid distorting edge effects. If the entire cost of investments for a given project were charged in the period the project was installed, the timing of investments that the model would recommend would be distorted. Investments in the latter part of planning period would be discouraged because the capacity installed is likely to generate greater costs than the benefits observed during the planning period. It would also represent a poor representation of reality since investments are normally financed from loans that are repaid periodically. A capital recovery factor is applied to new investments in order to convert the capital costs associated with capacity expansion in the model to an even stream of repayments that are sufficient to cover the original costs and interest charges for the productive unit over the period of its useful lifetime. For existing plants, capital costs are treated as sunk costs.

The capital recovery factor for productive unit m can be represented as:

$$\delta^{m} = \frac{\rho\,(1+\rho)^{\zeta_m}}{(1+\rho)^{\zeta_m}-1} \quad \text{------------ (4.8)}$$

$$= \frac{\rho}{1-(1+\rho)^{-\zeta_m}} \quad \text{------------ (4.9)}$$

where

δ_m = capital recovery factor

ρ = discount rate per time interval; and

ζ_m = useful life of productive unit m.

Applying the capital recovery factor to the investment cost approximation, we obtain the periodic investment charge on a capacity increase for productive unit m at plant I as

$$\phi_{km} = \delta_m\ (w^m y_m + V_m h_m) \quad \text{---------------------- (4.7)}$$

The model would not begin to incur the periodic investment charge which may be interpreted as a rental payment on an investment until the period in which the project is installed, but it should incur the rental in each time period after the unit is put into use. A full derivation of the capital recovery factor can be found in Kendrick and Stoutjesdijk (1978).

4.3. THE STRUCTURE OF THE MODEL

The complete dynamic investment planning model of the iron and steel sub-sector is specified in this section. This is done by first presenting all the symbols used in the model followed by a statement of the constraints and objective function. The four principal parts of this section are the definition of sets and indices, the decision variables, parameters or constants and the constraints and objective function.

4.3.1. Set and Indices

The various sets included in the model denote plants, marketing centres, productive units, processes and commodities. The sets used in the model are defined as follows:

$i,\acute{i} \in I$ = steel plants
$j \in J$ = major markets
$m \in M$ = productive units
$p \in P$ = processes
$c \in C$ = commodities used or produced in the steel industry.
$me \in ME$ = expansion units and
$\tau, t \in T$ = time periods

$l \in L$ = export market
$n \in N$ = mines

where

N = {Itakpe, Enugu}
J = {Lagos, Onitsha and Kano}
M = {blast finance, basic oxygen furnace, direct reduction units, electric arc furnace, continuous casting units and rolling mill}
P = {pig iron production, sponge iron production, steel production in BOF, steel production in electric arc furnace, continuous casting and steel rolling}
C = {iron ore, pellets, coke, natural gas, electricity, scrap, pig iron, sponge iron, limestone, billets, rolled steel scrap, oxygen, liquid steel and flat steel}
ME = {blast furnace, basic oxygen furnace, electric arc furnace, flat steel plant}
T = {1993-1995, 1996-1998, and 1999-2001}

The set of commodities can further be disaggregated into smaller subsets. The subsets of C are:

CR = Domestic raw materials
CV = Imported raw materials
CI = Intermediate product
CF = Final products
CE = Export commodities

where

CR = {electricity, natural gas, scrap, and limestone}
CV = {Coke, Pellets}
CI = {Billets}
CF = {Flat steel, Rolled or Non-Flat steel}
CE = {Steel, Billets}

4.3.2. The Decision Variables

The decision variables in the model are production z, shipments x, exports e, imports v, and purchase of raw materials u. Apart from time subscript which is added to all the variables to indicate that they are dynamic, other subscripts are added to some of the variables to make them specialized variables. For example, Z_{pit} represents the production level of all processes p at plant i in period t. x_{cijt} is the shipments of final products from plant i to market j in tonnes per year for time period t, $x_{ci\acute{i}t}$ stands for interplant shipments of intermediate products (billets) in tonnes from plant i to another plant í’ in time period t while x_{cnit} represents the shipment of raw materials in tonnes from mine n to plant i in time period t. A list of all the decision variables in the model are shown in Table 4.1.

Another set of decision variables, h_{mit} and y_{mit} are also included in the model to represent investment activities. h_{mit} represents the expansion of productive unit m at plant i in time period t while y_{mit} is the zero-one (integer) variable for investment in productive unit m at plant i in time period t. A separate group of variables is also included in the model to define the components of total cost. ξ is the present value in Naira of producing, transporting and importing the required amount of steel minus export revenue generated by the steel plants. ϕ_{kt} is the capital cost in time period t, ϕ_{lt} represents the recurrent, raw material and labour cost, ϕ_{IIt} stands for transport cost and ϕ_{et} is export revenue.

TABLE 4.1:

LIST OF DECISION VARIABLES FOR THE MODEL

Symbol	**Definition**
ϕ	Cost groups
ϕ_k	Capital cost
ϕ_I	Recurrent, raw material and labour cost
ϕ_{II}	Transport cost
ϕ_β	Import cost
ϕ_E	Export revenue
Z	Production level
x	Shipments
v	Imports
u	Domestic purchases
e	Exports
h	Capacity expansion
y	Zero-one investment decision variable and

4.4 PARAMETERS OR CONSTANTS

Parameters are required for input-output coefficients, capacity utilization, market requirements, prices and transport costs.

The input-output coefficients relate commodities to processes. They are defined mathematically as:

a_{cp} = volume of (or quantity of) input (-) or output (+) of commodity c by process p when it is operated at the unit level. Parameters are also defined for each productive unit in each plant. The capacity utilization coefficients are represented by b_{mp}. $b_{mp} = 1$ if productive unit m is used by process p and zero if it is not in use. K_{mi} represents the capacity of productive unit m in plant i in metric.

The notation for steel requirements by marketing centre j in thousand tonnes per time period is given by dcj.

Prices require a disaggregated treatment. A distinction is made between the prices paid by the steel plants for domestic raw materials, prices paid by marketing centres for imported final products, and prices received by the steel companies for exported products. The notation for these parameters is shown in Table 4.2.

The last set of parameters are transport cost. This is also disaggregated into the unit transport cost for transporting final products from plant i to market j, unit transport cost for transporting final products from port to the market, intermediate products from plant i, to another plant í and the cost of transporting raw materials from mine n to plant i. A list of all the parameters in the model are presented in Table 4.2.

TABLE 4.2

PARAMETERS IN THE MODEL

symbol	**Definition**
a	Process input (-) or output (+)
b	Capacity utilization coefficient
k	Initial capacity
Θ	Number of years
d	Market requirement
$\hat{e}$	Upper bound on exports
$\hat{h}$	Maximum capacity expansion
ρ	Discount rate.
δ_m	Capital recovery factor
w	Fixed charge portion of investment cost
v	Linear portion of investment cost
P^d	Domestic prices
p^v	Import prices

p^e	Export prices
u	Unit transport cost

4.5. CONSTRAINTS

The constraints include the basic technological relationships that describe the supply side of the model, export constraint and a demand constraint that is intended to take care of the market requirements for steel. The technological constraints are specified in three sets of material balance constraints for final products, intermediate products and raw materials and in a set of capacity constraints. These constraints are presented below.

1. Material Balance Constraints on Final Products

$$\sum_{p \in P} a_{cpi} Z_{pit} \geq \sum_{j \in J} x_{cijt} + \sum_{l \in I} e_{cilt} \qquad \begin{array}{l} c \in CF \\ i \in I \\ t \in T \end{array}$$

This constraint states that the amount of steel production during time period t should at least be equal to the sum of domestic shipments of steel and exports. The supply of steel must at least be equal to demand to ensure that there is no excess demand. The symbols on the right hand margin of the inequality $c \in CF$, $i \in I$ and $t \in T$ indicate that there must be an inequality of this type in the model for all final products, all plants and all time periods.

2. Material Balance Constraints on Intermediate Products

$$\sum_{p \in P} a_{cp} Z_{pit} + \sum_{\substack{\acute{i} \in I \\ \acute{i} \neq I}} x_{c\acute{i}it} + V_{cit} \geq \sum_{\substack{i \in I \\ i \neq I}} x_{ci\acute{i}t} + \sum e_{ci\acute{i}t} \qquad \begin{array}{l} c \in CI \\ i \in I \\ t \in T \end{array}$$

The constraints state that the production of intermediate products at plant i by all processes p during time period t augmented by shipments of intermediate products from other plants and imports must at least be equal to the sum of total shipments of intermediate products and exports of intermediate products. This indicates that the supply of intermediate products must at least be equal to the demand for intermediate products.

3. Material Balance Constraints on Raw Materials and Labour

$$\sum_{p \in P} a_{cpit} Z_{pit} + U_{cit} + V_{crit} \geq 0 \qquad \begin{array}{l} c \in CR \\ i \in I \\ t \in T \end{array}$$

This constraint states that raw materials and labour inputs used by all processes p at plant i during time period t must at least be equal to the sum of amounts of input purchased locally and imports from abroad.

4. Capacity Constraints

$$\sum_{p \in P} b_{mp} \; Z_{pit} \;\le\; K_{mi} + \sum_{\substack{\tau \in T \\ \tau \le t}} h_{mi\tau} \qquad \begin{array}{l} i \in I \\ m \in M \\ t,\tau \in T \end{array}$$

The capacity requirement of each productive unit m for all processes p at plant i cannot exceed the total available capacity denoted by initial capacity and total capacity expansion. Thus, the total capacity requirement for any productive unit must not exceed what is available at any particular time.

5. Maximum Capacity Expansion Constraints

$$h_{mit} \;\le\; \hat{h}_{mit} \; y_{mit} \qquad \begin{array}{l} m \in M, \\ i \in I, \\ t \in T \end{array}$$

The addition to capacity of productive unit m at plant i in time period t cannot exceed the upper bound placed on capacity expansion. Thus, no capacity can be installed beyond what is technically feasible for a productive unit at a given plant.

6. **Capacity Expansion Constraints: Zero-one**

$$y_{mit} = 0 \text{ or } 1 \qquad m \in M,\; i \in I,\; t \in T$$

The integrality constraint simply states that the binary variable y representing investment is restricted to be either zero or one. It is one when investment takes place and zero when there is no investment.

7. **Export Constraints**

$$\sum_{l \in L} e_{cilt} \leq \hat{e}_t \qquad c \in CE,\; l \in L,\; t \in T$$

The total value of exports of steel products from all plants i at any given time period is limited to an exogenously specified amount.

8. **Market Requirements Constraints**

$$\sum_{i \in I} x_{cijt} + V_{cjt} \geq d_{cjt} \qquad C \in CF,\; j \in J,\; t \in T$$

This constraint simply states that sthe total supply of steel, equal to production plus imports, must at least equal the exogenously specified demand for steel.

9. Non-Negativity Constraints

$Z_{pit} \geq 0$	$p \in P,$	$i \in I,$	$t \in T$	
$x_{cijt} \geq 0$	$c \in CF$	$j \in J,$	$i \in I,$	$t \in T$
$x_{ciit} \geq 0$	$c \in CI$	$i \in I,$	$t \in T,$	$i \in I$
$x_{crt} \geq 0$	$c \in CR$	$i \in I,$	$t \in T$	
$V_{crt} \geq 0$	$c \in CR$	$i \in I,$	$t \in T$	
$V_{cjt} \geq 0$	$c \in CF$	$j \in J,$	$t \in T$	
$e_{cilt} \geq 0$	$c \in (CI \cup CF)$	$l \in L,$	$i \in I,$	$t \in T$
$U_{crit} \geq 0$	$c \in CI$	$i \in I,$	$t \in T$	
$h_{mit} \geq 0$	$m \in M,$	$i \in I,$	$t \in T$	
$y_{mit} = 0$ or 1	$m \in M,$	$i \in J,$	$t \in T$	

The non-negativity constraints require that all the variables in the model be limited to values greater than or equal to zero. One subset of the variables, the investment variables y_{mit}, is limited to take on only the values zero or one.

4.6 THE OBJECTIVE FUNCTION

The objective function is to minimize the discounted costs of production, transportation, investment and importation of steel products less export revenues during the period covered by the model. It is specified as follows:

10. $$\text{Min } \xi = \sum_{t \in T} \delta_t \left(\phi_{kt} + \phi_{lt} + \phi_{\pi t} + \phi_{\beta t} - \phi_{Et}\right)$$

Discounted net cost	=	Capital costs	+	Recurrent, raw material and labour costs	+	Transport costs

+ Import costs - Export Revenues

where

$$\delta_t = \sum_{\tau=1}^{\Theta} (1 + \rho)^{-\Theta(t-1)-\tau}$$

[Discount factor]

Θ = number of years per time period

Each of the components of the objective function is now specified specified in detail as follows:

$$\phi_{kt} = \sum_{i \in I} \sum_{m \in M} \delta_m \left(W_{mi\tau}\, y_{mi\tau} + V_{mi\tau}\, h_{mi\tau}\right)$$

Capital = Fixed charge + Linear portion of capital cost

w_{mit} is the fixed charge in the linear approximation of the investment cost function. Since it is a constant in the objective function, it needs to be eliminated if no new capacity is installed hence it is linked to $y_{mi\tau}$, which is an integer variable that can assume only two values 0 or 1, where the former is chosen if no capacity is constructed. The variable $h_{mi\tau}$ represents the capacity or scale of the productive unit that is constructed while the coefficient $V_{mi\tau}$ is the variable portion of the investment cost fuction.

$$\phi_{lt} = \sum_{\tau=1}^{t} \sum_{i\in I} \sum_{m\in M} \beta_{mi\tau} h_{mi\tau} + \sum_{C\in CR} \sum_{i\in I} p^{d}_{Cit} \; U_{cit}$$

Recurrent Costs = Recurrent Cost related to capacity + Local raw materials and labour costs

$$\phi_{\pi t} = \sum_{c\in CF} \Big(\sum_{i\in I} \sum_{j\in J} u_{cijt} \, x_{cijt} + \sum_{i\in I} u_{cjt} \, v_{cjt}$$

$$+ \sum_{i\in I} \sum_{l\in L} u_{cilt} \; e_{cilt} \Big)$$

Transport costs = Final products (Domestic + Imported + Exported)

$$+ \sum_{C\in CI} \Big(\sum_{i\in I} \sum_{\substack{\acute{i}\in I \\ \acute{i}\neq i}} U_{ci\acute{i}t} \, x_{ci\acute{i}} + \sum_{i\in I} U_{cit} \, V_{cit}$$

$$+ \sum_{i\in I} \sum_{l\in L} U_{cilt} \, e_{cilt} \Big)$$

\+ Intermediate products = (Interplant + Imports + Exports)

$$+ \sum_{C \in CR} \left(\sum_{i \in I} U_{cit} V_{cit}\right) + \left(\sum_{i \in I} U_{cit} x_{cit}\right) ;$$

\+ Raw materials (Imported + Domestic)

$$\phi_{\beta t} = \sum_{C \in CF} \sum_{j \in J} P^{v}_{cjt} V_{cjt} + \sum_{C \in (CI \cup CR)} \sum_{i \in I} P^{v}_{cit} V_{cit}$$

Import costs = Final products imports + Intermediate, raw material and labour imports

$$\phi_{Et} = \sum_{C \in (CF \cup CI)} \sum_{i \in I} \sum_{l \in L} P^{e}_{cilt} e_{cilt}$$

Export Revenues = Export revenues from final and intermediate products.

4.7 SOLUTION PROCEDURE

The model comprises of 1,687 non zero elements, 538 constraints, 865 regular variables and 126 binary variables subdivided into 13 blocks. It was solved at the Centre for World Food Studies, Vrije University, Amsterdam using Zoom / XMP ---- 386/486 version of GAMS on a Compaq 386s/25 computer in 27.520 seconds. GAMS statement of the model can be found in the appendix.

4.8 THE DATABASE

Planning models are only useful analytically if the results have operational relevance. The meaningfulness of the results depends to a large extent on the reliability of data. We shall now describe the data base for this study.

A visit to the Federal Ministry of Mines, Power and Steel, Lagos at the precursory stage of this study indicated the paucity of data on the Nigerian iron and steel industry. Thus, the data for this study were obtained from both primary and secondary sources. The bulk of the data were generated from the different steel plants and complemented by data from other diverse sources such as publications of the Federal Office of Statistics, Steel Journals and periodicals; Central Bank of Nigeria, International Steel Institute and commissioned studies on the Nigerian iron and steel industry.

The data requirements for this study are quite extensive, These include data on estimates of the demand for steel in Nigeria, marketing centres, productive processes, input-output coefficients, steel prices, cost information, transport cost of steel products etc. The specific data and their sources are discussed as follows:

4.8.1 Plant Capacity

The designed capacities of the productive unit are shown in table 4.3. They represent the maximum attainable capacity utilization rate at each of the plant locations.

TABLE: 4.3

DESIGNED CAPACITY OF PRODUCTIVE UNITS (1000 TONNES PER YEAR)

	DSC	ASC	OSRC	KSRM	JSRM	MINI STEELWORKS
BLAST-FUR		1350				
DIR-RED	1020					
EAF	1000					
BOF		1400				
CAST-BILL	9600	1300				
CAST-SLAB						
ROL-LONG	300	1090	210	210	210	1241
ROL-FLAT						

Source: Survey Data, Delta Steel Company Aladja, Warri

4.8.2 Input-Output Coefficients

The iron and steel industry is characterized by a series of technical coefficients that relates inputs to output. They specify the amount of inputs required to produce a given unit of output. For this study, the input-output coefficients are presented in the usual convention whereby input coefficients are denoted by a negative sign and output coefficients by a positive sign.

TABLE: 4.4

INPUT-OUTPUT COEFFICIENTS

	PIG-IRON	SPONGE	STEEL-EL	STEEL-BOF	CONT-CAST (BILL)
IRON-ORE	-0.02	-1.08			
PELLETS	-1.4				
COAL	-0.6				
LIMESTONE	-0.1				
NAT-GAS		-0.57			
ELECTRI	-0.09		-0.58		0.04
SCRAP				-0.11	
PIG-IRON	1			-1.02	
SPONGE		1	-1.09		
LIQ-STE			1	1	-1.05
BILLETS					1
SLAB					
LONG STE					
FLAT STE					
+					

	CONT-CAST (SLAB)	ROLL-LONG STE	ROLL-FLAT STE
IRON-ORE			
PELLETS			
COAL			
LIMESTONE			
NAT-GAS			
ELECTRI			
SCRAP	0.02	0.02	0.03
PIG-IRON			
SPONGE			
LIQ-STE	- 1.04		
BILLETS		-1.05	
SLAB	1		-1.05
LONG STE		1	
FLAT STE			1

Source: Adapted from Kendrick, et al (1983). The Planning of Investment Programs in the Steel Industry.

It was practically impossible to obtain these coefficients for Nigeria. The approach adopted is to modify the input-output coefficients for similar plants in other countries having the same vintage. The input output coefficients are taken from the blast furnace plant at SICARTA and the direct reducing plant at AHMAS, both in Mexico. These are reported in Kendrick, et. al (1983).

4.8.3 Projected Demand for Steel in Nigeria

There are various conflicting estimates of the demand for steel in Nigeria (see chapter two). The seemingly large differences in estimates are inevitable considering the fact that they were undertaken at different periods when the Nigerian economy was experiencing fluctuations. The projected demand for steel in Nigeria are adapted from a commissioned study by Phoenix Services (1990). This represents the most realistic estimates. Based on this report, the demand for flat and long steel in 1991 were taken as 648.9 and 793.1 thousand tonnes respectively while the annual growth rate was assumed to be eight percent based on historical information.

In terms of composition, it is anticipated that the demand for flat steel would remain at 45 percent and that of long products at 55 percent.

4.8.4 Transport Costs

Transport costs are calculated on the basis of annual requirements of each facility at full capacity production. The envisaged annual movement of materials at each plant are shown below.

TABLE: 4.5

TOTAL ANNUAL TONNAGE OF MATERIALS TO BE MOVED AT EACH PLANT

	TO	FROM
ASC, Ajaokuta	4.8 m	2.6 m
DSC, Aladja	1.99 m	300,000 660,000
JSRM, Jos	220,000	210,000
KSRM, Katsina	220,000	210,000
OSRC, Osogbo	220,000	210,000

Source: Federal Ministry of Power and Steel, Lagos.

It is being envisaged that Ajaokuta Steel Company would require 4.8 million tonnes of raw materials to produce 2.6 million tonnes of finished products per annum during the first phase of its operation. Similarly the total annual tonnage requirements for Delta Steel Company, Aladja is 1.99 million tonnes and finished products of 300,000 tonnes together with 660,000 tonnes of billets to be shipped to the inland rolling mills at Osogbo, Jos and Katsina. Each of the three mills is being expected to receive 220,000 tonnes of billets, and distribute 210,000 tonnes of finished products.

Three modes of transportation are incorporated in the model, these are road, rail and waterway. Inspite of the fact that the bulk of raw materials and finished products are at present transported by road.

The estimated freight rate for the different raw materials and finished products using different mode of transportation are given in table 4.6

TABLE: 4.6

COMPARABLE FREIGHT RATE FOR DIFFERENT RAW MATERIALS AND FINISHED PRODUCTS

MODE OF TRANSPORTATION	RAW MATERIALS (KOBO PER TONNE KILOMETRE)	FINISHED PRODUCTS (KOBO PER TONNE KILOMETRE)
ROAD	6	15
RAIL	3	8
RIVER	2	6
OCEAN	1	3

Sources:
1. Freight rates by Nigerian Railway Corporation
2. Central Water Transport Company and
3. Estimates by Delta Steel Company, Aladja.

Transport cost of final products from plants to marketing centres:

N2.50 x 0.015 (Road Distance from plant i to market j) Interplant shipments of billets N4.00 x 0.015 (Road Distance from plant i to another plant Í where i ≠ Í) Raw materials = N150.00.

The transport cost for raw materials is highest because most of the raw materials are imported from distant sources. Apart from the transport cost for raw materials where the various components are lumped together, each rate consists of fixed and variable components. The fixed cost includes the cost of loading, unloading and handling.

The distances in kilometres involved in the transportation of the various products are presented in tables 4.7 and 4.8 respectively.

TABLE: 4.7

ROAD DISTANCE FROM PLANTS TO MARKETS IN KILOMETRES

	DSC	ASC	OSRC	KSRM	JSRM
LAGOS	455	572	254	1082	594
IBADAN	424	455	113	930	1068
WARRI	20	335	389	861	1311
ONITSHA	187	323	420	697	1292
PORT-HARCOURT	197	516	626	841	1440
KANO	1178	664	986	420	174
KADUNA	916	454	721	280	430

Source: Nigerian Road Distance Maps and Publication of the Federal Ministry of Transport and Communication.

TABLE: 4.8

INTERPLANT ROAD DISTANCE IN KILOMETRES

	DSC	ASC	OSRC	KSRM
ASC	355			
OSRC	412	332		
KSRM	1331	839	980	
JSRM	881	564	998	594

Source: Delta Steel Company, Aladja Protocol and Information Division

4.8.5 Investment Costs

The investment or capital costs used in this study are shown in table 4.9.

TABLE: 4.9

INVESTMENT COSTS

	FIXED COST (N MILLION)	VARIABLE COST (N MILLION)
BLAST FURNACE	2700	2450
BASIC OXYGEN FURNACE	1200	1060
DIRECT REDUCTION	1000	1025
ELECTRIC ARC FURNACE	420	395
FLAT PLANT	2500	2245

Source: Adapted from Metal Bulletin, World Steel and Metal News, February, 1990.

All sunk costs, including previous expenditure and outstanding commitments are excluded from the analysis. For all the alternatives considered in the model, the investment cost include fixed cost and variable components. The fixed cost consist of the cost of the equipment as well as the installation costs corresponding to each of the alternatives. While the variable operating costs are based on standard physical inputs converted into money cost and labour inputs.

The cost of site preparation and off-site facilities are incorporated through the use of a site location factor. The appropriate annual allocation of rental charge on capacity installed is incorporated through the use of a capital recovery factor. The opportunity cost of capital is assumed to be 10 percent while the plant equipment life is taken to be 15 years. This results in a capital recovery factor of 0.1315.

4.8.6 Prices

There is uncertainty whether the current recovery of prices has run its course. The approach adopted in this study is to select the near term prices as the basis for this study. Import prices were taken as an average of January - March 1990 prices. Europe F.O.B US$/Tonne and converted using an exchange rate of N18.6/US$. This prices are shown below;

TABLE 4.10

IMPORT PRICES (₦ PER TONNE)

IRON-ORE	744
COAL	1395
BILLETS	5115
LONG STEEL	5580
FLAT STEEL	8091

Sources: Adapted from World Steel - Dynamics and Metal Bulletin, Jan. - March, 1990.

The domestic raw material prices are presented in Table 4.10 while export prices are shown in Table 4.11.

TABLE: 4.11

DOMESTIC RAW MATERIAL PRICES (₦ PER TONNE)

LIMESTONE	75
ELECTRICITY	0.45 per KWH
SCRAP	180
BILLETS	1500
NATURAL GAS	141.2/1000 m^3

Source: Delta Steel Company, Aladja June, 1992

TABLE: 4.12

EXPORT PRICES (₦ PER TONNE)

LONG STEEL	5208
BILLETS	4800

Source: Delta Steel Company, Aladja June, 1992

ENDNOTES

1. Other objectives may include income distribution, maximization of employment benefits, the need for geographical dispersal of industries and other social and political criteria. Other objectives such as maximizing the sum of consumer's or producer's surplus are however possible.

2. The major distinction between integrated and non-integrated steel plants can be attributed to the fact that integrated plants have the entire set of processes from raw material preparation to rolling of products, while non integrated plants lack one or more of the production processes.

CHAPTER FIVE

THE EMPIRICAL RESULTS

5.1 INTRODUCTION

In this chapter, we present the empirical results of the inter-temporal mixed integer programming model described in chapter four. First, we shall discuss the set of basic results obtained from a version of the model that employs the most realistic assumptions about the Nigerian iron and steel sub-sector. Subsequently, we explore a number of alternative scenarios based on different assumptions. A sensitivity analysis of crucial parameter estimates forms the concluding part of the chapter. The scenarios investigated include production at Ajaokuta, the effect of removal of subsidy on natural gas on the steel plants, the impact of the utilization of local ore by the steel plants, the implication of alternative transport routes for the Nigerian iron and steel industry and the role of exports.

The model results include the level of production of all commodities, the quantity of raw materials and final products imported, exports of billets and long steel and total demand for steel. They are all reported in tonnage. In addition, a variety of results relating to operating costs, capital cost, cost of transportation, import cost and export revenues are reported in value terms.

5.2 THE BASIC RESULTS

These results are obtained on the basis of the most likely assumptions about the Nigerian iron and steel industry. They provide the basis for comparing different versions of the model. Some of the actual institutional constraints confronting the industry were imposed on the model, and relaxed in alternative versions. The results obtained correspond to the actual production pattern in the base year.

Some of the underlying assumptions behind the basic case are as follows:

a) An upper bound of 30 per cent is placed on capacity utilization in all the steel plants. This is not significantly different from what has been obtainable in all the steel firms ever since they commenced operations. None of them has been able to utilize up to 30 per cent of the installed capacity for any particular year. For example, The First National rolling Plan (1990 - 1993) Pp. 117 acknowledges the fact that Delta Steel Company, has since it was commissioned in 1982, operated at below (less than 25 per cent) of its installed capacity. Its inability to operate optimally has had adverse effect on the inland rolling mills

b) Only the existing steel plants are included in the analysis. These include Delta Steel Company, Aladja, the three inland rolling mills at

Osogbo, Jos and Katsina and the private steel plants. Ajaokuta Steel Company is not explicitly considered. However, the already commissioned 400,000 per year light section and bar mill as well as the 150,000 tonne wire rod mill are included in the analysis.

c) In conformity with the current pattern of operations in the industry, exports are not allowed in this version of the model.

d) Interplant shipments are limited to billets so as to allow Delta Steel Company to supply billets to the inland rolling mills at Osogbo, Jos and Katsina as mooted in the plans.

e) The demand for steel is assumed to grow at 8 per cent per annum during the entire planning horizon. This appears to be more realistic historically and given the economic recession that adversely affected steel consumption in Nigeria. The sensitivity of this growth rate is however tested.

f) Economics of Scale in investment cost function are allowed for all plants.

An overview of the main results of the base case is presented in Table 5.1. The results are divided into six broad categories namely, costs, demand, production, imports, exports and capacity expansion. Three broad conclusions can be drawn from the information in the table. First, in spite of the fact that several productive units including a flat steel plant were proposed for capacity expansion, the model did not support the construction of any plant during the entire planning horizon. Second, despite the installed overcapacity in the production of long steel, the nation's steel plants are unable to meet the domestic demand for long steel. And finally, all the requirements for flat steel are met from imports during the entire planning period.

TABLE 5.1

SUMMARY OF RESULTS FOR BASE CASE

Objective Function Value = ₦4078.7 Million

	1993 - 1995	1996 - 1998	1999 - 2001
Cost (Thousand Naira/year)			
Capital	-	-	-
Recurrent	158,972.00	227,460.00	313,860.00
Transport	38,617.46	46,879.71	57,279.81
Imports	625,908.00	909,840.00	1,255,440.00
Export Revenue	-	-	-
Total Cost	823,497.46	1,184,179.71	1,626,579.81
Total demand (thousand tonnes/year)			
Flat Steel	817.427	1,029.723	1,297.154
Long Steel	999.058	1,258.55	1,1584.40
Production (thousand tonnes/year)			
Pig Iron	-	-	-
Sponge Iron	337.03	340.00	340.00
BOF	-	-	-
Liquid Steel	328.00	330.00	330.00
Billets	318.04	320.00	320.00
Long Steel	720.00	723.67	723.67
Flat Steel	-	-	-
Imports (thousand tonnes/year)			
Iron Ore	387.637	392.844	392.844
Coal	-	-	-
Billets	-	-	-
Long Steel	279.058	534.88	861.72
Flat Steel	817.425	1,029.723	1,297.154
Exports (thousand tonnes/year)			
Billets	-	-	-
Long Steel	-	-	-
Capacity Expansion			
Blast Furnace	-	-	-
Bof	-	-	-
Direct Red	-	-	-
EAF	-	-	-
Flat Plant	-	-	-

5.2.1 The Demand for Steel Products

Table 5.2 presents the regional demand for steel products during the entire planning horizon. These are represented by the steel requirements of the three major marketing centres included in the study. Thus, Nigeria's total requirement for flat steel is estimated at 817,424 tonnes per annum between 1993 and 1995. This is projected to increase to 1,029,058 and 1,297,154 tonnes per annum during the second and third planning periods respectively. Similarly, 999,058 tonnes of long steel would be required per annum between 1993 and 1995 with Lagos accounting for the major share. This increases to 1,258,550 tonnes per year during the second planning period and eventually to 1,584,410 tonnes per year between 1991 and 2001.

TABLE 5.2

REGIONAL DEMAND FOR STEEL IN NIGERIA (THOUSAND TONNES PER YEAR)

	1993 - 1995		1996 - 1998		1999 - 2001	
	Flat Steel	Long Steel	Flat Steel	Long Steel	Flat Steel	Long Steel
Lagos	326.971	399.631	411.889	503.420	518.862	634.164
Onitsha	245.228	299.723	308.917	337.565	389.146	475.623
Kano	245.228	299.723	308.917	337.565	389.146	475.623
Total	817.427	999.058	1,029.723	1,258.550	1,297.154	1,584.410

Nigeria's requirements for flat steel are met from imports since the model did not recommend the establishment of any flat steel plant and there is no existing plant currently configured to produce flat steel. However, the demand for long steel is met both from imports and domestic production.

5.2.2. The Production of Final and Intermediate Products

The production figures for intermediate and final products by all the plants during the entire planning horizon are presented in Table 5.3. A look at the table reveals that only Delta Steel Company produces billets. About one third of the billets are used in-house while the rest are shipped to the inland rolling mills at Osogbo, Jos and Katsina where they are processed into long steel products.

The last column of Table 5.3 presents the current undiscounted marginal cost of production of billets and long steel for all the firms during the entire planning horizon. A major puzzle as revealed by the table is the extremely high marginal cost of production. They are much higher than the international price of steel for all the plants except Delta Steel in the second planning period and all the firms in the last planning period. This, perhaps, indicates that the nation's steel plants are inefficient producers.

TABLE 5.3

THE PRODUCTION OF FINAL AND INTERMEDIATE PRODUCTS

Plant Location and Product	Time Period	Production (thousand tonnes)	Unutilized Capacity	Total Installed Capacity	Marginal Cost (Naira per tonne)
Delta Steel Company					
Billets	1993 - 1995	318.04	649.96	960.00	6557.03
	1996 - 1998	320.00	640.00	960.00	4926.39
	1999 - 2001	320.00	640.00	960.00	3701.27
Long Steel	1993 - 1995	99.97	200.30	300.00	7147.16
	1996 - 1998	100.00	200.00	300.00	5369.80
	1999 - 2001	100.00	200.00	300.00	4034.39
Ajaokuta Steel Company					
Long Steel	1993 - 1995	44.00	486.00	530.00	8234.02
	1996 - 1998	44.08	485.95	530.00	6639.00
	1999 - 2001	45.02	484.98	530.00	5126.40
Osogbo Steel Rolling Mill					
Long Steel	1993 - 1995	70.00	140.00	210.00	7879.74
	1996 - 1998	70.00	140.00	210.00	5920.17
	1999 - 2001	70.00	140.00	210.00	4447.91
Jos Steel Rolling Mill					
Long Steel	1993 - 1995	68.90	141.10	210.00	7879.74
	1996 - 1998	69.00	141.00	210.00	5920.17
	1999 - 2001	69.00	141.00	210.00	4447.91
Katsina Steel Rolling Mill					
Long Steel	1993 - 1995	67.50	142.50	210.00	7879.74
	1996 - 1998	69.00	141.00	210.00	5920.17
	1999 - 2001	70.00	140.00	210.00	4447.91
Mini-Mills					
Long Steel	1993 - 1995	370.63	830.24	1201.00	7679.74
	1996 - 1998	370.94	830.06	1201.00	5720.17
	1999 - 2001	369.65	831.35	1201.00	4347.91

5.2.3 FOREIGN TRADE

Imports have an important role to play in the model. The base case solution indicates that all requirements for iron ore and flat steel are imported during the entire planning horizon. Similarly, imports of long steel increase progressively from 279,086 tonnes per annum during the first planning period to 534,849 tonnes per year during the second planning period, and finally to 861,717 tonnes per year in the third time period to augment domestic production. There are no exports since they were not allowed in this version of the model. The amount of steel products slated for imports in the three time periods are shown in Table 5.4.

TABLE 5.4

IMPORTS OF STEEL PRODUCTS IN THOUSAND TONNES PER YEAR

	1993 - 1995		1996 - 1998		1999 - 2000	
	Flat Steel	Long Steel	Flat Steel	Long Steel	Flat Steel	Long Steel
Lagos	326.971	9.14	411.889	18.721	518.862	149.721
Onitsha	245.228	115.761	308.917	277.561	389.146	375.623
Kano	245.228	154.184	308.917	238.565	389.146	375.623
Total	817.427	279.087	1,029.723	534.847	1,297.154	900.967

5.2.4 Shipment of Final Products

The shipments of final products from plants to marketing centres are shown in Table 5.5. There is no clearly discernible shipment pattern except that each plant tends to serve the nearest market. Thus, Osogbo Steel Rolling Mill and the private mills serve the Lagos Market while the two northern based plants, Katsina and Jos Steel Rolling Mills both serve Kano. Though an obvious oversimplification, it is assumed for the purpose of shipment that all the private mills are located in Lagos.

The last three rows in the table show imports. Shipments from abroad increase progressively during the entire planning horizon as local plants exhaust their operating capacities.

TABLE 5.5

SHIPMENT OF LONG STEEL FROM PLANTS TO MARKETING CENTRES (THOUSAND TONNES PER YEAR)

	TIME PERIOD	LAGOS	ONITSHA	KANO
Delta Steel Company	1 2 3	- - -	99.97 100.00 100.00	- - -
Osogbo Steel Rolling Company	1 2 3	70 70 70	- - -	- - -
Jos Steel Rolling Mill	1 2 3	- - -	- - -	68.9 69.0 69.0
Kastina Steel Rolling Mill	1 2 3	- - -	- - -	67.5 70.0 70.0
Mini-Mills	1 2 3	285.621 370.590 369.650	88.999 - -	- - -
Imports	1 2 3	9.142 18.721 149.471	115.761 277.561 375.623	163.326 238.565 336.623
Ajaokuta Steel Company	1 2 3	44.00 44.08 45.02	- - -	- - -

5.2.5 Capacity Expansion

In view of the current absence of any facility for producing flat steel in Nigeria despite the seemingly high demand for these steel types, perhaps the results of greatest interest are investments. Investment activities for either iron or steel production in five types of productive units were proposed to the model for capacity expansion to be located in any of the five plants included in the study. These are blast furnace, basic oxygen furnace, direct reduction unit, electric arc furnace and a flat steel plant comprising a slab caster and flat rolling mill. The model did not recommend any capacity expansion. According to the results, it is sub-optimal to construct any plant during the planning horizon.

Several reasons can be adduced why the model did not recommend any capacity expansion. First, imports are more economical because they are relatively cheaper than domestic production. Second, there is absence of raw materials needed to produce these commodities domestically. The cost implication of establishing these firms is very high in view of the declining value of the Naira since the deregulation of the foreign exchange market on March 5, 1992. Finally, the existing firms are very inefficient. There is no guarantee that any new plant will be more efficient.

5.2.7 Costs

The objective function value is ₦4078.7 million. This is the total discounted cost of meeting Nigeria's requirement for steel over the entire planning period. For the first planning period, the capital cost is zero since no capacity is installed. However. ₦36.6 million would be required as transport cost per year, and ₦626 million for importation of raw materials and finished products. There is no export revenue since exports are not included in the model. The cost requirements for the second and third planning periods can be found in Table 5.1.

5.3 **SCENARIO 1**

Production of Steel at Ajaokuta

Ajaokuta Steel Company has been on the drawing board since 1979 when it was incorporated. Production of steel at Ajaokuta Steel Plant is being anticipated to commence before the present administration relinquishes power. This scenario investigates the likely effect of steel production at Ajaokuta Steel Company on the nation's iron and steel industry.

Unlike the base case, there is no bound on capacity utilization while a limited amount of export is allowed in the model. The bound on export is 50,000 tonnes per year for each plant. Thus, Ajaokuta and Delta Steel Companies would be able to export as much as 50,000 tonnes of billet per year each. Similarly, all the Steel plants would be able to export long steel subject to an upper bound of 50,000 tons per year each. Table 5.6 presents a summary of the results obtained under this scenario. The total discounted net cost of meeting the demand for steel over the planning period is ₦4,423.5 million.

A comparison of this result with the base case indicates that the total discounted cost increased substantially by ₦345.15 million or 8.5 per cent. A closer examination of the cost breakdown indicates that the increase in cost can be attributed to two major factors: first is increase in the cost of imported raw materials and second, the higher recurrent cost needed to operate the steel plants. For example, the cost of imports increased from ₦625.9 million per year in the first planning period in the base case to ₦742.2 million for the same period under this scenario. This is clearly inferior to the base case. The implication is that Ajaokuta Steel plant would impose extra cost on the nation.

A comparison of the production pattern of final and intermediate products under scenario 1 with the pattern under the reference solution is presented in Table 5.7. The major changes are in Ajaokuta Steel Plant which becomes operational and the level of capacity utilization which increases substantially in all the other steel plants. The capacity utilization over the entire planning period increases from an average of 30 per cent in the base case to between 44.55 per cent for Ajaokuta and 98.9 per cent for Delta Steel Plant. All the domestic requirements for long steel are met locally while the shipment pattern is slightly distorted as a result of steel production at Ajaokuta. In spite of the reduction in

TABLE 5.6

SUMMARY OF RESULTS FOR SCENARIO 1

Objective Function Value = ₦4423.5 Million

	1993 - 1995	1996 - 1998	1999-2001
Cost (thou. Naira/year)			
Capital	-	-	-
Recurrent	235,540.00	227,460.00	313,860.00
Transport	36,901.81	46,879.71	57,279.81
Imports	742,160	1,216,560	1,562,160
Export Revenue	-144,000	-144,000	-144,000
Total Cost	870,601.81	1,331,542.2	1,864,257.86
Total demand (thou. tons/year)			
Flat Steel	817.427	1,029.723	1,297.154
Long Steel	999.052	1,258.55	1,584.40
Production			
Pig Iron	445	708.5	1,132.3
Sponge Iron	1,020	1,020	1,020
Liquid Steel	1,320	1,564.91	1,942.21
Billets	1,260	1,455	1,831
Long Steel	1,124.06	1,383.55	1,709.4
Flat Steel	-	-	-
Imports			
Iron Ore	1,917.5	2,247	2,997.154
Coal	97	102	124.3
Billets	-	-	-
Long Steel	-	-	-
Flat Steel	817.427	1,029.723	1,297.154
Exports			
Billets	50	50	50
Long Steel	125	125	125
Capacity Expansion			
Blast Furnace	-	-	-
Bof	-	-	-
Direct Red	-	-	-
EAF	-	-	-
Flat Plant	-	-	-

imports of final products, import cost increases considerably as a result of increase in importation of iron ore and coking coal. There is no capacity expansion. All the requirements for flat steel are met from imports.

TABLE 5.7

THE PRODUCTION OF FINAL AND INTERMEDIATE PRODUCTS UNDER SCENARIO 1 (THOUSAND TONNES PER YEAR)

Plant Location and Products	1993 - 1995		1996 - 1998		1999 - 2001	
	Base Solution	Scenario 1	Base Solution	Scenario 1	Base Solution	Scenario 1
Ajaokuta						
Billets	0	350	0	545	0	871
Long Steel	44	244.058	44.08	443.55	45.02	769.4
Delta						
Billets	318.04	960	320	960	320	960
Long Steel	99.97	300	100	300	100	300
Osogbo						
Long Steel	70	190	70	190	70	190
Jos						
Long Steel	68.9	190	69	190	69	190
Katsina						
Long Steel	67.50	200	70	200	70	200

5.4 SCENARIO 2

Utilization of Itakpe Iron Ore by the Steel Plants

Procurement of raw materials constitutes a major aspect of the expenditure of steel plants in Nigeria. Delta Steel, at full capacity, is designed to utilize about 1.5 million tonnes of oxide pellets per annum while Ajaokuta Steel Company would require 2.6 million tonnes of iron ore sinter and 1.3 million tonnes of coking coal per year. Despite the fact that Nigerian coal has low quality because of its non-coking nature and high sulphur and ash content, Itakpe could supply the two integrated steel plants at Aladja and Ajaokuta with about 40 and 100 per cent of the total requirement of iron ore respectively of which is currently imported from Liberia, Sweden and Brazil at exorbitant costs.

This scenario examines the option for Itakpe to produce sinter concentrate for Ajaokuta and super concentrate for Delta Steel Company.

Table 5.8 presents a summary of the results for this scenario. Our objective function value of ₦4078.7 million in the base case reduces to ₦3852.7 million, a difference of ₦225.3 million. The major differences between the base case and the results for this scenario are import cost and recurrent expenditure. Import cost declined substantially from ₦625 million in the base case during the first planning period to ₦324 million for the same period. Similarly, it also declined from ₦909.8 and ₦1253.4 million for the second and third planning periods in the base case to ₦664 and ₦966.7 million respectively for the same period in this scenario. This reduction can be attributed mainly to the fact that iron ore which used to be an imported raw material is now sourced locally. Recurrent expenditure increases substantially during the entire planning horizon in this scenario. About ₦144 million is also generated from exports every year during the entire planning horizon.

TABLE 5.8

SUMMARY OF RESULTS FOR SCENARIO 2

Objective Function Value = ₦3852.7 Million

	1993 - 1995	1996 - 1998	1999 - 2001
Cost (thou. Naira/year)			
Capital	-	-	-
Recurrent	396,120	499,020	628,620
Transport	31,789.83	40,044.77	50,000.83
Imports	324,280	664,380	966,780
Export Revenue	144,000	144,000	144,000
Total Cost	608,189.83	1,059,444.77	1,501,844.88
Total demand (thou. tonnes/year)			
Flat Steel	817.427	1,027.721	1,297.154
Long Steel	999.052	1,258.55	1,584.41
Production (thou. tonnes/year)			
Pig Iron	463	720.4	1,147
Sponge Iron	1,020	1,020	1,020
Liquid Steel	1,321	1,564	1,942.32
Billets	1,260	1,456	1,831
Long Steel	1,124.058	1,383.72	1,709.4
Flat Steel	-	-	-
Imports (thou. tonnes/year)			
Iron Ore	-	-	-
Coal	93	102	124.3
Billets	-	-	-
Long Steel	-	-	-
Flat Steel	817.427	1,027.721	1,297.154
Exports (thou. tonnes/year)			
Billets	50	50	50
Long Steel	125	125	125
Capacity Expansion			
Blast Furnace	-	-	-
Bof	-	-	-
Direct Red	-	-	-
EAF	-	-	-
Flat Plant	-	-	-

5.5 SCENARIO 3

Alternative Transportation Route

The iron and steel industry is primarily transport- oriented. The locational distortion of the steel plants continues to impose severe cost on the industry. At full capacity, Delta Steel Company is planned to transfer about 690,000 tonnes of billets to the inland rolling mills at Osogbo, Jos and Katsina annually. Large tonnage of bulky raw materials and finished products are also shipped from inland producers to end users by road. Billet transfer from Delta Steel Company to the inland rolling mills is currently accomplished in truck loads of 20-22 tonnes.

A viable alternative to the present transportation system is more intensive use of railways and waterways as the major means of transportation. With the exception of Osogbo Steel Rolling Mill, none of the public steel plants is currently linked to the national railway system. An Inter-Ministerial Committee for Infrastructural Facilities for Steel Companies has already proposed several rail projects. These include Oturkpo-Ajaokuta (202km), Onne-Port-Harcourt (13km), Osogbo - Ajaokuta(200km), Warri - Osogbo (300km) and Kano-Katsina (175km). Some of them are already under construction.

This scenario evaluates the probable effects of a more efficient transportation system, relying more on railways, on the Nigerian iron and steel industry. This will however, require a more efficient national railway network and a huge investment expenditure for rail construction, river dredging port development and facilities for loading and off-loading raw materials and finished products. The underlying assumption is that all raw materials and intermediate products are transported by rail while the finished products are trucked by road. A summary of the results for this scenario is presented in table 5.9.

TABLE 5.9

SUMMARY OF RESULTS FOR SCENARIO 3

Objective Function Value = ₦3791.2 Million

	1993 - 1995	1996 - 1998	1999 - 2001
Cost (thou. Naira/year)			
Capital	-	-	-
Recurrent	396,120	499,020	628,620
Transport	15,137.54	19,068.94	24,021.37
Imports	324,280	664,380	966,780
Export Revenue	-144,000	-144,000	-144,000
Total Cost	595,537.54	988,468.94	1,475,421.37
Total demand (thou. tons/year)			
Flat Steel	817.427	1,029.723	1,297.154
Long Steel	999.058	1,258.55	1,584.40
Production (thou. tones/year)			
Pig Iron	463	720	1,147
Sponge Iron	1,020	1,020	1,020
Liquid Steel	1,320	1,565	1,942
Billets	1,260	1,456	1,831
Long Steel	1,124	1,384	1,710
Flat Steel	0	0	0
Imports (thou. tones/year)			
Iron Ore	-	-	-
Coal	93	102	124.3
Billets	-	-	-
Long Stee	0	0	0
Flat Stee	817.43	1,027.72	1,297.15
Exports (thou. tones/year)			
Billets	50	50	50
Long Steel	125	125	125
Capacity Expansion			
Blast Furnace	-	-	-
Boa	-	-	-
Direct Red	-	-	-
EAR	-	-	-
Flat Plant	-	-	-

In spite of the fact that the objective function value reduces considerably from ₦4078.7 million in the base case to ₦3791.2 million in this scenario, a correct indication of the role of a more efficient transportation system can only be grasped by comparing the results of this scenario with that of Scenario 2 so as to isolate the impact of more intensive use domestic raw materials. The major differences are the objective function which decreases by 612 million Naira and transport cost which reduces considerably during the three planning periods. Production levels are not affected. However, there are minor adjustments in shipments of finished products from plants to markets.

5.6 SCENARIO 4

Aggressive Export Drive

Despite the slump currently affecting the world steel market as a result of the global economic recession, Nigerian Steel has considerable export potentials, especially in the ECOWAS subregional market and other parts of Africa.

Notwithstanding the steel making capabilities of a few African countries such as Algeria, Libya, Arab Jamahiriya and Nigeria, Steel consumption in Africa is sustained mainly through imports from E.E.C. countries, Japan and other European countries. Only about 12% of total steel requirement is produced in Africa. Table 5.10 attempts to highlight the diverse sources of Steel in Africa. With more competitive production costs, Nigeria can claim

TABLE 5.10

SOURCES OF AFRICAN STEEL

European Community	-	44.9%
Other European Countries	-	27.6%
Japan	-	12.8%
Taiwan	-	1.8%
U.S.A.	-	0.5%
South Korea	-	0.3%
Domestic Production	-	12.3%

Source: Computed from United Nations (1991) The Steel Market in 1990 United National ECE/Steel/73 New York.

substantial part of this Market. Considerable opportunities also abound outside Africa in spite of the high level of protection currently accorded steel in several countries. This has been demonstrated by Zimbabwe's National Steel Company (ZISCOSTEEL) which successfully exported about 350,000 tones of steel annually, including 200,000 tones of billets exported outside Africa between 1981 and 1985.

This scenario investigates the likely impact of exports of steel products on the Nigerian iron and steel industry. Table 5.11 gives the summary of results for this scenario. About 175,000 tones of billets and 225,000 tones of finished products would be exported annually between 1993 and 2001.

The objective function value in the base case decreases substantially to ₦2402.3 million indicating that export is clearly profitable to the Nigerian iron and steel industry. Table 5.12 presents the amount of billets and finished products exported by each plant.

TABLE 5.11

SUMMARY OF RESULTS FOR SCENARIO 4

Objective Function Value = ₦24,023 Million

	1993 - 1995	1996 - 1998	1999 - 2001
Cost (thou. Naira/year)			
Capital	-	-	-
Recurrent	491,080	648,280	802,151
Transport	41,526.24	49,517.67	58,568.54
Imports	345,270	598,801	877,680
Export Revenue	-450,200	-450,200	-450,200
Total Cost	427,678.24	846,398.67	1,288,199.54
Total demand (thou. tons/year)			
Flat Steel	817.427	1,029.72	1,297.15
Long Steel	999.052	1,258.55	1,584.40
Production (thou. tons/year)			
Pig Iron	685	934	1,492
Sponge Iron	1,020	1,020	1,020
Liquid Steel	1,472	1,645	2,129
Billets	1,385	1,581	1,956
Long Steel	1,224	1,483	1,809
Flat Steel	-	-	-
Imports (thou. tons/year)			
Iron Ore	-	-	-
Coal	98	112	133
Billets	-	-	-
Long Steel	-	-	-
Flat Steel	817.4	1,029.7	1,297.15
Exports (thou tons/year)			
Billets	175	175	175
Long Steel	225	225	225
Capacity Expansion			
Blast Furnace	-	-	-
Boa	-	-	-
Direct Red	-	-	-
EAR	-	-	-
Flat Plant	-	-	-

TABLE 5.12

QUANTITY OF BILLETS AND FINISHED PRODUCTS EXPORTED BY EACH PLANT(THOUSAND TONNES PER ANNUM).

Ajaokuta	Billets -	175
	Long Steel -	35
Delta Steel	Billets -	0
	Long Steel -	90
Osogbo Rolling Mill	Long Steel -	25
Jos Steel Rolling Mill	Long Steel -	25
Katsina Steel Rolling Mill	Long Steel -	25
Minimills	Long Steel -	25

5.7 SCENARIO 5

Natural Gas Pricing

Nigeria National Gas Company currently supplies natural gas to the steel plants at a price of ₦141.21/1000 m^3, Nigeria Electric Power PLC at ₦105.9/1000 m^3 and other users at ₦185.02/1000 m^3. In line with the current wave of subsidy removal in the country, this scenario investigates the impact of the removal of this subsidy on natural gas on Nigerian steel plants.

The summary results for this scenario is presented on Table 5.13. The objective function value is ₦4481.3 million. A comparison of the result of this scenario with the base case and scenario 1 indicates that it will cost the steel plants ₦57.8 million more, if this subsidy is removed. The major increase is in the recurrent and raw material cost mainly at Delta steel plant that utilizes direct reduction technology for steel making.

TABLE 5.13

SUMMARY OF RESULTS FOR SCENARIO 5

Objective Function Value = ₦4481.3 Million

	1993 - 1995	1996 - 1998	1999 - 2001
Cost (thou. Naira/year)			
Capital	-	-	-
Recurrent	247,540.07	253,608.00	324,100.22
Transport	36,901.81	46,879.71	57,279.81
Imports	742,160	1,216,560	1,562,160
Export Revenue	-144,000	-144,000	-144,000
Total Cost	882601.88	1373047.71	1799541.03
Total demand (thou. tons/year)			
Flat Steel	817.427	1,029.723	1,297.154
Long Steel	999.052	1,258.55	1,584.40
Production			
Pig Iron	445	708.5	1,132.3
Sponge Iron	1,020	1,020	1,020
Liquid Steel	1,320	1,564.91	1,942.21
Billets	1,260	1,455	1,831
Long Steel	1,124.06	1,383.55	1,709.4
Flat Steel	-	-	-
Imports			
Iron Ore	1,917.5	2,247	2,997.154
Coal	97	102	124.3
Billets	-	-	-
Long Steel	-	-	-
Flat Steel	817.427	1,029.723	1,297.154
Exports			
Billets	50	50	50
Long Steel	125	125	125
Capacity Expansion			
Blast Furnace	-	-	-
Bof	-	-	-
Direct Red	-	-	-
EAF	-	-	-
Flat Plant	-	-	-

5.8 SENSITIVITY ANALYSIS OF THE RESULTS

A detailed sensitivity analysis or break-even analysis of the results has been precluded by the high cost of computer runs. Several parameters have however, been examined to determine the stability of our results. We obtained the value of each parameter that would lead to a change in the base case or reference solution. In effect, this is a single-parameter, break-even analysis that indicates the value at which the optimal solution would remain feasible. This is performed for investment cost, exchange rate, and import and export prices. Finally, a brief description is given of the Computer runs associated with alternative demand projections.

5.8.1 Investment Costs

For new capacity expansion to take place, a pertinent question is how sensitive is the erection of a new plant to the capital cost used in the study. Specifically, how can the investment cost for a flat steel plant be before its construction can become efficient. The value was found to be ₦274 million. Among the sites considered, Osogbo was chosen as the optimal site while the plant is to be constructed during the first planning horizon. However, this amount is only 11 per cent of the capital cost of ₦2500 million for a flat steel plant utilized in the study.

5.8.2 Exchange Rate

The major components of total cost affected by the exchange rate are capital cost, import price of raw materials and finished products and export prices. The incentive to produce domestically was found to increase as exchange rate increases and vice-versa. Conversely, the incentive to export was also found to increase with the exchange rate. Imports of long steel is found to be inefficient at an exchange rate of ₦34.34/US $. This is significantly greater than the exchange rate of ₦18.60/US $ used in the study. Export of steel is also found to be inefficient at ₦9/US $.

5.8.3 Import and Export Prices

The import and export prices for final products used in this study are the long term prices expected to prevail over the planning period. In our base case, all requirement of flat steel are to be imported while the amount of long steel being anticipated to be met from imports are 279.058, 534.88 and 862 thousand tonnes during the first, second and third planning horizons respectively. A pertinent question raised is, how high could the price of long steel rise before imports become infeasible. The C.I.F import price will have to rise to ₦8,985 per tonne before imports become infeasible. Compared with the expected long-term price of ₦5,580 per tonne which is being expected to prevail, there is 61.02 per cent flexibility before the break-even point is reached.

5.8.4 **Alternative demand projections**

The demand projections in the study assumed a growth rate of 8 per cent per annum. Two alternative growth rates of 6 and 12 per cent were used respectively and the model was rerun. In both cases, the results obtained were not significantly different from the base case. There was no radical departure from the results previously obtained.

CHAPTER SIX

SUMMARY OF MAJOR FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

A major preoccupation of the preceding chapters has been the formulation of a development strategy for the Nigerian iron and steel industry which will enable the country to meet her medium and longer term demand for steel optimally. Specifically, the study evaluates the present structure and development potentials of the industry. It designs the timing, size, location and choice of technology of major investment projects to be undertaken in the Nigerian iron and steel industry between 1993 and 2001 using the methodology of mixed integer programming. While the results of our model are tentative and constrained by the model's deficiency in capturing the real world, as well as data limitation, they do provide some clear and logical guidelines which indicate the direction to cost saving activities in the Nigerian iron and steel industry.

In this concluding chapter, we present a summary of major findings, recommendations, policy implication, limitation of the study and indications for further research.

6.2 SUMMARY OF MAJOR FINDINGS

The major empirical findings of the study are described as follow:

Despite the fact that the installed capacity of long steel products in Nigeria far exceeds their demand, the nation's steel plants are unable to meet the domestic requirements of long steel during the entire planning horizon. This stems from the relatively low level of capacity utilization, inefficiency and competition from exports. As much as 279,000 tonnes of long steel need to be imported annually between 1993 and 1995. This increases to 535,000 and 723,000 tonnes per annum in the second and third planning horizons respectively. However, Nigeria can be self sufficient in the production of long steel with increased capacity utilization and more efficient production techniques.

All existing steel plants are inefficient producers. Except for Delta Steel company, the estimated marginal cost of production of steel is greater than the world price of steel for all the operating steel plants, especially in the first planning period. For example, the estimated marginal cost of long steel production between 1993 and 1995 is estimated to be N7147.16 per tonne for Delta Steel company, N7879.74 per tonne for the inland rolling mills and ₦8234.02 for the already commissioned mills at Ajaokuta while the estimated world price of steel expected to prevail during the entire planning horizon is N5,580 per tonne.

There are inherent problems posed by the locational distortion in the spatial configuration of the steel plants. These problems are manifested in the absence of raw materials and critical inputs for the rolling mills, and high transportation costs.

With a large overcapacity in the production of long products and no facility for the production of flat rolled products in Nigeria, the option for their domestic production was examined in the context of the seemingly large demand for flat steel in Nigeria. The study does not recommend any plant construction during the stipulated planning period. Several other productive units were equally proposed for capacity expansion. These include a blast furnace, basic oxygen furnace, direct reduction unit and electric arc furnace. The study thus concludes that it is not optimal to construct any new plant between 1993 and 2001.

The study indicates that Ajaokuta Steel Company, the biggest and most ambitious steel plant in Africa may turn out to impose extra cost on the economy when it commences operations. This derives largely from the potential high cost of production as a result of total dependence on imported iron ore and coking coal. As much as ₦345.15 million is being estimated to be the cost on the nation between 1993 and 2001. The option for domestic sourcing of most of the raw materials currently being imported was also investigated. The study concludes that as much as ₦226 million will accrue as savings to the nation during the planning horizon if

Nigerian Iron Ore Mining project, Itakpe should supply 2.15 million tonnes of sinter concentrates to Ajaokuta and 550,000 tonnes of super concentrates to Delta Steel Company, representing 100 and 40 per cent of their iron ore requirements respectively between 1993 and 2001.

Finally, an export-oriented strategy is clearly beneficial to the Nigerian iron and steel industry. An aggressive export pursuit will result in considerable savings if Nigeria can capture the required export market for long steel and billets. In order to capture and preserve an export market of about 400,000 tonnes of steel products per year, the steel plants need to increase the utilization of excess capacity that currently exists as well as produce at internationally competitive prices.

6.3 RECOMMENDATIONS AND POLICY IMPLICATION

Several policy issues have to be redressed if a viable steel industry is to become a reality in Nigeria. Given the present scenario, our results show that it is unlikely that any additional investment, either public or private, in crude steel facilities will take place in the foreseeable future beyond the commissioning of the first phase of Ajaokuta Steel Company. Our findings indicate that a multi-pronged approach is needed in restructuring this sub-sector. The main thrust of the restructuring programme should be geared toward the following:

. . . . . optimal utilization of the commissioned
mills to enhance capacity utilization.

. . . . . pursuit of investment in infrastructural
support facilities for the commissioned mills.

. . . . . domestic sourcing of raw materials

. . . . . timely commissioning of Ajaokuta Steel Company, and

. . . . . An aggressive export pursuit.

Despite the installed overcapacity, the public steel plants have not been able to meet current demand due to a myriad of problems affecting them. These problems include: lack of working capital, shortage of raw materials and other consumables, unreliable power supply, inexperienced operation and maintenance crew and unstable management. Although government's disposition towards these plants has increased since 1989, concerted efforts should be made to provide them with adequate funds for working capital and rehabilitation. In the interim, they should be given top priority in the foreign exchange market since a substantial part of their raw materials are currently imported. Efforts should also be made to restructure the power supply base of the steel plants in order to guarantee quality and reliability.

Latent economic and operational problems have arisen as a result of locational distortion in the spatial configuration of the steel plants. There is thus the need to expand the national railway system to connect Delta Steel Company and the inland rolling mills as a competitive and more efficient alternative to the prevailing truck transportation. The possibilities of water transportation of raw materials and finished products should also be explored. These would no doubt entail huge investment of capital expenditure for rail construction, river dredging, port development, and purchase of equipment for loading and off-loading steel related materials and products.

Although, no conversion activity was considered in the model, it will be desirable to convert one of the strands in Delta Steel to enable it produce billets with a cross section of 100 x 100 mm required by Ajaokuta Steel Company. The mini mills should also be redesigned to enable them utilize billets to be produced by Ajaokuta Steel Company on inception.

While it is important that Ajaokuta Steel Company should be commissioned on time, it will be desirable if the plant can be cost efficient. From the emerging lessons from the commissioned mills, adequate provision of raw materials should precede plant commissioning. It is thus imperative that Itakpe should be completed before the plant is commissioned. The completion of the mine, benefication plant, and rail link as well as stockpiling of iron ore should precede the commissioning of Ajaokuta Steel Company. As a matter of expediency, the government should examine the option of increasing the scale of Ajaokuta Steel Company as the as the first phase planned capacity of 1.3 million tonnnes of liquid steel per annum does not justify the huge investment on infrastructure and ancillary facilities. Government should also consider the option of embarking upon joint venture agreement with reputable foreign firms to operate both Ajaokuta and Aladja Steel plants.

An objective assessment of the option for domestic sourcing of raw materials for the steel plants is an urgent necessity. The government should initiate a research programme aimed at improving the quality of locally available raw materials. Itakpe has ore deposits suitable for upgrading to blast furnace sinster feed and superconcentrate for Delta Steel. In the interim, efforts should be made to secure long term supply of raw materials for Delta Steel from Brazil and Liberia.

The possibility of exporting long steel products and billets should be seriously examined. According to Snook (1981), competitiveness is the key to prosperity in the steel industry. Despite the freight advantage over alternative supply sources in Africa, the ability to export would depend on ability to achieve much lower production cost. Following the recession of the 1980s, the global steel industry went into massive restructuring of capacities and facilities . Though the restructuring is incomplete, the world steel industry is to a large extent operating better automated facilities, using more efficient production processes.

The success of Japan and Korea in capturing a significant part of the world steel market has been attributed to their careful scrutiny of the many production variables influencing efficiency, and their determined application of standardized operating procedures based on evaluation of amassed data. The implication for Nigeria is the need to establish a body comprising of steel technocrats to assume a planning role in the Nigerian iron and steel industry. Such a body should be saddled with the responsibility of collecting and analysing data on the Nigerian iron and steel industry, designing investment strategy, product mix, marketing and strategic planning, as well as the appropriate level of protection. The Brazilian model will best serve our purpose. Here, CONSIDER, an organ of the Central government's ministry of Industry and Commerce plays this crucial role.

The government should also proceed with the privatisation of the inland rolling mills and full commercialisation of Delta Steel company, recognizing that this can successfully be achieved only if production is market driven and redundant capacity eliminated. The various envisaged projects are heavily-laden with cost implications for the government . In the course of rationalization, several governments aided the domestic steel industry. British Steel is today rated as one of the most profitable in the world. It is unlikely that it would have received this acclaim without the massive financial support provided by the British government in the process of its return to private ownership. For emerging steel industries as we have in Nigeria, substantial support is needed from the government.

6.4 LIMITATIONS OF THE STUDY

The study has several limitations . A complete expansion programme will include management, operations and financial planning. This study deals with only one basic aspect of a comprehensive steel expansion programme; the economic engineering aspect.

The restriction of the criterion for project selection to cost minimisation is another major limitation. In reality, there are several complexities involved in planning the steel industry. Other objectives may include income distribution, minimisation of employment benefit, spatial consideration and other political and social criteria. In view of the multiple and often conflicting objectives, a multi-objective goal programming framework should have been more appropriate. However, mixed integer goal programming is still in its infancy as there is currently no algorithm for solving large mixed-integer goal programming problems.

Another limitation of the study is the regional dissagregation. This is too small to enable us carry out an objective assessment of alternative transport routes.

There are certain improvements which could be made to the model to enhance its operational usefulness. First, it would be desirable if demand could be made endogenous and price responsive. This will lead us to the realm of non-linear (quadratic) mixed-integer programming which is still relatively underdeveloped. The study could also benefit from an improved data base especially on costs and technical coefficients. It will be desirable to utilize technical coefficients derived from the Nigerian iron and steel industry.

Despite all these limitations, the present approach represents an advancement over other known techniques. It is hoped that the experiments have served the suggestive purpose of highlighting the implication of adopting different policies in the Nigerian iron and steel industry.

6.5 INDICATIONS FOR FURTHER RESEARCH

In view of the enormous operational problems currently afflicting the Nigerian iron and steel industry, it is being suggested that efforts should be made to develop a static programming model for the Nigerian iron and steel industry which is relatively more effective in analysing operational problems. This will form the basis for a study of the operational procedures in the Nigerian iron and steel industry.

It will be desirable if the present study can be extended to include other ECOWAS countries. This extension is likely to make the study an Economic Integration study of the iron and steel industry. This will enable projects to be established on a more efficient scale than would be possible on the basis of the domestic market of one individual country.

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APPENDIX 1

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General Algebraic Modeling System
Compilation


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   5    SET     I   STEEL PLANTS              /DSC      DELTA STEEL COMPANY
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                                                                          MILL
   8                                           JSRM     JOS STEEL ROLLING MILL
   9                                           MM       MINI MILLS /
  10
  11            IM  MINES                     /AOI      ASSOCIATED ORE ITAKPE
  12                                           ECM      ENUGU COAL MINE/
  13
  14            J   MARKETS                   /LAGOS    LAGOS
  15                                           ONIT     ONITSHA
  16                                           KANO     KANO /
  17
  18
  19
  20            C    COMMODITIES              /IRON-ORE TONS
  21                                           PELLETS  IRON ORE PELLETS (TONS)
  22                                           COAL     TONS
  23                                           LIMESTO  LIMESTONE(TONS)
  24                                           NAT-GAS  NATURAL GAS (1000N CU M)
  25                                           ELECTRI  ELECTRICITY (MWH)
                                                                      ELECTRIC
  26                                           SCRAP    TONS
  27                                           PIG-IRON TONS
  28                                           SPONGE    SPONGE IRON (TONS)
  29                                           LIQ-STEEL TONS
  30                                           BILLETS   TONS
  31                                           SLAB      TONS
  32                                           LONG-STE  LONG STEEL (TONS)
  33                                           FLAT-STE  FLAT STEEL (TONS)/
  34
  35
  36           CF(C) FINAL PRODUCTS           /FLAT-STE
  37                                           LONG-STE  /
  38
  39           CI(C) INTERMEDIATE PRODUCTS       /BILLETS /
  40
  41           CR(C) RAW MATERIALS            /IRON-ORE
  42                                           PELLETS
  43                                           COAL
  44                                           LIMESTO
  45                                           NAT-GAS
  46                                           ELECTRI
  47                                           SCRAP
  48                                           PIG-IRON
  49                                           SPONGE
  50                                           LIQ-STEEL
  51                                           SLAB/
  52
```

```

        CE(C) EXPORT PRODUCTS        / LONG-STE, BILLETS /


        CS   INTERPLANT SHIPMENTS              /BILLETS/


        P   PROCESSES   /
GAMS 2.25  386/486 DOS                         92/07/01 11:56:50  PAGE      3
NIGSTMD1


                       PIG-IRON      PIG IRON PRODUCTION
                       SPONGE        SPONGE IRON PRODUCTION
                       STEEL-EL      STEEL PRODUCTION IN ELECTRIC ARC
                       STEEL-BOF     STEEL PRODUCTION IN BOF
                       CAST-BILL     CONTINOUS  CASTING OF BILLETS
                       CAST-SLAB     CONTINOUS CASTING OF SLAB
                       ROL-LONG      ROLLING OF LONG PRODUCTS
                       ROL-FLAT      ROLLING OF FLAT PRODUCTS/

        M   PRODUCTIVE UNITS/
                        BLAST-FUR    BLAST FURNACE
                        DIR-RED      DIRECT REDUCTION UNITS
                        EAF          ELECTRIC ARC FURNACE
                        BOF          BASIC OXYGEN FURNACE
                        CONT-CAST    CONTINOUS CASTING UNITS
                        ROL-MILLS    ROLLING MILLS
                        FLAT-PLANT   FLAT STEEL PLANT /

        ME(M) EXPANSION UNITS  /
                        BLAST-FUR    BLAST FURNACE
                        BOF          BASIC OXYGEN FURNACE
                        DIR-RED      DIRECT REDUCTION UNITS
                        EAF          ELECTRIC ARC FURNACE
                        FLAT-PLANT   FLAT STEEL PLANT/

        T  TIME PERIODS  /
                        1993-1995
                        1996-1998
                        1991-2001  /

        ENERGY(CR)              /NAT-GAS, ELECTRI /

        ALIAS           (T, TP), (I,IP), (J,JP) ;

SCALAR      BASEYEAR    BASE YEAR              / 1991 /
            THETA       YEARS PER TIME PERIOD / 3 /

PARAMETER   MIDYEAR(T)  PERIOD MID-YEARS    ;
MIDYEAR(T) = BASEYEAR + THETA*ORD(T) ;

PARAMETERS   EH  TOTAL EXPORT RESTRICTION (1000 TPY)
             EB  MAXIMUM EXPORT PER PLANT (1000 TPY);
    EH(T) = 100; EB(T) = 25;


      TABLE A(C,P) INPUT OUTPUT COEFFICIENTS

           PIG-IRON  SPONGE  STEEL-EL  STEEL-BOF    CAST-BILL

IRON-ORE    -0.02     -1.08
PELLETS     -1.4
```

```
COAL        -0.6
LIMESTO     -0.1
NAT-GAS               -0.57
ELECTRI     -0.09              -0.58                   0.04
SCRAP                                    -0.11
PIG-IRON     1                           -1.02
SPONGE                  1      -1.09
LIQ-STEEL                        1        1           -1.05
BILLETS                                                  1
SLAB
GAMS 2.25  386/486 DOS                      92/07/01 11:56:50  PAGE      4
NIGSTMD1



LONG-STE
FLAT-STE
 +

            CAST-SLAB    ROL-LONG        ROL-FLAT

IRON-ORE
PELLETS
COAL
LIMESTO
NAT-GAS
ELECTRI
SCRAP        0.02          0.02              0.03
PIG-IRON
SPONGE
LIQ-STEEL   -1.04
BILLETS                   -1.05
SLAB         1                              -1.05
LONG-STE                    1
FLAT-STE                                      1



PARAMETER   DT  TOTAL DEMAND FOR FINAL PRODUCTS IN 1991 (1000 TONNES)
                    / FLAT-STE 648.9, LONG-STE  793.1   /

            DD(J)   DISTRIBUTION OF DEMAND / LAGOS 0.40, ONIT .30,
                                                       KANO .30 /

            D(CF,J,T) DEMAND FOR FINAL PRODUCTS (1000 TONNES ) ;

D("LONG-STE",J,T) =   793.1 *  DD(J) * (1 +  8 / 100)
                           **(MIDYEAR(T)-BASEYEAR) ;

D("FLAT-STE",J,T) =  648.9  * DD(J)  * (1 + 8 / 100)
                           **(MIDYEAR(T)-BASEYEAR) ;

DISPLAY D;

                    TABLE  B(M,P)  CAPACITY UTILIZATION

              PIG-IRON  SPONGE  STEEL-EL  STEEL-BOF  CAST-BILL

BLAST-FUR        0.3
DIR-RED                   0.3
EAF                                 0.3
BOF                                           0.3
CONT-CAST                                               0.3
ROL-MILLS
```

```
FLAT-PLANT
  +
               CAST-SLAB      ROL-LONG     ROL-FLAT

BLAST-FUR
DIR-RED
EAF
BOF
CONT-CAST
ROL-MILLS                  0.3
FLAT-PLANT

```

```


TABLE K(M,I)  INITIAL CAPACITY OF PROD UNITS (1000 TONNES PER YEAR)

              DSC       OSRC     KSRM    JSRM      MM

BLAST-FUR
DIR-RED      1020
EAF          1000
BOF
CONT-CAST    9600
ROL-MILLS     300      210      210      210      1241
FLAT-PLANT

   TABLE RD(*,*)   ROAD DISTANCE FROM PLANTS TO MARKETS IN KILOMETRES

              DSC       OSRC       KSRM      JSRM    IMPORTS

LAGOS         455        254       1082       594      120
ONIT          187        420        697      1292      197
KANO         1178        986        420       174      990
EXPORTS        30        254        841       594



    TABLE RI(I,*)   INTERPLANT ROAD DISTANCE IN KILOMETRES

              DSC           OSRC        KSRM

OSRC          412
KSRM         1331            980
JSRM          881            998          594


PARAMETER   MUF(I,J)  TRANSPORT COST: FINAL PRODUCTS          (N PER TON)
            MUV(J)    TRANSPORT COST: IMPORTED FINAL PRODUCTS (N PER TON)
            MUI(I,IP)    TRANSPORT COST: INTERPLANT SHIPMENTS    (N PER
                                                                  TON)
            MUR(I)   TRANSPORT COST: RAW MATERIAL SHIPMENTS  (N PER TON)
            MUE(I)    TRANSPORT COST: EXPORTS                 (N PER TON)
                                                                    ;


     MUF(I,J)     = (2.50 +  0.015*RD(I,J))        $ RD(I,J);
     MUV(J)       = (105)                                 ;
     MUI(I,IP)    = (105)                                 ;
     MUR(I)       = (150                     )            ;
```

```
     MUE(I)      = (105)                              ;

DISPLAY  MUF, MUV, MUI, MUR, MUE;

          PARAMETER  PV IMPORT PRICES (CIF NAIRA PER TON)/

 IRON-ORE    744
 COAL       1395
 BILLETS    5115
 LONG-STE   5580
 FLAT-STE   8091  /

         PARAMETER PD DOMESTIC RAW MATERIAL PRICES IN NAIRA/

```

```
 LIMESTO          75
 SCRAP           180
 BILLETS        1500  /

        PARAMETER EG ENERGY PRICES/

 NAT-GAS        0.15
 ELECTRI        0.20 /

          PARAMETER PE EXPORT PRICES / LONG-STE 5208
                                       BILLETS  4800 /

     TABLE TS TIME SUMMATION MATRIX
            1993-95   1996-98   1999-2001
1993-95        1         1           1
1996-98        1         1           1
1999-2001      1         1           1

SET TT TIME LAG MATRX / 1993-95.1996-98, 1996-98.1999-2001 /

  TABLE INV 1NVESTMENT COST

*   FIX FIXED COST IN MILLION NAIRA
*   PROD VARIABLE COST IN THOUSAND NAIRA /TON/ YEAR

                 FIX       PROP

BLAST-FUR       2700       2450
BOF             1200       1060
DIR-RED         1000       1025
EAF              420        395
FLAT-PLANT      2500       2245

PARAMETER    OMEGA   FIXED CHARGE PORTION OF INVESTMENT
             NU      VARIABLE PORTION OF INVESTMENT
             HB      MAXIMUM  CAPACITY EXPANSION
             SF      SITE FACTOR ;

SF           = 1.3*.001 ;
OMEGA(M)     = SF*INV(M,"FIX" );
NU(M)        = SF*INV(M, "PROP");
HB(M)        = 600 ;

PARAMETER    SIGMA   CAPITAL RECOVERY FACTOR
             DELTA   DISCOUNT FACTOR
```

```
             LIFE    LIFE OF PRODUCTIVE UNIT
             RHO     OPPORTUNITY COST OF CAPITAL
             SER     SHADOW EXCHANGE RATE ;
LIFE =  15;  RHO = .1 ;  SER = .65 ;

SIGMA     = RHO* (1 + RHO) ** LIFE / (( 1 + RHO)**LIFE-1);
DELTA(T)  = (1 + RHO)**( 1988 - MIDYEAR(T) )
          + (1 + RHO)**( 1987 - MIDYEAR(T) )
          + (1 + RHO)**( 1986 - MIDYEAR(T) ) ;


VARIABLES   Z      PROCESS LEVEL                          (1000 TPY)
            XF     DOMESTIC SHIPMENTS OF FINAL PRODUCTS   (1000 TPY)
            XI     SHIPMENTS OF INTERMEDIATES    (1000 TPY)
            XR     DOMESTIC SHIPMENT OF RAW MATERIALS     (1000 TPY)
            VF     IMPORTS OF FINAL PRODUCTS              (1000 TPY)
```

```
            VR     IMPORTS OF RAW MATERIALS               (1000 TPY)
            E      EXPORTS                                (1000 TPY)
            H      CAPACITY EXPANSION                     (1000 TPY)
            Y      BINARY VARIABLE (EXPANSION)

            PSI          TOTAL COST (DISCOUNTED)                (MILL N )
            PSIK         CAPITAL COST                           (MILL N )
            PSIP         RECURRENT COST                         (MILL N )
            PSIL         TRANSPORT COST                         (MILL N )
            PSII         IMPORT COST                            (MILL N )
            PSIE         EXPORT REVENUE                         (MILL N )

POSITIVE VARIABLES  Z, XF, XI, XR, VF, VR, E, H ; BINARY VARIABLES Y ;

EQUATIONS   MBF        MATERIAL BALANCE : FINAL PRODUCTS    (1000 TPY)
            MBI        MATERIAL BALANCE : INTERMEDIATE PROD (1000 TPY)
            MBR        MATERIAL BALANCE : RAW MATERIALS     (1000 TPY)
            CC         CAPACITY CONSTRAINT                  (1000 TPY)
            MD         MAXIMUM CAPACITY EXPANSION           (1000 TPY)
            ECC        EXPORT CONSTRAINT (COMMOD AND PLANT) (1000 TPY)
            MR         MARKET REQUIREMENT CONSTRAINT        (1000 TPY)
            OBJ        ACCOUNTING : TOTAL DISCOUNTED COST   (MILL N )
            AKAP       ACCOUNTING : INVESTMENT COST CHARGE  (MILL N )
            APSI       ACCOUNTING : RECURENT COST           (MILL N )
            ALAM       ACCOUNTING : TRANSPORT COST          (MILL N )
            APII       ACCOUNTING : IMPORT COST             (MILL N )
            AEPS       ACCOUNTING : EXPORT REVENUE          (MILL N);



MBF(CF,I,T)..   SUM(P, A(CF,P)*Z(P,I,T)) =G= SUM(J, XF(CF,I,J,T))
                    + E(CF,I,T) ;


MBI(CI,I,T)..   SUM(P, A(CI,P)*Z(P,I,T)) + SUM(IP, XI(CI,I,T))
                  $ CS(CI) =G= SUM(IP, XI(CI,I,T))$CS(CI) ;

MBR(CR,I,T)..   SUM(P, A(CR,P)*Z(P,I,T) + XR(CR,I,T)$PD(CR)
                + VR(CR,I,T)$PV(CR)) =G= 0 ;

CC(I,M,T)..     SUM(P, B(M,P)*Z(P,I,T)) =L= K(M,I) + SUM(TP $
                TS(T,TP),H(M,I,TP) );

```

```
 346  MD(I,M,T)..     H(M,I,T) =L= HB(M)*Y(M,I,T) ;
 347
 348  ECC(CE,I,T)..    E(CE,I,T) =L= EB(T) ;
 349
 350  MR(CF,J,T)..    SUM(I, XF(CF,I,J,T) + VF(CF,J,T)) =G= D(CF,J,T);
 351
 352
 353  OBJ..             PSI =E= SUM(T, DELTA(T)*(PSIK(T) + PSIP(T) + PSIL(T) +
 354                         PSII(T) - PSIE(T) )) ;
 355
 356  AKAP(T)..         PSIK(T) =E= SER*SUM(TP$TS(T,TP), SIGMA*(SUM((I,M),
 357                            OMEGA(M)*Y(M,I,TP) + NU(M)*H(M,I,T))));
 358
 359  APSI(T)..         PSIP(T) =E= SUM((CR,I), PD(CR)*VR(CR,I,T)) ;
 360
 361  ALAM(T)..         PSIL(T) =E= SUM(CF, SUM((I,J), MUF(I,J)*XF(CF,I,J,T))
 362                                   + SUM(J, MUV(J)*VF(CF,J,T))
 363                                   + SUM(I, MUE(I)*E(CF,I,T)))
GAMS 2.25  386/486 DOS                           92/07/01 11:56:50  PAGE      8
NIGSTMD1



 364                                + SUM(CR, SUM(I, MUR(I)*VR(CR,I,T)));
 365
 366
 367  APII(T)..         PSII(T) =E= SER*SUM((CF,J), PV(CF)*VF(CF,J,T)) + SER*
 368                                   SUM((CR,I),PV(CR)*VR(CR,I,T));
 369
 370  AEPS(T)..            PSIE(T) =E= SUM((CE,I), PE(CE)*E(CE,I,T)) ;
 371
 372
 373  MODEL  NIGSTMD1  PROBLEM  / ALL /;
 374
 375  SOLVE  NIGSTMD1 MINIMIZING PSI USING MIP;
 376
GAMS 2.25  386/486 DOS                           92/07/01 11:56:50  PAGE      9
NIGSTMD1
Symbol Listing


SYMBOL       TYPE   REFERENCES

A            PARAM  DECLARED      106  DEFINED      106       REF       333
                         337      340
AEPS         EQU    DECLARED      329  DEFINED      370 IMPL-ASN       375
                         REF      373
AKAP         EQU    DECLARED      325  DEFINED      356 IMPL-ASN       375
                         REF      373
ALAM         EQU    DECLARED      327  DEFINED      361 IMPL-ASN       375
                         REF      373
APII         EQU    DECLARED      328  DEFINED      367 IMPL-ASN       375
                         REF      373
APSI         EQU    DECLARED      326  DEFINED      359 IMPL-ASN       375
                         REF      373
B            PARAM  DECLARED      161  DEFINED      161       REF       343
BASEYEAR     PARAM  DECLARED       95  DEFINED       95       REF        99
                         154      157
C            SET    DECLARED       20  DEFINED       20       REF        36
                          39       41       54      106
CC           EQU    DECLARED      320  DEFINED      343 IMPL-ASN       375
                         REF      373
CE           SET    DECLARED       54  DEFINED       54       REF       348
                       2*370  CONTROL      348      370
```

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                        3*350    4*353    2*354    2*356      357    2*359
                        2*361      362      363      364    2*367      368
                        2*370  CONTROL       99    2*103      153      156
                          293      333      337      340      343      346
                          348      350      353      356      359      361
                          367      370
THETA       PARAM    DECLARED       96  DEFINED       96      REF       99
TP          SET      DECLARED       93      REF    2*344      356      357
                      CONTROL      343      356
TS          PARAM    DECLARED      254  DEFINED      254      REF      344
                          356
TT          SET      DECLARED      260  DEFINED      260
VF          VAR      DECLARED      302 IMPL-ASN      375      REF      315
                          350      362      367
VR          VAR      DECLARED      303 IMPL-ASN      375      REF      315
                          341      359      364      368
XF          VAR      DECLARED      299 IMPL-ASN      375      REF      315
                          333      350      361
XI          VAR      DECLARED      300 IMPL-ASN      375      REF      315
                          337      338
XR          VAR      DECLARED      301 IMPL-ASN      375      REF      315
                          340
Y           VAR      DECLARED      306 IMPL-ASN      375      REF      315
                          346      357
Z           VAR      DECLARED      298 IMPL-ASN      375      REF      315
                          333      337      340      343


SETS

C           COMMODITIES
CE          EXPORT PRODUCTS
CF          FINAL PRODUCTS
CI          INTERMEDIATE PRODUCTS
CR          RAW MATERIALS
CS          INTERPLANT SHIPMENTS
DEFINITION
ENERGY
I           STEEL PLANTS
IM          MINES
IP          Aliased with I
J           MARKETS
GAMS 2.25  386/486 DOS                            92/07/01 11:56:50  PAGE      12
NIGSTMD1
Symbol Listing


SETS

JP          Aliased with J
M           PRODUCTIVE UNITS
ME          EXPANSION UNITS
P           PROCESSES
T           TIME PERIODS
TP          Aliased with T
TT          TIME LAG MATRX


PARAMETERS

A           INPUT OUTPUT COEFFICIENTS
B           CAPACITY UTILIZATION
BASEYEAR    BASE YEAR
D           DEMAND FOR FINAL PRODUCTS (1000 TONNES )
```

```
CF          SET     DECLARED       36  DEFINED       36      REF      151
                       2*333      334    3*350      361      362      363
                       2*367  CONTROL      333      350      361      367
CI          SET     DECLARED       39  DEFINED       39      REF    2*337
                       3*338  CONTROL      337
CR          SET     DECLARED       41  DEFINED       41      REF       91
                       3*340    2*341    2*359      364    2*368
                     CONTROL      340      359      364      368
CS          SET     DECLARED       57  DEFINED       57      REF    2*338
D           PARAM   DECLARED      151 ASSIGNED      153      156
                         REF      159      350
DD          PARAM   DECLARED      148  DEFINED      148      REF      153
                         156
DEFINITION  SET     DECLARED        3
DELTA       PARAM   DECLARED      286 ASSIGNED      293      REF      353
DT          PARAM   DECLARED      145  DEFINED      146
E           VAR     DECLARED      304 IMPL-ASN      375      REF      315
                         334      348      363      370
EB          PARAM   DECLARED      102 ASSIGNED      103      REF      348
ECC         EQU     DECLARED      322  DEFINED      348 IMPL-ASN      375
                         REF      373
EG          PARAM   DECLARED      246  DEFINED      246
EH          PARAM   DECLARED      101 ASSIGNED      103
ENERGY      SET     DECLARED       91  DEFINED       91
H           VAR     DECLARED      305 IMPL-ASN      375      REF      315
                         344      346      357
HB          PARAM   DECLARED      277 ASSIGNED      283      REF      346
I           SET     DECLARED        5  DEFINED        5      REF       93
                         185      208      217      219      220      221
                       2*224    2*333      334    2*337      338    2*340
                         341    2*343      344    2*346      348      350
                       2*357      359    2*361    2*363    2*364      368
                         370  CONTROL      224      226      227      228
                         333      337      340      343      346      348
                         350      356      359      361      363      364
                         368      370
IM          SET     DECLARED       11  DEFINED       11
INV         PARAM   DECLARED      262  DEFINED      262      REF      281
GAMS 2.25  386/486 DOS                            92/07/01 11:56:50  PAGE     10
NIGSTMD1
Symbol Listing


SYMBOL      TYPE    REFERENCES

                         282
IP          SET     DECLARED       93      REF      219  CONTROL      226
                         337      338
J           SET     DECLARED       14  DEFINED       14      REF       93
                         148      151      153      156      217      218
                       2*224      333    3*350    2*361    2*362      367
                     CONTROL      153      156      224      225      333
                         350      361      362      367
JP          SET     DECLARED       93
K           PARAM   DECLARED      185  DEFINED      185      REF      343
LIFE        PARAM   DECLARED      287 ASSIGNED      290      REF    2*292
M           SET     DECLARED       70  DEFINED       70      REF       79
                         161      185      281      282    2*343      344
                       3*346    4*357  CONTROL      281      282      283
                         343      346      356
MBF         EQU     DECLARED      317  DEFINED      333 IMPL-ASN      375
                         REF      373
MBI         EQU     DECLARED      318  DEFINED      337 IMPL-ASN      375
                         REF      373
```

```
MBR         EQU    DECLARED      319  DEFINED      340 IMPL-ASN      375
                        REF      373
MD          EQU    DECLARED      321  DEFINED      346 IMPL-ASN      375
                        REF      373
ME          SET    DECLARED       79  DEFINED       79
MIDYEAR     PARAM  DECLARED       98 ASSIGNED       99      REF      154
                        157      293      294      295
MR          EQU    DECLARED      323  DEFINED      350 IMPL-ASN      375
                        REF      373
MUE         PARAM  DECLARED      221 ASSIGNED      228      REF      230
                        363
MUF         PARAM  DECLARED      217 ASSIGNED      224      REF      230
                        361
MUI         PARAM  DECLARED      219 ASSIGNED      226      REF      230
MUR         PARAM  DECLARED      220 ASSIGNED      227      REF      230
                        364
MUV         PARAM  DECLARED      218 ASSIGNED      225      REF      230
                        362
NIGSTMD1    MODEL  DECLARED      373  DEFINED      373 IMPL-ASN      375
                        REF      375
NU          PARAM  DECLARED      276 ASSIGNED      282      REF      357
OBJ         EQU    DECLARED      324  DEFINED      353 IMPL-ASN      375
                        REF      373
OMEGA       PARAM  DECLARED      275 ASSIGNED      281      REF      357
P           SET    DECLARED       60  DEFINED       60      REF      106
                        161    2*333    2*337    2*340    2*343
                    CONTROL      333      337      340      343
PD          PARAM  DECLARED      240  DEFINED      240      REF      340
                        359
PE          PARAM  DECLARED      251  DEFINED      251      REF      370
PSI         VAR    DECLARED      308 IMPL-ASN      375      REF      353
                        375
PSIE        VAR    DECLARED      313 IMPL-ASN      375      REF      354
                        370
PSII        VAR    DECLARED      312 IMPL-ASN      375      REF      354
                        367
PSIK        VAR    DECLARED      309 IMPL-ASN      375      REF      353
                        356
PSIL        VAR    DECLARED      311 IMPL-ASN      375      REF      353
                        361
```

```
SYMBOL      TYPE   REFERENCES

PSIP        VAR    DECLARED      310 IMPL-ASN      375      REF      353
                        359
PV          PARAM  DECLARED      232  DEFINED      232      REF      341
                        367      368
RD          PARAM  DECLARED      197  DEFINED      197      REF    2*224
RHO         PARAM  DECLARED      288 ASSIGNED      290      REF    3*292
                        293      294      295
RI          PARAM  DECLARED      208  DEFINED      208
SER         PARAM  DECLARED      289 ASSIGNED      290      REF      356
                      2*367
SF          PARAM  DECLARED      278 ASSIGNED      280      REF      281
                        282
SIGMA       PARAM  DECLARED      285 ASSIGNED      292      REF      356
T           SET    DECLARED       86  DEFINED       86      REF       93
                         98       99      151      154      157      293
                        294      295    2*333      334    2*337      338
                      2*340      341      343      344    2*346    2*348
```

```
DD          DISTRIBUTION OF DEMAND
DELTA       DISCOUNT FACTOR
DT          TOTAL DEMAND FOR FINAL PRODUCTS IN 1991 (1000 TONNES)
EB          MAXIMUM EXPORT PER PLANT (1000 TPY)
EG          ENERGY PRICES
EH          TOTAL EXPORT RESTRICTION (1000 TPY)
HB          MAXIMUM  CAPACITY EXPANSION
INV         1NVESTMENT COST
K           INITIAL CAPACITY OF PROD UNITS (1000 TONNES PER YEAR)
LIFE        LIFE OF PRODUCTIVE UNIT
MIDYEAR     PERIOD MID-YEARS
MUE         TRANSPORT COST: EXPORTS                  (N PER TON)
MUF         TRANSPORT COST: FINAL PRODUCTS           (N PER TON)
MUI         TRANSPORT COST: INTERPLANT SHIPMENTS     (N PER TON)
MUR         TRANSPORT COST: RAW MATERIAL SHIPMENTS   (N PER TON)
MUV         TRANSPORT COST: IMPORTED FINAL PRODUCTS  (N PER TON)
NU          VARIABLE PORTION OF INVESTMENT
OMEGA       FIXED CHARGE PORTION OF INVESTMENT
PD          DOMESTIC RAW MATERIAL PRICES IN NAIRA
PE          EXPORT PRICES
PV          IMPORT PRICES (CIF NAIRA PER TON)
RD          ROAD DISTANCE FROM PLANTS TO MARKETS IN KILOMETRES
RHO         OPPORTUNITY COST OF CAPITAL
RI          INTERPLANT ROAD DISTANCE IN KILOMETRES
SER         SHADOW EXCHANGE RATE
SF          SITE FACTOR
SIGMA       CAPITAL RECOVERY FACTOR
THETA       YEARS PER TIME PERIOD
TS          TIME SUMMATION MATRIX


VARIABLES

E           EXPORTS                                (1000 TPY)
H           CAPACITY EXPANSION                     (1000 TPY)
PSI         TOTAL COST (DISCOUNTED)                (MILL N )
PSIE        EXPORT REVENUE                         (MILL N )
PSII        IMPORT COST                            (MILL N )
PSIK        CAPITAL COST                           (MILL N )
PSIL        TRANSPORT COST                         (MILL N )
PSIP        RECURRENT COST                         (MILL N )
VF          IMPORTS OF FINAL PRODUCTS              (1000 TPY)
VR          IMPORTS OF RAW MATERIALS               (1000 TPY)
XF          DOMESTIC SHIPMENTS OF FINAL PRODUCTS   (1000 TPY)
GAMS 2.25  386/486 DOS                     92/07/01 11:56:50   PAGE     13
NIGSTMD1
Symbol Listing


VARIABLES

XI          SHIPMENTS OF INTERMEDIATES   (1000 TPY)
XR          DOMESTIC SHIPMENT OF RAW MATERIALS     (1000 TPY)
Y           BINARY VARIABLE (EXPANSION)
Z           PROCESS LEVEL                          (1000 TPY)


EQUATIONS

AEPS        ACCOUNTING : EXPORT REVENUE           (MILL N)
AKAP        ACCOUNTING : INVESTMENT COST CHARGE   (MILL N )
ALAM        ACCOUNTING : TRANSPORT COST           (MILL N )
APII        ACCOUNTING : IMPORT COST              (MILL N )
APSI        ACCOUNTING : RECURENT COST            (MILL N )
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```
CC         CAPACITY CONSTRAINT                  (1000 TPY)
ECC        EXPORT CONSTRAINT (COMMOD AND PLANT) (1000 TPY)
MBF        MATERIAL BALANCE : FINAL PRODUCTS    (1000 TPY)
MBI        MATERIAL BALANCE : INTERMEDIATE PROD (1000 TPY)
MBR        MATERIAL BALANCE : RAW MATERIALS     (1000 TPY)
MD         MAXIMUM CAPACITY EXPANSION           (1000 TPY)
MR         MARKET REQUIREMENT CONSTRAINT        (1000 TPY)
OBJ        ACCOUNTING : TOTAL DISCOUNTED COST   (MILL N )


MODELS


NIGSTMD1   PROBLEM



COMPILATION TIME     =        6.758 SECONDS       VERID MW2-00-037
GAMS 2.25  386/486 DOS                       92/07/01 11:56:50  PAGE     14
NIGSTMD1
E x e c u t i o n
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