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# Technological Change and Project Execution in a Developing Economy

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# TECHNOLOGICAL CHANGE AND PROJECT EXECUTION IN A DEVELOPING ECONOMY

## Evolution of Ajaokuta Steel Plant in Nigeria

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## PREFACE

The following report resulted from a research project carried out between 1986 and 1987 by Mr. Oyebanji Oyeyinka and Mr. Oluwole Adeloye on the evolution of Nigeria's Ajaokuta Steel Plant. The project examined plans made and agreements reached in regard to the plant's construction and subsequent operation. Its chief objective was to determine the extent to which such plans and agreements were in fact followed. The project had special interest in the plant's opportunities for, and obstacles to, technology transfer.

Features that make this report important include the relative complexity of the technology with which it is concerned. As the authors point out, with the exception of the steel plant under study, in sub-Saharan Africa, practically all such plants have later been suspended or abandoned entirely, for reasons stemming ultimately from that complexity. Although Asia's experience in this regard has been far better, Latin America's experience has been similar.

For a developing country, the relative complexity of the steel industry means that the construction of a steel plant will entail several, or even many, actors some, or even most, of whose interests may be disparate. There are consequently many possibilities of both willful and honest "mistakes". Some of the value of this report certainly lies in what it reveals in that regard.

Finally, the report owes its value also to its authors' knowledge of the plant studied. Both authors were on the plant's staff at the time they made their study, one as a Deputy Manager of production and the other as a Deputy Manager of production planning and control.

I hope that researchers and decision-makers in Nigeria and elsewhere in Africa, will find this report useful. I must emphasize, however, that the International Development Research Centre does not necessarily agree with the views and recommendations contained in it.

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## Introduction

This work examines industrial development as it is reflected in creation, adaptation, and assimilation of technology. Studies have established that such mastery of technology can be brought about only by deployment of resources in a systematic and sustained manner. Although developing countries, especially the late starters, introducing a new technology on the scale and complexity of an integrated steel plant do not have to master the basis of the technology, they will face formidable technomanagerial challenges without the mastery. They must build massive infrastructures and human capital. These efforts exact enormous resources and take years. Khun's paradigmatic category may not be out of place.

Nigeria is a late starter; it is technologically far behind South Korea, Brazil, and India, as is reflected for example in the research being done. Whereas research in the more advanced developing countries deals with innovative changes in the mature industries (steel, capital goods, etc.), the effort in this work and in most related research in Nigeria is limited to examination of the introduction of technology.

Specifically, this research:

- Reviews the literature on transfer of technology in the steel industry and on the development of the steel industry in Nigeria;
- Undertakes a case study of the Ajaokuta Steel Company (ASC), examining the planning (including feasibility studies and other documentation);
- Evaluates the contractual relationships between ASC and external suppliers of technology, with a view to determining the extent to which a continuing reliance on external participation is assumed; and
- Examines ASC's training and other efforts to develop human resources, concentrating especially on the use and maintenance of transferred technologies.

According to the United Nations Industrial Development Organization (UNIDO 1985), steel production in developing countries increased from 1.5% of the world total in 1950 to about 11% in 1983; on a per-person basis this is equivalent to 20-30 kg or 104 x $10^6$ t, whereas the corresponding figure for developed countries is 400-600 kg. The total number of countries that have established integrated steel plants in Africa, Asia, and Latin America is few -- about 13 -- and the degree of self-sufficiency, that is, percentage of demand provided by local production varies markedly by region: Latin America 73%, Asia 56%, Middle East 12%, and Africa 7%. Africa's abysmal performance is also illustrated by its per-person steel consumption -- about 8 kg (compared with about 300 kg for developed countries).

Practically all projects under implementation in subsaharan Africa, with the exception of the Ajaokuta Plant in Nigeria, have been either abandoned or frozen. Similarly, with the exception of SICARTA in Mexico and ACOMINAS, COSIGUA, and some minor projects in Brazil, all steel projects in Latin America have been either frozen or cancelled. In contrast, countries of Asia (China, South Korea, Taiwan) have displayed dynamism, have enjoyed healthy project financing, and have installed capacities at low costs, emerging generally strong in steel technology.

The commonest cause of delays and cancellation is shortage of funds. The extensive infrastructures normally required to support steelmaking projects in developing countries contribute significantly to the total costs, and few countries can make the investment without securing loans. The external debt carried by developing countries is such that creditors have been reluctant to provide additional loans, especially as most developing countries have experienced serious difficulties servicing their debt. Also, the nature and the source of financing strongly influence project implementation: projects with a high percentage of local equity, as in South Korea, rarely suffer project delay (UNIDO 1986).

Steel development demands a high level of skills, technical and organizational capability, and systemic sophistication (supply of capital goods and technical services). These are components that are available (partially or wholly) in most of the Asian nations, whereas they must be imported by African countries and paid for in foreign currency. Lack of financing, therefore, is a sign of more fundamental problems.

Because of the large, diverse, and specialized nature of steelmaking equipment, investment in just the technology, especially for integrated plants, is thousands of millions of dollars. The cost per unit of installed capacity has risen over time (an average US$350/t in 1965 compared with US$1700/t in 1980) and varies markedly between regions (UNIDO 1986) (Table 1). The costs are still rising so time overruns are very expensive, and the increase in costs from delays sometimes makes project completion practically impossible.

The large capital requirements limit ownership in developing countries to governments and usually joint ventures (Maxwell 1982). Other characteristics of steelmaking contribute to the profound effects such investments have on the economy. Maxwell (1982) summarized them as the indivisibility of steel plant equipment, the long gestation, the irreversible nature and widespread implications of the process chosen, the idiosyncrasies of each plant, and the complexity of the processes. For example, because of the indivisibility of equipment, designers (initially or during expansion) prefer to build in extra capacity in units like rolling mills. Then overall capacity can be expanded without unduly large investments in new plant units. These add-ons -- temporarily (and indefinitely) unproductive -- can be a dilemma for steel plant designers.

**Long Gestation**

A long gestation is inextricably linked with inflated costs. The bigger the project, the higher the costs of delay, manifesting in contractual escalation costs, production losses, and prolonged paybacks

Table 1. Cost (US$) per unit (t) of installed capacity in selected countries (UNIDO 1986).

| Region and country | Company | Year | Cost (US$/t) | Comments |
|---|---|---|---|---|
| **Subsaharan Africa** | | | | |
| Tanzania | -- | -- | 400 | Project frozen indefinitely |
| Uganda | -- | -- | 3500 | -- |
| Nigeria | Delta | -- | 2000 | Includes infrastructures |
| | Ajaokuta | -- | 6000 | Includes infrastructures |
| **North Africa** | | | | |
| Algeria | Bellara | -- | 2000-3000 | Estimate |
| Tunisia | El-Fouladh | -- | 600 | Expansion, $8 \times 10^4$ t/year |
| Libya | Misurata | 1981 | 2700 | Estimate |
| Egypt | Dekheila | -- | 1000 | Estimate |
| **Latin America** | | | | |
| Mexico | SICARTA | 1976 | 850 | -- |
| | SICARTA II | 1982 | 2000 | Estimate |
| Brazil | -- | -- | 500 | Expansion |
| | ACOMINAS | 1986 | 900 | -- |
| | -- | 1979 | 1200-1700 | -- |
| | -- | 1985 | 3000-4000 | -- |
| **Asia** | | | | |
| Pakistan | PIPRI | 1979 | 1900 | -- |
| India | Vizakpatnam | 1985 | 3000 | -- |

continued

Table 1 continued.

| Region and country | Company | Year | Cost (US$/t) | Comments |
|---|---|---|---|---|
| | Tata | 1985 | 1000 | Expansion, 2.4 x $10^6$t |
| China | PAOSHAN | -- | 3000 | -- |
| Taiwan | CSN-Kaoshiung | 1978 | 430 | 1st stage |
| | | 1982 | 700 | 2nd stage |
| | | 1986 | 500 | 3rd stage |
| South Korea | Posco (POHANG) | 1982 | 422 | 9.6 x $10^6$t/year |
| | Kwang Yang | -- | 650 | 1st stage, 2.7 x $10^6$t/year |
| | KISCO | -- | 850 | Expansion |

with attendant interest payments on borrowed money. Public exasperation with the steel projects in Nigeria has been largely caused by the long time that it has taken the plants to materialize as well as the huge sums of

money invested. The repercussions on the economy as a whole are so widespread and debilitating that an investigation of the sources and causes of long gestation is almost essential for a study such as this one.

Projects like the creation of steel plants are a process: a series of interconnecting actions -- past, present, and future -- not "phased" or discrete periods of development. Past actions and outcomes largely influence current and future actions and decisions. In other words, the evolution of a project such as Ajaokuta Steel Plant in Nigeria is affected as much today by decisions taken at its conception as it is by, for example, a decision to add a new slab caster. In fact, the decisions taken 15 years ago may have compelled the contemporaneous action. Nevertheless, classifying decisions and events into phases or categories simplifies analysis and discussion. Gestation, as used by Maxwell (1982), comprises all the events from preinvestment through construction and startup to operation.

Preinvestment starts when the company that will build, own, and operate the plant is legally constituted. In this period, planning, feasibility studies, and financial negotiations are undertaken. Political sanction is also obtained.

Construction begins when the preinvestment effectively ends, consisting of civil engineering works; procurement and construction of structural and infrastructural facilities; erection and installation of process plants; dry testing; and commissioning. Detailed engineering and fabrication of equipment may predate this phase. Startup of steelmaking is taken to mark the end of the construction period, although other sections of the plant may begin operations later.

Startup, according to Maxwell (1982), lasts "from the beginning... of production...till the achievement of annual output..., which corresponds to...nominal production capacity." Under this classification, some plants (especially in developing countries) remain in this phase indefinitely without achieving anything near their nominal capacity because of a myriad of constraints (management problems, inadequate raw materials, power outages, and absence of ancillary facilities). Maxwell has subdivided startup, defining "technical startup" as the period from the start of production until staff learn to operate the plant. Implementation is the sum of time involved in construction and startup.

The literature on Latin American steel plants indicates that a long gestation for greenfield plants is the rule, rather than the exception. The time involved ranges from 3 to 19 years with an average of 10-11 years for both greenfield plants and major expansions. The average is 3-4 years each for preinvestment, construction, and startup.

A look at Indian plants reveals a similar pattern. Bokaro Steel Ltd was incorporated in 1964, with commissioning, for an initial capacity of 1.7 x $10^6$ t, scheduled for 1971. Actual commissioning was 1976. Implementation took 2 years. The expansion to 4.0 x $10^6$ t, scheduled to be completed in 1977, was realized in 1984.

The first stage of Bhilai
Steel Plant had a modest time overrun of 2 years (1959 versus 1961), but expansions to 2.5 and 4.0 x $10^6$ t had 8-year overruns. In the case of Ajaokuta, 12 years passed (1971-83) between the incorporation of a formal body to oversee steel development in Nigeria to commissioning of the finishing mills (wire rod mill and light section mill). A rescheduling took place in 1985 and 19 years will have slipped by (1971-90) before the full integration of the plant. What's more, the revised schedule has been termed optimistic by many. This record compares with the longest gestations documented in recent literature -- the expansion of the Acerias Paz del Rio Plant (19 years) and establishment of the Chimbote (18 years) and Somisa plants (16 years).

The reasons for such long gestation are relatively few. Preinvestment is delayed by either a shortage of funds for the capital-intensive operation or a political intervention -- usually government's planning of the steel industry. The main reasons for long gestation in construction include suspensions of foreign exchange remittances by the central bank, delays involved in securing financing of equipment from suppliers, equipment delivery delays, and organizational problems. Startup seems to be bedeviled by conceptual errors in design of the overall or an individual plant; weaknesses or defects in equipment fabrication or plant construction; inadequate preparation of the plant's workforce; shortages in supply of key raw materials such as iron ore and coal; shortages in the supply of key services like electricity; overoptimistic demand forecasts.

This list of problems has been distilled from case studies (Maxwell 1982). One of the key problems is building on a "greenfield" location -- virgin lands in developing countries, which incurs 75% more spending than an industrialized site and 35% more than a site with some infrastructure (UNIDO 1983). This is demonstrated clearly in Maxwell's study (1982, p. 107):

> In the Paz del Rio plant, the lack of availability on time of the planned electrified railway to haul ore and coal from nearby mines to the plant led to some shortages in these raw materials during the start-up period...while lack of sufficient electricity supply slowed...production in Paz del Rio and Chimbote greenfield plants.

These examples run disturbingly parallel with what our study has documented for Ajaokuta Steel Plant. Recently, African Business magazine (May 1986) reported comments by the minister for steel development, Professor T. David-West:

> It would have made more sense to have given priority to...iron ore mining...than to the construction of the steel mills. Mining at Itakpe in Kwara State should logically have started five years before the Ajaokuta works were commissioned.

The former minister also remarked that it was "important to synchronize the development of the mine with the completion of the Ajaokuta blast furnace." These observations are quite poignant because of the serious lags that existed between the development of the mines (as well as other infrastructure) and the steel plant.

The problems can be grouped not only by phase but by focus:

- Finance, including shortage of foreign exchange, high indebtedness, complete or almost total importation of capital goods, technology, and engineering services.
- Planning and management resulting from inexperience, low levels of technological and organizational skills, and lack of precedents.
- Political control, bureaucratic interference, and shifting government policies.
- Mode of execution, including behaviour of contractors involved

with project implementation in terms of perceived advantages and commitment.

- Available and required infrastructure.
- Conceptual design, fabrication, and modifications.
- Lack of critical inputs, such as raw materials, spare parts, and consumables, power supply, etc.
- Inexperience of personnel, particularly the startup team.

How much damage is incurred by any one of these focuses is determined directly by the size, complexity and nature of the project.

The seeds of long gestation are planted long before the effects are noticed and current as well as future actions and decisions could be enriched by a careful look at decisions taken ex ante. This demands a review of the evolution of steelmaking in Nigeria.

**The Evolution of Steelmaking in Nigeria**

The Nigerian government, soon after independence, sought to build an iron and steel industry as the core of its industrial infrastructure. The availability of cheap steel in various forms (bars, sheets, and plates) is considered a key to development of nations because iron and steel form more than 80% (by weight) of all metals in general use. Production of steel would, therefore, quicken industrial development and encourage local manufacture of capital goods. Early suggestions were to establish rolling mills, based on imported steel ingots; mini steel plants were also considered to recycle steel scrap.

Feasibility studies were commissioned and examined. The discovery of iron ore deposits at Udi and Agbaja and coal at Enugu, however, along with the potential for electricity from the Kainji Dam Project, then approaching completion, favoured the establishment of an integrated iron and steel complex.

Broadly, the two steelmaking processes involve either mini steel facilities or integrated plants, the latter of which are typified by a conventional blast furnace/open hearth furnace (BF/BOF or OHF) or a direct reduction electric arc furnace (DR/EAF). Mini steel facilities are characterized by low economies of scale; low investment per tonne of installed capacity; rapid construction and, thus, reduced time and cost overruns; relatively fast and simple buildup of production; low energy consumption, especially for scrap; and negligible associated environmental pollution. The main disadvantages are a restricted product mix; an expensive main energy source (electricity); and vulnerability to price fluctuation and availability of scrap. Integrated plants have an advantage where markets are large, annually producing up to $10 \times 10^6$ t of steel in diverse shapes and items; also they can combine different sources of energy. However, they require large capital outlays; often incur cost and time overruns during construction; experience a slow production buildup; require an extensive infrastructure and organization; and pollute the environment.

Between 1961 and 1965, several firms were invited to submit proposals for the construction of an integrated iron and steel complex in Nigeria. These firms, all of Western origin, were of the opinion that available raw material could not support an integrated steel works economically with the available technology. A proposal was, however, accorded serious examination. This was for a plant using the "strategic Udy process," which was then at pilot plant stage, under development in the USA. The government formed the Nigerian Steel Associates, a joint venture with Westinghouse and Koppers. The project did not, however, take off as the process did not pass commercial-scale testing.

In 1967, a UNIDO study cited Nigeria as a potential market for steel, and a team of Soviet steel experts visited Nigeria the same year to conduct a study into the feasibility of establishing an integrated iron and steel works. Their study recommended a blast furnace/basic oxygen route of iron and steelmaking. The study admitted that the local ores were of poor quality and recommended further geological surveys. A contract was awarded in 1970, to Technoexport of USSR, to determine the quality and quantity of deposits of iron ore, coking coal, limestone, dolomite, and refractory clays available in Nigeria for the operation of an iron and steel complex.

In 1971, the Nigerian Steel Development Authority (NSDA) was formed. The Authority was responsible for the planning, construction, and operation of steel plants in the country as well as carrying out necessary geological surveys, market studies, and metallurgical research. The Authority also examined various processes, including direct reduction with natural gas, even though this process required high grade iron ore not known to be available in the country. On this basis, the NSDA, in 1973, commissioned V/O Tiajpromexport (TPE) to prepare a preliminary project report for the proposed steel plant.

The report recommended that production of $1.3 \times 10^6$ t of long (rods, bars, and light structures) and flat products. The plant was to be sited at Ajaokuta and would utilize iron ore from Itakpe. NSDA accepted the report's recommendations in 1975 with a few modifications, mainly in the plan for production: $1.3 \times 10^6$ t long products in the first phase and $2.6 \times 10^6$ t (an added $1.3 \times 10^6$ t flat steel sheets) as soon as expansion was feasible.

In the same year TPE was commissioned to prepare a detailed project report based on the earlier recommendations. The resulting document recommended an integrated steel works, the first phase of which would include:

- A plant with two batteries of 49 coke ovens each, for a total annual capacity of $9 \times 10^5$ t of coke;
- A plant with two sintering machines producing a total of $2.64 \times 10^6$ t/year;
- A plant consisting of one blast furnace producing pig iron -- $1.355 \times 10^6$ t/year;

- A plant to produce lime -- $9.1 \times 10^4$ t/year;
- A plant for processing the by-products of the coke ovens to produce dehydrated tar, ammonium sulfate, etc.;
- A plant for steelmaking -- two LD converters, 135-t capacity each, and three 4-strand continuous casting machines;
- A complex incorporating a billet mill with a capacity of $7.9 \times 10^5$ t/year, a medium section and structural mill of $5.6 \times 10^5$ t/year, a light section mill and bar mill producing $4 \times 10^5$ t/year, and wire rod mill of $1.3 \times 10^5$ t/year.

Also, the report provided for early expansion to $2.6 \times 10^6$ t steel/year, half of which would be flat products. The final expansion would be to $5.2 \times 10^6$ t/year. At this stage, more flats as well as heavy sections would be produced. The report was submitted in September 1977 and accepted in 1978 after several modifications. The plant layout was broadly specified and a tentative master schedule for completion of the plant was included.

Then started a series of protracted negotiations between NSDA and TPE for the construction of the plant. Negotiations were frequently deadlocked, and a final contract emerged only after a high level delegation (led by the Chief of Staff, Supreme Headquarters, General Musa Yar'Adua, then the de facto Vice President under the military government of General Obasanjo) undertook a journey to the USSR and met with high level Kremlin officials. Finally, in July 1979, a contract was signed with TPE for the preparation of working drawings, supply and installation of equipment, and construction of special steel works for the Ajaokuta Steel Project.

In 1979, NSDA was broken up into various organizations, including Ajaokuta Steel Co. Ltd (ASCL). In 1980, a contract for civil engineering was signed with Western firms; Wimpey was to do the building of a metallurgical training complex and BOSKALIS, a river port. Project management was awarded to Pan African Consultancy Services Ltd (PACS) and Metallurgical Engineering Consultants (MECON) of India. Construction work began the next year, but within 2 years erection came to a virtual standstill, and the partners began to negotiate and attempt to reactivate civil works and to set up a more realistic contract.

**Other Steel Projects**

Ajaokuta was not the only steel project of the government. In 1975, the federal government was advised of the potential for production of steel by direct reduction (DR), with the fuel being some of the natural gas that was being flared at the time.

A delegation from Nigeria toured various countries to see the types of DR plants in operation and assess their performance. Following this, the government decided to establish two DR-based plants: one in Port Harcourt and the other in Warri, each with a capacity of $5 \times 10^5$ t/year. One of the plants was finally shelved, and, in October 1977, an agreement was reached between the federal government and a consortium of 10 German and Austrian firms to construct a plant with an annual capacity for $1.0 \times 10^6$ t/year liquid steel. Part of the steel would be finished in the plant's $3 \times 10^5$ t/year light section mill while the remaining steel would be rolled in major market centres in the country.

In 1979, contracts were signed for three rolling mills, to be built in Katsina, Jos, and Oshogbo. The Katsina plant was constructed by Kobe of Japan while the Oshogbo and Jos plants were constructed by German companies. Each of the plants was designed to produce bars and wire rods -- $2.1 \times 10^5$ t/year. These were to be rolled from billets produced in Aladja.

The Delta Steel Plant was commissioned 29 January 1982, while the rolling mills, were completed on a turnkey basis.

Apart from the ambitious programs, undertaken all at once, the 1981-85 development plan made provisions for:

- A flat products plant with a capacity of 1.5-2.0 x $10^6$ t/year to be finished into sheets, plates, coils, thin plates, and welded pipes;
- An alloy and special steels plant to produce 8-18 x $10^4$ t/year;
- An iron and steel foundry complex; and
- An aluminum smelter.

The contract required TPE to supply and install units. NSDA was required to arrange for the civil works of the plant and the erection base and to build a river port.

The strategies and sequence adopted may be examined with the benefit of hindsight. The initial options can be summarized as the establishment of:

- Mini steel mills using scrap and an electric arc furnace;
- Rolling mills; and
- An integrated steel works.

The rolling mills were scheduled for completion up to 3 years before the primary plants and, when completed, would have to operate at less than 20% capacity because of the lack of steel available to roll.

The proposal for mini steel mills was questionable because the local supply of good scrap was poor and the infrastructure couldn't support steelmaking by an electric arc furnace. However, as such plants are usually of low capacity, the experience gained in establishing and operating them could have offset some of the costs from a lack of economic feasibility.

The approach adopted resulted in a long gestation and a huge escalation in costs.

The total capacity for long products was to be 2.36 x $10^6$ t (including private rerollers), although projected demand for long products was 7.5 x $10^5$ t/year and for flat products 8 x $10^5$ t (Table 2).

Undertaking these overly ambitious projects at the same time turned the steel dream into a nightmare. Today the federal government of Nigeria owns two contracts for integrated steel plants -- Ajaokuta employing the conventional BF/BOF process and Delta making use of the DR/EAF technology, with combined installed capacity of $2 \times 10^6$ t/year. The government also has three inland rolling mills with a total capacity of $6.3 \times 10^5$ t/year, the raw material for production to be billets from the uncompleted integrated plants. The rolling mills will compete with private steel mills (Table 3). Even if finances had not dried up and all projects had been completed as planned, the labour force capable of managerial and technical

Table 2. Projected steel demand, Nigeria ($10^3$ t/year) (Nigeria, PRC 1981).[a]

| | World Bank | PRC (Nigeria Ltd) | | Economic Commission for Africa | | | |
|---|---|---|---|---|---|---|---|
| Projection for | 1990 | 1990 | 1995 | 1990 | | 2000 | |
| Ingots | - | - | - | 183 | (222) | 417 | (689) |
| Bars, rods, light structurals | 1440 | 2222 | 3306 | 948 | (1148) | 2156 | (3559) |
| Medium structurals | 350 | 803 | 1251 | - | | - | |
| Flat products | 1880 | 3513 | 4060 | 1162 | (1407) | 2643 | (4362) |
| Tubes, pipes | 250 | - | - | 764 | (926) | 1739 | (2870) |

[a] Total demand projected by PRC was similar to that by MECON for 1985 (4.7 and $4.0 \times 10^6$ t) and 1990 (6.9 and $6.0 \times 10^6$ t) but was much higher than that by the Delta Steel Company -- 1985: $2.8 \times 10^6$ t; 1990: $3.6 \times 10^6$ t.

Table 3. Capacity and location of privately owned rolling mills in Nigeria.

| Firm | Location | Installed capacity ($10^4$ t/year) |
|---|---|---|
| Qua Steel | Eket | 10 |
| Universal Steel | Ikeja | 8 |
| Continental Iron and Steel | Ikeja | 15 |
| Sels Metal | Ikeja | 10 |
| Federated Mills | Ofa | 14 |
| Allied Steel | Onitsha | 10 |
| General Steel Mill | Asaba | 5 |
| Nigerian-Spanish Engineering | Kano | 19 |
| Mayor Engineering | Ikorodu | 29 |
| Oro Steel | Ilorin | ?? |
| Kwara Commercial Metal and Chemical Industry | Ilorin | 4 |
| Union Steel | Ilorin | ?? |
| Asiatic Manjarin Industries | Ikorodu | 6 |
| Niger Steel | Enugu | 3 |
| Metcome (Nig) Ltd | Owerri | 3 |
| Others (estimated) | | 2 |

support numbered too few to absorb the technology.

The factors that deserved more consideration during the planning stages included:

- The stage of technological advancement and all available options in the field;
- The pool of trainable or usable personnel;
- The demands and limitations of the market to be served by the

product;

- The effects of the gestation period and the economic climate in which projections have been made;
- The scale, complexity, and nature of processes; and
- The availability of raw materials and infrastructure (Table 4).

The nature, quality, and availability of raw materials employed in steel plants impact on the decision about technology. In fact, input materials and the choice of technique are more or less inseparable. For example, while natural gas is the dominant energy form in the DR/EAR process, it finds only an auxiliary use in the BF/BOF process in which coking coal is the major fuel. Nigeria has fairly large deposits of iron ore but a paucity of coking coal. The coal available is riddled with ash and sulfur. The available iron ore can be beneficiated fairly cheaply to meet the requirements of Ajaokuta's blast furnace, but direct reduction (Delta Steel Plant) demands a high ferrous content (about 66%), from ore with an iron content of 38%. The cost is high. Imported ore may be cheaper than local ore because of the expensive beneficiation and transport. Ajaokuta is already manacled by its reliance on costly imported coking coal. The fuel for DSP's DR plant is natural gas, which is so abundant in Nigeria that large portions of the associated reserves (gas that accompanies oil drilling) are still being flared. The main reserves are practically untouched. Therefore, on one hand, the plant that is operable on a cheap fuel may have to rely on imported iron ore, and on the other is a plant operable with local ore but doomed to imported fuel (coal). The raw materials are about four times the product, and Ajaokuta alone will process more than $5.0 \times 10^6$ t of raw materials to realize its production of $1.3 \times 10^6$ t/year.

Nigeria's iron ore falls into two categories. First are the hematite-magnetite iron mines, the most explored. A reserve at Itakpe, 66 km from Ajaokuta, is estimated to be $300 \times 10^6$ t, containing an average 38% iron,

Table 4. Raw materials for the development of the steel industry in Nigeria.[a]

| Raw material | Source | Role | Plant requirements ($10^3$ t/year) | |
|---|---|---|---|---|
| | | | Delta | Ajaokuta |
| Iron ore | Itakpe Hill, Ajaba Noko, Shoko-shoko, and Agbaja | Sinter; sent to blast furnace to produce pig and molten iron | 1550 | 2200 |
| Coal | Enugu, Lafia, and imported | Carbonized in coke ovens; powers furnace | -- | 1300 |
| Limestone | Jakura, Mfamosing, and Ubo | Used in sintering and heating of iron ore | 130 | 690 |
| Scrap | Recycled and imported | Melted in electric arc furnace; used as coolant in the steel-making shop | 250 | 293 |
| Bauxite | Imported | Used to maintain slag fluidity | ?? | 13 |
| Dolomite | Osara and Burum | Low grade: used as flux in iron making; high grade: used for tarbonded brick refractories | ?? | 250 |
| Refractory clay | Onibode, Oshiele and Ozubulu (Imo) | Used to produce bricks in alumino-silicate plant | ?? | ?? |

continued

Table 4 continued.

| Raw material | Source | Role | Plant requirements ($10^3$ t/year) | |
|---|---|---|---|---|
| | | | Delta | Ajaokuta |
| Manganese (t/year) | Imported | Used to control quality of metal in blast furnace | ?? | 85 |
| Water[b] | Widespread | Cooling | 83 | 120 |
| Natural gas[b] | Widespread | Powers furnace | 2000 | 370000 |

[a] All other materials except oil are imported, including iron alloys, aluminum, sulfur, caustic soda, tar.

[b] Water and natural gas are indicated in $10^3$ $m^3$/hour.

which can be beneficiated relatively cheaply to about 63% iron. The iron ore at Ajabanoko, Chokockoko, and Agbaja is similar to Itakpe ore, with a reserve of 150 x $10^6$ t. The other deposit is an olitic sedimentary type, estimated to be about 3000 x $10^6$ ; it is located in the Agbaja-Lokoja-Koton-Karifi area. It contains high levels of phosphorus and zinc, and beyond the initial feasibility reports, has been investigated very little.

The two known coal deposits in Nigeria are at Enugu and Lafia/Obi. The latter has coking properties but is high in ash and in sulfur, and the deposit itself has structural problems. The Enugu deposit, on the other hand, is reasonably free of the impurities but is noncoking. It may play a role as fuel in a coal blend for metallurgical use, but various studies have been commissioned to this end without success. Thus, coking coal is to be imported from abroad initially. Technologies exist that will ensure at least 20% of a fuel blend could be Enugu coal. The savings would be significant (Oyeyinka 1984). Another deposit at Okaba, has high ash content and low tar yield and disintegrates on carbonization, although its use in the production of steel has not been ruled out.

Limestone is being supplied to Delta Steel by Cross River Limestone at Mfamosing. Delta has equity in the deposit. A deposit at Jakura has been proposed for Ajaokuta because of proximity to the plant, but Jakura limestone would have to be formed into briquettes. As with coal and most of the other materials, the government has not taken a definitive stand on its use, and negotiations include whether or not to award contracts for the supply of briquetting machines.

Deposits of dolomite lie in Burum, near the federal capital ($4 \times 10^6$ t), and Osara ($2 \times 10^6$ t), also not far from the plant site. Both deposits need to be fully explored, and the issues of ownership and mining rights resolved. Refractory deposits are found in Oshiele/Onibode (very far from Ajaokuta) and in Ozubulu (Imo State).

Both bauxite and ferric alloys are to be imported, although low-grade manganese has been reported in Tundun Kudi (northern Nigeria -- $2 \times 10^6$ t) and bauxite in Oju, Benue State.

**The Ajaokuta Dream**

Although not yet reality, the operations at Ajaokuta will be straightforward. The raw materials section consists mainly of open yards and silos to store the ores, coal, lime, etc. A plethora of separators, crushers, and sieves remove unwanted foreign matter, size the output, and segregate the materials before sending them to process units.

To prepare coke, the plant has 49 ovens for each of two oven batteries (5.5 m high, with a useful volume of 30.3 $m^3$). The capacity of the batteries is $9.0 \times 10^5$ t/year. The sintering plant has two machines to produce 100% self-fluxed sinter ($2.64 \times 10^6$ t/year). The plant is part of raw materials' preparation and is designed to use iron ore from the Itakpe mines.

Ironmaking is done by a single blast furnace, $2.0 \times 10^3$ $m^3$ capacity. It has been adapted with facilities for natural gas injection to reduce coke consumption. This produces pig iron, $1.5 \times 10^5$ t annually for use in foundries while the remaining molten iron is sent to the steel shop. The $5 \times 10^5$ t of slag produced annually as by-product is used in cement.

The steelmaking shop consists of two LD converters of 130 t capacity each, three two-strand continuous machines, and the lime shop. There are four rolling mills:

- The 320-mm light section mill,
- 150-mm wire-rod mill,
- The 900/630 billet mill, and
- The 700-mm medium section and structural mill (Table 5).

The greenfield nature of the plant, the unreliability of public utilities, and the dearth of small-scale suppliers in the immediate environment of the plant meant that the development of the steel works had to include special provisions for spare parts manufacturing facilities, power plants, etc. Prominent among the facilities for Ajaokuta were a comprehensive repair complex with its own foundry, forge shop, and heat treatment and hard surfacing shop; a thermal power plant and turbo blower station; an oxygen plant; refractory shops and a lime plant; and laboratories and transportation facilities.

In addition, are facilities generally referred to as the external infrastructure, made up of railways, roads, port facilities, and electric power systems.

For example, there was a proposal to construct a line from Onne port through Port Harcourt to Ajaokuta, although it was shelved for financial reasons. A line between Itakpe and Ajaokuta is to carry iron ore; and the line running from Obi through Lafia and Makurdi is to carry local coal.

Table 5. Product mix of milling operations at Ajaokuta.

| | Size (mm) | Production ($10^3$ t/year) |
|---|---|---|
| **Light Section (320 mm)** | | |
| Equal angles | 25 x 25 to 50 x 50 | 150 |
| Bar flats | 6-12 x 12-70 | 25 |
| Hexagons | 10-26 | 25 |
| Squares | 10-30 | 50 |
| Rounds | 10-30 | 50 |
| Tees | 30-60 | 50 |
| Channels | 30-45 | 150 |
| **Wire rod mill (150 mm)** | | |
| Rod-in coils | 5.5-6.0 | 80 |
| | 6.0-10.0 | 20 |
| | 10.0-12.5 | 10 |
| Concrete reinforcing bars | 6.0-12.0 | 20 |
| **Medium section (700 mm)** | | |
| Universal beams | 80 x 220 | 25 |
| | 100 x 220 | 25 |
| | 80 x 300 | 50 |
| | 160 x 300 | 50 |
| | 152 x 30.5[a] | 50 |
| Broad flanges | 102 x 152[a] | 50 |
| Beams | 100 x 100 | 50 |
| Standard channels | 100 x 240 | 25 |

continued

Table 5 continued.

| | Size (mm) | Production ($10^3$ t/year) |
|---|---|---|
| Light-web channels | 100 x 240 | 25 |
| | 240-300 | 25 |
| | 254-305[a] | 25 |
| Parallel flanges channels | 80 x 250 | 50 |
| Equal angles | 70 x 70 x 11 to 130 x 130 x 12-14 | 50 |
| Unequal angles | 80 x 50 x 5 to 160 x 100 x 9-14 | ?? |
| Bar flats | 10 x 20 x 70-150 | 10 |

[a] This value is the metric equivalent to the size, actually measured in inches.

Onne port was to be built to handle imported raw materials and finished products for Ajaokuta, but with the cancellation of the rail program, the use of Onne port as part of the system is questionable, as is the readiness of the port itself.

Electric power facilities include one 330-kv double circuit transmission line from Benin City to Ajaokuta and a 330/132 kV substation in Ajaokuta; and the captive electric power system at the plant site in Ajaokuta.

## Planning the Plant at Ajaokuta

To understand the setup at Ajaokuta, one needs to look closely at the planning and the subsequent actions of the decision-makers in government. The decision on the site for the plant deserves mention.

NSDA predicated its choice of location for the Ajaokuta Steel Project primarily on the source of iron ore. The locational study contained in the preliminary project report presented a detailed technoeconomic analysis based on scenarios in which local or imported ores were used. The locational study considered (Table 6):

- Operating costs of fuel and raw materials delivery to the steel plant, and shipment of finished products to consumers.
- Capital cost of water, electricity, and natural gas supply to the plant.
- Cost of plant construction, substructure work, and site leveling, specific to each site.
- Cost of construction of the township.

Two suitable zones were defined: the coastal zone stretching for about 100 km between Forcados and Port Harcourt and the central zone of the country along the banks of River Niger south of Lokoja for 50 km to Onitsha.

Eleven possible locations in these areas were distilled down to three: Warri, Onitsha, and Ajaokuta.

The report recommended Onitsha on the premise that the use of local ores would save precious foreign exchange.

Political factors outweighed the economic considerations, although the reasons are a matter of conjecture. The preliminary report was submitted for consideration in 1974: 3 years after a civil war in which the eastern zone of the country (with Onitsha its boundary and trading capital) attempted to break away and set up a separate nation. With the

Table 6. Estimated capital and operating costs ($10^6$ NGN) for a steel plant at three possible sites in Nigeria, 1984 (NSDA 1974).

| | Ore supply | | | |
|---|---|---|---|---|
| | Imported and local | | Local | |
| | Warri | Onitsha | Ajaokuta | Onitsha |
| **Capital costs** | **729** | **609** | **748** | **599** |
| Transport, water, electricity, gas supply | 405 | 341 | 359 | 331 |
| Substructure work and site leveling | 182 | 142 | 231 | 142 |
| Steel plant township | 142 | 126 | 158 | 126 |
| **Operating costs** | **187** | **143** | **201** | **163** |

memories of the war and its scars still fresh, the authorities might have hesitated to site a project of such huge cost in Onitsha. Also, the security of government property and the safety of incoming workers from other regions of the country could not be guaranteed.

In other words, the decision was economically suboptimal but, perhaps, politically justifiable. We suggest that it is no use pretending that noneconomic factors are irrelevant. In fact, they tend to be decisive in developing countries, so policy analysts must seek to accommodate them. In contrast, the decision on technology seemed economically sound. The main groups involved were the main contractor (TPE of the USSR), the Nigerian engineers (NSDA), and the consultants to NSDA (SOFRESID of France).

The preliminary report by the Soviets considered two options for the ironmaking plants:

- Two blast furnaces with an effective volume of 1033 $m^3$ each, or
- A single blast furnace with an effective volume of 2000 $m^3$.

SOFRESID and NSDA engineers agreed that either option would meet the requirement for hot-metal production. The preliminary report pointed out that labour efficiency with a single furnace is higher by about 30%, and the prime cost per tonne of hot metal is about the same for the two options.

Nevertheless, the report favoured the other option to avoid complete shutdowns when repairs were needed. SOFRESID observed that the equipment proposed in the report was obsolete by Western standards and recommended areas for improvement.

The final decision was in favour of a single 2000 $m^3$ blast furnace capable of annually producing $1.355 \times 10^6$ t hot metal and incorporating high top pressures as well as auxiliary fuel injection. Arguments that favoured the single large furnace included an expanding market for steel products, constraints on the amount of available land, and a high rate of capacity utilization. A major drawback of the equipment chosen was its requirement for 100% sinter as raw material. Small furnaces are more tolerant of poor quality raw materials, i.e., more local coal could have been incorporated in the coal blend, and small furnaces are easier for inexperienced operators to manage: mistakes are easier to correct and reliance on instrumentation and controls is less critical.

Given the environment in Nigeria, pure scale effects constitute a less valid reason than furnace availability and operability.

NSDA engineers made their decision without the benefit of hindsight or technical skills that accumulate from operating such plants. They were optimistic that the national economy would remain buoyant to finance an expansion in capacity immediately after the completion of the first phase and that the blast furnace of the first phase would be the training ground for the following ones.

The expected growth in demand for steel products evaporated with the collapse of the economy. Clearly, decision-makers must build in some allowance for uncertainty and change. ASCL probably cannot finance even the coke it requires (US$150 million yearly) under present economic conditions. Movement of the exchange rate has seriously eroded Nigeria's import capacity. In 1986, the exchange rate was about US$1 = NGN 0.60; today it is US$1 = NGN 3.50.

Uncertainty derives not only from the economy but also from the technological environment -- particularly the weak capability to maintain equipment on a sustained level and the lack of local supplies of spare parts and machines. Learning was taken for granted and was not given serious attention in decision-making. The project's evaluators made no attempt to analyze the potential opportunities for gains in technical know-how offered by the two options. In fact, few if any long-term social objectives were considered in the decisions.

The steelmaking shop proposed in the preliminary report consisted of two oxygen converters, each with 130-t capacity. This proposal was accepted, as the concept of oxygen steelmaking was well established. Less clearcut was the decision on the process for casting. Traditionally molten steel is poured into ingot moulds, allowed to cool, and then reheated and shaped. A more recent technique -- continuous casting or concast -- casts the molten steel directly into blooms (typically 260 x 260 or 335 mm x 6 m), billets (100-150 $mm^2$ x 12 m), or slabs. Concasting has increased the yield of cast steel and has great advantages in productivity, material handling, and fuel costs.

The preliminary report recommended the use of concasting, and SOFRESID agreed. However, the consultants did not agree on the product. The Soviets recommended blooms (with later reduction to billets in a mill) and slabs. SOFRESID suggested casting billets directly because of the reduction in capital and operating costs. It is not clear why the Soviets recommended a bloom caster. It is suspected that the technology of billet casting was still new to Soviet steel plant designers; hence there would not have been a manufacturer from the Eastern bloc who could supply the plant.

The advantages put forward for the Soviet proposal were that:

- It is easier to cast blooms than billets.
- It is possible to produce variable sizes of billets in a mill thereby increasing flexibility for sales.
- A billet mill is a simple rolling mill with few stands, and, thus, is not likely to constitute a production bottleneck.
- Natural gas for operation of reheating furnaces is locally available so costs for converting blooms to billets will be a local cost (except for imported rolls and accessories).

The evidence is that Nigerian engineers carefully considered the technical and economic factors involved and decided in favour of bloom casting.

Casting the billets directly would have been preferable, as this would have resulted in some standardization in the rolling mills and would have eliminated the need for a billet mill.

The decision of NSDA engineers could have been influenced by their training in Indian steel plants where continuous casting facilities were not yet available and would have seemed to be a significant advance.

For the rolling mills, the preliminary report proposed a product mix consisting of equal amounts of flat and long products, a total $1.3 \times 10^6$ t. This was based on the current demand.

However, the national economy was booming, and the construction industry was enjoying higher growth than the manufacturing sector. Large office blocks, industrial complexes, and long bridges were being built, and the government had plans for heavy industrial investment in liquefied natural gas, petrochemical plants, and fertilizer plants. All of these would require large amounts of steel sections, mainly long products.

The result was optimism about growth, and this led to a decision that the first stage of the plant would be devoted to long products, and the second -- an expansion to 2.6 x $10^6$ t that was expected immediately -- would be devoted to slabs that could be rolled into flat sheets.

The preliminary report recommended:

- An 800-mm billet mill,
- A 450-mm medium section and structural mill,
- A 250-mm light section and wire rod mill,
- A 1700-mm hot strip mill,
- A cold rolling mill,
- A corrugated sheet mill,
- A hot rolled coilcutting unit,
- An electrolytic tinning unit,
- A pipe spiral welding plant, and
- A pipe electric welding plant.

This proposal was based on the recommended production of equal amounts of long and flat products. The steel concast plant would be made up of one bloom caster and two slab casters. The blooms cast would be further reduced in billet mills, then finished in 450-mm and 250-mm mills. The slabs would be reduced first in the hot strip mill and the cold rolling mill before being finished as corrugated sheets, electrotinned sheets, spiral welded pipes, and electric-resistance welded pipes.

Hindsight shows that the change of the original concept of the plant was a grievous error. The overall interest of the country would have been served best by a mixture of flat and long products. Today, Nigeria is flooded with long products, and every industrial concern voices the demand for flat products. The refrain has led the government to adopt what it calls "Accelerated phase of expansion -- flat products stream." What it proposes is to add a slab caster, a hot strip mill, and a cold rolling complex with associated auxiliary facilities to produce hot rolled and cold rolled products. The new setup would take about half the molten steel from the units of the first phase (that is, no expansion in capacity initially). The implication is that a decision rejected more than a decade ago is now being adopted at a huge cost.

Optimism about future economic growth was probably also to blame for the inclusion of a medium section and structural mill, which was done at the suggestion of NSDA. The contractor noted that demand for medium sections was low and recommended, instead, a section forming unit. A forming unit offers higher labour efficiency and lower capital cost than a medium section mill. It is, however, slower and not amenable to high tonnage production.

NSDA engineers decided in favour of a high capacity medium section and structural mill to anticipate growth in demand from heavy industry, including the plant itself. The final design of the rolling mill was further modified, after the detailed project report, at advanced stages of project execution to incorporate production of rails. Thus the concept behind the design of the mill, that of supporting national infrastructural development, was broadly reinforced. The mill is designed to produce 249 standard profiles of structural sections and $1.0 \times 10^5$ t of steel rails -- a total capacity of $6.1 \times 10^5$ t.

The maintenance philosophy put forward in the preliminary report at the suggestion of Nigerian engineers was a central system of repair facilities. Thus the report made elaborate provisions in departmental workshops for machining of new spare parts and consumable equipment. Provision was also made for large repairs -- an iron and steel foundry, forge and fabrication shop, machine shop, and a shop for heat treatment and hard surfacing.

SOFRESID questioned the rationale for such enormous facilities, saying that:

- The provision was excessive for a steel plant by usual standards;
- The plan featured duplication and overequipping of the departmental shops.

Table 7. Requirements for spare parts in repair shops.[a]

| Repair items | Estimated annual requirement ($10^3$ t) | In-plant production ($10^3$ t) | Balance to be bought ($10^3$ t) |
|---|---|---|---|
| Iron castings | 4.33 | 4.23 | 0.10 |
| Steel castings | 4.58 | 4.48 | 0.10 |
| Nonferrous castings | 0.19 | 0.19 | - |
| Forgings | 4.48 | 2.28 | 2.20 |
| Long products | 2.10 | - | 2.10 |
| Steel structures | 2.50 | 2.20 | 0.30 |
| Cast-iron rolls | 0.86 | - | 0.86 |
| Steel rolls | 1.60 | - | 1.60 |
| Copper plates | 0.17 | - | 0.17 |
| Machining of new parts and consumable equipment | 8.36 | 8.29 | 0.07 |
| Remachining for reclaiming and rehabilitation | 1.43 | 1.43 | - |

[a] Plant design capacity with a two-shift operation.

The shop also featured excessively large cranes (for example, 10-t crane was proposed for the forge shop where the maximum weight of a forged part would be 500 kg; 30-t cranes were proposed for the steelmaking shop, although the maximum weight of steel structures expected was 10 t). The repair shops proposed for power equipment would be able to cope with repair of 13 000 electrical items annually. The estimated requirements for spares at the facilities were astronomical by any standards (Table 7). Also featured were a rubberizing workshop, an equipment storage and charging station, a block of workshops dedicated to the steelmaking plant, a workshop for the rolling mills, a workshop for rolling stock, and a workshop for the coke-oven and by-product plant.

In spite of objections by SOFRESID the proposal was essentially upheld with a slight downsizing of the design provisions in the detailed report.

The repair shops were to supply 67% of the spares, although some are specialized products that cannot be economically produced outside dedicated plants. That the work, according to the report, represented a two-shift operation suggested that 50% increase was possible in three shifts.

In engineering circles, Soviet equipment is regarded as generous in its allowance for capacity. It is large and electronically unsophisticated. The Soviets make allowances for weak industrial cultures by building in extra capacity. For example, a Soviet contractor will supply a 2500-t/day furnace to a developing country, labeling it a 2000-t/day furnace. This is safe for the contractor as it is then easy to demonstrate the guaranteed performance, and plant operators are able to meet design capacity easily.

This practice has endeared Soviet technology to several developing countries where most steel plants have remained wholly government owned.

Overdesign is not necessarily negative. It may serve as the basis for growth and minor innovations. For example, Maxwell (1982) observed the preponderance of overdesign in some Latin American steel plants, noting that initial imbalances removed the need for investment in new capacities during expansion.

The elaborate provision for spare parts manufacturing was aimed at developing a local capability for repair and replacement of worn plants and manufacturing whole machines where necessary. Development of the capability for effective utilization of these plants would lead to the independence of the plants from outside suppliers and would be a base for manufacturing parts (in case of amendments to the design of the contractors' equipment in order to adapt it to specific local conditions or increase the productive capacity).

What in an economist's view is overcapacity could in the long run provide the financial buffer that enables the steel plant to break even. The facilities already have received a deluge of manufacturing orders from outside firms.

Dahlman et al. (1978) have documented how the repair shop of USIMINAS steel plant grew into a successful manufacturing concern through systematic investment in human and material resources. USIMEC (the name of the machine-making subsidiary) designs and builds all needed capital goods for USIMINAS and serves outside consumers. What USIMEC is doing for USIMINAS, the Growth Shop is doing for Tata Iron and Steel Co. (TISCO) in India.

The reason that such commercial endeavours are possible is that local suppliers cannot support industry. This is underlined by the experience at Delta Steel Plant: 6 years after commissioning, Delta (which is nearer than Ajaokuta to an established industrial environment) still cannot obtain the rudimentary spares and consumables locally.

In other words, great foresight was displayed in the design of the repair facilities. The Soviets, probably because of their experience in supplying steel plants to developing countries, favoured the adopted approach, whereas SOFRESID, the French consultants, found the facilities superfluous. In France, it may not be cost-effective to burden a firm with such provisions, which in themselves may pose organization problems.

**Thermal Power Plant**

Process equipment of the steel plant can be categorized on the basis of its tolerance to power interruption. Equipment that may create danger to operating personnel or sustain severe damage is usually regarded as critical equipment and must be supplied power from at least two feeders.

In most developing countries, the prime source of power is the national grid, supported by a by-product power generation from within the steel plant itself. A minimum of 30% of the peak power demand should be generated within the plant for security reasons, even when the plant can purchase all its power requirements.

The preliminary report recommended three 55-MW generators, fueled by oil or natural gas. SOFRESID recommended an alternative that would make the steel plant totally independent of the national grid and even generate an excess to sell to the national grid, using three 110-MW generators. NSDA engineers opted for two 55-MW generators to generate 100 MW. The peak power demand is 220 MW. The in-plant power generation was based on the available by-product fuel and the minimum power demand to carry the critical equipment of the plant.

The two independent sources of power are a technical requirement, although some agencies contend that both sources may come from the National Electric Power Authority (NEPA). This argument is flawed by the fact that NEPA has never been reliable.

However, running a full size 110-MW power plant places a heavy load on the technical and organizational management of the steel plant. The organization has to cope with power generation (a large complex plant on its own), a spares-manufacturing complex, and large waterworks, and the integrated steel complex. The diverse activities require a very able technical administration. The integrated plant includes plants with widely different technical characteristics. For example, the coke oven by-product plant is similar to a petrochemical complex and a mini fertilizer plant; the link between ironmaking, steelmaking, and continuous casting is sensitive to, and intolerant of, poor planning and sloppy management. Because of the managerial competence required, some form of goal-oriented decentralization seems appropriate, although it may also be a source of problems. Where government allocation of finances to projects can be affected by pressure groups and the priorities of government change rapidly because of political instability, one section of a project may proceed smoothly while another essential component, under a separate management organization, experiences delay.

A good example is the development of the Itakpe mines: the contracts for the ore beneficiation plant and the Ajaokuta-Itakpe rail line were not awarded until 1987, 4 years after the blast furnaces at Ajaokuta should have been commissioned, and the contracts require a minimum execution time of 22 months. How developing countries, with their limited resources, can avoid such incongruencies is unclear. The choices seem to be one large organization with complex and diverse technical arms under a single umbrella or a number of independent smaller organizations trading services with each other but with a central coordinating agency.

## Major Actors and Their Roles in the Ajaokuta Steel Project

The actors -- their activities, management capabilities, and strategic conceptions -- strongly influenced the events and shaped the evolution of the firm. The Ajaokuta project involved three main types of actors:

- The owner or client -- ASCL as proxy for the federal government of Nigeria;
- The development contractor -- TPE, the Soviet company that supplied working drawings, and structures as well as installing the process units; and
- The contractors for civil engineering work -- primarily Fougerolle Nigeria Limited/Fougerolle SA; Bilfinger and Berger Bauaktiengellschaft/Julius Berger Nigeria Limited, and Dumez Nigeria Limited/Dumez Afrique, although George Wimpey was awarded a contract for the training school complex; Boskalis was

contracted for the river port; and two of the civil works contractors (Julius Berger Nigeria Limited and Fougerolle Nigeria Limited) were given contracts for infrastructure.

Most capital-intensive enterprises in developing countries are totally or partially owned by government. Therefore, ultimately government control or influence on project implementation and subsequent running of the firms is significant and fashions the path of development of the enterprise. Nigeria is no exception. This difference between developing and industrialized country firms is crucial.

The major obligations of the development contractor in the Ajaokuta project were:

- Preparation of working drawings for all the construction, erection, and special civil works;
- Delivery of the equipment, steel structures, refractories, rolled stock, pipes, and other articles and materials required to carry out the erection and special civil works at the plant units and the erection base;
- Erection and special civil works at the plant units and the erection base as well as training of Nigerian workers to master the erection specialties;
- Supervision of startup and commissioning of plant units;
- Provision of technical assistance during the operation of the plant, as spelled out in a supplementary contract; and
- Training of Nigerian personnel to operate the plant.

The main obligations of ASCL for the execution of works were:

- Preparing the units and the site for erection, including readying storage areas for equipment, steel structures, pipe, refractories, etc.
- Undertaking civil work for the construction of the erection base;
- Ensuring availability of river and sea ports and river port facilities;

- Building upland and lowland canals;
- Providing offsite water supply, sewage treatment, rail and roads, and natural gas pipelines;
- Ensuring availability of national and international communication facilities;
- Establishing township for main contractor and Nigerian personnel;
- Investigating further sources of raw materials (coal, limestone, dolomite, refractory clays, and iron ore concentrate) and submitting the results to the contractor at a stipulated time to be determined later;
- Coordinating, managing, and supervising construction of all the plant in cooperation with Soviet experts participating in the technical supervision of civil works to guarantee quality of work; and
- Providing local personnel for erection work.

Perhaps the most critical of ASCL obligations was civil works, without which the site could not be made ready for installation of plants and equipment. This component of construction turned out to be the rate-determining step in the evolution of Ajaokuta and the Achilles' heel.

Details of the civil contract were finalized in September 1980. The broad schedules for construction of civil works and erection of steel structures and equipment were agreed on by ASCL and TPE during a series of meetings in Moscow lasting from December 1980 to February 1981.

For the main civil contractors, the plant site was divided into three lots (Table 8).

By the middle of 1981 all the contractors had overcome the problems of site access and had their workforces fully mobilized. The tempo of work built gradually and continued for 2 almost years. The first signal of a major disruption was in July 1983 when Dumez and Fougerolle started slowing their pace. By December 1983, Dumez had completely stopped work. In August 1984, Fougerolle limited work to minor finishing touches and

Table 8. Division of lots for civil works contracts in Ajaokuta Steel Plant project.

| Lot | Contractor | Civil work for: |
|---|---|---|
| I | Fougerolle SA/Fougerolle Nigeria: joint venture | Raw material plants, coke ovens, blast furnace, thermal power plant |
| II | Bilfinger and Berger | Steelmaking shop and rolling mills |
| III | Dumez Nigeria/Dumez Afrique: joint venture | Auxiliary shops, lime and refractory plants |

demobilized almost completely the expatriate personnel.

Bilfinger and Berger continued work and, by the third quarter of 1986 had almost fulfilled the obligations as well as picking up work left undone by the other two contractors. For example, work abandoned by Dumez and required for the commissioning of the mill and the power plant was transferred to Bilfinger and Berger in January 1985. The units involved were the water recirculation system, the mechanical repair shop, the forge and fabrication shop, and the power equipment repair shop. The transfer has enabled these units to reach an advanced stage of completion. The performance of the contractors was clear from the proportion of work completed (Table 9).

The major reason for deceleration and eventual demobilization by the civil contractors was that funds earmarked for the project were exhausted primarily because of forces external to the firms. When the contract was negotiated, it was anticipated that the economic landscape was not stable and a cost escalation factor was included in the agreement. However, allocations did not take into account potential escalations and the negotiated loan was frozen at NGN 838 million.

Table 9. Status of civil works to be completed for commissioning of major units of the Ajaokuta Steel Plant, 1981-86 (PACS/MECON 1987).

| | Progress (weighted average %) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | Total to December 1986 |
| Priority mills (light section and wire rod) | 11.96 | 67.25 | 20.25 | commissioned | | - | - |
| Thermal power plant and turbo blower station | 6.83 | 26.76 | 30.47 | 22.04 | 7.75 | 2.46 | 36.31 |
| Billet mill | 1.70 | 2.08 | 31.19 | 35.49 | 14.39 | 10.04 | 94.89 |
| Coke ovens and by-product plant | 3.95 | 19.81 | 23.84 | 7.98 | 3.41 | 2.28 | 61.27 |
| Ironmaking plant | 5.34 | 18.26 | 24.60 | 14.05 | 3.83 | 2.71 | 68.79 |
| Steelmaking plant | 4.64 | 8.47 | 26.24 | 24.50 | 2.38 | 2.43 | 68.63 |
| Raw material preparation plant | 2.99 | 14.49 | 33.67 | 7.40 | 2.75 | 3.74 | 65.04 |
| Medium section mill | 1.55 | 0.48 | 7.45 | 17.78 | 22.30 | 23.97 | 73.53 |
| Other | 0.67 | 14.04 | 2.51 | 2.51 | 12.40 | 12.83 | 44.96 |

Moreover, wages and salaries were based on prices in 1981, and no allowance for increases was made. Sociopolitical and economic forces were already at work to make a mess of the calculations. A new civilian administration was voted into power at the end of 1979. The government, as part of its economic program, abrogated the system of zoning whereby skilled, semiskilled, and unskilled labour were paid at different rates. An increase of between 196% and 384% in wages resulted for some categories of labour.

The world economic recession with its concomitant effect on the Nigerian economy induced the introduction of the Economic Stabilization Act, which caused sharp escalations in the costs of raw materials (both local and imported), transportation, and services.

The civil contractors utilized enormous amounts of cement and steel structures purchased locally and abroad and hauled large quantities of these materials over long distances. Thus, their costs were seriously affected.

Also, tenders in March 1980 for civil contracts left out main units and offsite facilities necessary for the general operation of the plant; for example, the permanent water supply intake, water treatment plant, general purpose drinking water supply, sewage treatment plant, sludge disposal system, and plant boundary wall were not included because the design data and specifications were inadequate. Similarly, construction of low-cost housing for officers of civil contractors and site facilities subsequently added to the costs of civil works.

Other key infrastructure outside the 1980 tenders was the river port and the metallurgical training complex. These eventually ballooned costs.

During construction, changes are made: equipment is added to strengthen original designs; excavations and earth fillings deviate from original estimates; and design errors compel modifications and therefore substantial cost revisions. For Ajaokuta, some examples are:

- The transfer of work from Dumez to Bilfinger and Berger; and
- The decision of the federal government to modify the medium section and structural mill to produce rails;
- Modifications to the foundation of the blast furnace (the foundation, 17 x 17 x 1.5 m, required continuous pouring of concrete for more than 36 h).

The final stoppage of civil works came with the formal demand by the contractors for an activation of the contractual formula for price fluctuations. The price fluctuations demanded were 1.9 for Dumez (the first to abandon work) and 1.6 for Fougerolle.

However, anomalies in the price fluctuation formula (as contained in the contract) had previously been pointed out by consultants -- especially as the formula affected wages.

By March 1983, the government had directed that ASCL negotiate with the contractors to arrive at a realistic and equitable formula for price fluctuation. Protracted negotiations followed and after more than 2 years, a formula of 1.5 was fixed. For future escalation in material and labour, a system of basic rates was fashioned, with the base rate being that in April 1984. The standstill and negotiations saved the project about NGN 125 million, but the costs in time overruns and lack of production cannot be easily calculated.

From November 1980, the civil works were expected to span 54 months. More than 70 months have elapsed and much is still left to be done. Meanwhile, the costs, originally estimated at NGN 838 million, have catapulted to NGN 1484 million. After the new agreements and new commissioning dates for the plant units, other external threats emerged to make the new timetable unrealistic -- uncertainties in the economic climate (the collapse of oil prices) and the shackles created by bureaucracy.

The new commissioning dates were predicated on the assumption that import licenses for the contractors (for the 1985 financial year) would be released by August 1985. In fact, the licenses were not in place for more than a year. The civil contractors, who were expected to resume work once the deadlock was broken, had not done so by late 1986, partly because the new mode of payment for the civil works was being processed through the bureaucracy, and partly because the import licenses had not materialized.

The contractors resumed work toward the close of 1986, but before the end of the first quarter of 1987, new problems relating to the mode of payment had brought the work to a standstill once again.

The abrupt halt to the civil works, paradoxically, made little difference overall. Infrastructural facilities, external to the plant, are meant to supply, process, and convey raw materials to the plant. Even if the steel plant itself had been constructed on schedule, delays in the installation of these facilities would have rendered it inoperable. The most important delays occurred in:

- The Itakpe iron ore mine, which produces the concentrates to feed the Ajaokuta plant, 56 km away. A company to mine and process the ore, the Association Ore Mining Company, later renamed the Nigerian Iron Ore Mining Company, has existed since 1980, but the contract for the civil works and the beneficiation plant of the Itakpe ore mines was only recently awarded (August 1986) despite letters of intent signed 1983. The tenders had to be renegotiated. The main contract was won by KOCH of Germany, but closely associated facilities (the civil works and the Osara dam project to supply domestic and industrial water) were awarded to JLGT (Nig) Ltd. The projects were to be financed by the contractors and contractual agreements " ...not binding on the Federal Government if contractors failed to raise the necessary funds..."
- The railway link between Itakpe and Ajaokuta to transport iron ore, the contract for which was awarded only in 1987.
- The development of mines or quarries for limestone, dolomite, refractory clay and of transport facilities to convey the raw materials to Ajaokuta.
- The development of a bulk transportation system for imported raw materials, like coal, from Onne port to Ajaokuta.

These major links in an intricate network of supply facilities (mines, power, ports, rail lines, and roads) are in a sorry state. The lack of coordination between institutional subsystems responsible for these facilities and the final user (ASCL) has delayed the development of the facilities, as has the precarious state of the economy.

The most obvious manifestation of the delays was the need to set new dates for commissioning the plants. Originally, the steelmaking plant, the last shop to be commissioned, would have begun operation in March 1985. A new schedule (a revision of the master plan) (Table 10) was agreed upon in August 1985 at the meeting of a Soviet delegation of technical experts and their Nigerian counterparts.

Table 10. New and original dates planned for commissioning of plant units of Ajaokuta.[a]

| Production unit | Commissioning date | | Time overrun (months) |
|---|---|---|---|
| | Original plan (1981) | Revised plan (August 1985) | |
| Light section mill | June 1983 | -- | -- |
| Wire rod mill | December 1983 | -- | -- |
| Thermal power plants (2) | March 1984 | October 1986 | 31 |
| | September 1984 | December 1986 | 27 |
| Billet mill | June 1985 | December 1986 | 18 |
| Medium section mill | March 1986 | June 1988 | 27 |
| Coke-oven batteries (2) | March 1984 | September 1988 | 54 |
| | December 1984 | September 1989 | 57 |
| Raw materials preparation plant | September 1984 | December 1988 | 51 |
| Ironmaking plant | September 1984 | March 1989 | 54 |
| Steelmaking plant | March 1985 | June 1989 | 57 |

[a] Given current economic conditions, the new dates probably will have to be revised.

Some of the direct and indirect costs of delay are for:

- Tied-down capital in the form of half-completed civil works, partially installed equipment and plant units, uninstalled structures, equipment and idle tools, and equipment used for erection.
- Demobilization and remobilization of workers.
- Refurbishing equipment. With time, conservants like grease and oils used to protect equipment from rust lose their potency. Of about $1.8 \times 10^5$ t of equipment, half is expected to need reconservation.
- Protecting installed, but idle, plant units from a hostile environment. For example, one coke-oven battery is almost completed; although built with costly refractory bricks, it will degenerate and lose some of its intrinsic properties if left exposed and unprotected from weather elements. Elaborate layers of chamote bricks will have to protect, for example, its top. This kind of protection will be necessary for the blast furnace, steelmaking shop, and other facilities.
- Depreciation of completed but idle units.
- Deferment of supply of plant and equipment, erection, and commissioning. Penalty clauses are clearly spelled out in the global contract for failure to abide by scheduled commissioning arrangements and subsequent execution of performance guarantee tests. The repair shop complex has been completed. It has about 220 machine tools (lathes, drills, planers, and so on). If, after "no-load testing to ascertain that equipment has been supplied, erected and is fit for load test," the repair complex should stay idle because of the lack of cutting tools as well as materials to work on, load tests may be delayed. If the commissioning were delayed because ASCL could not supply requisite materials, the company would be required to pay highly

for the extra period that the contractor's personnel remain on the job.

- Interest on unproductive loans from civil contractors (the civil contracts were 100% externally financed and the bulk of the money is to be paid back in foreign exchange).
- Escalation of prices.
- Idle human capital and loss of faith and morale -- the large turnover of skilled and unskilled workers waiting (in some instances for over a decade after formal training in steel plant operations) for the plant to come on stream. The firm has lost several experienced engineers and administrators for political reasons manifested in mass purgings, allures of better pay in the private sector, and sheer frustration.
- Unrealized output in steel tonnage and revenue.
- Technical assistance.
- Failure to contribute within the economic plan of the country.

The major factor causing delays was the nature and complexity of the project. The decisions taken and their subsequent implementation demand unusual technomanagerial capacities. Because of the paucity of these kinds of capabilities in developing countries such as Nigeria, it is not surprising that the project has faltered.

Practically all the capital goods -- structures, columns, vessels, and reactors -- had been made abroad and embodied detailed knowledge acquired over many years of design and fabrication. Not being a party to the designing and fabricating is an operator's first major handicap. Understanding the technical basis of design limits guesswork and enhances judgment in use, and maintenance. Clearly, the project demanded massive investment in training and development. Our investigation shows that "learning the ropes" of a new technological system is not enough to launch a steel plant; the other barriers imposed by underdevelopment are daunting.

To make matters worse, Nigeria embarked on another integrated steel plant, employing a different steelmaking process (direct reduction), and three inland rolling mills at about the same time as it began Ajaokuta. Each of these undertakings would stretch the human and material resources of the country.

Almost all equipment and structures have been delivered and more than 50% erected. The plant units were designed to operate on the BF/BOF process and not any other. All subsystems and ancillary units are meant to support this particular technological regime. Therein lies the irreversibility of a decision taken, in this case, by those who drew up the preliminary project report in 1973. The progression is gradual from what seems a relatively simple act -- selecting among alternative technologies. The project moves inexorably from a simple system (possible with decision-makers of particular capability) to a regime of complex organizations (with decision-makers of a different kind and far different technomanagerial capabilities). The way in which almost all costs become fixed over time and the uneconomic logic of reversing decisions about heavy investment when practically all equipment and structures have been delivered and erected underpin the irrevocability in processes of this kind. The process, because of the huge financial costs, assumes a life and momentum of its own.

The nature of the project, i.e., a greenfield plant, and the mode of execution (not turnkey) join to bring together various institutions within the "enabling system" and bring to the fore issues concerning technological accumulation: the weakness in the engineering within the participating subsystems as far as projects of this magnitude and complexity are concerned, the weakness in organizational capacity, and the weakness of interactions between the enterprises. These weaknesses are essentially human and reflect the stages of, and the plan for, human resources development before, during, and after a project. From this perspective, one can examine the training and development of staff for the Ajaokuta project.

## Personnel Training and Development

At an early stage (primarily during preinvestment when the detailed project report was being discussed), the need to fill the yawning gap in knowledge between NSDA staff on one hand and the Soviet specialists on the other was acutely felt. To make discussions with the Soviets meaningful and to contribute more positively to the detailed reports, staff of NSDA embarked on preliminary training on steel plant design and operations. Training was provided in several countries:

- USSR (Zaparozhye and Cherepo vetse),
- Italy (Italsider - Taranto),
- Canada (Stelco),
- USA (US Steel),
- Japan (Nippon Steel),
- France (SOFRESID),
- Britain (BSC - Corby).

Training was mainly ad hoc, lasting from 3 to 9 months, and NSDA simply took what was offered, responding to the stimuli and pressures induced by the need to make sense of suppliers' proposals. The contents of the courses varied and were usually predesigned. Participants supplemented the opportunities by regularly reading journals on iron and steel. NSDA maintained an up-to-date library on steel manufacturing.

Some of the ad-hoc arrangements continued until 1974, when several senior staff of NSDA were sent to MECON (India) to study general layout and transport, civil engineering design, structural and project engineering, etc.

### Training in India

The first program, in 1974, was initiated with the Steel Authority of

India Limited (SAIL). At that time, the Indians offered the least-cost training, and the major contractor handling Ajaokuta, the USSR, had been involved in the construction and operation of two integrated steel plants in India -- Bhilai and Bokaro. The success of Bhilai, a publicly owned steel plant, had undoubtedly influenced the decision.

The training program was designed entirely by SAIL, each trainee spending 9 months on specialized work and 9 participating in shift work.

The contract between SAIL and NSDA was valid for 4 years starting August 1974; and the scheme involved mainly executive and engineering staff. The experience of early trainees resulted in two major amendments: the period was changed to a total 12 months and training in some critical equipment like cranes was included. The intention was to equip executives and engineers with skills that would enable them to keep vital operations going and to judge the performance of workers.

A third major amendment to the contract was in costs. Effective 1 March 1978, the price for each trainee went up from $100/month to $160.

Training for steel plant personnel was conducted at Bhilai, Bokaro (both, Soviet), and Rourkela steel plants (West German); Coal India; and the National Mineral Development Corporation among others. Some design training took place at MECON's design office in Ranchi.

The 1978 contract was revised in 1982, but the new version contained no substantial modifications. Broadly, the trainee's program was divided into three periods:

- General training,
- Specialist training, and
- Management training.

In the first phase, the trainee was taken through all the activities of the steel plant -- from raw material receiving, handling, and preparation to the finishing ends -- in this case, the rolling mills. The trainee then spent some time interacting with the engineers, technicians, and shop hands in specific operations or maintenance. Next was training focused on, for example, coke ovens, by-products, or steelmaking. Shift work was mandatory.

Training manuals and programs had been designed to detail the progression from one unit of the shop to another. The third part of the program was a general management course that lasted 2 weeks. The course sought to familiarize trainees with basic accounting, project implementation, production and materials management, personnel management, marketing, and safety.

A separate contract with MECON of India proposed training another 636 -- 157 engineering staff and 402 operators and nonexecutives. The Indian training program was scheduled to take off in 1982-83 with 290 personnel but never got off the ground.

The other major external source of training was the USSR.

**Training in the USSR**

Training was offered in and by the USSR through the bureau for external aid in education, which provided scholarships to hundreds of Nigerians yearly to do specialist courses. The main fields of study covered by the scheme -- relevant to Ajaokuta -- were metallurgy, mining, mechanical engineering, civil engineering, and electrical/electronics engineering. Selected personnel of the company traveled to the USSR for the courses, which lasted for 5-6 years.

The commitment of the USSR to provide scholarships at Soviet technical colleges and institutes "on the basis of free-of-cost scholarships, payable by the Soviet Union, with a view to providing education for the various professions required for the effective operation of the Ajaokuta Iron and Steel Plant", was explicit in the global contract. The contract and its revisions provided for training of almost 2000 Nigerians.

By the agreed schedule, 179 persons were trained in the Soviet Union in 1981, and between 329 and 414 persons were trained in 1982. These personnel were mostly for the priority rolling mills (light section mill and wire rod mill) as well as for the operation of the thermal power plant, the gas facility and the electric power facility. By the first quarter of 1986, 639 persons had been trained, and according to minutes of discussions in August 1985, 1017 trainees would be sent to the Soviet Union between 1986 and 1989.

The new schedule calls for training a reduced number, in the most critical categories, abroad. A "cascade" approach by which those already trained will impart their knowledge to others is now planned, mainly at the technician/operatives level. For example, two furnaces are in operation now in the plant obviating the need to send furnace operators abroad, and the metallurgical training complex will train vocational and crafts people.

According to the original contract, training was to be carried out "... in conformity with the training programmes prepared by the establishments where training will take place." This seems to reflect the climate of the time when NSDA had not the personnel, the confidence, or the capability to plan such a venture. Revisions to the contract reflected inputs originating from direct experiences of NSDA personnel (such as shortening the length of training and training in critical equipment). What has seemed to become permanent is the tendency to leave the planning of content to the foreign technical partner. For example, the contractor was to assign trainees "to the various establishments taking into account the relevance of these establishments to the training programs, the similarity of the available equipment to that to be supplied to purchaser." The training experiences of personnel suggest that the issue needs to command serious attention.

Also, the contract stipulates: "Industrial and technical training of trainees shall be conducted in the Russian language. However, to ensure more efficient training, PURCHASER'S trainees shall, prior to coming to the USSR [emphasis ours] for industrial and technical training, study the required minimum of the Russian language in PURCHASER'S country."

What has been the rule is that the obligation to ensure knowledge of the Russian language has been at best treated with levity.

When trainees get to the USSR a language program, not exceeding 3 months, is normally arranged along with training in their field of specialization. Not surprisingly, most trainees never really understand the language. This deficiency imposes serious constraints on learning. As most texts are printed in the Russian language, trainees who wish to explore technical points in books and journals find the barrier as much in the library as on the shop floor. Invariably, they misinterpret technical information, as do the interpreters who are language rather than technical specialists. The communication gap sometimes leads to protracted and unproductive periods of clarification and repetition -- time that could be employed more gainfully.

## Training in Nigeria

The technical and vocational group constitutes the largest category of personnel required for running the plant. According to the detailed project report, 7757 nonexecutive personnel will be required to run the plant. This prediction is in line with UNIDO'S (1984) estimates.

To meet the requirement, the metallurgical training complex was to be built to train about 2000 at a time in 25 different trades and skills. Graduates annually would number about 900. Fully equipped classrooms and workshops for practical training, as well as hostel facilities were to be provided. The current complement of staff at Ajaokuta comprises 666 engineers and technicians and 1163 other workers (Table 11).

However, the thinking that impelled an investment in a massive training institution made no provisions for the future, when the knowledge gap will have been narrowed. At the inception of planning for the project and for the industry in Nigeria, no metallurgical school was in existence.

Today the picture has changed significantly. A number of universities and polytechnic institutes now turn out metallurgists and metallurgical engineers. A survey carried out in 1973 (and updated in 1976) indicated that certain skills simply could not be met by educational programs in the country. At that time, metallurgy, metallurgical engineering, mining, refractory technology, and instrumentation and control were not covered by any institution. These findings prompted the initiation, in 1977, of a postgraduate diploma course and master's degree programs at the University of Lagos. The aim was to equip chemical engineers, chemists, and mechanical engineers with the basic concepts of metallurgy. Emphasis was

Table 11. Personnel working in production departments of Ajaokuta Steel Plant, 1987.

| | Engineers and technicians | Workers |
|---|---|---|
| Coke oven | 18 | 4 |
| Steelmaking shop | 21 | 79 |
| Ironmaking (including blast furnace) | 18 | 29 |
| Maintenance (including lime and refractories shops) | 95 | 190 |
| Power and utilities | 173 | 205 |
| Central maintenance | 108 | 76 |
| Research and quantity control | 47 | 14 |
| Production, planning, and control | 17 | 3 |
| Light section mill | 50 | 200 |
| Wire rod mill | 49 | 208 |
| Billet mill | 70 | 155 |

placed on physical and extraction metallurgy. Since then, 10-20 engineers have passed through the program annually, and Ife, Benin, and Akure universities as well as some polytechnic institutes have been turning out graduates in metallurgy and material sciences. A gross underutilization of capacity will ensue unless plans are made for the Ajaokuta training complex.

Two of the rolling mills are in operation and (compared with the theoretical levels published in 1984 by UNIDO) are overstaffed by engineers and technicians and critically short of workers. Ordinarily, the ratio of workers to engineers and technicians is about 10:1. The ratio at Ajaokuta is about 3:1. Only 65% of the required workers are available in the mills and the engineer/technicians are mainly staff hastily drafted from other units of the plant when the mills were about to be commissioned. Apparently this was to provide a cushion for staff losses and to expose others to operational conditions. Since this was not a formal element of policy, no arrangements were made to prepare such personnel for their new environment. As a result, personnel trained to run the coke oven and steel shop, were converted overnight to mill operators.

The coke oven plant illustrates the state of the training program (Table 12). The shortfall is 58% of engineers. Of the required total staff, more than 61% should receive training locally (254 workers), and none of these have been recruited.

Similarly, in the steelmaking shop, only 1 of the 68 engineering staff has undergone training in the USSR. A handful were trained in India 7-8 years ago but have not had the opportunity to put their acquired skills into practice.

Both the coke oven plant and the steelmaking shop are yet to be commissioned, so the staff could participate in equipment erection, dry test runs, and the final commissioning of their plants. The familiarity developed with plant equipment prior to commencement of commercial operation could be crucial to the efficient operation and development of a

Table 12. Personnel in the coke oven and by-product plant of Ajaokuta, May 1987.

| Description | Engineers | Workers |
|---|---|---|
| Total staff required | 55 | 417 |
| Number to be trained (global contract) | 50 | 163 |
| Personnel already trained in USSR | 18 | 35 |
| Balance to be trained in USSR | 32 | 128 |
| Balance to be trained locally | 6 | 254 |
| Total personnel trained (India and USSR) | 19 | 31 |
| Expected staff strength in 1987 | 51 | 57 |
| Shortfall | 37 | 57 |

no-nonsense maintenance crew. At present, engineers are underengaged or suboptimally employed, and many have left after having been trained.

The strategy for delayed recruitment and cross-posting of trained personnel from plants under construction to completed plants arose mainly for financial reasons (and partly for reasons that may be associated with organizational politics). The main point is that when financial commitments to large projects of this nature start to dwindle, training is the first program to suffer. This has a crippling effect, leading to the prolonged infancy of the firm.

There are other shops in the plant that are fully constructed and yet are constrained by shortages of trained personnel. The most poignant example is the central repair shop complex. From the experience of other plants such as USIMINAS (Brazil), this complex should be fully exploited to make money for the firm. The firm has been deluged by inquiries from potential customers. Of the 115 engineers required for the shop, not one has been formally trained. This shop is incontrovertibly the most complex and best equipped in subsaharan Africa -- with a projected staff of 1677 of which 702 are expected to be highly skilled workers (Table 13). To date, few of these workers have been recruited, although more than 200 machine tools have been fully installed and the shop commissioned.

Table 13. Personnel required for the central repair shop complex of Ajaokuta at full capacity.

| Shop | Engineering staff | Skilled workers | Semi-skilled workers | Unskilled workers | Service staff |
|---|---|---|---|---|---|
| Foundry | 17 | 78 | 48 | 57 | 17 |
| Forge and fabrication | 12 | 53 | 34 | 38 | 10 |
| Mechanical repair | 40 | 254 | 145 | 37 | 15 |
| Pattern and building repair | 20 | 67 | 82 | 93 | 9 |
| Power equipment | 26 | 250 | 152 | 106 | 17 |

The statistics are one measure of the deficiencies; our participation in the project, close observation of the system as well as direct interviews with various personnel enabled an analysis that goes beyond the statistics. We have several observations.

The recruitment, training, and development of personnel have been inadequate. The number of personnel lags seriously behind the required numbers for both commissioned units and those under construction. It would seem that the plant will face a crisis of personnel, both skilled and unskilled.

Commissioning of key units is being carried out without the participation of carefully prepared well-trained teams. The welding of trained personnel into working teams and the integration of these teams into the testing and commissioning procedure are not even being attempted. For large technological processes such as Ajaokuta Steel Plant, semipermanent working teams should be constituted to ensure technology acquisition -- starting from within the enabling system (government in this case) and extending to the board of directors and other levels within the firm).

Political instability, culminating in frequent changes in the leadership of government ministries and in the portfolios, boards of directors, general managers and senior management staff, makes continuity almost impossible. For example, ASCL, since its inception 8 years ago, has had three general managers -- excluding the project manager who retired at the start of construction. Half of the period was spent under direct ministerial control, as there was no board of directors (while a new government tried to identify and name its own people). The other half was shared by two boards of directors. The major disadvantage of direct ministerial control lies with bureaucratic delays and the lack of flexibility required for the efficient running of a corporate manufacturing enterprise.

No one stays in any seat, or manages any portfolio, long enough to develop sufficient appreciation of the importance of the roles in technology acquisition. Under such conditions, it is impossible to accumulate the required technomanagerial skill on the job (learning from past errors). Yet, this is the basis of an enduring technomanagerial buildup. This situation is by no means peculiar to Nigeria. Perhaps the way to seek continuity is to assume a system that insulates large technological projects from the weak political culture of developing countries.

One of the prerequisites for the smooth transfer of knowledge is a shared and common understanding of language. Yet, no serious effort has been made to ensure that language is not a barrier. Interpreters can never substitute for direct communication.

It is questionable now, with the advantage of hindsight, whether what has been attempted could possibly have achieved its objective -- given Nigeria's recent entry into the steel-producing league, the shortage of experience, and the low level of technological capability.

It is doubtful that a team, of the type needed, could be raised under the circumstances to cope with the plant the size and complexity of Ajaokuta.

The industrial behavioural pattern required, the level of organizational discipline needed, and the time required to achieve these have not been on the side of the project. It may be that the assumptions resulted from misconceptions about the technical and managerial know-how available in the country.

The major factors that have resulted in damaging time and cost overruns also contribute to the unhealthy state of the training program. The delay in implementation tends to justify (on the surface) shifts in the training program: "Why train people when there is such uncertainty on completion date?"

The learning process, however, is -- cannot be otherwise -- suboptimal when staff's familiarity with the technology does not go beyond textbooks. The staff whose training took place a long time ago, despite an unpreventable atrophy of their knowledge and skill, do form the bulk of management and by all accounts have a better appreciation of the issues than those who are completely uninitiated in plant practices.

The requirements that emphasize certain basic qualifications, especially for skilled and unskilled workers, have not always informed the selection process. For parochial and political reasons, personnel whose mental abilities are inadequate have been installed. Conscious steps should have been taken to ensure that a project of this nature attracts and trains the best and the brightest graduates of the universities and polytechnics. This could have been achieved by open and preemptive recruitment. For example, while the company experiences critical shortages of personnel in certain disciplines (electrical and electronic engineers and electrical technicians), college graduates are roaming the streets elsewhere in the country looking for employment.

The chain of learning is broken when newly trained personnel leave for higher paying jobs; yet the company pays the lowest salaries in the manufacturing industry and is thus a training ground. The accumulation of the required technological skills is clearly impossible under these conditions.

Nontechnical staff (excluding those in operations and maintenance) such as stores management, inventory control, finance, and the training unit receive little or no training, although they need a "technical" understanding of the respective disciplines.

A lack of confidence has manifested itself in the firm, resulting from overreliance on outsiders and consultants for tasks that Nigerians have proved themselves capable of doing. For example, the Soviets have delayed handing over the bulk of spares and consumables to ASCL officers, so the plant sometimes must wait for parts that were delivered years ago but are locked up in the stores to be documented.

There are no computer facilities to handle the 200 000 drawings and 20 000 t of spares, and study of information storage and retrieval problems has hardly begun. The company realizes the need for computer facilities but has been denied funds or has been caught in bureaucratic delays while continuing to strain under a problem that will require years of expert effort to solve. In the company archives (which stores drawings and various operation and maintenance manuals) there are only one or two hands who have a modicum of training on documentation and registration. The company library -- a centre for intellectual activity when the detailed project report was submitted -- has turned into a storage for old books.

The gradual decline in the caliber of managers charged with responsibility for the firm's training program may reflect the true place of training in the management priorities of the firm. Once, the training managers were highly trained engineers who were deeply committed to the project and who appreciated the role of training in the acquisition of technological capability. Not only is training no longer headed by an engineer, it has been relegated to a small unit that has little role in the scheme of things.

Other crucial segments in acquisition of knowledge, such as periodic programs for engineers and managers, do not receive adequate attention. When something comes up, it is usually at the initiative of the managers or engineers. Thus intermediate personnel rise to senior management levels without being retrained. There is no clear vision of how training and development should be related to appointments and promotions. The unit cannot be isolated from the system as it is. The role of training in overall skill acquisition has to be kept in view.

The basic functions and roles of a training management team are the recruitment and selection of candidates; the comprehensive, intensive, and extensive study of the basic training program contents to ensure proper personnel placement; the comprehensive study and maintenance of up-to-date information on the human resources of the firm; control of and accessibility to facilities required for training and development; monitoring of the trainees' program (basic, in-plant, and posttraining or operational phase performance); and subsequent development and upgrading of personnel as they change roles or get promoted.

The training team currently does not have the capability to manage the task, which is essential to systematic accumulation of know-how.

## Conclusions and Recommendations

To meet the objectives of this study, we have examined the different phases of the project to create a steel plant in a developing country.

While the process is continuous, the compartmentalization of events simplifies analysis. One conclusion of this work is that events interact in a continuing fashion -- the evolutionary nature of the project cycle in which decisions taken a decade earlier impinge on, and critically shape, today's events. To analyze events, we divided the process into:

- Preinvestment,
- Construction, and
- Startup and poststartup or operation.

In this work, only the first two fall within our scope: however, the effects of the activities carried out in the construction stage impact upon the succeeding phases. In addition, we have examined training and development as well as general issues concerning project implementation (particularly the effects of long gestation).

Preinvestment was characterized by the sharing of functions between major contractors (suppliers of equipment), the client, and other participants. The major contractor was commissioned to provide a preliminary report, followed by detailed discussions with Nigerian engineers before the final reports emerged. Events demonstrated quite clearly that project formulation and execution are complex and multifaceted, demanding an in-depth knowledge of the technology, and a team of skillful people.

The many issues that called for attention at a later date showed how little prepared we were. The sheer magnitude of problems relating to raw materials and the infrastructure of the plant belied the initial optimism and exposed the fragility of the inchoate organizational arrangement that was expected to produce steel for Nigeria.

The elements during project formulation that shaped the way the project moved were finance (supply and services) and the schema or procedure of implementation.

The civil works contractors (who were also the suppliers of external credit) dictated the pace of the project. ASCL was expected to survey and explore for all the raw materials; to provide port facilities; to construct rail and road networks, and so on. A critical assessment of the relative management capability, experience, and human resources of the organization should have been undertaken at a very early stage. Our findings suggest that the magnitude of work, given the resources available, was thoroughly underrated. There seems to have been no concise plan on how to move forward with the assigned roles. The consequences are that precious years meant to plan and act were frittered away, while bickering prevailed between participants because the responsibilities for crucial activities were not clearly and concisely defined.

The source and nature of financing seriously limited the control by the owner and imposed unhealthy penalties in the long run. The supply of technology, equipment, and the erection thereof were done by one firm (the Russian group, TPE). The execution of civil works on the other hand was by three contractors from industrialized Western countries. The financing of both was through export credit, and no major problems have arisen in this matter between TPE and ASCL. However, delays and cost overruns have stemmed from the actions of the civil contractors. They have exercised total control on the rate of progress because without civil works, no erection of plants can take place. Therefore the long gestation could be said to have arisen from:

- The inconclusive nature of the terms and methods of payment, as the formula for fluctuation was never firmly agreed upon; more than 2 years was lost in negotiations before one emerged.
- The shoddiness of financial provisions for future escalations (none was provided and so none was available when the need arose).
- The absolute control on the source of finance by the contractors.

As the spectre of delay clouded the project, the world economic situation contributed to the storm. Exchange rate fluctuations (at a serious disadvantage to Nigeria in the recent past) were a determinant of the final cost of the project.

During execution, two major issues arose:

- The choice of self-administration of the project (departmental execution as opposed to a turnkey approach), and
- Multiple contracting of the civil works to three different firms.

In the case of the former, the sad conclusion one must come to is that laudable and nationalistic as the effort to self-administer the project is, the decision was not appropriate. Proof can be found in the recent action by government (advised by experts from the firm) to contract out the modification of the first stage (under the so-called accelerated flats production) on a turnkey basis. Everything, from the market survey to the preparation of technical documents for this stage has been done either by the Indian consultants or the Russians. What is telling is that Nigerians can competently handle major aspects, but there is dependence on consultants. This reliance on outsiders easily translates to a mistrust of the abilities of local staff. This malaise started from a lack of serious effort to organize a team for each of the critical areas around which a future plant could be built. One finds pockets of excellence scattered all over -- they are not just badly organized; no organization is evident. The perception is that Nigerian engineers within the firm cannot possibly handle serious design work, despite evidence to the contrary.

The need for teams is paramount for future modifications and expansions if the assimilation of technology is an objective. The nature of steel technology demands combinations of expertise to put together the different components of the plant. This is usually accomplished through umbrella units like the "design bureau," wherein a congregation of specialist design engineers find solutions to technical problems.

This team-forming effort -- when blessed by continuity, coherence, and excellence in composition as well as careful and systematic training in critical areas -- has a chance of giving high returns. This sort of effort has, unfortunately, not been observed in the firm. It is essential if

Nigeria is ever to be free from reliance on foreign suppliers and consultants.

The inability of planners to appreciate the magnitude of the work kept them from making the extra preparations needed to meet the challenges of project formulation and beyond. Grafting steelmaking technology to the Nigeria -- particularly at the scale attempted -- represents a Gestalt shift.

The complexity of the technology does not end with the hardware; mastery of technology rests with the crucial supply of the human elements. This dimension has not been given sufficient attention.

The experience with the civil works belied the idea that one can get the best value when contracts are shared among competing firms. When problems arose, ASCL was forced to negotiate on three different fronts at one time. This made the task arduous, unwieldy, and time-consuming and may explain why negotiations to revise the fluctuation formula took such a long time. Also, organizing technological mastery from three firms increases difficulties. Financial arrangements that are acceptable to one firm may not suit another, etc.

Nigerians may have been too optimistic in allocating to themselves a magnitude of work that in the long run affected the quality of initial planning. To date, the work done on the plant site greatly outweighs what has been done on the various infrastructural facilities and raw materials (functions expressly assigned to the client). The quality of planning has come to haunt the progress of work in several ways and the "breathing space" provided by a long gestation is not being usefully employed in organizing to meet the future.

The gestation includes overruns before commissioning as well as extra time spent trying to attain nominal plant capacity. It is not difficult to see the close correlation between the schema of execution and the rate of progress: poor planning inevitably manifests in delays during project execution. What's more, the absence of teams who have had sufficient technical exposure will make an early startup difficult.

A realistic stock-taking of capabilities should precede the choice of implementation strategy. When the costs are added and compared with the benefits, one may find not only that time overruns have taken their toll with respect to financial losses but that valuable skilled personnel have been lost during the long years of waiting.

As a guarantor of finance capital, the state was seriously disturbed by influences and power external to it. This has been demonstrated clearly by the long delays associated with this project. The project's financing and, more poignantly, the inability to sustain required foreign credit exposed the weakness and fragility of the state's financing power.

Thus, the firm must aspire to ensure that it gets projects off the ground as speedily as possible and avoids harmful delays. It must pursue the acquisition of technology so that it can rely in future on its own efforts.

Technology acquisition is a desired social objective, but, to achieve it, firms must be
able to shield themselves from the environment. They must garner sufficient technological capability to adapt strategically to environmental constraints. Aggressive pursuit of technical capacity and the attendant maturation forge for a firm a new image in the public eye. Then, it can chart technological growth that fulfills its idiosyncratic objectives -- based on the requirements of its founding ideals.

Clearly, to avoid falling prey to the the lack of raw materials, inadequate infrastructure, lack of local suppliers of parts, a firm must erect protective armour and then begin to set strategic goals.

**Recommendations**

Based on this analysis, we recommend that:

- Government prepare adequately (through training) before attempting to execute a project with the ramifications of Ajaokuta Steel Plant.

- Decision-makers make allowance for acquisition of technology through both critical components -- the embodied knowledge (residing in the human entity and cumulatively acquired over time) and the disembodied knowledge (exemplified in capital goods and all other physical manifestations of technology).
- Efforts be made to keep abreast of information -- on the technological state of the art, on innovative activities, and on the strengths and shortcomings of suppliers and technical partners. This ensures an optimum return on investment.
- Steelmaking projects -- and similar endeavours -- be conceived within the context of the country. Practically all the capital goods necessary for implementation were imported. This state of affairs suggests that steel production was conceived of in isolation. The steel industry supplies the basic materials for the capital goods sector, while capital goods production supplies the types of machinery and equipment to erect plants. Industrial policy must not only articulate this symbiotic relationship, but a link must be actively promoted to ease the pain of project execution and to promote indigenous manufacturing. It is difficult to see a truly indigenous technological effort taking root without a dynamic capital goods sector.
- The steel plant itself, for example the machine tools in ASCL's repair shop complex, be used to satisfy demands outside the steel plant. This effort will not only contribute to the economy but also develop an indigenous technological capability and enhance adaptive abilities.
- A rigorous inventory of our resources be undertaken of the raw materials needed in steelmaking and should be stepped up. This demands the upgrading of the technomanagerial abilities of the

various institutions concerned with these matters.

- A study examine the present status of the industrial sector and the adequacies or otherwise of the present institutional arrangements responsible for exploring, exploiting, and allocating resources to final users and of those responsible for providing infrastructures.
- Those making financial arrangements for projects seriously consider the nature and source of funds. Indigenous equity financing and the encouragement of local capital financing would reduce the risk of a costly foreign-credit squeeze that has been the bane of this project's execution.
- A rethinking be done to correct the present anomalies in institutional coordination to strengthen future organizations responsible for implementation.

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