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STEELPLANT TECHNOLOGICAL DEVELOPMENT IN LATIN AMERICA

A Comparative Study of the Selection and Upgrading of Technology in Plants in Argentina, Brasil, Colombia, Mexico and Peru

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This book is based on five published plant case-studies by different authors, namely: Philip Maxwell, (Acindar, Argentina, Working Paper N° 4); Carl Dahlman and F. Valadares Fonseca, (USIMINAS, Brasil, Working Paper N° 21); Luis Alberto Pérez Aceves and Jesús Pérez y Peniche (Altos Hornos de Mexico, Mexico, Working Paper N° 24); Germán Puerta (Acerías Paz del Río, Colombia, Working Paper N° 26); Jaime Gianella (Siderurgia de Chimbote, now SIDERPERU, Peru, mimeo).

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INTRODUCTION

The steel industry is a classic symbol of industrialization. It has been taken as such in Latin America and promoted as a "leading sector" carrying with it the flag of national pride and prestige. Steel has been singled out for special protection and promotion by the governments of Brasil, Argentina and Mexico since the Second World War, by Colombia and Chile since the early 1950s and by Peru and Venezuela since the later 1950s. Paraguay, Ecuador, Bolivia and even Honduras are now joining in.

A good reflection of the priority given to steel is that - combining figures for all Latin America, steel production has grown at an average compound rate of over 10% per year for the past three decades! By 1978, total Latin American production was 24 million ingot tons, roughly 80% of total steel consumption. Another reflection of the importance governments attach to steel is that well over half of total production takes place in majority government-owned and controlled plants.

Furthermore - whilst the Latin steel industry is already of great size and significance, the region's governments are planning to more than quadruple its size by the year 2000 to meet a predicted average annual 7.5% increase in domestic steel demand between now and the end of the century. These expansion plans are not mere fantasies on paper. Latin governments and steel companies in the last few years have been investing about U.S. $ 2.5 billion annually in new and expanded steelplants, not counting additional investments in related infrastructure. This corresponds to some 15-20% of the world's investments in the steel industry in this period.

Clearly then both the actual and the future importance of the steel industry in Latin America justify studies by economists to evaluate past performance in the industry and extract lessons that might help in managing the vast expansions now underway.

Yet -sad to report- the record of the Latin American steel industry is only sparcely covered by retrospective scholarly analysis. For example, not one published book exists on the economic history of the Argentine steel industry. We could trace only two on Brasil's (dated 1957 and 1964), one on Mexico's (dated 1958), none on Colombia's, none on Peru's. Quite probably there do exist other published books or Ph.D theses to supplement the above small list - but we can assert that, if these exist, they are neither readily available nor easily traceable by librarians.

True, there is remarkably good technical, statistical and -increasingly- economic documentation regularly published on the industry by the National Steel Industry Associations and through the Instituto Latinoamericano de Fierro y Acero (ILAFA) whose publications and congresses have been going continuously for over seventeen years. But these sources only rarely provide information of a truly critical kind. For their raison d'etre is to promote the future growth of the steel industry rather than to conduct searching scholarly analysis of past performance. A similar problem applies to the information in government planning reports on the industry which are always heavily influenced by political and promotional considerations.

Therefore, what is largely missing is the "independent voice" of the scholar, the academic, the historian in evaluating the past performance of the Latin American steel industry. In fact we have calculated that on average, for every one million U.S. dollars invested in the continent's steelplants only about $30 has been spent on retrospective scholarly studies on how these investments have developed. Most Latin American steelplants have not been subject to any scholarly "hindsight" analysis at all.

Considering the valuable experience now built up in the Latin American steel industry, and its obvious relevance to improving future performance, this particular ratio of "scholarly research" dollars to "investment" dollars seems laughably small. The present book -and the case-studies on which it is based- may be regarded as a contribution to improving this ratio.

Our book is based on five detailed case-studies of individual Latin American steel firms, namely: Acindar, in Argentina (the leading private-sector Argentine firm which produces non-flat products), USIMINAS in Brasil (one of the big three Brasilian state steel firms, producing flat products), AHMSA in Mexico (the largest state steel firm producing both flat and non-flat products), Acerîas Paz del Rîo in Colombia (the largest Colombian steel firm,producing mainly non-flat products), and the state-owned Siderúrgica de Chimbote in Peru, later renamed SIDERPERU.

All these firms have a long record. Acindar began producing steel in 1943. Altos Hornos de Mexico in 1946, Acerîas Paz del Rîo in 1954, Chimbote in 1958 and USIMINAS in 1963. So all the plants have had roughly between two and four decades of experience. This is important from the research viewpoint because, as Werner Baer has put it:

> "Given this length of time, a more definitive analysis may be made of the adaptation of factors of production to the technology, of technology to factor availability, and of changes in the relative efficiency of the industry. That is, a long enough time has passed for the economist to be able to make some judgements about the extent to which the infant industry has grown up"

The central idea in our case studies was to trace out in detail the "learning process" which occurred in Acindar, USIMINAS and AHMSA as regards choosing, mastering and developing the technology of steel production. We sought to identify the particular "learning path" and the associated "technology path" followed in each firm. What technology was initially chosen and why? How did the firms learn about its availability? How did they build-up experience in getting the plant going? What was the relationship with foreign technology suppliers in this process? What learning processes were associated with the increase of production experience gained by these firms and what consequent technical changes did they introduce so as to upgrade their plants? What role was played by factors external to the firm - such as government planning decrees, crises in the availability of raw materials or other problems - in these learning processes? What role was played by internal firm policies such as the setting up of new technical departments? By exploring these questions we aimed to build up a detailed picture of the "learning path" which these plants followed from their inception through to recent times.

Our book now follows up these individual studies of Acindar, USIMINAS, Acerías Paz del Río, AHMSA and Chimbote by presenting and comparing information from the 5 case-studies, with the following aims in mind:

(a) to clarify some of the factors which influenced and determined the learning and technological paths followed by our five firms in their plants

(b) to identify particular learning paths, learning sequences and methods that seem to have been efficient and successful, and if possible see why

(c) to identify other learning paths, sequences and methods which were clearly less satisfactory, and again to see why

(d) to draw practical policy conclusions for steelplant managers, government steel planners, and institutions providing finance for the steel industry

Notice that we shall <u>not</u> be attempting to make any "absolute" evaluation of how effective the learning process in the plants has been. So we do not, for example, provide evidence which would enable retrospective judgements to be made on whether or not infant industry protection was justified in the particular plants examined.

Instead, our approach in this book may be said to throw some light on relative, not absolute, learning performance. Our assumption is that, first, if a country is going to have a steel industry, then there are bound to be some "learning paths" which lead to more efficient and successful plant performance than others; and, second, that a close look at actual historical experience in a number of Latin American plants might reveal some useful lessons in this respect.

Chapter 1 describes basic characteristics of steel technology and innovation. It shows how these generate three major "issues" for those responsible for planning and running steelplants.

Chapter 2 provides a brief synthesis of the five plant case studies and comments on the kind of learning paths revealed and on the factors which appear to have influenced the paths taken in the plants.

Chapter 3 examines some of the determinants of the initial choices of technology made both for new plants and subsequent major expansions. It points to the strong influence which "planning imperfections" and "economies of scale concepts" had in determining some of these choices. This chapter then goes on to examine the duration of the "gestation period" that was involved in the whole process of planning, constructing and starting up the plants, and pinpoints several factors which tended to prolong the gestation period.

Chapter 4 concentrates on one aspect of the upgrading of plant performance over time - namely the stretching of plant capacity. It explores the extent of capacity stretching achieved in the plants, the facturs that stimulated it and the methods used to bring it about.

Chapter 5 explores further aspects of the "upgrading" of plant performance achieved over time in all the plants, through the introduction of minor technical changes.

Chapter 6 contrasts the "defensive" and "offensive" approaches to introducing technical change as illustrated by the experience of two of the plants, and argues in favour of the "offensive" approach.

Finally Chapter 7 summarises the main findings reached in the study and the planning conclusions which derive from them. These relate (1) to more effective planning methods in the selection and gestation of technology (for new plants and major expansions), and (2) to suggestions for a more systematic approach to the upgrading of existing plants via minor technical changes introduced at low investment cost.

Some "caveats" are in order: First, it would be quite wrong to pretend that this study summarises all the worthwhile findings from the individual case-studies. These case-studies stand in their own right and have more findings and insights than the representation of them we have given here. For example the USIMINAS study has excellent material on the evolution of government policy, which is only very briefly touched on her.

Second, the chapters of our study have, in the main, had to be written at great speed. This was necessary in view of the time constraints on the comparative study. Our objective was to bring to light a significant percentage of the important research findings contained in the case-studies rather than aim to be more comprehensive.

Furthermore, on the whole we have tried to maximize "content" as against "polished exegesis". Therefore the reader is asked to forgive the many rough spots he will detect in the study.

Finally there is no doubt that the present study could greatly benefit from a round of detailed comments and reactions. That is why the designation "Working Monograph" is the appropriate one for the work as presented here.

Nevertheless the study does, we think, fulfil its promise of showing that comparative analysis can be a powerful tool for extracting worthwhile planning conclusions. It will be up to the reader to see if he agrees.

CHAPTER 1

STEEL TECHNOLOGY, INNOVATION AND PLANNING ISSUES

Scope of the Chapter

As this book describes case-studies of technology in steel-plants, it is obvious that the specific technological characteristics of steelmaking -as opposed to cement, plastics or woodworking- are going to play a prominent role in the analysis.

It is therefore useful for the non-specialist reader to grasp some basic elements of what steel production technology involves, i.e. the kinds of processes and machinery involved, as well as the kinds of products produced and the types of plants that exist. Furthermore, it will be useful for the reader to have some notions about how steel technology has been evolving - i.e. progressing through innovations.

Accordingly, this first chapter provides a brief introductory guide to some key characteristics of steel technology and innovations. It also shows how these characteristics generate specific "issues" that confront steel plant planners, executives and engineers, and which we shall be exploring in the case-studies.

1. Outline of Steel Production Processes

As a first step it is vital for the reader to know what steel production involves.

"Steel" itself is the generic name given to metals which contain mainly iron plus controlled small amounts of other chemical elements such as carbon, manganese and silicon which impart valuable strength characteristics and other useful properties to iron.

Its production starts from iron-ore or scrap and involves several successive process stages which lead through to the range of finished steel products such as plates, sheets, bars, beams, wire, tubing, etc.

The principal processing stages and products of industry are shown in diagram 1.1 below. Steel itself is made at the "Steel-Works" stage and involves a chemical and metallurgical process whereby pig iron (or scrap or sponge-iron pellets) gets transformed in a vessel into batches of homogeneous hot liquid steel of exactly the required chemical composition, ready to be poured out of casting.

The purpose of the steelmaking process is to change the chemical composition of the pig iron a/ (or of the melted scrap or pellets b/) through adjusting downwards the proportion of some elements, and upwards the proportion of others, so as to achieve the precise proportions of carbon, silicon, manganese and other elements -together with the majority element iron- which conform the particular 'grade' of steel which it is desired to produce,

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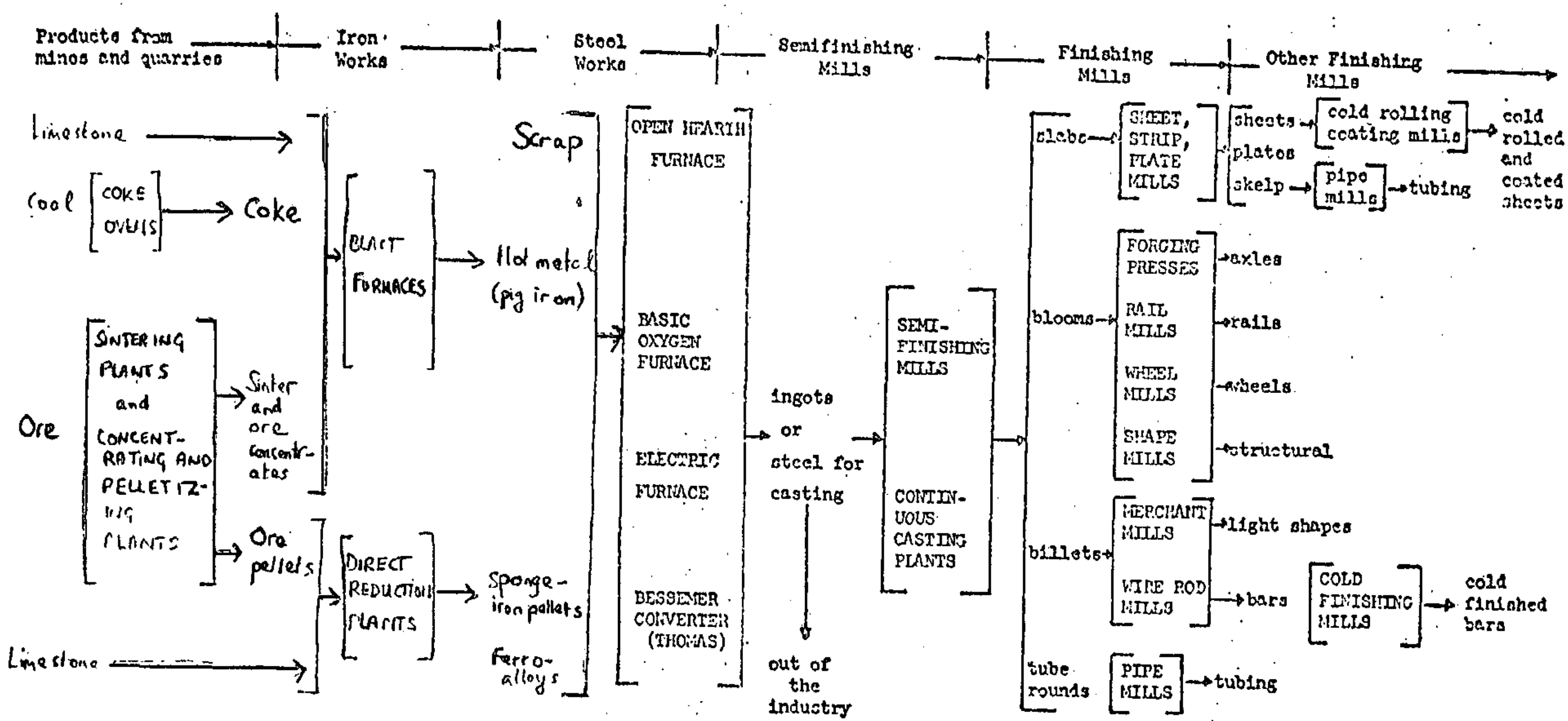
a/ The pig iron from blast furnaces contains about 94-96% of iron, plus 3-4% carbon, plus smaller percentages of other elements such as silicon, manganese, phosphorus, etc.

b/ Melted scrap, depending on its source (e.g. from outside or inside the works) also contains various impurity elements, and sponge iron pellets made in Direct-reduction plants consist of about 90% iron, 8% unreduced ore, 2% carbon plus other minor impurities.

Diagram 1.1: Principal Processes and Products of the Steel Industry



Source: Adapted by author from P. Nueno, A Comparative Study of the Capacity Decision Process in the Steel Industry: The U.S. and Europe, Ph.D., Harvard Business School, 1973, p. 35

and which in turn give the required mechanical and physical properties to the final product. a/

The output of steelmaking is hot liquid steel which must then be immediately cast. This is done either in ingot moulds forming "ingots", or, increasingly, it is done by pouring the liquid steel directly into continuous casting machines. In ingot casting, the ingots after cooling get reheated and then rolled in "semi-finishing" mills to either blooms, billets or slabs, which are the key intermediate products of steelmaking operations. In continuous casting, the blooms, billets or slabs are produced directly in a single process which results from the cooling of liquid steel in the casting mould.

In both cases, the resulting intermediate products then form the input to one of the range of different kinds of finishing mills, as shown in the diagram.

These finishing mills display a considerable variety, depending on the end-products being produced. "Merchant" mills for non-flat products are often fairly general-purpose, and may alternately be set to turn out bars, sections, beams, wire-rod etc. Hot mills for flat products can also be general purpose, but the modern tendency in large plants is for these mills to be specially designed for plate, sheet or strip. Similarly

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a/ Common "mild" steels contain typically 0.10 to 0.25% of carbon, whilst so-called "special" steels include both "high-carbon" steels (e.g. above 0.6% carbon) and "alloy" steels (which are steels containing alloys such as molybdenum, tungsten, vanadium, chromium, nickel and manganese, etc. in proportions above some specified minimum). During steelmaking, steps must also be taken to control the level of "impurity" elements such as phosphorus and sulphur which are contained in the steel, as too much of these may produce metallic "inclusions" or other metallurgical defects which reduce the quality or performance of the end products containing them.

in non-flat products, there exist specialist bar mills, and wire-rod mills, as well as tubing mills. Beyond the hot mills, flat products may also pass into cold reduction mills, or in the case of wire-rod, to be"drawn" into fine wire. Further processing such as heat treatment, annealing, and providing special surface finishes to products is also carried out in steel plants - so that the "finishing" technology of steelplants is actually considerably more complex than is shown in the diagram.

Most plants specialize in producing either "flat" products, or "non-flat" products, though some big plants produce both. In any event, it is normal for plants to produce several different classes of flat or non-flat products. E.g. a flats producer may turn out sheet, strip and tinplate for cans; a typical non-flats producer may turn out reinforcing bars, sections, and wire-rod. In addition it is usual for steel plants to service a wide variety of different customer specifications as to the shapes, sizes, thicknesses, grades of steel required and surface-finishes needed.

Thus most steelplants are decidedly multi-product plants as well as multi-stage plants. This fact, coupled to the wide variety of physico-chemical, mechanical and metallurgical transformations carried out in steel processing, and to the sophisticated machine-intensive nature of most of the processing stages, means that a central characteristic of steelplants is their inherent technological complexity -both in construction and operation.

An important consequence of the multi-stage character of the industry is that steelplants can differ greatly according to the degree of vertical integration embodied in their operations.

Thus at one end of the scale are "fully-integrated" plants, which incorporate all the processing stages through from ironmaking to at least the basic finishing operations. a/ Then come "semi-integrated" plants, which involve just steelmaking and finishing (starting out from scrap). Finally, there are "non-integrated" plants, which only have finishing mills installed and which buy all their supplies of billets, slabs, etc. from outside sources.

In most countries, from 70-95% of crude steel is produced in integrated plants - while some 5-30% is produced in semi-integrated plants. 1/

As for the scales of plants in the steel industry, these vary widely but - in terms of sheer size, space occupied, and tons of product produced - are often extremely large compared to plants in most other industries.

The majority of fully-integrated steel plants in the world are producing in the range of 1 million to 6 million tons of steel per year.

Semi-integrated plants tend to be much smaller, usually producing some 100,000 to 500,000 tons per year.

Non-integrated plants rolling semis into finished products are rarely much bigger than 300,000 tons per year, and can produce as little as 10,000 tons per year.

However -leaving aside small non-integrated plants (which we shall not be concerned with in this book)- it is quite obvious from these output figures that we are dealing here with a very large-scale industry indeed.

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a/ It is quite common for integrated plants to sell an appreciable proportion of their semi-finished products to other firms.

A further interesting feature of steel processing technology -which can be noted by referring back to the diagram- is that there exist several alternative combinations of technologies (i.e. different process routes) for producing the same final product. Thus the initial raw material for plants may be iron ore, scrap,or pellets of nearly pure iron. Reduction of ore may take place in blast furnaces or in direct reduction plants. Refining to steel may occur in oxygen converters, open-hearth furnaces or electric arc furnaces. Transformation to semi-products may occur via ingot casting followed by primary conversion (i.e. rolling), or directly via continuous casting. Hot-rolling of semis may take place in one or more mills, which may be continuous or discontinuous. Some further variations are also possible in the finishing stages. This means there are often important issues of "choice of techniques" to be resolved by governments and firms planning new steelplants or major expansions of existing ones.

In summary, we have noted how steel plants straddle a whole range of different technologies, scales, techniques, degrees of vertical integration and product mixes.

Nevertheless, the multi-stage, multi-product, and complex character of steel technology, and the fundamentally "large-scale" character of most steelplants compared to plants in other industries constitute a set of notable common features.

2. Nature of Innovations in the Steel Industry and at the Plant Level

So far, we have outlined the processes involved in steel production, and briefly sketched the different kinds of plants, processes, machinery, products etc. that exist in this industry.

However, as steel technology is not static, but has been constantly evolving over the past century, and is still doing so, it is clearly relevant to a historical study such as ours to know something about how the technology has been progressing -i.e. to know something about the characteristics of innovation and technical change in the industry. The following remarks are therefore addressed to this.

The first point to note is that steel technology has been undergoing momentous changes in the last three decades. So much so that it is common nowadays to read that the steel industry is still in the midst of a "technological revolution". This revolution can be considered to have started in the 1950s with the introduction of the oxygen converter and it has been followed up by the advance to commercial feasibility of such major innovations as continuous casting, direct reduction, very large blast furnaces, ultra-high power electric-arc furnaces, high speed rolling mills, etc.

Although at first sight the relatively low published expenditure of the steel industry on R & D might seem to contradict the idea that a "technological revolution", is ocurring it is nevertheless an accurate description - at least if one judges the "revolutionary" character of a period of innovation by the results it produces. Thus, the combination of several major "breakthrough" innovations added to the cumulation of the many thousands of minor improvements made in steelmaking processes and plant design in the last three decades have had very notable repercussions. In particular they have radically affected such matters as the optimum scale and location of plants, the different types of process technologies used, the balance amonst raw materials and energy sources used in the industry, the types of transportation required for getting the raw materials to the plants as well as the manning requirements, skill levels and management needs of the industry.

These repercussions have in turn helped to fuel some major shifts in the competitive patterns of the world steel industry, as is shown most notably by Japan's striking emergence as the world's N°1 steel exporter, displacing traditional exporters, and by the rapid growth in many domestic markets of steel output coming from "mini" plants offering sharp competition to longer established giant rivals.

In view of these dramatic developments deriving from the "technological revolution" in the steel industry, it is not surprising that quite a number of studies of innovation, diffusion of innovations, productivity of new technology, etc. in the steel industry have been carried out by economists and technologists in recent years.

However, the interest of economists seems to have been "one sided" in the sense of leaning mainly towards the study of "major"breakthrough innovations. This is reflected, for example, in the relative frequency of studies of the innovation and diffusion of the oxygen converter 2/, of continuous casting 3/ and, direct-reduction technology 4/. In contrast, studies of "minor" or "incremental" innovations in the steel industry seem to have been neglected. Yet, as Gold has pointed out:

> "Concentration on major innovations cannot be regarded as adequate coverage of technological advances in view of the possibility of comparably significant contributions from the cumulation of numerous smaller improvements" 5/

In support of Gold, we can refer to abundant evidence in the technical literature which shows that "incremental" innovations have been exceedingly important in such areas as improving the performance and increasing the scale of blast furnaces 6/, increasing the efficiency and capacity of open-hearth furnaces 7/, increasing the speed of rolling mills 8/, developing higher-powered and more efficient electric arc furnaces 9/, etc.

There can therefore be no doubt that, technologically speaking, the revolution in steel technology is the result of the combination of (i) major "breakthrough" innovations, and (ii) evolutionary improvements both in the pre-existing and the new technologies. However the economic literature on the industry has concentrated rather one-sidedly on major innovations, and has not yet gone very deeply into the economics of the "evolutionary improvements", i.e. minor innovations. This is, therefore, an important area requiring further exploration.

Another significant feature of steel industry innovation, is that its sources have been multiple. They include equipment manufacturers, steelplant contractors, engineering consultants <u>and</u> steel firms who develop innovations and improvements directly on their own plants. As a matter of fact, innovation at the individual steelplant level -which is of central concern in this book- has <u>not</u> been very much studied by economists though steel producing firms are certainly significant contributors to the overall innovation process.

Once again, the reason why the contribution to innovation made by steelplants is not much written about is that it mostly has to do with minor innovations. This is because the majority of steel producing firms are never "early adopters" of frankly-still-experimental major new processes. Indeed they understandably prefer to adopt major new processes only once these have been well proved and that fact becomes widely acknowledged in publications.

Nevertheless, a considerable amount of minor improvements and adaptation to steel production processes, equipment and operating procedures are constantly being developed in most steelplants.

Furthermore, it should not be forgotten that it is operating experience in steelplants which provides much of the vital "feedback" of information to equipment and process suppliers which they use in introducing their own successively improved generations of equipment.

Finally, it is worth emphasizing that the phenomenon of plant level innovation is definitely not confined only to tuning up, adaptation and improvement" work in new plants to iron out their initial design errors and debug the process.

This was shown by A. Bailetti in his study of capital investment in the U.S. Steel Industry, 10/ where he reported that, between 1950 and 1974, capital investments for modernizing existing steelplants (i.e. for upgrading these plants and replacement of individual units) amounted to 55% of all capital investment in the industry. The point is that upgrading expenditures introduce a whole series of usually minor improvements and additions to existing plant and equipment. As for replacement expenditures, Bailetti himself pointed out that "in an industry faced with continual technological innovations, such as the iron and steel industry, plant facilities seldom are replaced by equipment with identical operating characteristics" - in other words, replacement expenditures are also often used for the introduction of minor technical changes.

Therefore, if the experience of the U.S. steel industry is any guide, one would expect to find in all steelplants that minor innovations form a prominent element in their overall technological evolution. a/

3. Technology-related Characteristics that Influence Steelplant Planning

Several notable characteristics of steel technology and

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a/ It is, of course, true, that much minor technical change comes to plants directly "embodied" in additional and/or replacement equipment ordered by the plant from suppliers. Similarly, much of the improvement and "upgrading" of plant performance involves the acquisition of supplementary equipment. Nevertheless there is always a significant level of experimentation and original technical input required by the plants themselves in order to correctly formulate their requirements, specify the precise equipment and its characteristics that will do the job, and then integrate this successfully into the unique existing complex of equipment, materials flows, etc., which characterize their particular plant.

innovation generate difficulties that repeatedly arise in planning, constructing, and starting-up steelplants, and then subsequently in modernizing them. These characteristics include:

- .the extremely large capital investment requirements for plant and equipment
- .marked indivisibilities in equipment units
- .the long gestation period of steelplant investments
- .the irreversibility and profound future influence of initial process choice
- .the idiosyncratic nature of each individual steelplant
- .the complexity and incomplete theoretical specification of steel processes

In this section, each of these characteristics are now described in turn, as a prelude to a summary of their effect on planning which will be taken up in the subsequent section.

(i) Large Capital Investment Requirements

These arise because of the heavy, sophisticated and specialized nature of steelmaking equipment. Even in small plants, additional stages or expansions may cost tens of millions of dollars. For new capacity, investments of hundreds of millions of dollars would be normal for semi-integrated plants, and thousands of millions dollars for integrated plants (roughly $1.000 million per million tons of annual ingot capacity). This level of investment has several implications. First, it means that for large, integrated plants, the level of resources required usually far outstrips what private entrepreneurs in most developing countries can borrow, or afford to invest; therefore, if a developing country is going to have one or more large integrated steelplants, the government has to step in as majority owner and provider of the capital required. This is one main reason why the large integrated steelplants in Latin America are nearly all state-owned. Second the fact that such large investments are required means that it is frequent practice for both state and privately-owned plants to borrow much of the required funds via long-term loans from banks or in the form of long-term credits from equipment suppliers; in practice, the negotiation of these loans is often a protracted process lasting months and sometimes years - and this of course injects considerable delays and uncertainties into the investment-process. Third, the size of investment requirements means that they often simply exceed what steel firms can convince budget-minded governments or skeptical bankers to lend. This has the effect that steelfirms are frequently -or even chronically- unable to carry out desirable investments in modernization and expansion, and so have to "make do" with their existing facilities at lower levels of investment. Thus the existence of huge capital requirements plays a critical role in steelplant planning, technological choices, and the way plants get developed throughout their lifetime.

(ii) Marked Indivisibilities in Steelplant Equipment Units

Closely related to large capital requirements are the marked indivisibilities a/ that obtain in several stages of the steelmaking process, for instance in blast furnaces, oxygen converters and rolling mills. b/ A major effect of these indivisibilities is that incremental capacity in these individual stages cannot economically be supplied by adding whole new units. The solution usually adopted to this problem by steel plant planners is to

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a/ These indivisibilities are associated with economies of scale in capital investment costs per ton of capacity and in operating costs per ton of output.

b/ For example in modern large integrated plants the average output per unit of equipment such as blast furnaces, oxygen converters and strip mills can be over 2 million tons per individual unit per year. The Japanese have built blast furnaces with outputs of over 4 million tons per year.

deliberately "oversize" the most indivisible equipment units when a plant is first installed (or during subsequent major expansions). Then as demand expands, addition of auxiliary equipment to the main units and/or additions of capacity in the more "divisible" stages of the process mean that production capacity can be raised in incremental steps without having to invest in new principal units or engage in the corresponding major disruptions of plant foundations, wiring, services, layout, materials flows, etc. which would be required whenever a very large new unit has to be integrated into an existing production scheme. a/

These considerations mean that the initial scaling and sizing of steelplants and their main equipment units pose genuinely difficult problems for the consultants and executives who plan plants. How big should the main unit be? It is better to have three medium-sized converters or two larger ones? Two blast furnaces or one? How much "imbalance" between and within stages should be deliberately built into the design?

Successful decisions on these matters hampered by the difficulties of making accurate demand forecasts, and by political considerations which make it uncertain when one will next be able to get government approval or funds to add new capacity. b/ Moreover there is sometimes also a major "technological" uncertainty to deal with -i.e. will plant management and staff be able to efficiently run very large (and correspondly sophisticated) units?

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a/ This is the classic problem studied by H. Chenery (1952) 11/, and A. Manne (1967) 12/.

b/ This is often a decisive consideration. Indeed, "It is very deep in every steel manager's training that his first duty is to keep the works 'unbalanced' in order to have a claim for the next round of investment funds". Fabian Society (1974) 13/

In any event, marked indivisibilities in steelplant equipment units mean that initial plant scale and sizing decisions are very influential on a steelplant's technological and economic future - and therefore deserve extremely careful consideration at the planning stage.

(iii) The long gestation period of steelplant investments

A third influential characteristic of steel-technology is the "long gestation period" that is usually required for bringing steelplant investments into operation, which can range from two to ten years depending on the size and sophistication of the plant concerned, as well as on the previous experienee of the owning firm.

According to Hunter (1970) 14/ who reports on British steel experience, "a time span of two to three years from the final investment decision until the commissioning of the plant ....is by no means unusual", while E. Gana (1976) 15/ reporting on Latin American experience, notes that "four to eight years normally run from the feasibility studies through to the start up of finished plants".

These estimates refer to the time taken up to the commissioning of the plant (i.e. up to the point at which, following equipment and plant trials, the project owner accepts that the contractual obligations and contractually guaranteed performance levels of the plant units have been fulfilled). However a good deal of further time is often subsequently taken for plants to actually achieve in practice and on a sustained basis, the full levels of productivity and rated output for which they were designed.

The overall period of time taken from initiating production to achieving rated output on a sustained basis is called the "start-up period", and was found by Baloff (1963) 16/ in his studies of start-ups in two U.S. steelplants to range from two months for an electro-tinning process to over three years for oxygen steelmaking furnaces.

These years that pass in the gestation period naturally have an important economic impact on the firm concerned due to the heavy capital charges it has to pay in the interim on its new installations whilst they are still idle or not fully working.

Hence it is a critical matter for the economic future of steelplants whether they can manage to get through"gestation" period efficiently, or whether, on the contrary, they encounter major construction mishaps or serious delays in learning how to control their plant's technology and run it at rated levels.

The sheer complexity of steelplant technology, the by-no-means completely determinate nature of the processes involved a/, and the many "idiosyncratic" elements of process technology that are associated with each individual steelplant b/ mean that a complex, protracted and difficult learning process is nearly always required to get new plants properly "run in", and to permit their staff to acquire sufficient experience to adequately control the overall process and set of variables involved.

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a/ The inherent complexity of process variables and the lack of precise theoretical models to describe what is going on in blast furnaces, steel furnaces and rolling operations means that a great deal of empirical knowledge and experience needs to be gained so as to control them efficiently. See Subsection 3 (iv) below.

b/ The actual detailed process conditions that characterize each steelplant are highly idiosyncratic because of innumerable variations between plants in terms of different equipment and raw material characteristics, distinct grades of steel being processed, different size-ranges of intermediate products, variations in operating practices and end-product specifications, etc. - which means that simple copying of techniques used in other plants is usually impossible. See Subsection 3(v) below.

In view of these considerations, there can be no doubt that the gestation period of steelplants deserves special consideration by planners, particularly as it is well known that gestation time and costs are frequently underestimated, and often deliberately so, to make projects appear more economically attractive that they really are.

(iv) The "irreversibility" and profound future influence of initial process choices

A fourth characteristic worth drawing attention to, because of the long amortization periods which are normal in steelplant investments (often 10 to 25 years), is the "irreversible" nature to the initial process choices.

In this context, it should be recalled that steelplant investments are very much location bound, as the technology involves "large, heavy very specialized equipment units which are expensive to build, difficult to move, and have limited salvage value" 17/

Furthermore, as Bela Gold (1976) has explained, once the process has been selected, this has an extremely important determining effect on the future range of technological possibilities open to the plant - for "it is apparent that the basic nature of (steel) productive processes is less amenable to managerial manipulation than output and capacity levels" 18/. In other words, once the process has been selected, firms then have to live with their choice for at least the next ten years, and very possibly twenty or even thirty years or more.

Given the existence of a range of alternative processes and process-routes for obtaining particular kinds of steel products (including varying degrees of plant integration), the question of what process to choose is often a difficult one to answer. This is compounded by the fact that the technological possibilities for improving the efficiency or flexibility of different processes are also likely to be distinct. Furthermore, relative prices of key energy inputs like coal, fuels, and electricity are likely to change (sometimes drastically) over such long periods as 10 to 25 years, so that optimum process choice at current relative factor prices is not the right criterion for making the decision.

In any event, their long lasting effects mean that initial process choices are extremely influential in the steel industry. This is why in our case studies we shall be exploring if lessons can be learned from the way past process choices were made by our plants and how these worked out in practice.

(v) The "idiosyncratic" nature of every individual steelplant

This refers to the fact that there are significant elements of novelty and "idiosyncracy" in every new steelplant (or expansion of an existing one) that gets built. In fact major items of steelplant equipment are nearly always customized "one-off" items, incorporating either some new features, or constituting an individual and unique combination of existing features. Overall plant design is also unique in the sense of representing a specially considered solution to the particular (unique) combination of requirements and conditions laid down by the customer. Hence steel firms are always in the position of operating plants which, though they may have many similar features to other plants, are never quite the same. This fact alone is sufficient to generate a requirement for minor innovation at the plant level.

Besides differences in plant and equipment design, steelplants are also "idiosyncratic" in terms of the particular set of raw material characteristics that they handle, and in the detailed nature of the product-mix that they have to produce. So this adds further "variables" which differentiate one steelplant from another and lead to a requirement for plant-level innovation.

(vi) The inherent complexity and incomplete theoretical specification of steelplant processes

A related powerful reason which reinforces the need for plant level innovation is that the physico-chemical and metallurgical processes taking place inside such equipment as sinter-plants, blast furnaces, oxygen converters, continuous casters, rolling mills, etc. are by no means 100% scientifically known and theoretically specifiable. Even minor changes in the levels or combination of process variables can introduce significant, and not always predictable, changes in the process and its output, yield, etc. The consequence is that theoretical insight needs, in all cases, to be supplemented by (and often preceeded by) the acquisition of empirical experience with the process. Indeed empirical experience is indispensable in permitting gradual improvement in the plant's "control heuristic" over the process, as well as in suggesting to personnel useful adaptations and innovations to improve control, raise yields, reduce down-time, etc.

In other words, both process "idiosyncracy" and technological complexity leading to incomplete theoretical specification of processes lead to the need for plant-level innovation. Experience acquired in other (always somewhat different) plants cannot simply be copied without adaptation even in the event that this experience is fully placed at the disposal of other plants besides the originating one.

4. The Planning Issues Raised

Having now described several influential technology-related characteristics, this section proceeds to identify some major planning issues which are raised by them:

The first issue has to do with the difficulties that surround the making of economically satisfactory initial decisions regarding process selection, plant scale and sizing decisions in the steel industry. Thus:

Huge capital requirements mean that capital market imperfections and political considerations impinge heavily on these initial choices - both delaying the investment decision process and biasing its outcome.

Also, planners may seriously underestimate the skills that will be needed by plant managements and staff to get through the gestation period of their plants successfully. Mistakes and mishaps in design and construction, and underestimates of the time that will be needed to learn to operate and control the new investment once production is started, may lead to serious financial problems early on in the life of new plants.

These problems are, of course, additional to the already difficult process-selection problems involved in estimating future demand correctly, and estimating how relative factor prices will shift - problems which are particularly acute in the steel industry because of the long amortization and planning horizons involved.

Added to this is the problem of the "irreversibility" and long-lasting effect of initial process choice, which puts a premium on the planners getting these choices right to start off with.

All these factors boil down to a major planning issue which we can - in the context of the present reasearch - formulate as follows:

ISSUE N° 1 What factors do, in fact, determine initial process, scale and sizing chocies, and what factors -from and economic viewpoint- should be allowed to determine them?

However there is, of course, more to steelplant development than just the making of these initial choices. For, right or wrong, these initial choices have to be lived with. Hence, for all existing plants, (other than those which it is profitable to scrap and replace), the firms who operate them are naturally faced with two further issues, namely:

<u>ISSUE N° 2</u> What steps, what organization, what investments, can help to get plants through the critical "learning" period needed to master the acquired technology and get it working at rated capacity?

<u>ISSUE N° 3</u> Once rated capacity and performance levels are achieved, what further steps can be taken so as to improve plant productivity, output and performance? I.e. what further steps can be taken to modernize and upgrade the technology of existing plants?

So far as these latter two issues are concerned, plant managements will find themselves in an area in which the availability of "embodied" technical innovations from outside suppliers, and of technical assistance from other steel firms does <u>not</u> by any means solve all their problems - because of plant idiosyncracy and because of the need for "in-plant" empirically-developed process control heuristics.

This naturally puts a premium on how plants develop their own <u>internal</u> technical and organizational capabilities - and this is one of the key topics examined in the case-studies.

References and notes to Chapter 1

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Chapter 2. SYNTHESIS OF THE INDIVIDUAL CASE STUDIES

This chapter provides a brief description and synthesis of the set of steelplant case-studies on which this book is based. These cover the following firms and periods. 1) Acindar, Argentina 1943-78 a/, 2) USIMINAS, Brazil 1956-77 b/, 3) Acerías Paz del Río, Colombia 1947-76 c/, 4) Altos Hornos de México, Mexico 1940-77 d/, 5) Chimbote (later Siderperú), Peru 1956-67 e/.

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b/ C. Dahlman and F. Valadares Fonseca, From Technological Dependence to Technological Development: The Case of the USIMINAS Steelplant in Brazil, Vols I and II, Working Paper 21, BID/CEPAL/PNUD, October 1978.

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e/ J. Gianella, Empresa Pública, Política y Gestión Tecnológica: El Caso de Siderperú, (State Firm, Policy and Technological Management: The Case of Siderperu), Part I: 1956 - 67, unpublished.

These case-studies were all planned to form part of the same inter-related set, and although in practice they were executed with some differences in methodology, their main objective and subject matter were basically similar.

The principal aim in all cases was to carry out a detailed empirical investigation into the technological development of these plants from their planning stage, through their construction, start-up and entire subsequent evolution up to recent times.

The idea was to generate detailed descriptive information on the overall stage by stage process of technological evolution inside these Latin American steelplants; to understand the main determinants of this evolution in terms of both the internal (firm and plant) variables and the external (contextual) variables affecting it; and to identify some of the main consequences of this technological evolution as expressed in improvements over time in plant performance.

It was also an implicit aim in each case-study to make use of the collected "package" of detailed descriptive information to generate some insights which would be useful to steel firm executives and engineers in specifying, operating and improving steelplants in the future, and useful to government planners or financial institutions anxious to evolve better guidelines for investments in this industry.

One other implicit aim, reflected in the Argentine, Brazilian and Mexican studies, but not in the Peruvian or Colombian ones, was to throw light on certain theoretical aspects of learning, technical change, and innovation activities at the plant level which could be of interest to the economics profession.

As might be expected, the various case-studies made better progress with some of these aims than others. For the general reader, much of the material in the studies would undoubtedly prove heavy going - as it contains a large dose of technological descriptions. The economic historian on the other hand, would probably be dismayed at the volume of "technological narrative" without too many organizing hypotheses to help make the story intelligible. There is indeed a certain "tyranny of facts" in the reports which makes them literally indigestible at one sitting.

However it is notable that despite all their manifold defects, produced in part by the novelty of this kind of study and in part by the enormously time-consuming and problematic data requirements involved, each study does manage (a) to bring forward and throw light on the same set of main explicative variables that are at work in plant technological evolution in all the cases, and (b) to illustrate, nevertheless, a strongly individual and characteristic historical "combination" of these variables and their impact, in each particular case.

1. Acindar, Argentina 1943-48

This first case-study looks at the technological record from 1943 to 1978 of Acindar, Argentina's leading private sector steelfirm, which is today a fully integrated producer of some 500,000 tons of rolled non-flat products per year, employs over 5,000 people, and has annual sales currently around the U.S. $ 150-200 million mark.

Acindar was deliberately chosen for study because of its technically innovative record expressed in many "home grown" adaptations included in its plants, as well as in technical articles published by Acindar personnel in Latin American steel congresses.

Also the firm's possesion of two fundamentally distinct "vintages" of plants (in distinct locations in Rosario and Villa Constitución) suggested it would be possible to observe a variety of different "technological learning experiences" in its history (i.e.both intra vintage and inter vintage).

Data was collected through several visits to the plants, through taped interviews, and analysis of various kinds of internal company memoranda, as well as through analysis of the firm's published Annual Reports and technical articles.

The main results obtained are now synthesized under three broad headings: 1) findings about the "acquisition phase" for technology, i.e. about the selection, construction and start up of Acindar's plants or major subsequent expansions thereof; 2) findings about the "improvement phase" for technology, i.e. about how Acindar upgraded and adapted in plants over time through minor technical changes and investments; 3) findings concerning the overall "learning path" pursued by Acindar given the strikingly imperfect and distorted external economic context in which it evolved (due mainly to severe planning conflicts within the Argentine steel industry as well as to Argentina's pronounced postwar macroeconomic instability).

1.1 Findings about the Acquisition Phase:

To explore the "acquisition phases" for technology in Acindar's record, the study examined first the selection, construction and start-up of the company's original plant built in Rosario in 1943; then that of its second plant built in Villa Constitución in 1947-51; and then that of the expansion of this second plant with a new rolling mill in 1969-71. Each of these acquisitions phases is now described:

Acindar's original steelplant was built in the grain port city of Rosario (Argentina's third largest conurbation), at a time *-during World War II- when all the usual channels of equipment* purchase and technology transfer from abroad were closed. This meant the building of the plant could only be achieved by a do-it-yourself operation using whatever technology Acindar could acquire or devise, from whatever sources were available. The result -described in detail in the study- was a triumph of local improvisation which involved the building of a "home-made" Siemens Martin furnace and the acquisition of used rolling equipment from Chile. It was also a crash course learning experience for Acindar's men. a/

Thanks to their ingenuity, the home-made Rosario plant was put together during 1943 and managed to turn out about 14,000 tons per year in its first few years, which, when sold at lucrative war time scarcity prices, enabled Acindar to amortize 75% of its initial capital costs after only three years of operations.

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a/ A young engineer was recruited from an already existing Argentine steelworks to design a scaled-up Siemens Martin furnace based on the drawings of a smaller furnace operated by the Argentine military; railway wagons were stripped down to provide structural beams for the furnace; some of the refractory bricks needed had to be "home-made" by crude glueing methods by Acindar's staff; second hand rolling equipment was brought across the Andes from Chile; and primitive improvised operating techniques were developed to actually produce the desired steel and round construction bars from the resulting assembly of machinery. Yet it worked.

Quite apart from the tangible economic benefits to Acindar reflected in these high operating profits and the ability of the firm's own men to design and build a second Siemens Martin furnace later on as well as modifying the first one, the early "do-it-yourself" years led to a very significant intangible benefit for the company. This was the great pride and confidence in their own innovative and technical abilities acquired by all the Acindar engineers and men whose efforts had brought the original plant to success -a pride still evident in interviews carried out more than thirty years afterwards. Indeed Acindar's willingness to undertake later ambitious expansions and to develop their own "home grown" innovations and adaptations in their plants probably owes much to their initial success in improvising their original plant in adverse conditions.

Although this original plant was expanded and modernized by Acindar after the war (in 1947-50), the small inland Rosario site was not suitable for the large ore-based integrated steelplant planned by Acindar's directors.

So, subsequently, Acindar's other steelplants were all constructed in Villa Constitución on a single large site actually on the banks of the river Paraná some 50km. from Rosario and accesible to small ore-carrying or billet-carrying ships coming up river from Buenos Aires.

Here, in the period 1947-51, Acindar put up its second plant -this was the rolling mill stage of what was intended later to be a fully integrated plant. It involved setting up a large, high speed continuous rolling mill of 215,000 tons per year capacity, on what was then a totally "greenfield" site, so that not just the plant, but considerable supporting infrastructure was needed.

For this project -when imports of technology were again possible, thanks to the end of the war- Acindar relied heavily on the technology recommended by U.S. mill-suppliers Morgans and on the technical training and assistance of several engineers from the major U.S. steel firm Republic Steel who had the initial operating responsibility for the plant and who tutored Acindar's men over a three year period to take their places. (At that time Republic Steel had an option to take out a 10% share in Acindar's equity).

Superficially it may appear that Acindar had here "retreated" from its active role in specifying, fabricating and operating their technology, as compared to when the Rosario plant was founded. However, this is not a correct evaluation for two reasons: first, the technological "jump" from simple slow, discontinuous rolling mills to sophisticated, high speed, continuous mills meant that Acindar's experience in the design and construction of the Rosario plant was quite insufficient for taking on much of a role in the design of the mill needed for the Villa Constitución plant; secondly, there was a question of opportunity costs -for the enormous scale of expansion which its new plant represented for Acindar meant that this small firm's limited managerial-technical resources were fully stretched on tasks such as helping to plan and organize the building of the needed plant infrastructure, recruiting and training many new workers and staff, expanding the firm's sales and marketing efforts, and simply learning to operate and manage the sophisticated large new mill and the greatly expanded scale of company operations that was now involved. Hence, even if Acindar's engineers had theoretically been able to make a bigger contribution to engineering design or auxiliary equipment fabrication for the new mill, this would have had a high opportunity cost in terms of other urgent tasks left unattended, due to the size and the rate of expansion then being undertaken.

The case-study goes on to analyse a third acquisition phase in Acindar's record. This was the installation of another high speed continuous Morgan rolling mill in its Villa Constitución plant in 1969-71 some twenty years later than when the first mill was installed.

Foreign firms still had the overall responsibility for core equipment supply and project execution for this second mill. However, in this case, Acindar's engineers made significant technical contributions to layout and to equipment specification, including requiring scores of detailed modifications regarding particular equipment items. Acindar engineers also supervised the local fabrication of many of the complementary items of the mill's equipment and support structures, etc. and actively took part in mill start-up. Evidently, the accumulation of 20 previous years of rolling mill operating experience in Acindar, plus experience of introducing their own modifications and improvements to their first mill, plus the superior knowledge of Acindar's own engineers (as compared to foreign suppliers) concerning their own specific technical requirements for the new mill - were what enabled Acindar to make significant technical contributions to the design and execution of the project

In summary, each of the three acquisition phases analysed illustrates different economic factors at work in this phase. The first, i.e. the construction of the Rosario plant reinforces the view of Hirschman (1967)[4/] that "crash" learning experiences which are induced when a firm has to find an improvised or innovative solution to meet the challenge involved (or else face the collapse of its project) can have valuable psychological effects in making firms more willing to take risks and innovate in the future, provided the outcome of such "crash" learning experiences is successful, as it was in this case.

The second (i.e. the 1947-51) foundation of the Villa Constitución plant) illustrates that major 'jumps' in technology when a firm expands may render its previous experience relatively inapplicable to the technological and equipment requirements of the new technology being acquired, and also that large scale expansions may greatly boost the opportunity costs of applying a firm's limited managerial-technical manpower to carrying out equipment design, engineering or construction tasks that can be contracted from outside specialist firms.

The third (i.e. the 1969-72 expansion of the Villa Constitución plant with a second Morgan mill) suggests how a firm's learning-from-experience over the years in operating, maintaining and improving a set of equipment can lead to a sort of "comparative advantage" being possessed by this firm as compared to foreign engineers and equipment suppliers when the time comes to work out the precise technical specifications of technologically similar equipment which the firm decides to add later on so as to expand its output.

1.2 Findings about the 'Improvement Phase' for Technology

The case-study also looked carefully at the kinds of investments, learning and research efforts and technical changes which were made by Acindar to improve, upgrade and adapt its plants in the years following the initial construction and the achievement of nominal (rated) capacity in these plants. This was done by analysing the expenditure on fixed assets in the firm's Annual Reports, and by examining data collected on some 263 minor technical projects carried out in the Rosario plant, 31 minor investment projects in the Acevedo plant, and a representative sample of 54 engineering and research projects carried out by the firm between 1970 and 1974.

The main findings were that (1) some 25-30% of all Acindar's investments in fixed assets were devoted to minor improvement-type investment to its existing plants and this was clearly reflected in the upgraded performance achieved over time in all the plants; (2) these improvement-type investments usually involved technical changes rather than mere duplication of equipment; (3) the objectives of these technical changes were broader than just the search for product cost-reductions; they also included product diversification, the "stretching" of plant capacity in existing product lines; corrective steps to deal with shortages and problems emerging in raw material supplies; and product quality improvements; furthermore many technical changes were aimed at more than one of these objectives simultaneously. (4) most improvement projects were clearly stimulated by the prior emergence of specific market demands, specific production problems or specific raw materials constraints; the firm was, in most cases,"reacting" to these stimuli by introducing technical changes, rather than "initiating" the changes itself; however a minority of improvement projects seemed to originate in the spontaneous suggestions of the firm's technical staff, or in the firm's desire to maintain its technological and market ascendancy by launching advanced products in certain product lines ahead of its competitors; (5) the minor technical changes introduced were apparently characterized by high expected rates of return (with payback periods estimated ex-ante in one project sample as being in the 6 months to 3 year range); also it was clear that, often, if minor technical changes had not been carried out, this would have had high opportunity costs in terms of the idle plant capacity that would have resulted from failure to introduce such changes in response to plant bottlenecks, production problems, market needs or raw material supply problems; (6) many of the minor technical changes -particularly in the Rosario plant- were conceived, designed and executed by the plant's own personnel, and often involved ingenious "sui generis" solutions which boosted plant performance at low investment cost; (7) even when the technical changes mainly involved the addition of ancillary machinery bought new from machinery suppliers (as was often the case in the main rolling mill plant) significant in-house technical effort from plant personnel was still observed, and was dedicated to specifying, adapting and fitting the new machinery into the pre-existing complex of existing machinery, process flows and procedures; (8) Acindar's capacity to specify, design and implement plant improvements was not "automatic" but depended on deliberate organization for its needed inputs of information, skills and resources;the main sources of these were the firm's Quality Control department and laboratory back-up, its Industrial Engineering department which does operations-research studies, the

Maintenance Engineering department, the Project Engineering department, and last but not least, the experience and information obtained from the engineers and technicians directly in charge of production;(9) there was, in contrast, no separate R&D laboratory or separate R&D staff, nor any fixed budget for research work, even though a certain number of clearly experimental research studies, tests, and pilot production attempts as well as project engineering studies and operational research studies were detected in the various technical departments; (10) the formal allocation of resources to technical capabilities was mainly done at the level of the budget and the procedures of each of the technical departments; these departments were also regularly required to contribute technical resources within their sphere to help implement new equipment investments decided by the "Investments Approval Committee" of the Board of directors.

These findings all point towards the economic and organizational importance of plant improvements in Acindar's record. In fact the large number of minor technical change projects encountered, the cumulatively high level of investment in them, the sophisticated organization needed to make them possible, and the need for minor technical changes created by changing external conditions in the firm's factor and product markets and by production problems in the plant itself,all show this. So, too, does the significant cumulative upgrading in performance obtained in all Acindar's plants. This was especially noticeable in the "old vintage" Rosario plant where effective capacities in the steel shop and rolling mills were increased by amounts ranging from 66% to 130% beyond nominal (original) capacities.

So Acindar's record suggest that the "improvement potential" of steelplants,and the "in-house" capacity to make good use of this potential, may repay careful consideration by steel firms who might well find it profitable to invest more money in minor plant improvements -and in their technical personnel and organization who can implement these improvements- than they are currently doing.

1.3 Findings concerning the overall "learning path" pursued by Acindar given the strikingly imperfect and distorted external economic context in which it evolved

A third set of findings from the case-study concern how factors in Acindar's external economic environment caused the firm's "technological learning path" to be rather less satisfactory than what the firm was capable of, both from Acindar's own private viewpoint and the social viewpoint.

One indicator of this is to compare the very rapid growth of Acindar's steelmaking assets and output in tis first decade 1943-53 with the much slower growth of these assets throughout most of the 1960's and 70s.

Thus in its first ten years of operations Acindar's energetic management and technical staff managed to build two plants and to become market leader with around a 40 % share of the domestic non-flats market.

However/further growth in steel production was greatly stunted
Acindar's
by exogenous factors beyond the control of the firm, having chiefly to do with the "troubled" postwar macroeconomic performance of the Argentine economy, the poor performance of the state steelworks SOMISA and the erratic official planning of the industry. Broadly speaking, official plans tended to overload the capacities of SOMISA with ambitious expansions, whilst holding back the semi-integrated private producers from integrating their plants.

The net result for Acindar was that, in its second and third decades, much of the technological development of the firm's steel-plants involved its management and engineers in seeking "second-best" and "third-best" expansion patterns and technological solutions, given that (a) the most obvious and desirable expansion path for the firm -which involved becoming an integrated producer much earlier on during the 1950s or 60s- was repeatedly delayed or blocked by the opposition of the official planners of the industry; and (b) development as a semi-integrated producer was made difficult for Acindar since it could not always count on getting all its needed supplies of semis (billets and slabs) either from SOMISA (due to the latter's performance problems) or from imports (owing to foreign exchange constraints for macroeconomic reasons).

A striking illustration of Acindar having to follow a "sub-optimal" technological path in response to such circumstances is provided by the technological record of the Rosario plant, which is documented in detail in the study. What emerges is that although this plant was acknowledged as obsolete some twenty years ago, it was nevertheless kept going by Acindar and subjected to a prolonged series of piecemeal technical adaptations and improvements before finally being scrapped only in 1978. The apparently "paradoxical" strategy of Acindar in improving this obsolete plant is shown to have been a rational response to the marked "imperfections" recurring in the Argentine steel industry in the form of raw materials import rationing and erratic government policy towards the private steel sector. So this is a case of a firm being forced to channel some of its resources down a "minor technological road" (i.e. improve an obsolete technology) when the "main road" involving switch to better practice technology was blocked by exogenous economic distortions and public policy.

Another clear instance of a "sub-optimal" technological learning path being pursued was the nearly eight years of planning, engineering, and management efforts uselessly expended by Acindar on a major plant integration project in the period 1961-68, during which, on four successive occasions, the Argentine government ratified their approval of the project, only to eventually cancel it in 1968 after Acindar had already invested heavily in planning and training many of its engineers, as well as in initial preparations of the site, and even in some equipment for the project.

In order to view this situation from the "social welfare" standpoint, the case-study also explains the position of the Government which believed that expanding the large integrated state steelworks SOMISA would lead to steel production at lower costs than in Acindar's projected integrated plant, because of economies of scale. But the actual learning path pursued by SOMISA, when required by the state to undertake rapid expansion up to 2 1/2 million tons of capacity, turned out to be clearly "sub-optimal". This was because of the long delays experienced by SOMISA in this expansion due to some important constructional and operational mistakes made which required extensive "compensatory" engineering and investment by SOMISA to put things right.

On the basis of these outcomes for Acindar and SOMISA -as well as some data collected about the development of other firms in the industry- a criticism of Argentine official steel industry policy emerges: it is that the pattern of Argentine state interventions to determine choice-of-techniques, scale of plant and division of labour between public sector and private sector firms in the steel industry seems to have consistently underestimated the economic importance of learning activities - in effect underutilising the learning capacities of Acindar and other private sector firms, whilst overloading the learning capacity of the state steel firm, SOMISA.

The result was to generate "sub-optimal" learning paths and compensatory R&D in both private and state sectors - implying a notable waste of resources, many years of lost time in achieving national self-sufficiency in steel, and consequent more acute national balance of payments problems.

An important lesson from the Acindar case-study is that policy should seek to take advantage of available learning resources (whether these are in the private or public sector firms) via steps which not only put these resources to work (and avoid leaving them idle) but which also ensure that they learn in the right areas and/or techniques, rather than being partially wasted by being applied to obsolete techniques, or to "compensatory" activities made necessary by previous planning blunders.

2. USIMINAS, Brasil 1956-77 [a/]

The Brasilian study tracks the technological record of USIMINAS (Usinas Siderurgicas de Minas Gerais) which by 1979 was producing over 3 million tons of flat steel products per year and which is the largest, most successful and efficient of Latin America's state-owned integrated steelplants.

It shows how USIMINAS profited and then emerged from their 1956-66 stage of dependence on their Japanese joint-venture partners, how they greatly boosted the capacity and productivity of their initial plant design at near zero investment cost during 1966-72; how they subsequently undertook on schedule a series of very rapid expansions in the period from 1973 to the present day; and how they have now evolved to the point of developing technology of their own and selling technical assistance both nationally and internationally.

Apart from analysing and contrasting the two different principal methods of technical change used by USIMINAS - viz. upgrading existing plants versus acquiring new plant - the study shows that USIMINAS owes its success to a consistent, long-term, and aggressive technological strategy emphasizing intensive learning alongside foreign technology suppliers, heavy investment in upgrading and training of own technical personnel, and the development of a comprehensive technological infrastructure including basic engineering, project engineering and research. So this is a case, as its authors explain, of a firm which "rather than seeking to resist foreign technology .. has successfully sought to pull itself up by it" .. and "shows what is possible when the domestic

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a/ This study is based largely on secondary sources of data, as direct plant visits were ruled out by the reluctance of the company to co-operate in this regard. However, access was provided to the company's excellent information and documentation services, and this enabled the joint research team of an economist and an engineer to bring together a very substantial volume of technical, economic and organizational data on USIMINAS's record.

partner pursues an aggressive technological strategy".

Several of the particular facets which help to explain USIMINAS' remarkable performance, and which are disclosed in the case-study, will now be briefly reviewed.

One such facet is the workings of the "joint-venture" arrangement between USIMINAS and a consortium of Japanese firms led by Nippon Steel (later to prove itself the world's number one steel company in size and technical performance). This arrangement proved excellent from USIMINAS' point of view. This was because the Japanese put an unusually heavy and dedicated engineering, technical assistance and financial effort into getting USIMINAS's original plant built, started up and operating successfully - their motivation being that they wanted to provide the world a "showcase" of what the Japanese could do as equipment suppliers in the world steel plant market then dominated by the U.S.A., Germany and England. Equally important is that USIMINAS's management made very good use of the rich "learning" opportunities provided to their own staff by this partnership with the Japanese.

This rapid learning enabled the Brasilians to completely take over the running of the plant in 1966, and begin introducing their own substantial changes in organization to improve on what the Japanese had set them up with. The study also shows that USIMINAS made carefully planned and intensive use of continued technical assistance from Nippon Steel (and other companies) after the first ten year "apprenticeship" period (1956-66) was over. In a sense then, one can think of USIMINAS as having been "tutored" throughout its development by the world's premier steel company (Nippon Steel), and having proved capable of rapidly absorbing more and more advanced aspects of steel technology whilst steadily increasing their own independent technical and innovative capacity.

A second facet analysed in the study relates to the "exogenous" conditions of USIMINAS' development including both the market demand situation, and the increasing levels of Brasilian government intervention and planning in the industry's expansions throughout the 1960s and '70s.

In this regard, it is shown how the domestic steel market recession of 1964-68 which began just as USIMINAS was starting production had the effect of greatly sharpening the firm's financial crisis (which had been caused mainly by the rapid inflation of the cruzeiro during USIMINAS's construction period) and how this situation provoked two very creative technical responses from the firm. These were, first, a notable and successful effort to raise the quality of plant output so as to be able to break into export markets to mitigate the domestic demand crisis; and second, a successful effort to boost sales revenue and reduce production costs at low levels of additional investment through squeezing more and more output out of the initial plant installations through a long sequence of minor operative and technical improvements to "stretch" their capacity.

Subsequently, from 1969 onwards, quite new exogenous market conditions prevailed. The market boomed, and the government came actively onto the scene offering subsidised capital to those firms whose expansion plans fitted with the government's investment criteria. In this environment, USIMINAS now faced the very different challenge of planning, engineering and bringing on stream and then up to full capacity working, a great deal of new plant and equipment so as to expand output up to 1.8, then 2.4, and then 3.5 million tons per annum, all during the 1970s. The remarkable thing is that this very fast rate of expansion, not just of capacity but of output, was achieved on schedule by USIMINAS, in contrast to some notable delays experienced in the similar expansion programmes of the two other comparable large Brazilian integrated flat products firms, COSIPA and CSN. This was mainly due to the unusually effective internal organizational response developed by USIMINAS to cope with these "exogenously demanded" expansions.

The analysis of this organizational response is another facet covered by the study. Already, earlier in 1966, USIMINAS undertook a major administrative reform to streamline plant operations when the Japanese left, which included the setting up of a "standard cost" system for the tracing and detailed analysis of product cost components, coupled with making systematic contrasts of their plant's performance with that of comparable plants internationally. However, the beginning of the major expansion programmes stimulated the company to (a) reorganize itself to develop strong internal basic project engineering and detailed project engineering capacity, as well as equipment manufacturing capacity to help handle the expansions and (b) to boost its information search capacity and its internal technical change capacity and research capacity to help in constantly improving plant performance and operating efficiency. To help make all this possible, the firm also invested very heavily in the training of its own staff and in technical assistance and technology contracts with the leading steel firms helping to supply inputs to the expansion projects. In other words USIMINAS systematically exploited and invested in the oportunity to learn from, and alongside, its foreign suppliers, so as to absorb relevant knowledge and skills, and so as to be in a position to handle things independently second time round. Moreover, in the course of this, they were guided by their own explicit long-term strategy of putting together within their own organization all the essential engineering, technical, information, and research backup needed to manage their expansions, keep abreast of and introduce the latest technical changes, and develop their own specifically needed innovations.

3. Acerías Paz del Río, Colombia 1947-76

This case-study traces the technological record a/ of Colombia's leading steelworks, Acerías Paz del Río, from its foundation in 1947 through to 1976. Throughout this whole period, Paz del Río was the country's only fully integrated steelworks, b/ and it accounted for roughly 90% of national output of rolled products in the period 1955-59, roughly 75% in the 1960s falling to around 55% in 1976. The study therefore deals with easily the dominant firm in the Colombian steel industry.

The technological record of this firm is, however, fundamentally a "troubled" one, which can be divided into two basic periods. The first is from 1947 to 1960. It corresponds to the founding of the enterprise, the planning and building of the plant, its start-up, and the difficulties experienced in building its output up to initially rated capacity levels. The second period, which overlaps with the first, is from 1957 to 1976 and corresponds to the firm's efforts to correct the design-defects of the original plant and simultaneously greatly expand the plant's capacity, a programme which proved subject to long delays and serious difficulties in execution, and in final results, and which was still incomplete in the last year covered by the study (1976).

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a/ There is very little data in this case-study on costs, prices, productivity profits or the overall economic performance of the firm. However it can be deduced that several of the major technological difficulties experienced must have rebounded very negatively on plant productivity and product costs.

b/ The study analysing Acerías Paz del Río also documents the development of Colombia's four semi-integrated works. However, the record of these works is not analysed in this book.

The following account -which is based strictly on the data provided in the case-study- now resumes several of the main features of these two periods.

The founding of the plant was mainly the result of government promotion. The officially backed Instituto de Fomento Industrial (IFI) proved in the 1940s that large deposits of iron ore, coal suitable for coking, and limestone were available in the Boyaca region, which made an integrated steelplant based entirely on local raw materials feasible. This led to the official founding of the "Empresa Siderúrgica Nacional de Paz del Río" in 1947 with 20% of its capital provided by IFI, but most of the rest still needing to be subscribed.

In fact, this points to the main immediate difficulty experienced by the company, which was shortage of finance. True, further help was provided by the Government in terms of capital contributions from the treasury and a special steel promotion tax which was deductible for those individuals buying shares in the company. However these measures could only partially finance the project -which made the obtaining of substantial foreign loans essential.

Following the delivery of the first feasibility report, commissioned in 1948, the World Bank was approached for a loan of $US 50 million to build an integrated plant with 193,000 tons per year of capacity. The Bank, however, refused this request alleging that the Paz del Río project as set out in the feasibility report was overoptimistic in its demand, price and cost projections. In fact the Bank recommended that a semi-integrated coastal steelworks based on imported scrap should be built, rather than the projected integrated Paz del Río works which would be located at Belencito, 200 km north of Bogota, at 2570 meters above sea level in the mineral rich zone discovered by IFI in Boyaca. This refusal of the loan touched off an intense national, political controversy, which ended with the government permitting the Empresa Nacional Siderúrgica Paz del Río to negotiate and obtain an alternative loan of $ 26 million dollars, on tougher interest terms, from a consortium of

French suppliers and Banks, to build a somewhat smaller version of the integrated plant at Belencito, with 126,000 tons of steelmaking capacity.

This loan was signed in 1951. The engineering was done by a U.S. engineering firm with help from the French equipment suppliers and the plant was built, and started up in October 1954. However, it then took virtually six years, until 1960, before the plant was producing at its nominal capacity. According to the case-study - which was based largely on evidence drawn from plant personnel - this long delay was due to several conceptual errors, as well as design, construction and equipment defects, in the plant's original technology.* The most fundamental problems were (1) the lack of a sinter plant in the original design - badly needed for exploiting the high percentage of fine particles characteristic of the iron ore mined in the Boyaca region[a/]; (2) the lack of provision for an adequate electric energy supply, which troubled the first five years of the operations of the plant's electric arc furnace and held up the creation of adequate haulage capacity by electrified railway to bring the iron ore and coal to the plant; (3) the lack of inclusion in the plant's original technology of a versatile primary rolling mill, which forced the company to specialise in producing a narrower range of products than was set out in the plans; (4) various construction weaknesses and defects alleged in the coke washing plant, blast furnace and steelshop.

Perhaps some of these problems may be partly attributable to the nature of the agreement signed with the French equipment-supplying consortium, which was a "tied" loan, made available to Acerias Paz del Rio mainly in the form of equipment provided by the consortium itself. Hence there appears to have been little or no bidding around for alternative equipment suppliers

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a/ The point is that fine particles were unsuitable for direct charging to blast furnaces. So the lack of a sinter plant forced the firm into having to mine an uneconomically high tonnage of iron ore per ton of pig iron produced in the blast furnace.

* One should not, however, assume that fault lay with the suppliers, since no evidence was collected from them, and the case-study does not indicate under what constraints or instructions they were operating.

or specifications, and possibly not enough control by the Colombian side over what their suppliers provided. [a]

The net result of these serious technological problems, coupled undoubtedly to the inexperience of the company's own staff (40% of the workers were illiterate, and the company had to set up its own schools for them), led to a delay of six years from the start up of the plant in 1954 through to the point in 1960 when it achieved production levels at its nominal capacity of around 120,000 tons per annum.

The "second" period of Acerias Paz del Río mentioned above - i.e. 1957-76 involved the "correction" and improvement of the initial plant, and substantial additions of new equipment as well as adaptations to increase its capacity. Like the first period, this second period was also plagued with difficulties though it contains within it a remarkable technological "success story" in regard to the plant's blast furnace.

The original plan for the correction-cum-expansion of Acerías Paz del Río was put forward in 1957, and would have included a second blast furnace to lift pig iron capacity from 177,500 to 377,000 tons per year. However an acute demand crisis of 1957-58 forced postponement of the whole plan until 1960, and in fact the main finance for the plan was only secured (from the World Bank) in 1963.

Furthermore, for reasons not described in the report, (but which may have had to do with low demand projections and financial restrictions within the company), this second blast furnace was never built within the period covered by the study, i.e. right up to 1976. Instead, the main corrections and expansions of the plant that took place (mainly in the 1963-68 period) were (1) the installation of the sinter plant, (2) the installation of a versatile, large-scale blooming-slabbing mill with a capacity of one million tons per annum i.e. nearly four times the existing steelmaking capacity of the plant, (3) the installation of a 400,000 ton per annum 'Steckel' mill for

a/ Possibly too, the lack of finance for the project encouraged the firm to try to get its plant "on the cheap" by accepting the omission of key installations.

the hot-rolling of flat sheet steel, and (4) several modifications to the existing blast furnace to boost its productivity and capacity.

Unfortunately, there was a major problem with this expansion which was that it did not include a cold-rolling mill for flat products. Yet, during the 1960s the rapidly growing internal Colombian demand for steel flat products was mainly for cold-rolled, not hot-rolled sheets. In fact demand for the latter was calculated in 1975 as only about 35,000 tons per annum. The consequence was that the Steckel mill could only be operated, right up to 1976, at around 5% of its capacity. As for the 1 million ton blooming-slabbing mill, this could only be operated at up to 25% of its capacity, producing mainly blooms for Paz del Río's main line of non-flat products,but very few slabs, for lack of a cold rolling mill beyond the Steckel to feed them to.

The German advisers called in by the firm in 1968 advised the installation of a cold rolling mill. However by 1972 when Acerías Paz del Río wished to acquire this mill, they postponed purchase due to lack of adequate electrical energy supplies. (In fact the energy problem dating from the founding of the plant was still not completely solved in 1976, owing to low thermoelectric generating capacity from the local power company and inadequate transmission lines to the plant.).

A further blow to the projected acquisition of the cold rolling mill fell in 1974 when the acute shortage of steel on the world market and the consequent plant investment boom led the equipment suppliers to double the price of the mill, which Acerías Paz del Río could not afford - especially since the shortages of steel also meant that the company would have had difficulty in importing the needed supplies of slabs with which to produce the coils to feed its new mill.

A further relevant point is that from 1975 to the end of 1976 (the end point covered by the study) the major rationalisation and expansion programme needed for Acerías Paz del Río - at a cost of some US$ 500 million - has been stalled for lack of finance and lack of agreement with the Colombian government on its form of participation in the company.

For all these reasons, the expansion programme put forward in 1957 still cannot be considered as having been properly completed by 1976, nineteen years after its formulation.

By way of interpretation, one can see that financial problems (themselves partly connected to the difficulties experienced with the initial plant) have plagued Paz del Río's expansion programme. Also, there seem to have been some very faulty demand projections for flat products underlying the programme. Furthermore one can surmise that unstable Colombian demand conditions have been a negative factor in the growth and finances of the firm. Thus, out of the twenty five years from 1951 to 1976, apparent internal steel consumption in Colombia rose 13 times, and dropped 12 times. Moreover the last few years covered by the report, 1972-76, were ones of clear economic stagnation. Clearly too, exogenous factors such as the world steel crisis, and the firm's not fully satisfactory relations with the Colombian Government, have not helped.

Nevertheless, not all the record is one of gloom. For one thing, the case-study hints but does not document that in spite of the manifold difficulties the company has managed to be profitable, exploiting its dominant position in the Colombian steel market.

For another thing, Acerías Paz del Río has achieved some remarkable increases in the productivity and the capacity of its blast furnace between 1954 and 1976:- for example, in 1960 over 4 tons of raw material had to be charged to the blast furnace per ton of pig iron produced. In 1975, only 3.24 tons of raw materials were required. The original (nominal) capacity of the blast furnace when first operated was 500 tons per day of pig iron. In 1976 this had been boosted by multiple modifications to 840 tons/day, and plans were imminent to boost it further to 1,000 tons per day -- i.e. a 100% increase compared to the original capacity. Furthermore, the plant's engineers and technical staff had by this stage (1976) clearly achieved considerable internal capacity to conceive and execute their own technical changes and innovations.

Nevertheless the two points that stand out strongest in the Acerías Paz del Río case-history are (1) the extent to which the technical efforts of the plant have had to be devoted to corrective or "remedial" measures and investments to cope with the difficulties provoked by the localization of the plant, its poor initial "technological profile" , and the investment constraints which afflicted its expansion plans; and (2) the immensely long time taken from the planning stage through to full implementation of both the initial plant (13 years), and the expansion programme (19 years), as well as the extent to which various exogenous factors as well as faulty planning helped to exacerbate these situations.

4. Altos Hornos de México (AHMSA), Mexico, 1940-1977.

The Mexican study covers the technological evolution of the state-owned integrated steel plant Altos Hornos de México (AHMSA) which was constructed during the Second World War.

The analysis shows how (a) the initial choice of AHMSA's technology (which consisted of obsolete, used, "scrap" equipment which was all that could be obtained at the time), and (b) the effects of the successive "imperfections" introduced by government policy, and (c) the virtually permanent excess demand situation in the protected Mexican domestic market, have all strongly conditioned the technological strategy followed by the firm -- a major consequence of excess demand being that technical changes to increase output were more important in most periods than technical changes to reduce production costs.

At the level of individual plant sections and equipment units, the study found that an impressively large number of minor technical changes were introduced by AHMSA, in most cases as reactions, or "defensive" responses to specific urgent operational problems or needs, rather than as the result of carefully pre-planned efforts. It was also discovered that most of these technical changes could be classified into a relatively discrete number of recurring "areas of engineering challenge" or, to use another phrase, "natural trajectories of technical change" that apply in steelplants.

The authors' conclusion is that it would be profitable for steelplants to have a more explicit and offensive strategy towards the generation of minor technical changes than the almost wholly "defensive" strategy observed in the present case.

A further feature of AHMSA's record is that - following upon the notable effort of improvisation which was made by AHMSA to get their initial plant going (based on reconditioning used equipment) the firm acquired great confidence in their own abilities and adopted the policy of always using a heavy input of their own design and construction skills in subsequent plant expansions. As a result, AHMSA's second and third blast furnaces, were substantially AHMSA designed and constructed rather than merely being commissioned from international suppliers.

However the firm's fourth blast furnace which started up in 1971, was, in a change of policy, bought from international suppliers of engineering and equipment, and AHMSA experienced considerable technical problems in getting this rather more sophisticated furnace to work properly.

Even more troublesome appears to have been the results of acquiring, also from international suppliers, a new B.O.F. steelmaking plant with three oxygen converters which started up during 1971 and 1972. AHMSA's acquisition of this technology is alleged by the AHMSA engineers interviewed in the case-study to have involved some design errors by the foreign suppliers [a/], and to have been undertaken with inadequate technical and organizational preparation on AHMSA's side. As a result, AHMSA's technical efforts had to be devoted first to a longish process of "learning-by-doing" with the new technology (they had used Siemens-Martin steelmaking before) and, subsequently, to undertaking several "remedial" technical changes to mitigate or remove the problems alleged to have been inherent in the original plant design. Some indication of the problems experienced is that by 1977, the last year covered in the study, this steelshop was still not working at its nominal capacity even though start-up had begun six years before, in 1971.

This example illustrates a possible error that even experienced steel firms with considerable technical ability, like AHMSA, are prone to making. This is to underestimate the problems involved when firms make "jumps" to fundamentally different (and more sophisticated) technology. Such "jumps" probably make it more difficult for the firm to specify correctly or to understand what it is acquiring, and unless very active steps are taken by firms to get first class advice on these matters and to engage in very energetic prior consultations, paying

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a/ One should not, however, assume that fault lay with the suppliers, since no evidence was collected from them, and the case-study does not indicate under what constraints or instructions they were operating.

maximum attention to specific local conditions, then the technology selection may slide out of the firm's hands to such an extent that

design errors, construction errors and start up errors are more likely to ensue.

5. Siderúrgica de Chimbote. 1943 - 1967.

This case-study looks at the period from 1943 onwards to 1967 covering the foundation and early years of operation of the plant known as the Siderúrgica de Chimbote, which was later renamed SIDERPERU. Most of the data in the report relate to the period from 1956-67 during which the plant produced a maximum annual output of 82,000 ingot tons. It was the original intention of the study to cover the whole period from the foundation of the plant through to 1976, including the major amplification of the plant implemented in the second half of the 1960s and the subsequent "plant balancing project" of 1975. Circumstances, unfortunately, ruled out completion of the study. The part completed was the analysis of the first-stage up to 1967. So it is only some selected features of this first stage which will now be resumed here. During this period virtually the entire output of the plant consisted of non-flat, mild steel products for the construction industry.

The main feature of interest in the study is, without doubt, the very badly mistaken choice of initial technology that was made for the Chimbote plant. This consisted in the use of an unprecedented and technologically inefficient and costly steelmaking method which was highly intensive in its use of electricity, coupled with the use of a method for making pig iron that was also electricity-intensive, for a plant whose supply of electric energy proved to be very costly as well as insufficient in quantity.

How did this happen? Several factors seem to have contributed. First the main government objective in promoting this project seems to have been to gain political capital by launching steel production in Peru rather than by any marked concern with the efficiency of the operations once launched. (A concern which begun to show itself more clearly after the first few years of very high cost operations). Secondly, the project was not implemented in a planned, unified and organic way but in piecemeal fashion, in fits and starts, owing to financial shortages and administrative reorganizations within the corporation managing the project. Third, there was apparently an almost complete lack of technical capacity at that time on the Peruvian side, which led to passive reliance on the specifications, equipment and training recommended by the chosen foreign suppliers. Fourth there seems to have been a badly mistaken assumption underlying the Chimbote project that the plant would be able to count on a fully adequate and cheap supply of electric energy; in practice the opposite proved to be the case as the cost of its energy to the company included helping to pay for the installation of local generating and transmission facilities. Fifth, the small size of the initial capital of the company in charge of operating the plant (U.S.$2,1 million) suggests that, possibly, the effort to have a plant of some kind at rock-bottom initial investment cost may have played some role in the lack of selectivity displayed.

Yet even with all these contributing factors, it is difficult to understand the actual choice of steelmaking method that was made. This consisted of the technologically unprecedented method of refining a charge consisting of 50% molten pig iron and 50% solid scrap in electric arc-furnaces. Normally it is considered that pig iron should only be used as up to 10% of the charge in arc furnaces, and should be charged in cold solid form, not as hot metal, and in any event is only advisable for use when the carbon content of the scrap is less than 0,5%. The 50 - 50 hot-metal/scrap charge used in Chimbote, in contrast, is reckoned to require the input of about 50% more electric energy, and to take up 50% more refining time than the normal method of melting a 100% scrap charge with adequate carbon content. It also produces violent chemical reactions in the furnaces, which make the refining process difficult to control and which cause abnormally heavy wear on the furnace refractory linings.

In other words, the steelmaking process selected for Chimbote was inherently inefficient, even supposing the availability of a satisfactory and cheap supply of electric energy.

The pig iron making technology chosen was also mistaken in the sense that it involved the electricity-intensive method of electric-reduction furnaces rather than a conventional blast furnace. In the event, both the high cost of producing pig iron (due to electricity costs) and the undesirability of charging so much pig iron to the steelmaking furnaces resulted in the firm deciding never to work these two reduction furnaces at their full nominal capacity. In fact production from these furnaces began to be deliberately reduced from 1962 onwards.

Another element of poor initial selection of technology was the small, obsolete, manually operated flat products rolling mill initially acquired, but closed down five years after plant start-up, in 1963.

Altogether, then, it is clear that the Chimbote plant had an inauspicious technological start.

Another aspect worth noting is the long gestation time involved in the foundation of the plant. Thus, it took seven years from the initiation of the project in 1943 to the first contract for acquiring major pieces of plant equipment, in 1950. It then took four more years until the corporation organizing the project had got itself fully mobilized for the construction work, which it managed to complete by 1956 under the supervision of the foreign suppliers. It then took approximately two years more until 1958 before most of the plant installations can be considered to have definitely started up. And then a further three years until crude steel output had reached the nominal capacity of the electric arc furnaces. These long construction and start up delays added to the economic burdens imposed by the physical inefficiency of the process itself(caused by the erroneous initial choice of technology). This led to very high unit production costs which were additionally inflated by overmanning and excessive administrative costs.

The case-study suggests that the problems described in the previous paragraphs were partly caused or aggravated by (a) the lack of managerial or technical capacity in Peru at that time able to handle the very great "jump" in scale and complexity which the plant then represented in terms of Peru's previous industrial experience, and (b) the complete lack of any coherent government policy or adequate government criterion towards this state enterprise in its early years.

So this was, given the country and the period, a large "infant enterprise" launched with a difficult birth into an unprepared environment.

Interestingly, however, the subsequent development was somewhat more encouraging - for the case-study documents an important learning process on the part of the Chimbote plant's staff signalled by (a) an initial period from roughly 1958-61 of learning to control the original process, and then (b) a period from about 1962 onwards of gradually introducing some minor technical changes at very low investment cost into the plant, which led to improved productivity, especially in the steel furnaces and merchant rolling mill whose effective production capacities were stretched substantially beyond the initial nominal levels, and where costs were reduced between 1961 and 1965 by 25% and 26% respectively.

It is notable however, that the Chimbote plant hardly diversified its production at all during the period under study, nor introduced special grades of steel, and in this sense fell behind the requirements of the more diversified steel demand profile then emerging in Peru.

This failure of the plant to diversify is in part attributable to the difficulties posed for such diversification by the steel making process used, in part to the great heterogeneity of the imported scrap supplies used by the plant, and in part to the lack of the investment funds that would have been needed.

However, probably more important than all these reasons was that the restricted goal set by management of improving the plant's productivity and output in its few, existing specialised products for the construction industry was coherent with the political pressures under which the Chimbote plant then operated in Peru. For its management needed to justify the extensive tariff protection granted to the plant in 1962, lower its criticisable high prices, and thus help persuade the government to contribute the large sums needed for the expansion of the plant that was planned since the early 1960s. This led to the objectives of (a) setting prices as low as possible (which cut into profits and reinvestible surplus) and (b) trying to achieve cost reductions via low-cost technical changes designed to expand plant output in existing lines and increase efficiency.

This policy did cut costs considerably, but the low profit margins implied an increase in the plant's degree of dependence on government financing for its proposed expansion. This expansion, implemented at the end of the 1960s, involved a conventional blast furnace, two LD steel converters, and a continuous billet caster, all quite different from the technologies originally selected.

6. Comments on the "synthesis" of the five case-studies

6.1 The kind of "learning path" involved in steel plant development:

The longish retrospective look that was possible in four out of the five case-studies makes it clear how the "learning path" in a steel plant is not merely a process of learning to manage efficiently the initial steel plant that is built. For the path also consists of learning to expand and improve the efficiency of the initial plant beyond its nominal (i.e. initially rated) performance levels through introducing "incremental" investments and technical changes.

Yet the matter does not end there either. For the learning path, when viewed in the long timescale we are talking about, also involves introducing major (not just incremental) new expansions into the existing plant, which may literally double or treble the size of the plant over a period of just a few years, and may usually be expected to involve profound changes not just in plant scale but also in plant technology and organization as well - plus all the problems attendant on having to graft major new activities onto a pre-existing complex.

Hence the "learning path" for steel plants is really not a simple one at all. It involves learning to manage the initial plant, learning to incrementally improve it, and learning to organize and "digest" subsequent major plant expansions. a/

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a/ This latter point does not seem to be much reflected in infant industry literature, yet it is too important a feature of steel plant development to be left out of account

6.2 Different steelplant "biographies", and differential performance along the learning path:

A second point emerging from the above synthesis is how different the "biographies" of the five plants were. Each plant's path is seen to be profoundly historical and idiosyncratic, and the performances of the five plants along their learning paths also appear to be distinct. This is important to grasp as a counterweight to the idea that all steel plants are destined to develop in exactly the same way following the same sequence and the same kind of path.

Notice, for example, the enormous differences between say, the development of Acerías Paz del Rio and that of USIMINAS, or between Chimbote and Acindar. Some plants started out with poor technology selection, others with adequate or exact selection. Some plants appear to have had greater initial internal managerial and technical capacity than others. Some plants made more use of outside technical assistance than others. Some plants had more help from their government than others, etc. etc. The different pattern of initial conditions plus different subsequent external conditions and also different internal firm "adaptive capacities" clearly differentiate the paths along which steelplants develop, and this should be a "sign of alert" to steel industry planners to avoid the simplistic belief that learning to "drive" a steel plant is as assured a process as learning to drive a car. There are a large number of difficult and complicated variables that need to be managed, and a long and difficult learning process is involved.

6.3 Factors affecting steelplant learning paths and performance:

Many factors appeared to be at work in influencing the observed plant learning paths and performance. However it was noticeable how the same main group of influential factors cropped up in virtually all cases. These can be briefly summarised as follows:

- The nature of the technology initially selected (both for the original plant, and in subsequent expansions). This factor is clearly of such long lasting importance that it merits the closest analysis.

- A set of "internal capability" factors such as the degree of previous technical and managerial experience of the firm's staff; the extent to which plant staff were active or passive learners in relation to foreign technology and technical assistance, and the character of the plant's technical organization and the changes introduced in it over time.

- External factors: especially the impact of the government as planner, regulator, price-setter, financier, guarantor, owner (in state companies), supporter, or opponent, in steel industry policy; also, too, external factors such as macroeconomic demand conditions; the nature, quality and reliability of the plant's key raw material supplies, such as ore, coal, or scrap; the advance of world steelmaking technology; the availability and conditions attaching to external sources of finance.

6.4 Topics for subsequent chapters:

Our analysis in subsequent chapters does not try to trace the impact of all the above mentioned factors in anything like a comprehensive manner.

Nevertheless, the major influence of (1) initial technology selection (2) various internal capability factors, and (3) various external factors, does emerge clearly in the chapters that follow, whose subject matter is now detailed.

Chapter 3, that follows next, analyses some of the determinants of the technology initially selected for the plants (and expansions). It also looks into the duration of the gestation period that was involved in planning, constructing and starting up the plants and expansions, up until the point when nominal capacity was achieved. Thus the chapter throws light on some of the factors that made for relatively efficient or inefficient technology selections.

Chapter 4 then explores in detail just one dimension of the process of incremental improvement of the plant beyond their nominal performance levels. This is the dimension whereby a plant's production capacity gets "stretched" beyond the nominal capacity. There is a good deal of empirical material in the case - studies on this topic.

Chapter 5 provides a discussion, based on the case-study material, of the kind of internal strategy (organizational, technical and investment strategy) steel plants might be advised to pursue with regard to the improving of steel plant performance and productivity over time.

Finally Chapter 6 develops some conclusions for steel plant planners based on the material in the previous chapters. Various external factors in steel plant development come into the analysis here, including the fact that decisions made by government planners constitute a major component of the external environment in which steel plants evolve.

References to Chapter 2.

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2/ P. Maxwell, 1st-best Technological Strategy in an Nth-Best Economic Context, BID/CEPAL BA 26, April 1978.

3/ P. Maxwell, Implicit R&D Strategy and Investment-Linked R&D. A Case Study of Acindar's R&D Projects, BID/CEPAL BA 44, November 1978.

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Chapter 3. TECHNOLOGY SELECTION AND THE GESTATION PERIOD

Scope of the Chapter

This chapter compares and analyses evidence from the case-studies about (1) some factors affecting selection of technology for new plants and major expansions, and (2) the duration and determinants of the "gestation period" involved in planning, constructing and starting up new steelplants or major expansions of existing ones.

In assembling this evidence we have been able to draw on items of information derived from the following technology selections and gestations listed on the next two pages in Tables 1 and 2.

Our information on these various technology acquisitions and gestations (mentioned in Tables 1 and 2) comes mainly from the case-studies. The information on SOMISA comes from Savio 1/, Castineiras 2/, and various SOMISA annual reports; the information on Acindar's direct reduction project comes from recent Acindar Annual reports.

Table 1: SAMPLE OF "GREENFIELD" (ENTIRELY NEW) PLANTS

Name of Firm, and location of Plant	Type of Plant Built	Nominal Capacity (tons/ yr.) (a)	Chronology of Overall Gestation Period (b)
Acindar, Rosario (Argentina)	Scrap-based steelmaking and re-bar rolling	18.000	1943-47
AHMSA, Monclova (Mexico)	Integrated plant producing plate and sheet.	100,000	1940-50
Acindar, Villa Constitución (Argentina)	Rolling plant, chiefly for non-flats	215,000	1947-54
Acerîas Paz del Río (Colombia)	Integrated plant, producing non-flats	162,000	1947-60
Siderúrgica de Chimbote (Perú) (c)	Integrated plant, based on electric-reduction furnaces, and electric-arc furnaces, producing non-flats.	66,000	1943-61
SOMISA, San Nicolás (Argentina)	Integrated plant producing mainly semis and sheet steel.	500,000	1947-64
USIMINAS, Minas Gerais (Brasil)	Integrated plant producing thick plates, sheet, and coils.	500,000	1956-66

(a) Expressed in ingot tons/year, except for the Acindar, Villa Constitución rolling plant for which capacity is expressed in rolled product tons/year.
(b) The exact definition of the "overall gestation period" will be given later on below.
(c) The name of the firm which initially operated this plant was S.O.G.E.S.A. Today the owning firm has been renamed SIDERPERU.

Table 2: SAMPLE OF MAJOR PLANT EXPANSIONS

Name of Firm	Type of Expansion Involved	Nominal Increase in Capacicy (tons/yr.)	Chronology of Overall Gestation Period
Acerías Paz del Río	Sinter plant, blooming-slabbing mill, hot-rolling mill, modifications to coke plant, (+new blast-furnace, not built).	162,000 to 350.000	1957-76
USIMINAS	Additional coke battery, sinter machine, and oxygen converter. Modified blast furnaces.	500,000 to 1,400,000	1965-74
AHMSA	Installation of BOF (Oxygen)steelshop with 3 converters.	Additional capacity of 1,000,000	1965--77
SOMISA	Installation of large new blast-furnace, a BOF (oxygen) steelshop, and continuous casting machines.	1,200,000 to 2,500,000	1968-78
Acindar (Villa Constitución)	Installation of new Morgan wire-rod rolling mill	215,000 to 475,000	1969-73
USIMINAS	Large new blast-furnace new BOF steelshop, new plate mill, and continuous casting machines	1,400,000 to 2,400,000	1970-77
Acindar (Villa Constitución)	Installation of new direct-reduction plant, electric-arc furnaces and continuous billet casters.	Additional capacity of 450,000	1972-79

1. SOME DETERMINANTS OF TECHNOLOGY SELECTION

In this first part of the chapter we illustrate a series of the factors which influenced technology selection, which came to light in the course of out case-studies. These factors were:

1. the shifting scale and technology frontier
2. the conditioning effect of plant 'heritage'
3. supply restrictions in international technology markets
4. financial conditioning factors
5. impact of government planning measures
6. convictions regarding economies of scale
7. relationships with previous technology suppliers

Each of thise factors is now briefly illustrated, in turn, and then a summary is provided at the end of the section which suggests that technology selection in steelplants often results from a quite severely restricted rather than open-ended "search" process.

1.1 <u>The shifting scale and technology frontier</u>:

We already pointed out in Chapter 1, section 2 that world steel technology has been constantly evolving in the last hundred years. This evolution certainly had its effect -over time- in the choice of technology for the plants and plant-expansions in our sample.

Two effects are clearly noticeable -namely a 'scale effect' and a 'new technology effect'. Let us now see this:

A glance back to Tables 1 and 2 shows a rough relationship between the 'age' of the new plants and expansions, and the amount of new or incremental capacity installed. Thus in the ore-based integrated greenfield plants (i.e. ones using blast furnaces) in Table 1, the oldest plant, AHMSA, started off at 100,000 t.p.a., the next oldest, Paz del Rio, at 162,000, and then SOMISA and USIMINAS at 500,000 t.p.a. each.

Also the average size of the expansions (i.e. the incremental capacity added), -which, logically, came later than the greenfield plants- was greater than the average capacity of the original greenfield plants. For instance the average size of the USIMINAS, AHMSA and SOMISA expansions mentioned in Table 2 is over 1,000,000 tons incremental capacity per annum, i.e. more than double the original installed capacity.

This trend to installing higher initial or incremental capacities over time was paralleled by an increase over time in the size and capacity of the individual main process units introduced. For example AHMSA started off, in its first ten years, with Siemens Martin furnaces of 135 tons per heat (batch) capacity, but then began adding further furnaces of over 200 tons per heat capacity. AHMSA's first blast furnace had a capacity of 100 tons per day. Its second, third, fourth and fifth blast furnaces had capacities of 1,000, 1,300, 1,500, and 4,500tons per / day respectively. The later blast furnaces of SOMISA and USIMINAS were also much bigger than their earlier ones.

Parallel phenomena were noted in electric-arc furnaces, and oxygen converters, and, to some extent, in rolling mills in our sample of plants.

Next, coming to the 'new technology' effect, Tables 1 and 2 show that, in many cases, major plant expansions were seized as opportunities for introducing new and different steel production technology than what these plants had used before. Thus we find AHMSA and SOMISA for their major expansions switching from Siemens Martin to BOF steelmaking technology (for the incremental capacity), Acerias Paz del Rio acquiring a sinter plant, various of the plants introducing continuous rolling mills, continuous casting etc. In contrast, in the period between the start up of the original greenfield plant (Table 1) and the major expansions (Table 2), such smaller expansions as took place were achieved either by "stretching" the capacity of the existing technology (see next chapter for details) or by adding further units (e.g. additional Siemens Martin furnaces) of the same technology already in use in the plant.

Broadly speaking, then, the major plant expansions in Table 2 nearly all represented not just the installation of a much larger increment to capacity than the originally installed capacity, but also usually involved the incorporation of equipment based on new technological processes which the plant concerned had not used before.

Both these "effects" -towards larger scale, and new technology- were consistent with, and influenced by, the advancing world state-of-the-art in steel technology, in which the trend to larger and larger integrated plants, based on large blast furnaces, oxygen steelmaking, and large scale continuous rolling mills has been a strong one, and in which there have been important breakthroughs in high-power large electric arc steel furnaces, in continuous casting and in direct reduction technology, which have been adopted all over the world in so called "mini" steel plants (in our sample, the Acindar example).

So in this sense, there is nothing obviously surprising about the scale and technology choices made in the expansions observed in our sample of plants.

precisely because

Nevertheless it is appropriate to note that/most of the Table 2 expansions did involve very large "jumps" in scale and technology compared to the original plants , these expansions (and the technology selection and gestation problems involved in them) can not be thought of as posing simply a repeat of the problems faced earlier.

1.2 The conditioning effect of plant "heritage" on subsequent plant expansions:

Another clear influence on the technology selections in our sample of plant expansions was that the design/selection of technology for incremental capacity had to be done whilst bearing in mind the important constraints and requirements posed by the production flows and processes of the already existing plant. In other words the pre-existing "heritage" of plant (and its organization) had an important impact on the character of the expansions selected. (Obviously technology for expansions has to be designed, and the new and pre-existing equipment mutually adapted, to optimize the performance of the whole of an expanded plant, not just the expanded part of it).

En passant, we noted convincing evidence from the AHMSA case-study that the disruptions to existing operations caused by major expansion programs can be greatly underestimated. For example the building and start up in 1976 of AHMSA's "Steelplant N°2" drew many staff away from the old Siemens Martin steelshop with serious negative effects on the latter's productivity. Even in USIMINAS, which has been outstandingly successful (compared to most other major integrated steelplants) in "digesting" its expansions, it was stated by company president Lanari that "one of the greatest costs of an expansion plan like USIMINAS's was the disruption it caused in normal operations", and he estimated that "these could be in the order of 20%"

However, to return to our theme of the determinants of technology selection, the main difference which "heritage" introduces into technology selection for expansions is a strong additional element of specificity in the selection process. For, besides the idiosyncratic elements which derive from the localization of a plant, the kinds of raw materials it will use, and the kinds of markets it will serve, the existence of a unique technological "heritage" in every plant adds greatly to the idiosyncracy of the expansion to be undertaken. It is in this context that the remark of Ing. R. Pujals of Acindar is relevant - "you might leave to outside consultants a completely new plant, but it is very problematic to hand over to outsiders the responsibility for expanding a plant that already exists".

1.3 Supply restrictions in international technology markets:

A further determinant of the technology selected in the plants in our sample was -particularly in two of the cases- the severe supply restrictions then obtaining in international technology markets.

We are referring here to the greenfield plants built during World War II by Altos Hornos de Mexico (AHMSA) in Mexico and by Acindar in Rosario, Argentina.

Because of war-time conditions there was no question of "shopping around" on the international market for steelplant equipment, because this was simply no longer available from the belligerent countries. So improvisation was the only course open.

In AHMSA's case they were able to secure some help from the American company ARMCO, and then located a small, old, disus blast furnace in Illinois, which they managed to dismantle, transport, recondition and re-assemble in Mexico with great ingenuity.

In Acindar's case, the firm managed to design and build its own Siemens Martin furnace, by doing an improvised scale-up based on some plans of furnaces already existing in Argentina; they were also able to locate and re-condition some primitive, second-hand rolling equipment from Chile.

Evidently, in neither of these cases, was the technology chosen the "best-practice" one, or anything close to it.

The two above-mentioned cases were the most obvious ones of supply restrictions in international technology markets affecting technology selection in our sample of plants, but they were not the only ones. The original acquisition by SOMISA in the early 1950's of a second-hand, but unused hot-rolling mill of American origin from the Czechoslovak government was held up for some years by objections from the U.S. government. And the hoped-for acquisition by Acerias Paz del Rio of a cold-rolling mill in 1974 was made impossible for the company when the suppliers failed to stick to their previously agreed price for the equipment when demand for this kind of equipment boomed.

1.4 Financial conditioning factors:

Amongst the most influential set of determinants of technology selection in many of the plants and expansions in our sample has been the availability (or relative non-availability) of finance to pay for the investment involved, as well as the conditions attached by the sources of finance to their provision of it.

Several examples of how financial factors and conditions have influenced technology selection in our sample of plants will now be mentioned, viz:

* ------ Acerias Paz del Rio had to build a smaller greenfield plant than the one they originally planned due to lack of sufficient finance; and they were "tied" by the terms of the loan eventually obtained to having the equipment specified and provided by the French consortium supplying the loan (Acerias Paz del Rio greenfield plant).

* ------ In the Chimbote greenfield plant lack of finance led, apparently, to a high degree of technical dependence, via a "tied loan" to a

French consortium.

* ---- In the case of the USIMINAS greenfield plant the joint-venture arrangement with Nippon Steel, and heavy reliance on Japanese equipment supplier credits, led to a largely Japanese supplied plant being erected based on Japanese designs and using deliberately chosen conventional(and reliable) technology, rather than trying out any of the latest developments in steelmaking technology at that time.

* ---- The apparent willingness of international lending institutions (e.g. Ex-Im bank, World Bank, Inter-American Development Bank) to lend large sums of money to national governments made several large-scale state plants and plant expansions possible -e.g. SOMISA's greenfield plant, the Acerias Paz del Rio expansion, SOMISA's 2 1/2 millions ton expansion, USIMINAS 2.4 million ton expansion.

* ---- Huge capital requirements have meant that private sector firms have generally not been able to build integrated steelplants based on the "classical" technology (i.e. blast furnaces, Siemens Martin or oxygen steelmaking at large scales, rolling mainly flat products); therefore private steelmakers such as Acindar in our sample have generally concentrated on relatively smaller scale scrap-melting operations in Siemens Martin or, more recently, electric arc furnaces, followed by rolling of (mostly) non-flat products, especially for the construction industry.

* ---- When Acindar attempted in the 1950s and 1960s to become an a small-scale integrated steel producer using classical technology the capital requirements of even this relatively small plant were still so high that the financial, legal and guarantee backing of the Argentine government was required for Acindar's project to be viable; but, as explained in the Acindar case study, the government did not -in the '50s and'60s co-operate, so this project fell through. a/

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a/ Actually there was government support and approval for the project on several occassions, but in the end this support was not sustained.

The general principle which emerges from the above examples is as follows: that huge capital requirements in steelplant investments regularly bring national governments onto the scene as part providers of the finance, loans, investment incentives or financial guarantees which are needed to make major steelplant investments (even ones in the private sector) possible. The consequence is that not just steel companies, but also their governments participate in the technology selection process. The point is that governments inject their own criteria into these selections, in addition to (and often over-riding) the companies' criteria.

But, further to this, the capital investment requirements are often so large that even national governments find themselves short of the resources needed for building and expanding steel plants. This leads the steel companies and their governments to have recourse to international loan finance, e.g. from the Ex-Im Bank, World Bank, Inter-American Development Bank etc., or from bi-lateral government to government credits, or from private international banks or equipment-supplier credits. Now these sources of finance also impose their criteria and conditions on technology selection - which, once again, may not necessarily co-incide with the steel company's or national government's criteria.

In fact technology selection for steel plants may not -in these conditions- necessarily be very open or wide-ranging in its consideration of possible options, nor economically quite as rational as desirable. Capital market "imperfections" in practice can mean that the technology for steelplants may be determined at least as much by bankers as by engineers.

1.5 Impact of government planning measures

Another critical factor in technology selection was the government planning process for the steel industry, which affected several of the technology selections in our sample. a/

The point that emerged in our case-studies is that this planning process often determined the fractions and sectors of domestic demand which state firms or private firms were required or permitted by their governments to fulfil. That is, government planning in several cases limited the spheres of action of the firms in our sample to satisfying certain types of demand -e.g. flats vs. non-flats, or semi-products versus finished products- and also played an important role in determining the scale of the plants whose construction would meet with government approval (and incentives).

For instance, SOMISA in 1968 had already had approved an expansion plan up to 2 million tons capacity, and Acindar had one approved for around 750,000 tons capacity - but a decree in late 1968 cancelled Acindar's project and required SOMISA to change its plans to expand up to 2 1/2 million tons capacity.

Government planning in Brazil also played a crucial role in modifying USIMINAS's expansion plans in the 1965-80 period, as well as the expansion plans of the other major state steelworks, CSN and COSIPA.

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a/ Actually "government planning measures", in practice prove to be an amalgam of (a) the sets of laws, special taxes and administrative regulations applying to the steel industry in each particular country, (b) the policies adopted by governments in their capacity as owners or controllers of state steel firms like SOMISA, AHMSA and USIMINAS, and (c) the actual formal plans, targets and investment guidelines laid down for the steel industry from time to time by the official ministries concerned and/or by the official planning organs for the steel industry such as the Dirección General de Fabricaciones Militares in Argentina, or the CONSIDER in Brasil.

Furthermore, it became clear in some of the case-studies that various political, not just economic factors, played important roles in the government planning and decision-making process - and hence in the decisions as to what scale and type of technology would be selected, and as to what kind of firm (state or private) would build the new plant or expansion concerned.

For example, considerations of "national security", as well as the official planning goal of "self-sufficiency in steel" greatly influenced the entire postwar steel industry policy of the Argentine government.

Another typically political theme which surfaced various times in the case studies (especially in the Argentine case, but also in the Brasilian and Colombian cases), was that of the political rivalry between public sector and private sector firms for influence and shares of overall national steel production capacity.

The conclusion is simply that the "government planning process" -which was one of the most important determinants of technology selection in many of the plants in our sample- must be seen as a process which works on the basis of political as well as economic motivations. Hence technology selection in major steelplant investments is not merely a techno-economic problem.

1.6 Convictions regarding economies of scale

A further influential factor on technology selections appears to have been the convictions about the attainability of economies of scale in large integrated plants which were held by government planners.

These convictions were clearly expressed on many occasions by the official Argentine planners (DGFM) right from the days of General Savio (founder of the DGFM) onwards, and have also obviously been held by the

Brasilian planners with regard to the big three Brasilian state firms. The selection of a 1 million ton per annum blooming-slabbing mill for the Paz del Rio expansion in the 1960s also suggests these convictions were held in Colombia, and the sheer size and scale of AHMSA's recent expansions suggests that this firm, too, is a "de facto" believer in the economies of scale attainable in large integrated plants.

It is also interesting that in Acindar's greenfield plant in Villa Constitución (gestation in the 1947-54 period), one of the main reasons advanced by the company's president for installing what, at the time, was such a large rolling mill, was to benefit from the economies of scale it would bring.

From the viewpoint of technology selection, the important point is that these convictions about economies of scale have certainly influenced both government planners, and private company executives in choosing the plant scales to be aimed at in the planning (and planning-approval) stage.

1.7 Relationships with previous technology suppliers:

A further factor which in the case-studies seems to have had some influence in technology selection was the existence of previous contracts and relationships with former technology suppliers, who often got chosen again when it came to plant expansions.

Thus Acindar has regularly made use of Morgans as mill suppliers, Republic Steel and H.K. Ferguson as engineering advisers, Boynton as consultants, and Concast as continuous caster suppliers.

AHMSA had a long standing relationship with Armco in relation to the building of their first three blast furnaces.

SOMISA also had a long relationship with Armco, and later another long relationship with Kaiser Engineers.

USIMINAS has had a permanent (and very effective) relationship for technology supply and technical assistance with Nippon Steel, and with various other Japanese and German suppliers.

On the other hand, there were also cases observed when some of the plants in our sample broke off relationships with previous suppliers, apparently unsatisfied (or even very unsatisfied) with supplier performance. Without mentioneng supplier names, we can simply state that Acerias Paz del Rio has tried out a long list of changed equipment suppliers and engineering consultants over the years. SOMISA, has quite recently made important changes in this respect too.

However the point remains that previous experience with equipment and engineering suppliers is a conditioning factor in future supplier selection.

1.8 Summary. Technology selection as a "restricted" search process:

As shown above, a wide variety of factors were seen to have influenced the technology selection process in our sample of plants, and it was clear from the case-studies that several other factors, in addition to those mentioned above, had some influence as well. a/

However, enough information has been presented above for us to reach a simple conclusion - namely that the process whereby a "technology" (i.e. a technique, a plant scale, and a set of suppliers) gets selected in steelplants does not necessarily resemble the "textbook" process in which entrepreneurs are supposed to be able to freely choose that combination of technique-scale-suppliers from the perfectly known "complete set" available on the world market, which will maximise their profits.

a/ One important one was forecast market growth rates, which influenced the "optimum degree of imbalance" that was built into steelplants as provision for future output expansion.

In fact it looks as though it may sometimes be mistaken to conceive of the searching, screening and learning effort to choose a technology for steelplants as involving a comprehensive scanning over a wide range of technological possibilities, alternative scales, and alternative sources of supply, resulting in some optimal combination of all three (which is the kind of process that textbook entrepreneurs are visualised as performing).

Instead, in many of the cases mentioned, technology selection seems to have resulted from a quite limited or restricted search process - one which was conditioned by financial, political, planning, supply and heritage constraints to focus choice around a strictly limited portion of the techno-economic horizon, and sometimes, too, around a strictly limited range of different potential technology suppliers.

In fact we saw that often the whole searching, screening and learning effort to select a technology got channelled strongly towards particular techniques, scales of plant, or technology suppliers in the early stages of project planning (e.g. the Acerías Paz del Rio and USIMINAS greenfield plants, SOMISA's 2 1/2 million ton expansion).

Now whilst such a procedure may produce good results in some cases, the danger of "restricted search" is obvious: -namely, that it may miss-out on alternatives which offer greatly superior techno-economic prospects- but which get ruled out-of-court early on because of the presence of one or more of the previously mentioned financial, political or other constraints on the technology search and selection process.

Given the enormous difficulty of making good technology selection choices in the steel industry (for the reasons outlined in Ch. 1) and given the irreversibility and profound future effect of the choices that do get made, it would seem, prima facie, undesirable that technology selection should be so hemmed in that only "restricted search" is possible.

If this is right, then it would be useful if the sometimes heavy costs of "restricted search" could be made sufficiently clear to national governments and steelplant planners so that at least some of the main constraints leading to such restricted search might be eased.

2. THE DURATION OF THE GESTATION PERIOD

In this second part of the chapter our purpose is to analyse empirical evidence collected in the case-studies about the gestation period of the new plants and expansions that were listed earlier in Tables 1 and 2. The gestation period refers to the entire time-span involved in planning, building and starting up steel plants (or expansions) until they are producing at output levels equal to their nominal capacity.

Our focus is on how long the various different stages of steelplant gestation last, and on the determinants of gestation time. This is because both the duration of gestation, and its determinants, are economically important factors to allow for in the planning of steelplants, and in estimating the profitability of investments in new plants and expansions.

Our presentation of data on the gestation period comes in four sections. Section 2.1 classifies the overall gestation period into three sub-periods. Section 2.2 provides empirical evidence on the duration of each of these three sub-periods in our sample of plants and expansions, and discusses factors which helped prolong gestation in particular cases. Section 2.3 then presents some hypotheses about the determinants of gestation time.

2.1 Framework for analysing the gestation period

In what follows, we classify the gestation period into three distinct, successive, chronological periods. The division adopted is: (i)"Pre-investment period", (ii)"Construction period", (iii) "Start-up period". We also define (iv) an "Implementation period", and (v) an "Overall gestation period." This classification is now explained:

(i) "Pre-investment period":

For entirely new plants this period is taken to start from the date when the company which was to build, own, and operate the plant was first legally constituted.

For major expansions of existing plants, the period is taken to start from the date when the first serious planning-study or feasibility study for the proposed expansion was begun.

The pre-investment period includes all the time taken in the preparation and execution of all the needed planning and feasibility studies, and all the time taken in negotiating the necessary finance from equipment suppliers, national development banks, international development banks, etc. It also includes all the time needed to secure whatever interim and definitive political and planning approvals and financial guarantees prove to be needed from the government of the country in which the plant is built in order for the project to go ahead. If basic and conceptual engineering studies was performed prior to the securing of project finance and definitive government planning approval, then those engineering studies are also included in the pre-investment period.

(ii) "Construction period":

This period will be taken to have formally started from the moment when both the overall financial "package" for the project has been secured and the necessary definitive government planning approvals and guarantees regarding the project have also been secured.

The construction period includes all the steps required to execute the building of the complete new plant or expansion. A classification problem that can arise is that in some projects, construction of individual parts or stages may be begun before overall project financing and/or final political approval has been secured, i.e. before the pre-investment stage is complete. Nevertheless we shall retain our formal definition of the "construction period" as beginning only when the pre-investment stage has ended.

The activities that may be included in the "construction period" (and some of which may have been begun during the pre-investment period) include: the detailed engineering of the plant; procurement engineering, equipment specification; putting the various "packages" of equipment up for tender (if tendering is involved); inspection and reception of equipment from suppliers; on-site civil engineering; design, procurament and construction of off-site installations; construction of roads, rail-links, port-facilities and other needed infrastructure; supervision of local and foreign contractors; erection and installation of plant equipment; dry-tests and commissioning of equipment units; leading up to the completion of the whole plant and the start-up of production from its main process-stages.

In fact it is quite usual for the various main stages of integrated plants to have distinct start-up dates separated by intervals of up to two years. In these cases, when we are analysing such plants as a whole, we shall consider their "overall" start-up date as coinciding with the start-up date of their steelmaking sections, which, according to our definitions, will simultaneously mark the end of the construction period.

(iii) "Start-up period":

This period is considered to last from the beginning (i.e. start-up) of production from each of the main production stages (or plant as a whole) up until the achievement of an annual output level from these main stages (or plant as a whole), which corresponds to their nominal production capacity.

It often happens that the start-up periods of different main units vary somewhat in length. When analysing the start-up of integrated plants considered as a whole we shall focus on the start-up period of their steelmaking section.

Note that the end of our "start-up period" is signalled when the plant succeeds, in an actual calender year, in producing the yearly output for which it was rated. It is possible, however, that <u>prior</u> to this point, the plant's staff had already learned to operate the plant on a sustainable basis at its nominal <u>rate</u> of working - but that low demand or raw-material supply problems prevented the plant from being actually operated at this rate for an entire year. The period from the start of production to when staff have learned to operate it at nominal capacity rates might, for example, be referred to as the "technical start-up period". So, on these definitions, it is possible for the "start-up period" to be much longer than the "technical start-up period" (which can happen if there are low demand problems or raw materials input problems). Of course it can also happen that the start-up period is long exclusively because of problems experienced in technical start-up.

(iv) "Implementation period":

This is simply the sum of the Construction period and the Start-up period, as defined formally above.

(v) "Overall Gestation period":

This is the sum of the Pre-investment period, the Construction period, and the Start-Up period, defined above.

2.2 Empirical Evidence on Gestation Time

In this section we present figures for the duration of the pre-investment period, construction period and start-up period, as defined in the previous section, for several "greenfield" plants, and for several major subsequent expansions of these plants. These figures are set out in Table 3 overleaf, and were derived from the sources mentioned previously.

We now comment on the data contained in Table 3:

2.2.1 Lengthy time-spans involved:

The first obvious feature is the sheer length of time involved in steelplant gestation ranging in our sample from 3 to 19 years and averaging about 10-11 years both for greenfield plants and major expansions. This gestation period was split, on average, roughly evenly between pre-investment, construction and start-up, each of which required on average from 3 to 4 years duration.

Even if one leaves the pre-investment period out of account, and concentrates only on the "implementation period", i.e. construction plus start-up, we are still talking about average implementation periods of over 7 years.

On the other hand there is a large range of variation in the durations of each period, viz. from 0 to 8 years in pre-investment, from 1 to 7 years in construction, from 2 to 8 years in start-up -- and from 3 to 19 years in overall gestation.

TABLE 3: DURATION OF THE SUCCESSIVE STAGES OF THE GESTATION PERIOD (Years)

Name of Firm	Nominal Capacity or Increase in Capacity	Chronology	Pre-investment Period	Construction Period	Start-up Period	Overall Gestation Period
GREENFIELD PLANTS						
Acindar (Ros.)	18,000	1943-47	0	1	2	3
AHMSA	100,000	1940-50	n.a.	4	6	>10
Acindar (V.-C.)	215,000	1947-54	1	3	3	7
Acerías Paz del Río	162,000	1947-60	4	3	6	13
Sid. de Chimbote	66,000	1943-61	8	7	3	18
SOMISA	500,000	1947-64	8	5	3	16
USIMINAS	500,000	1956-66	3	4	3	10
	AVERAGES		4.0*	3.9	3.7	>11
MAJOR PLANT EXPANSIONS						
Acerías Paz del Río	162,000 to 350,000	1957-76	6	5	8+	>19
USIMINAS	500,000 to 1,400,000	1965-74	4	5	1	10
AHMSA	+ 1,000,000	1965-77	n.a.	6	6+	>12
SOMISA	1,200,000 to 2,500,000	1968-78	2	3	5+	>10
Acindar (V.-C.)	215,000 to 475,000	1969-73	2	1	1	4
USIMINAS	1,400,000 to 2,400,000	1970-77	1	4	2	7
Acindar (V.-C.)	+ 450,000	1972-79	4	3	1+	>8
	AVERAGES		3.2**	3.9	>3.4	>10

n.a. = Information not available.
\+ = Start up still in progress at the end of the period studied.
* = Average of 6 plants for which information is available.
** = Average of 6 plants for which information is available.

The four shortest overall gestation periods involved the Acindar, Rosario plant, the Acindar Villa Constitución greenfield plant, the expansion of the Villa Constitución plant with a second rolling mill, and the most recent USIMINAS expansion mentioned in the table.

The three longest overall gestation periods involved the expansion of the Acerías Paz del Río plant (19 years), and the gestation of the Chimbote plant (18 years) and the greenfield plant of SOMISA in San Nicolás, (16 years).

An obviously important question is -what factors account for such large variations in gestation time?

But even without an account of the causes of these variations, the mere fact that gestation is, on average, so long is worthy of note in itself. Harold Wilson used to say that "a week is a long time in politics"; here what is at issue is that "a decade is a long time in industrial planning", never mind nearly two decades! For plainly it is very difficult to forecast what factor prices or product prices will be in ten years time, or what levels demand will have reached by then.

2.2.2 Some reasons for the long duration of the pre-investment period:

The two basic factors underlying the incidence of long pre-investment periods in our sample were (a) shortages of finance for highly capital intensive steelplant investments , and (b) political factors having to do with government planning of the steel industry.

This can be illustrated by considering the various cases of prolonged pre-investment periods in our sample:

* --- The clearest and most extreme case relates to the founding of SOMISA. This firm was founded in 1947 as a "mixed" enterprise, with a majority state shareholding, but with some private steel firms subscribing shares too. Right from the beginning, the idea was that the Argentine government would absorb the main financial burden implied by building the plant, as well as being responsible for its technical aspects (planning and operation) via the Dirección General de Fabricaciones Militares. However, contributions from the government treasury to the project for several years came only in drabs and drabs, and were inadequate to the real needs of the project.

This lack of enough government finance for the project was not only the government's fault. It was also caused by the fact that the initial planning of the project (and government approval of it), had greatly underestimated the true capital investment needs of the project. For one thing, rapid postwar Argentine inflation quickly made the originally planned budget contributions much too small. Secondly, SOMISA compounded its own problems by deciding to build a bigger plant than the one originally approved (viz. a 500,000 tons per year plant, rather than a 315,000 t.p.y. one), and by deciding to construct it with several additional installations which had not been included in the original plans. These factors, plus a rise in foreign equipment prices, all led to the capital investment requirements of SOMISA being vastly greater than was originally bargained for.

This situation -when coupled to the apparently "luke-warm" political support for the project from the Peronist government- meant the only possibility for proceeding with the project was to get large foreign loans, especially from the United States. However, at that time, a political dispute between the Argentine and U.S. governments meant that official U.S. institutions such as the Ex-Im bank were not extending loans to Argentine enterprises, a situation which persisted until around 1954/55. There were also some payments and credit problems pending with European gover governments and banks which remained to be solved too. Only by 1955/56 could U.S. loans be negotiated to enable SOMISA to acquire the majority of the equipment needed to complete its San Nicolás plant.

So the plant which Savio had predicted would already be started up by 1950, only had its main construction phase begun in 1956, and its start-up of steel production came in 1962, twelve years behind Savio's schedule! Most of this delay, however, can be attributed to the underestimated pre-investment period.

* ---- In the case of the foundation of Acerías Paz del Río, the huge cost of an integrated steelplant also put the project beyond the limited resources that could be raised by the Colombian government together with private shareholders. This first led to an approach to the World Bank for a U.S. $50 million dollar loan to build the plant and, when this was refused after an official Bank mission to Colombia, negotiations were taken up for an alternative loan from a French consortium to build a smaller plant. This sequence meant that the pre-investment period for the Paz del Río plant lasted four years.

* ---- In the foundation of the Chimbote plant, lack of finance again seems to have been the major difficulty which made the pre-investment period so long.

* --- In the expansion up to 1.4 million tons of USIMINAS, both the financial and the political factor were at work. Financially, USIMINAS at the time of planning this expansion was in an acute deficit situation owing mainly to substantial cost inflation on its original plant. As a result it found its requests for loan finance from international bank refused. It turned to the Brasilian government for subsidised capital, but the government -which was just then beginning to enter much more

strongly into steel industry planning - took from 1967 to 1969 to make its mind up favourably about USIMINAS's proposed expansion. Further delays then followed in wrangling between the BNDE (Brasil's National Development Bank) and USIMINAS over the guarantees which the former was to provide the latter with respect to equipment purchases. This is why the pre-investment phase lasted four years. Obviously both the financial and the political factor combine when it is the government itself which has to decide whether to provide subsidised capital and other incentives to steelplant investment projects (whether these projects are put forward by private steel firms or state ones). Which projects will get a positive decision from the government and which will be delayed or refused, is obviously not merely a technical process decided on entirely technical criteria. A major political element often enters the calculations.

* --- In the case of Acindar's expansion, involving the building of a direct reduction steelmaking complex, what delayed completion of the pre-investment period was, fundamentally, the long delays involved in the official project approval procedures of the Argentine government. Thus, although Acindar's project was presented to the Dirección General de Fabricaciones Militares in September 1972, it was not until January 1976 that the "definitive economic and financial scheme" for the project was approved by the Executive Power.

2.2.3 Some factors causing construction period delays

We now briefly resume some evidence on the causes of construction delays in the new plants and expansions.

* --- In the case of the greenfield Acindar Villa Constitución plant, the construction period took 3 years instead of the 18 months originally planned. The main factor at work here was exogenous to the company. It involved the suspension, by the Argentine Central Bank, of foreign exchange remittances for one year in 1947/48, which

delayed fabrication and delivery to Argentina of some of the equipment needed for the plant.

* --- In the Chimbote plant, the long construction period of 7 years appears to have been at least partly due to organizational problems in the State Corporation managing the project. It was only after a re-organization, taking place already 3 years into the construction period, (whereby construction and management responsibility was vested in a separate corporation) that construction was able to move ahead more swiftly. (But even so, a further four years were taken in completing the plant, and getting it started up).

* --- In the case of SOMISA's original greenfield plant, there appears to have been an unplanned delay of approximately one year in the production start-up of the steelmaking section, due to the delays involved in securing financing of the equipment for this section from a European consortium of suppliers. The steelmaking section had been deliberately left out of the overall financing for the plant as arranged with the Ex-Im bank of the U.S. Its acquisition was then delayed by the slowness with which the Argentine government was able to renegotiate some pending commercial debts problems with various European countries.

* --- In Acindar's Villa Constitución expansion involving a second rolling mill, a three month construction period delay was due to a U.S. dock strike which held up delivery of equipment.

* --- In SOMISA's $2\frac{1}{2}$ million ton expansion plan, the planned construction period of about 2 years was completed some 15 months behind schedule due to (a) some equipment delivery delays, mainly from Britain, and (b) some additional installation delays which postponed the expected start of production from the new blast furnace.

2.2.4 Factors helping to cause prolonged start-up periods

Several different factors causing start-up periods in the plants to sometimes be more prolonged than expected were detected in the case-studies. These factors can be resumed as follows:

(i) Conceptual errors in overall plant design

(ii) Conceptual errors in the design of an individual plant stage or of equipment within this stage (NB Design errors may be intrinsic to the plant or equipment, or may involve the inappropriateness of the chosen design to the specific local raw materials to be used or other local characteristics or working conditions).

(iii) Weaknesses or defects in equipment fabrication or plant construction

(iv) Inadequate preparation of the plant's workforce and/or technical staff with regard to the operation and management of the process being started up --leading to poor operating methods, slow learning about how to dominate the process, and (sometimes) damage to equipment requiring its premature shut-down and overhaul.

(v) Shortages in the supply of key raw materials, e.g. ore,

(vi) Shortages in the supply of key services, e.g. adequate electricity supplies.

(vii) Overoptimistic demand forecasts.

We now briefly illustrate these various factors using material from the case-studies:

First, design and construction errors. The effect of these is to render equipment, or stages within plants, or whole plants) incapable of producing at their rated capacity even if all other factors are working correctly (e.g. adequate supply of raw materials, correct operating practice, adequate demand levels). In consequence, the achievement of rated capacity is necessarily delayed until <u>remedial</u>

technological measures (involving design modifications, repairs and very often additional equipment as well) have been taken in the plant concerned. The illustrations from the case studies are as follows:

* --- In the foundation of Acerías Paz del Río, the company claimed there were construction weaknesses in the coke-washing plant, the blast furnace and steel-shop. Be that as it may, the blast furnace never reached its nominal capacity throughout its first "campaign" (i.e. with its first refractory lining), and only reached nominal capacity after a relining with modifications. The lack of a sinter plant in the original plant design also negatively affected blast furnace productivity and the attainment of nominal capacity.

* --- In the Chimbote plant, the very basic conceptual error was made of making the plant highly dependent on electric energy supplies, which were not available in sufficient quantity at the time and therefore involved the company in having to assist organize the building of new power generating facilities and transmission lines, which introduced further delays into the achievement of nominal capacity in the plant.

* --- In AHMSA's BOF (oxygen converter) steelshop, the company engineers interviewed in the case-study claimed that some design errors had been made by the suppliers of this steelshop, including errors arising from the inappropriatenses of the supplied equipment to local conditions. Mention was made of 11 specific design errors ranging from inadequate space for materials handling within the steelshop building, to poorly designed systems for oxygen injection, cooling and gas purification, insufficient number of cranes, etc., all of which were said to require remedial measures by AHMSA in the course of the start-up period. (one should not however, assume that fault lay with the suppliers, since no evidence was collected from them, and the case-study does not indicate under what constraints or instructions they were working).

* --- In SOMISA's 2½ million ton expansion plan, design and construction errors were alleged by the company to have been made by the

suppliers of the large new blast furnace constructed as part of the expansion. According to company annual reports, serious operating problems were encountered, right from the beginning of start-up of the blast-furnace in March 1964 which could not be righted by the suppliers. Normal functioning was not achieved, and after 2½ years of problematic, low-output working, the refractory lining of the blast furnace prematurely wore out, and the furnace was shut down. It remained out of action for an entire year whilst extensive design modifications and repairs were introduced in it, and was started up again in September 1977, three and a half years after its first start up. a/

Next we come to the problem of the inadequate training and preparation of the workforce, technicians and engineers for handling the many problems posed in steelplant start-up.

* --- This problem was specifically mentioned in the Chimbote case-study, in the study dealing with the foundation of the Acerías Paz del Río plant (where the majority of the workers taken on were illiterate and the company had to set up schools for them), and in the study on AHMSA in relation to the adoption of oxygen steelmaking technology by the company (for they had used Siemens Martin steel making previously).

* --- This problem also seems to have arisen in the case of SOMISA's $2\frac{1}{2}$ million ton expansion plan. Our reasoning is that for the second start-up of its new blast-furnace, SOMISA has now signed an extensive technical assistance contract with the Nippon Steel Company of Japan, which suggests that they judged the preparation of their own team to be insufficient by itself.

With regard to shortages in the supply of key raw materials and services, the cases arising in our sample which affected the start-up period, are as follows:

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a/ It is noteworthy, however, that SOMISA apparently made no legal claim against the suppliers.

* --- In the Paz del Río 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 original plant's start-up period.

* --- Also, the lack of sufficient electricity supply slowed down production in both the Paz del Río and Chimbote greenfield plants, (In Paz del Río, the electricity supply problem persisted right through until 1976).

Finally, we turn to the problem of inadequate demand as a cause of delaying a plant from producing at its rated capacity. This is, of course, an economic delay factor rather than a technological one. The case- studies provide two interesting examples of this problem:

* --- The first relates to the Paz del Río expansion programme where there appears to have been a gross overestimation of the demand for hot-rolled products. For whilst the firm in 1963 bought a hot-rolling mill with 500,000 tons per annum capacity, the actual demand for hot rolled sheet steel in Colombia during the 1960s and 1970s never exceeded around 40,000 tons per annum. The real growth in flat products demand was for cold-rolled, not hot-rolled sheets, and it was only considerably later in 1968 that the company first attempted to acquire a cold rolling mill.

* --- The second example of the demand problem is topical and relates to SOMISA's level of steel output in recent years. The plant's $2\frac{1}{2}$ million ton plan, conceived in 1968, expected that SOMISA would be producing and rolling over 2 million tons of steel per year by the mid 1970s. Yet this plan in retrospect can be seen to have been based on highly optimistic demand forecasts which did not prove out. To be fair, however, nobody in Argentina in 1969-70 or even in 1974-75 was predicting that the domestic

demand for steel in the years 1977, 78, 79, 80 would be as low as it has proved to be. So even though SOMISA's new blast furnace re-entered service in September 1977, the output of the plant since then, has been well below its nominal $2\frac{1}{2}$ million tons capacity -- e.g. steel production was 1,441,000 tons in 1978, it was 1,527,180 tons in 1979 and it may well go lower in 1980.

It is, of course, important for planners to look into the question of why demand gets overestimated, and how it might be estimated better, however we shall not go into that here.

A point we do want to make, however, is that there is another way of framing the problem of less-than-forecast demand as a cause of start-up period delays: -- namely, instead of saying that "demand has proved too small", one might suggest that "the plant was planned too big". We shall be taking up this idea later on.

Another point worth making isthat the factors causing start-up delays which were mentioned above mostly originate in decisions <u>which were made earlier during the pre-investment or construction period</u> (e.g. decisions on technology, on design, on plant sizing, on staff-capability to manage the selected process, on forecasts of raw materials and services availability, and on forecasts of expected demand).

Consideration of the foregoing evidence about the gestation period now invites the attempt to frame some hypotheses about the determinants of gestation time which might be helpful to steel plant planners (and to planners of other heavy, complex industrial plants). The framing of such hypotheses is not virgin territory, and we would here like to draw specific attention to a paper by Eckhaus [3/] which has stimulated our work on this subject, and which we shall cite later on.

Three possible "determinants" of gestation time for which some support from existing literature, as well as from our steel plant case-studies, can be adduced are: (1) the scale of the project that is contemplated; (2) the technological complexity of the proposed greenfield project or expansion; and (3) the extent of previous experience in steel plant design, construction, and operation of the owning firm.

We shall now mention some arguments in favour of the notion that longer gestation periods, and longer delays compared to planned gestation time, are likely to happen the greater the scale of the expansion is, the more complex the technology that it uses, and the less experienced the owning firm is in steelplant design, construction and operation.

One reason why larger scale projects are likely to involve longer gestation is that they involve greater capital investment requirements.[a/] This means more investment money is at stake, and is likely to make the project more of a target and more sensitive to delays and interference from its political opponents, Also the greater volume of loans needed is likely to make overall project

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a/ Even in small plants, additional stages or expansions may cost tens of millions of dollars. For new capacity, investments of hundreds of millions of dollars would be normal for semi-integrated plants, and thousands of millions for integrated plants -roughly U.S.$ 1.000 million per million tons of annual ingot capacity.

financing from government and other financial sources more difficult to negotiate.[a/] In other words, the larger the scale of the project is, the more vulnerable it is likely to be to long government planning approval lags and project financing lags. (In this sense, the SOMISA greenfield plant and the Paz del Río expansion provide graphic cases).

A second reason which links greater scale with longer gestation is that it leads to more complex and therefore time-consuming tasks in the project planning and design phases, and in the procurement, construction, and start-up phases than is the case with smaller plants. This is not only because there is "more" to be done and co-ordinated in each of these phases when a plant is bigger but also because larger-scaled steel plants tend to be more technologically complex too. This has been noted by Nueno, [b/] and also by Cartwright,[c/] who has stated that

> "Construction times for minimills are much shorter than for integrated BOS plants (18 months to 2 years as compared with 3 years or more), and the equipment is standardized and less technically advanced. As a consequence, returns on investment are obtained more quickly, and more certainly".

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a/ The marked dependence of conventional expansion projects on sources of finance external to the firm is shown by recent Latin American figures on the sources of finance for investments in new capacity in 1976 quoted by ILAFA. Only 14.3% of the required investments came from firms'own internal funds; 53.1% from other national sources; and 32.6% from international credits.

b/ In large-size blast furnaces, for instance, Nueno reports how "managers placed emphasis on the fact that larger sizes represented different, more advance , technologies, not only in the field of construction or operation of the units, but also in a variety of related fields", P. Nueno, 4/

c/ W. Cartwright, 5/

This hypothesis that short gestation times are related to smaller scales and lesser complexity of plants is consistent with what we found in our own sample, to the extent that three of the shortest gestation periods (Acindar's Rosario plant, and the two Acindar Villa Constitución plants involving the installation of rolling mills) relate to a very small scale plant, in the first case, and the building of just the rolling mill stages of a plant (rather than an entire multi-stage integrated plant) in the latter two cases.

This bring us on now to the significance of the owning firm's previous experience in affecting the duration of the gestation period. Here, we first turn to Eckhaus,[6/] according to whom

> "experience in the installation and starting of new investment projects creates a stock of skills that facilitate installation and start up". These skills can be augmented by formal education but only at marginal rates of substitution between education and experience which are limited by the requirement for some minimum amount of experience"....... "There are diminishing returns to this stock of specialized skills which assist in bringing new investment projects to maturity"

Thus, Eckhaus stresses how the experience that firms may gain in the course of previous construction and start-up periods will help to shorten these two periods when it comes to expansions --and he also postulates diminishing returns to a quasi-fixed stock of skills in the owning firm to explain why larger-scale projects, or faster rates of expansion, may lead to longer construction and start-up periods.

However, a point that Eckhaus does not deal with, but which emerges as important from the evidence presented earlier, is the question of how a firm's previous experience (or lack of it) will determine how effectively it will be able to participate in the specification of, and/or the design of the technology that is selected. Clearly, in grrenfield plants, inexperience predominates, and this appears to have been a principal factor leading, in the Paz del Río case and even more the Chimbote case, to these firms having accepted what was basically a poorly specified technology, --with the consequent need in both cases for expensive remedial measures and long gestation lags. In contrast, USIMINAS for its greenfield plant was able to solve its inexperience problem through a joint venture arrangment with the very experienced Nippon Steel Company of Japan. This meant USIMINAS received pretty sound advice on technology selection, and intensive technical, operational and managerial assistance to ensure that start-up would go smoothly. Acindar had done something similar previously, on a smaller scale, for the Villa Constitución greenfield plant, on which they received technical and operational assistance from the experienced Republic Steel Co. of the USA, who at that time had expressed interest in acquiring some 10% of Acindar's equity.

Further evidence of the importance of a firm's previous experience (or lack of it) at the technology specification/design stage comes from AHMSA's problems in the acquisition and implementation of its first BOF plant (one of the expansions mentioned in Table 2). The AHMSA case-study suggests that the firm's complete inexperience with oxygen steelmaking technology (they had used Siemens Martin steelmaking before), plus their inadequate technical and organizational preparation for the new technology contributed to their acquisition of a perhaps not fully adequate basic design from their suppliers, and to their very slow start-up with the new technology.

Also, SOMISA's problems with the new blast-furnace for their $2\frac{1}{2}$ million ton expansion seem to have been partly due to SOMISA's having contracted this new furnace on a turnkey basis (to assure rapid construction), with the consequence that SOMISA probably did not contribute as much of their own know-how as would have been desirable in the specification of the new furnace. At any rate, after first experiencing grave troubles in operating with their new furnace (which were mentioned earlier on), SOMISA then proceeded to use a great deal of their own previous operating experience gained on their first blast furnace so as to modify the design of the new one --with much better results, see Nicodemo.[7/]

Finally, it was shown in the USIMINAS case-study that this firm very actively used its previous operational know-how so as to suggest and insist on improvements to the design and specification of the equipment being installed in fullfillment of its ambitious expansion plans from 1968 through to 1980. These active design contributions from the firm itself contributed greatly to ensuring that the newly incorporated equipment was better adapted to the firm's experience and procedures, with less unknown variables to learn to manage, and more "bug-free", than if design and specification had been left entirely in the hand of outside consultants and contractors. The short start-up periods noted in Table 3 for both the USIMINAS expansions mentioned there are consistent with this.

In summary it would appear that a firm's previous experience - and how it can be brought to bear not only on construction and start-up, but also on design and specification of the technology - is an extremely important determinant of gestation time.

This leads on to a corollary hypothesis, which is that the extent to which a firm's previous experience will be relevant to a technology gestation may well depend on how much of a "jump" in scale and technology the new project represents compared to the

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scale and technology which the firm is used to working with [a/]. Our case-study evidence suggests that steel firms sometime over-reach themselves by by making scale or technology "jumps" which prove too big for them to handle, consequently greatly extending the length of the construction or start-up periods (e.g. AHMSA with its BOF plant, Chimbote's management with their original plant, SOMISA perhaps trying to "jump" at too fast a rate up to $2\frac{1}{2}$ million tons of output).

The implication is that the length of the gestation period which firms should expect is partly determined by the firm's own previous experience, and by the firm's realism (or lack of it) in making "jumps" in scale and technology which are in accord with its previous experience.

The problem with making big jumps is twofold:-
First, there is the "Eckhaus effect" whereby a big increase in scale may saturate (lead to diminishing returns from)the firm's quasi-fixed stock of staff who are sufficiently experienced to be able to adapt themselves to the complex construction and start-up tasks involved. Second, big jumps to new technology make it more difficult for the firm either to specify correctly or to sufficiently understand what it is acquiring from its suppliers, which increases the risk of acquiring poorly specified technology and the consequent risk of being involved in prolonged construction and start-up difficulties with attendant time and cost over-runs.

There are two obvious implications: <u>either</u> firms should make small enough jumps so that their previous experience will be adequate

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a/ "The general opinion of those actually using large-scale technology is that it is not possible to extrapolate the know-how required to design, build and operate relatively small units to the design, construction and operation of large ones, but it is the experience at a certain scale which allows, step by step, the adoption of larger scales..... The companies that have tried to make big jumps in ironmaking scale and technology have relied heavily on purchase know-how, but in spite of this, they have often had serious problems", P. Nueno, op.cit.

to the challenges involved; or, if big jumps (in scale and technological complexity) are planned, then firms will need to very actively utilize and supplement their existing experience sc as to be able to jump successfully..

Utilizing existing design, constructional and operating know-how is essential so that plant "heritage" will be duly taken into account, and local and firm-specific conditions explicitly included in the planning and design of expansions. Supplementing existing experience (to help cope with big jumps) involves heavy investment in first class consulting engineering, and heavy investment in extensive technical assistance during planning, construction and early operation of the ambitious new facilities. It also involves intensive investment in the education, training, and qualification of the firm's own technical personnel and workers with regard to the new technology being installed.

3. SOME PLANNING IMPLICATIONS

In this third part of the chapter, some implications for planners of the reported findings about technology selection and gestation are briefly mentioned.

1) So far as the determinants of technology selection are concerned, we noted how these had led, in quite a few of the cases examined, to what we called a "restricted search process" for technology.

In other words, the decisions as to the process technology to be selected, or the scale of the plant to be built, or the suppliers chosen -or, indeed, about other more detailed parameters of technology selection into which we did not go in detail- often seemed to get taken <u>without</u> what, to an economists mind, would be the desirable open and broad "scanning" of the techno-economic horizon in search of the most profitable technology. Instead, financial, political and other constraints led to early ruling out of vast parts of the techno-economic horizon in favour of particular technologies, scales and suppliers very "early on in the game".

This would not necessarily matter much if those large parts of the techno-economic horizon thus ruled out were genuinely irrelevant to the needs of the prospective project - but who can say if this was so? Rather, when one considers how poorly judged <u>some</u> of the technology selections reported on in the case studies turned out to be, the presumption must, in our view, be in favour of the idea that a broader-minded, more open and more intensive scanning of the techno-economic horizon of possibilities would be, at least from the economic point of view, an activity promising high returns.

2) A second, and related issue for planners with regard to technology selection, has to do with the frequency with which "plant specific" factors were left out of account, or seriously underestimated, in

making technology selection decisions. The commonest problem which emerged in many of the case-studies, was failure to take due account of the special characteristics of some of the key raw materials that would be feeding the plant once built - e.g. the type of local iron ore, or coal or scrap that it would be using. Another seriously underestimated variable in at least two of the plants was the impact of local climatic conditions. Yet another -extremely important- "plant specific" factor underestimated in some cases was the degree of disruption that major expansions would cause to pre-existing plant operations and output.

3) A third issue that emerged was how poor (and often grossly over-optimistic) demand forecasts had turned out to be, with the consequence that very large expansions tended to be planned and constructed only to end up functioning for long periods at low utilization levels.

4) When we looked at gestation periods, we noted that these often seemed to be quite badly underestimated - not only because of financing difficulties but also because the selected technology sometimes proved defective in design or conception, and sometimes, too, because the plant was planned on a scale or with a technology that represented too big a "jump" from the experience previously accumulated by the firm in question to enable the firm to carry out the expansion smoothly.

5) This in turn suggested the value of considering it might prove wiser to build somewhat <u>smaller</u> plants (so as not to run into such long gestation periods), and that there would be a strong case for heavier prior investment by steel firms in the training, education and qualification of their own staff with regard to specifying, constructing and operation of the planned new or expanded plant concerned, as well as a strong case for heavier investment by them in getting first class external technical assistance in connection with the entire gestation process.

6) The above "planning implications" can be considered as inter-related

and complementary in the following sense: that in the "pre-investment" stage of steel plants and expansions, more effort should be put into:

.. scanning the techno-economic horizon more broadly, and, careful consideration of the option to build *smaller* plants, as well as the option to build *bigger* ones.

.. very careful examination of plant specific factors, including *both* "technological" factors connected to localisation and plant heritage, *and* an estimate of whether the experience and capability accumulated by plant staff will be sufficient to enable them to manage the planned expansion reasonably smoothly

.. explicit consideration of what prior investments in staff training and education, and what investments in technical assistance will be needed to be coherent with the "hardware" that it is planned to acquire

.. the performance of real,not cosmetic,sensitivity analysis in feasibility reports which will show how project profitability will fall if gestation takes longer than expected, and if demand forecasts prove as inflated as they often are.

The above recommendations are not merely in favour of what, in the consulting engineering profession, is called more "front end investment" - i.e. investment in the pre-investment period when steel plants are being planned. Their real point is to concentrate attention on the particular group of factors whose missestimation or underestimation is what seems to have led to or justified the more serious technology selection errors and long gestation periods reported earlier.

References to Chapter 3.

1/ M.N. Savio, Obras del General Manuel N. Savio, published by SOMISA, Buenos Aires, 1973.

2/ P.F. Castineiras, Esto lo hicieron los argentinos, available through SOMISA, Buenos Aires 1972.-

3/ R. Eckhaus, "Absorptive Capacity as a Constraint due to Maturation Processes", in J Bhagwati and R. Eckhaus, Development and Planning Essays in Honour of Paul Rosenstein Rodan, M.I.T. Press, Cambridge, 1973.

4/ P.Nueno, A Comparative Study of the Capacity Decision Process in The Steel Industry: The U.S. and Europe, Ph. D. Harvard University, 1973.

5/ W. Cartwright, The Place of Mini Steelworks in the World, Hatfield Memorial Lecture, British Steel Corporation, London, 1971 Mimeo.

6/ R. Eckhaus, op. cit.

7/ M. Nicodemo,"Los Nuevos Altos Hornos en Argentina" (The new Argentine Blast Furnaces), Siderúrgia Latinoamericana, No. 211, November 1977.

Chapter 4: "CAPACITY-STRETCHING" IN THE STEEL PLANTS

This chapter */ takes up a finding which emerged during the case-studies: that the effective production capacity of the plants in our sample, (and of stages and units within these plants), seems to have been "stretched" over time, going far beyond nominal capacity in many cases.

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*/ In this chapter, we often refer to the case-studies. These are denominated as follows:

Acindar, Rosario Report(1976)= Philip Maxwell, Learning and Technical Change in the Steelplant of Acindar S.A. in Rosario, Argentina, BID/CEPAL BA 18, December 1976.

Acindar, Rosario Report (1978 version)= Philip Maxwell, First-best Technological Strategy in an "Nth-best" Economic Context, BID/CEPAL BA 26, April 1978.

Acindar Report (Draft Thesis Version)= Philip Maxwell, "Learning and Technology Policy in Developing Countries. A Case Study based on the Experience of the Argentine Steel Firm, Acindar S.A. 1943-1978". Draft D. Phil Thesis, Buenos Aires, 1980

USIMINAS Report= C. Dahlman and F. Valadares Fonseca, From Technological Dependence to Technological Development: The Case of the USIMINAS Steelplant in Brazil, Vols I and II, Working Paper N°21, BID/CEPAL/PNUD, October 1978.

Colombia Steel Industry Report= Germán Puerta, El Desarrollo Tecnológico en la Industria Siderúrgica en Colombia, (Tecnological Development in the Colombian Steel Industry). Working Paper N°26, BID/CEPAL/PNUD, April 1979, Spanish.

AHMSA Report= L.A. Pérez & J. Pérez y Peniche, Decisiones Tecnológicas al Nivel de Empresa. El Caso de Altos Hornos de México S.A., (Technological Decisions at the Firm Level. The Case of Altos Hornos de México S.A.), Working Paper N°24, BID/CEPAL/PNUD, October 1978, Spanish.

To be clear on meanings, "effective" capacity refers to the production capacity of a unit (stage, plant) which is sustainable in the practical working conditions of the unit assuming that sufficient labour, materials and other inputs are available to service the full utilization of the capital facilities. "Nominal" capacity is the capacity of a unit (stage, plant) which was contracted for by the owner when purchasing it. In practice, effective capacity varies throughout the lifetime of a unit (stage, plant). It usually begins well below nominal capacity during the start-up period, then rises during start-up to a figure fairly close to nominal capacity, and then continues subject to further variations as process conditions change and/or as modifications are introduced into the unit (stage, plant) itself. a/

What was found in the case-studies was that these modifications in some cases had the effect of stretching effective capacity very far beyond nominal capacity, achieving for example, more than twice nominal capacity.

Such large increases in capacity seemed intrinsically interesting to explore. Hence, this chapter is devoted to presenting several findings about capacity-stretching which were contained in the case-studies.

Section 1 documents the great extent of the observed capacity stretching.

Section 2 provides evidence of the "pervasiveness" in the plants of technical change projects which had capacity stretching amongst their objectives.

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a/ For valuable definitions and discussions of plant production capacity see Gold 1/ and Sercovich 2/.

Section 3 then documents one of the main reasons which led to extensive capacity stretching in the plants - namely the blocking of their "conventional" capital intensive investment options.

Section 4 reports on a variety of other incentives to capacity-stretching noticed in the case-studies.

Section 5 discusses the methods used to stretch capacity in the plants.

Section 6 briefly summarises the overall set of empirical findings presented in the earlier sections.

1. EXTENT OF CAPACITY-STRETCHING OBSERVED IN STEELPLANTS

The first finding we report on concerns the extent to which the effective capacity of many of the existing installations in the plants was "stretched" - often far beyond nominal capacity - as a result of experience gained in operating these installations and the technical changes introduced in them.

To illustrate this, we collect in Table 1 below some figures on the extent of capacity stretching observed in the USIMINAS, Acindar, AHMSA and Acerías Paz del Río plants in different kinds of steelmaking units within these plants.

The feature which clearly emerges is the great extent to which the effective capacity of the units shown in the table was stretched beyond nominal capacity. These increases ranged from effective capacity reaching 25% above nominal capacity to reaching over 130% above nominal capacity, impressive by any standards!

The 'novelty' of these results is not in their documentation of the existence of capacity-stretching. For example, years ago both Enos (1958) 3/ and Hollander (1965) 4/ drew attention to the output increases that could be obtained from largely unchanged plants in the fields of petrochemical and rayon plants respectively. Rather, if there is novelty in the results, it lies in the great quantitative significance that capacity-stretching seems to have had in these particular steelplants that were examined in different Latin American countries.

Table 4.1 Extent of capacity stretching observed in different plants and types of equipment

TYPE OF EQUIPMENT	PLANT AND UNITS	TIME PERIOD	NOMINAL CAPACITY OF THE UNITS AT BEGINNING OF PERIOD		EFFECTIVE CAPACITY REACHED AT END OF PERIOD		% CAPACITY - STRETCHING
Sinter strands	USIMINAS Original sinter plant	1967-73	770 000	tons/year1/	1 544 000	tons/year2/	101%
Coke ovens	USIMINAS Original coke plant	1970-73	507 000	tons/year1/	634 233	tons/year2/	25%
Blast furnaces	USIMINAS Furnaces 1 and 2	1966-73	504 000	tons/year1/	1 196 803	tons/year2/	137%
	ACERIAS PAZ DEL RIO Original furnace	1955-57	500	tons/day	840	tons/day	68%
Steel shops	ACINDAR (Rosario)						
	Siemens-Martin N°1	1944-73	2.75	tons/hour2/	6.32	tons/hour	130%
	Siemens Martin N°2	1949-73	3.68	tons/hour2/	6.32	tons/hour	72%
	Siemens Martin N°3	1964-73	3.80	tons/hour2/	6.32	tons/hour	66%
	AHMSA						
	Siemens-Martin N°1 to 3	1963-73	227	tons/day4/	410	tons/day4/	81%
	Siemens-Martin N°4 to 8	1963-72	393	tons/day5/	607	tons/day5/	54%
	USIMINAS BOF shop N°1	1966-72	500 000	tons/year1/	1 179 000	tons/year2/	134%
Rolling mills	ACINDAR (Rosario)						
	Billet mill	1955-74	8.30	tons/hour3/	19.00	tons/hour	129%
	Bar & Section mill	1955-71	9.90	tons/hour2/	17.20	tons/hour	74%

Source: Derived from data in Acindar Report (1976), Usiminas Report, AHMSA Report and Colombia Steel Industry Report.

1/ These figures all refer to the nominal capacity of the units concerned. In every case this nominal capacity was actually achieved in the year shown at the beginning of the time-period. (i.e. the start-up period leading to the achievement of nominal capacity is excluded from the figures in the table).

2/ These figures all refer to the working capacity of the units after completion of their start-up period and refer to their capacity in use (i.e. when not "down" for maintenance or repairs).

3/ Ditto as for 2/ except that capacity is expressed in tons. per shift hour.

4/ Average per furnace for the three furnaces.

5/ Average per furnace for the five furnaces.

literature on the steel industry about this capacity-stretching phenomenon, even in the literature dealing with economies of scale. 5/ One of the few exceptions to this rule is Rosegger (1975) 6/ who noted that

> "An additional element of expansion was provided by the frequently remarkable increases in the rated capacities of existing plants through accumulation of smaller technological improvements and through "learning-by-doing". Up-ratings of ten to fifteen percent over a five year span are not unusual. They constitute another variable in a more dynamic view of the determination of plant sizes and the achievement of targeted final outputs, further modifying the concept of optimal capacities"..............."If the history of iron and steel-works in developed countries is any guide, continuous technological changes and the concomitant creation of incremental capacities at individual stages can be regarded as the rule rather than the exception"

The results obtained in the sample of Latin American plants strongly support these views of Rosegger's. But whereas he talks of upratings of up to fifteen percent over a five-year time-span, we have here got cases where much larger percentage increases in effective capacity were obtained, for example up to 130% over a six to seven year time-span in the case of USIMINAS's first two blast furnaces and first steel shop, and 66% to 130% in Acindar's steelmaking and rolling units over periods ranging from 7 to 29 years.

A central feature of all the cases of "capacity-stretching" that were observed, was that it was brought about mainly by the introduction and accumulation of minor, incremental technical changes to the existing equipment. Furthermore, this piecemeal, incremental capacity-stretching was usually brought about at relatively low investment cost compared to the investment in the original installations, ensuring that the investment costs per unit of extra (stretched) capacity were far below the investment cost per unit of nominal (unstretched) capacity. a/

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a/ Between 1967-68 and 1976-77, approximately US$ 7 million was invested by Acindar in its Rosario plant (the one mentioned in the table) compared to $22 million in its "Acevedo" plant and $27 million in its "Marathon" plant. The Investments in capacity-stretching projects in the Rosario plant were considerably less than $7 million, and appear to have accounted for less than half this total, Source of Data: Acindar Project Investment Approvals Archive.

(N.B.this footnote continues overleaf

As to the sources of the incremental technical changes introduced, these involved in all cases a combination of (i) carrying out changes suggested by the plant's actual experience in operating the units concerned, i.e. "learning-by-doing, and (ii) copying technical changes and improvements adopted elsewhere on similar equipment after suitably specifying and adapting them to the idiosyncratic local equipment and conditions in the plant concerned.

In any event the sheer cumulative extent and consequent economic significance of the capacity-stretching observed in this sample of plants justify an effort to look more closely into the factors which led to it.

(continuation of footnote a/ from previous page)

In USIMINAS, the costs of "capacity-stretching" expansion from 500,000 tons nominal capacity to 1,200,000 tons was roughly estimated to have cost only US $ 40 millions compared to $ 261 millions in the original plant: see USIMINAS Report, Vol. 1, p. 186. Moreover, much of this $ 40 million involved technical assistance contracts and "what little investment occured was in small peripheral equipment such as sintering screens, roll crushers, minor modification in major equipment units etc." See USIMINAS Report, Vol. 1 p. 259.

In AHMSA, investments in the Siemens Martin steelshop after 1967 were minimal due to the priority given by the enterprise to investments in the forthcoming new BOF shop: see account in Section 4.3 below.

2. EVIDENCE ON THE "PERVASIVENESS" OF CAPACITY-STRETCHING TECHNICAL CHANGE IN STEELPLANTS

A second finding from the case-studies is that capacity-stretching projects were 'pervasive'.

By 'pervasive' what we mean is that (a) in each of the plants at any moment there were always an appreciable number of technical projects leading to stretched capacity going on in at least one production stage and often in two or three stages of the plant at the same time; (b) these projects usually represented a very significant fraction of the overall set of technical change projects being undertaken in the plants at any particular time.

Moreover this 'pervasive' nature of capacity-stretching seems related to the observation that besides being frequently a priority objective of technical change in its own right, capacity-stretching was also noticed to have frequently occurred as a secondary objective, necessary condition or spin-off benefit of technical changes introduced with other main objectives in view (e.g. reducing unit costs, raising product quality, varying input-mix, etc.)

Some detailed evidence in support of these observations comes from the Acindar case-study where two samples of technical projects were examined to see what objectives motivated them:

(i) a sample of 30 important technical changes introduced in the Rosario plant during its lifetime, obtained by listing all the technical changes at the plant which were singled out for mention in the complete set of Acindar's annual reports to shareholders.

(ii) a representative sample of 54 R&D projects carried out by Acindar in its Rosario, Acevedo and Marathon plants between 1970 and 1974 on which detailed information was available thanks to its having been specially prepared for an Argentine government agency.

Regarding the first sample of 30 important technical changes introduced in the Rosario plant, the reasons cited for these projects were;

Table 4.2 Objectives of 30 important technical changes in the Rosario Plant

Reasons given for introducing the technical changes	Number of technical changes carried out for these reasons (out of 30 technical changes)	
1. To increase production capacity	16	ANALYSIS OF INDIVIDUAL REASONS CITED
2. To improve product quality	8	
3. To reduce unit costs	7	
4. To introduce new products	5	
5. To react to fulloff in input quality	2	
1. and 3.	3	ANALYSIS OF MULTIPLE REASONS IN THOSE PROJECTS WHEN MORE THAN ONE WAS CITED
1. and 2. and 3.	2	
2. and 3.	1	

Source: P.Maxwell, Learning and Technical Change in the Steelplant of Acindar S.A in Rosario, Argentina, Monograph 4, BID/CEPAL, Buenos Aires, December 1976, p. 79.

The most striking point to emerge is the high frequency of production capacity increase amongst the objectives for introducing technical changes.

It is also clear that some of the technical changes were specifically aimed at more than one objective simultaneously.

Coming now to the second sample - referring to the 54 R&D projects drawn from all three of Acindar's plants- the information on these is

Table 4.3 Classification of the objectives of 54 Acindar R&D Projects

Classification of the objectives being sought	Number, and "Value" 1/ of the projects in which this was the primary objective		Number and "Value" 1/ of the projects in which this was either the primary objective or a secondary objective	
Objective	Number	Value, U.S.$	Number	Value, U.S.$
Launch of new products	21 (39%)	532,000 (19%)	21 (39%)	532,000 (19%)
Increased capacity for existing products 2/	13 (24%)	1,304,000 (46%)	19 (35%)	1,793,000 (63%)
Reduced production costs	10 (19%)	703,000 (25%)	17 (31%)	818,000 (29%)
Improved quality of existing products	3 (6%)	35,000 (1%)	12 (22%)	492,000 (17%)
Easing of raw material supply restrictions	6 (11%)	251,000 (9%)	6 (11%)	251,000 (9%)
Better working conditions	1 (2%)	11,000 (0%)	3 (6%)	52,000 (2%)
TOTALS	54 (100%)	2,836,000 (100%)	54 (100%)	2,836,000 (100%)

Source of data: Calculated from data in Philip Maxwell, Implicit R&D Strategy and Investment linked R&D: A Study of the R&D Programme of the Argentine Steel Firm Acindar S.A., plus supplementary data in Acindar's descriptions of these R&D projects as provided to the Argentine Sub-secretariat for Science and Technology.

1/ By the "value" of the project, what is meant is the total expenditure incurred by Acindar on its own labour input to these R&D projects, both skilled and unskilled labour. This figure gives a rough order of magnitude of the size of the project. However it is only rough because other project costs, such as on machinery, raw materials for pilot runs, expenditure on labour from outside firms etc, is not included.

2/ In only one of these projects was the addition of completely new capacity, rather than the stretching of existing capacity involved.

summarised in detail in Table 4.3.

The importance of capacity-stretching emerges very clearly indeed from this table. 24% of these projects had as their primary objective to increase production capacity for existing products (in every case except one by modifying existing equipment, not adding new units -i.e. by stretching capacity.) And fully 35% of all projects had increasing capacity included amongst their objectives as either the primary or a secondary objective. Furthermore, if we pay attention to the "value" of the projects and not just their number, the significance of capacity-increasing projects is seen to be further enhanced. For projects with capacity-increase amongst their objectives accounted for 63% of total project value. Moreover all of but one of these capacity increasing projects involved capacity-stretching and not duplication of facilities, and this one project was of low "value". So projects with capacity-stretching amongst their objectives accounted for virtually 63% of the total value of all the projects in the sample.

So, our analysis of both these samples of projects clearly supports our statements regarding both the pervasiveness of capacity-stretching projects and the importance of capacity-stretching as a primary objective for technical changes in its own right as well as a secondary or spin-off objective alongside technical changes undertaken for other reasons.

Without going into details here, these assertions are also strongly corroborated by the material in the USIMINAS and AHMSA reports where innumerable examples of capacity-stretching change are given--and where in both cases the need to distinguish capacity-increase as a separate objective of technical change distinct from (though related to) cost-reduction is emphasized.

Indeed the authors of the AHMSA study come to the conclusion that

"AHMSA's objective (was) not profit maximisation but to provide the steel products demanded by the country's industrialization" so that "AHMSA's technological efforts have been mainly directed to increasing production as the priority objective" rather than improving quality or reducing costs a/

In the USIMINAS study, the authors present extensive evidence of capacity-stretching technical change in the original equipment installed by the firm, and explicitly state that it is "useful to distinguish an increase in production as a separate objective" of technical change b/

In short the "pervasiveness" of capacity-stretching projects and the fact that capacity-stretching was often an independent objective in its own right were observed in all three of the plants.

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a/ AHMSA Report, p. 22, paragraphs 3 and 2

b/ USIMINAS Report, p. 62.

3. ONE MAJOR INCENTIVE TO CAPACITY STRETCHING: THE DELAYING OR BLOCKING OF CONVENTIONAL EXPANSION

It emerged in the steelplant studies that one of the main incentives which actually led Acindar, USIMINAS and AHMSA to stretch the capacity of their plants to such a notable extent, was the blocking or delaying of these firms' "conventional" expansion plans. To see this requires us to dip briefly into the history of the plants:

3.1. Capacity-stretching in Acindar's Rosario plant:

We start with the case of Acindar's Rosario plant. Chart 5.1 below shows that, apart from the notable "stretching" in the capacity of the plant's first Siemens Martin furnace achieved in 1949-50 a/, the main "stretching" in the capacity of the plant's installation took place from the early 1960s onwards.

Indeed from 1963-64 through to the early 1970s, the chart shows how the capacity of the billet mill was stretched from around 10 to almost 20 tons per hour, whilst that of each of the Siemens Martin furnaces was stretched from around 3.5 to almost 6 tons per hour. b/

Considering the obsolete character of the Rosario plant's installations, and the fact that this capacity-stretching was achieved on a deliberately low, indeed "shoestring" investment budget, one can well understand the pride which the Rosario plant staff and indeed Acindar's management, had in this achievement.

Nevertheless, the key to understanding the story of capacity stretching in the Rosario plant is that Acindar's management never wanted or planned to keep the Rosario plant going so long, nor to

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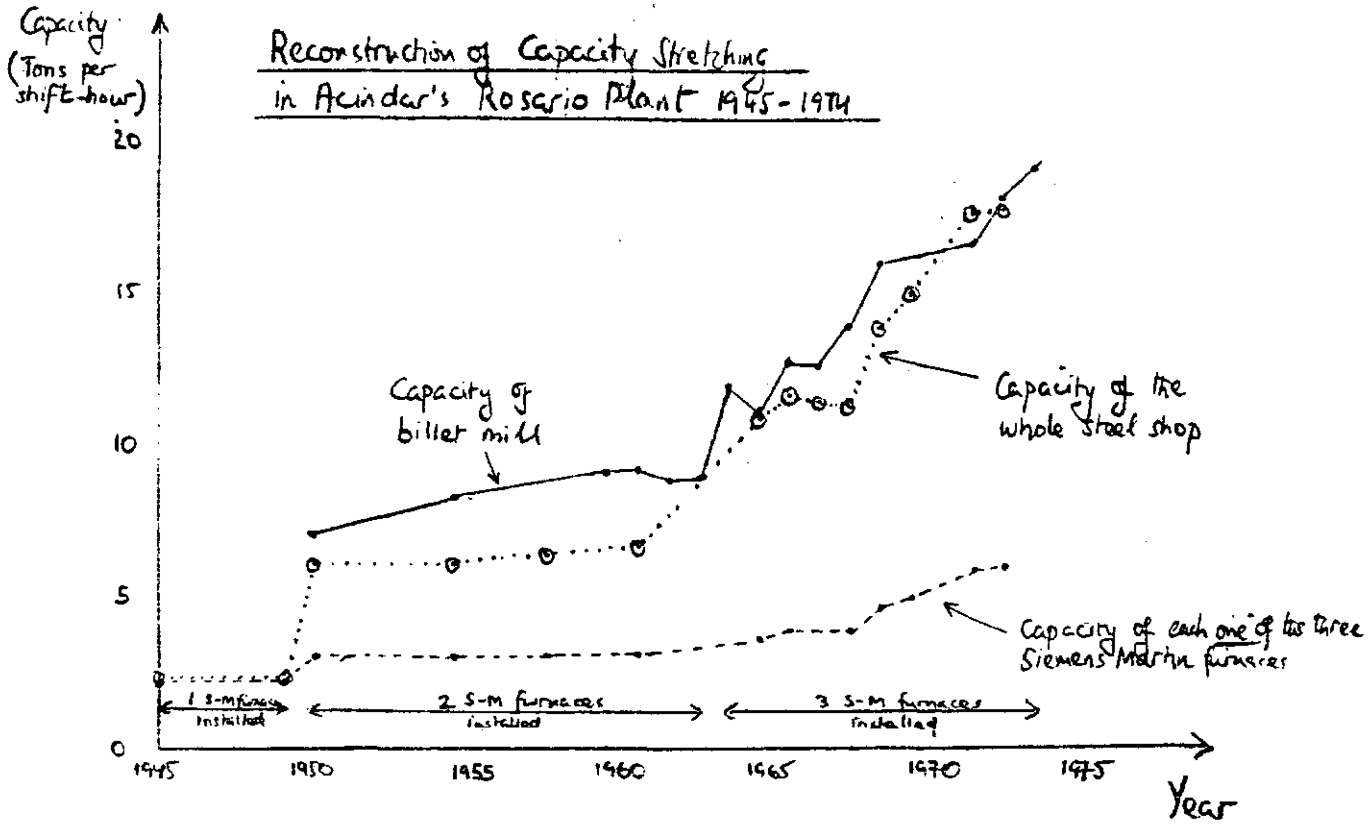
a/ This was achieved by rebuilding the furnace to enlarge its inner volume, and by introducing the use of cupola furnaces to melt part of the scrap load. This part of the load could then be charged into the Siemens Martin furnace as "hot metal", thus speeding up both the charging and the melting cycle in the Siemens Martin.

b/ Rosario's first Siemens Martin furnace went into action in 1943. This was enlarged and modernized in 1949. A second Siemens Martin, closely similar to the enlarged and modernized first one was also installed in this same year (1949). Subsequently, a third Siemens Martin furnace, similar in size and design to the earlier two was added in 1963-64.

CHART 4.1



Source: Reconstruction based on data in Acindar, Rosario Report (1976), with some interpolations of data in the period 1950 to 1960-61 ingeniously "stretch" its capacity in the way they did. Far from wanting to extend the life of the Rosario plant, Acindar's management wanted to scrap it ever since around 1953.

To see why, one must realise that the Rosario plant was built in 1943 at a time when the technology, the machinery and the skilled engineering help that would normally have been available from abroad to build a new steelplant was completely unobtainable, owing to World War 2 hostilities. So the plant got built thanks to the entrepreneurship and ingenious "do it yourself" technical improvisation organised by Arturo Acevedo, the founder of Acindar, and his colleagues. The result was a small-scale, patched-up, high-cost plant based on antique, partly second-hand technology. Even after the war when the plant was extensively modernized (with an additional samll Siemens Martin furnace, cupola furnaces for charging hot metal, a new ingot casting bay and a new small-scale billet mill) the plant was still far from the technological forefront.

What was at the technological forefront was Acindar's <u>second</u> plant, built at Villa Constitución some 50kms. from Rosario, and started up in 1951. Quite unlike Rosario, the Villa Constitución plant was conceived right from the start as a large scale "high technology" plant. It consisted of a modern continuous Morgan combination rolling mill for bar, rod and skelp, with a capacity of 215,000 tons per year, making use of billets as its raw material. It was conceived by Acevedo as the first stage of what was to be a fully integrated plant at Villa Constitución. The idea was that iron ore would be delivered by river to the port at the Villa Constitución site; then blast furnaces, steel refining and primary rolling would turn the ore into pig iron, steel and finally into billets to feed the already-installed Morgan mill.

Within this scenario, one can easily see why the small-scale originally improvised Rosario plant (which also had the disadvantage of being on a small inland site) was relegated to second place in the minds of Acindar's directors. The obvious place to invest and expand was in Villa Constitución, not Rosario. That was why the scrapping of the Rosario plant was always considered as either desirable, or likely to happen soon once the "integration project" for producing billets in Villa Constitución actually got underway.

What interfered with Acindar's plans -and thereby prolonged the life the Rosario plant- was that the company's ambitious integration project for Villa Constitución ran into a succession of frustrating bureaucratic difficulties between 1953 and 1975 arising mainly from opposition on the part of the Dirección General de Fabricaciones Militares (General Directorate of Military Production).

Altogether six different specific projects put forward by Acindar -each of which would have led to the integration of the Villa Constitución plant- were stalled or eventually frustrated from securing the definitive official approval and financial guarantees that were needed to proceed. a/ It was not finally until 1975 that Acindar got the green light to integrate its Villa Constitución plant.

Thus Acindar's persistent desire to substitute high cost, small-scale billet production on Rosario's outmoded equipment by lower cost larger-scale billet production on new equipment in Villa Constitución was persistently frustrated during more than twenty years!

Furthermore these same hopes and uncertainties surrounding the integration project also ruled out the idea of a really thoroughgoing modernization of the Rosario plant -which would have involved scrapping the old Siemens Martin furnaces, ingot casting and billet rolling equipment in favour of one or two modern electric arc furnaces and continuous casting facilities. This modernization was not carried out because of the expectation on the part of Acindar's directors that they would, before too long, get the go-ahead to integrate their

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a/ See Acindar, Rosario Report (1978 Version) p.10.

Villa Constitución plant and would thus be able to avoid all the disadvantages inherent in having to keep producing steel on the cramped Rosario site and then having to transport the billets 50 kilometers to Villa Constitución for rolling on Acindar's Morgan mill. In other words Acindar's directors never wanted to invest heavily in modernizing the Rosario plant because they always expected that the "superior" option of producing billets in Villa Constitución would open up, and that the expected future lifetime of the Rosario plant would therefore be short. So the "planning horizon" for the Rosario plant was therefore (a) always uncertain, and (b) believed to have a sizeable probability of being extremely short. This explains why Acindar's directors always wished to minimize any new investments in Rosario.

Finally, as we have shown in detail elsewhere, a/ all of the other natural ways for Acindar to have substituted Rosario's supply of billets by lower cost billets from other sources were also ruled out by the circumstances prevailing in the Argentine steel industry and economic context in successive years.

These above circumstances combined to repeatedly keep Acindar in a most curious position, consisting of:

1. having to maintain in action over more than twenty years an obsolete plant which they had always wanted to scrap
2. having constantly to try to expand this plant's billet production from the early 60s onwards so as to contribute to a reasonable degree of utilization of capacity in Acindar's main rolling mill plant, which could not be kept adequately provided by billets deriving from imports and domestic sources due to the frequently inadequate supply from the latter two sources.
3. having to achieve these two goals whilst restricting investment in the old plant to a bare minimum

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a/ See Acindar, Rosario Report (1978 Version) p.p. 6 to 11.

In this position it was out of the question to completely modernize the plant, which would have cost far too much, or to purchase a whole additional new production line to work alongside the existing one, which would also have cost too much. a/ The main avenue open to Acindar was therefore repeatedly to seek to "stretch" the capacity of its existing installations at Rosario at the lowest possible investment cost. This is exactly what they did.

3.2 Capacity-stretching in USIMINAS

Our next example relates to the way in which production in USIMINAS's original plant was stretched from the level reached in 1966 of 500,000 tons of flat products per year -which corresponded to the plant's nominal capacity- to over 1,200.000 tons per year by 1972. This was done without introducing any major new equipment units, and at very low investment cost. The reader is referred back to Table 5.1 where the impressive extent of capacity-stretching achieved in USIMINAS's various equipment units can be noted. Furthermore, Chart 5.2 below traces in detail the capacity-stretching achieved in USIMINAS's BOF steelshop. We now look at the circumstances in which these very notable results were achieved.

Like in the Acindar, Rosario case it must be said straightaway that a "stretching" on this scale was certainly not contemplated in the original plans for USIMINAS. What actually sparked off the succession of technical changes with which USIMINAS stretched the capacity of its plant was a deep financial crisis in the firm.

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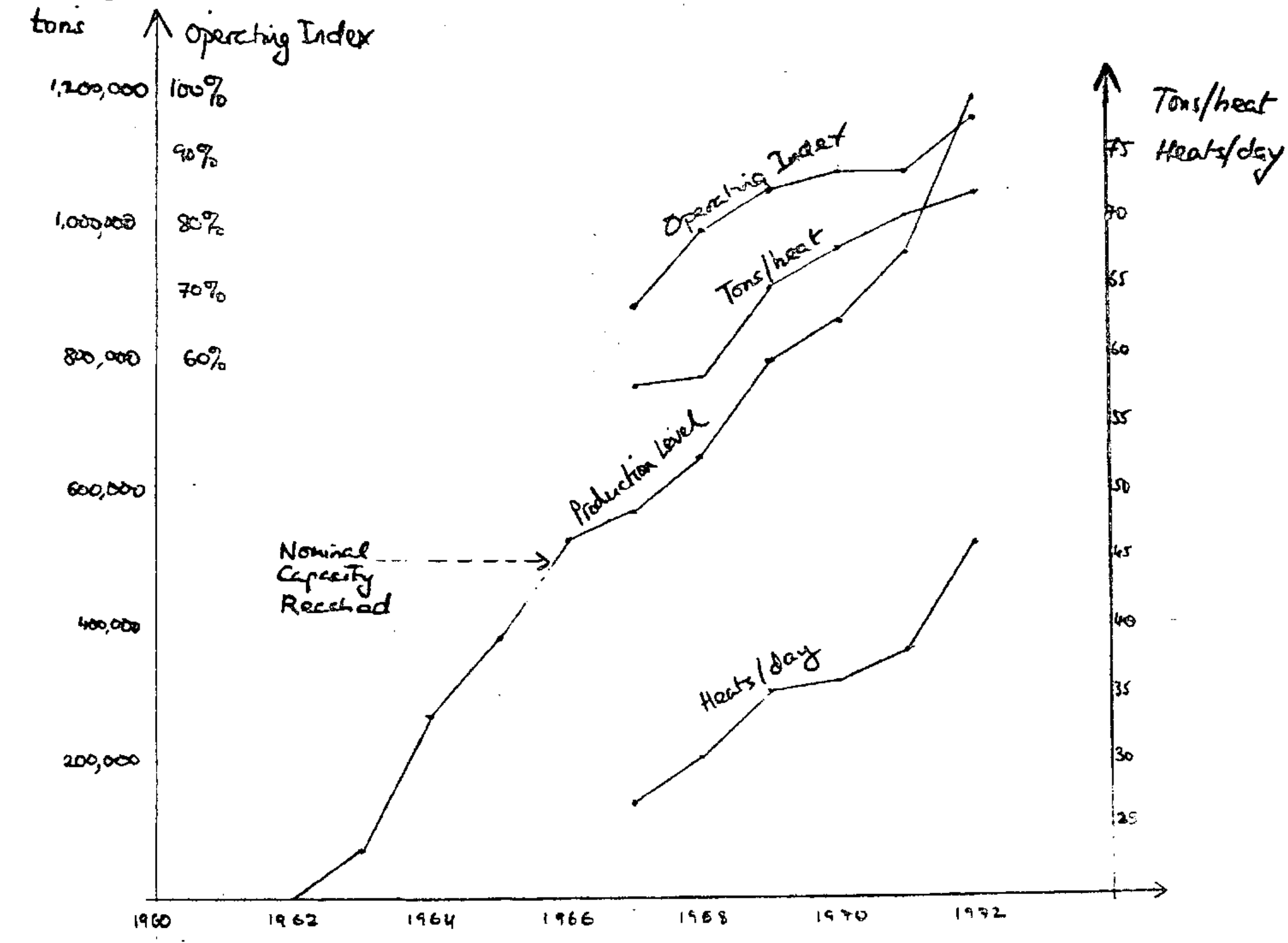
a/ Actually Acindar did add to the plant a third small Siemens Martin furnace identical to its two existing ones in 1964. (This was much to the chagrin of the plant's engineers's who wanted at the very least a much bigger and more modern Siemens Martin even if they could not have an electric arc furnace!). But this was the only instance of expanding plant capacity by the "conventional" means of duplicating existing production units. In every other main plant stage, the capacity of the existing installations was "stretched". and this was also done in the steelmaking section itself.

Chart 4.2 Capacity-stretching in USIMINAS BOF Steelshop No.1, 1963-72



Source: Figures from USIMINAS Report, Vol II, p. 136.

Accordingly, we shall first describe how this financial crisis arose.

Secondly, we shall describe how the "conventional" means which the directors of USIMINAS wished to use to increase their plant's output (and thence its sales and profits) so as to resolve their financial crisis were ruled out by the circumstances prevailing at the time -which then meant that the only alternative remaining was for USIMINAS to try to stretch the capacity of its existing installations at low investment cost.

To begin with, let us see how USIMINAS got into a financial crisis.

Several factors came together here. In particular:

1. The original investment required to construct the plant escalated a lot compared to forecast. This was caused by rapid Brazilian inflation in between the plans and the actual construction period, as well as the devaluation of the Brazilian cruzeiro. a/

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a/ USIMINAS Report, p. 47, 118, 119.

2. In 1964, just after USIMINAS started steel production, domestic steel demand in Brazil dropped by over 20% and did not fully recover until 1968. a/

3. Coupled to the retraction in demand, USIMINAS had the problem of the near simultaneous entry into the market of the flat-products output of the other new state-promoted firm COSIPA -which accentuated excess capacity in several types of flat products. b/

4. Price controls introduced at the beginning of 1965 kept the price of steel at an artificially low level while the cost of inputs was allowed to increase as a result of rapid general inflation. This situation was not righted by the government until 1968. c/

5. Furthermore, tariffs on imported steel products were reduced from an average 60% to 50% in 1966 and then to 40% in 1967, and on a substantial portion of flat products to as low as 15% -thus stiffening the competition from imports. d/

The net result of these five factors was that USIMINAS first built up large unplanned debts before entering production (due to the inflated initial investment cost) and then found it difficult to correct the situation upon starting up production because its sales income was lowered by a combination of low prices, low effective domestic demand and competition from COSIPA and imports.

Fortunately, this situation was perceived by USIMINAS early on, and led to two main responses by the firm designed to improve the situation. These were (a) a great emphasis on quality production for export sales which permitted USIMINAS to export 39% of its output

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a/ USIMINAS Report, p. 68.

b/ Ibid. p.73, 74, 76.

c/ Ibid. p. 74, 75, footnote to p. 77.

d/ Ibid. p. 76.

in 1965, 18% in 1966 and 33% in 1967, thus mitigating the domestic demand crisis; and (b) the launching by USIMINAS' directors of a strategy to greatly expand the plant's output so as both to increase sales income and reap economies of scale in investment costs and direct production costs.

Indeed, as early as the 1965, USIMINAS's directors, in their annual report reckoned that to break even, USIMINAS would need to attain a minimum production level of 1 million tons per annum. In the same year, they accordingly drew up an expansion plan to reach 1 million tons, which estimated that investments of around U.S.$ 70 millions would be needed (on top of the figure of U.S.$ 270 million which the original plant was reckoned to have cost). a/

This first expansion plan was submitted to an international financial agency in 1965 but was not approved because of the high debt-scales ratio of USIMINAS and the low prices and demand prevailing in the Brazilian market. Later on, in 1966, a more detailed project to expand up to 1 million tons and a preliminary project for 2 million tons were submitted by USIMINAS to the Consultants then doing the planning studies for the Brazilian government on the future of the national steel industry -but these projects to expand USIMINAS were not approved either.

In the event, it was only in 1967 that the government-appointed Special Advisory Group on the Steel Industry finally recommended that USIMINAS should be authorized to expand up to 1.4 million tons, a recommendation that was accepted in the 1968 National Steel Plan. This expansion was planned on the basis of substantial new investments and additions to the existing plant, e.g. additional coke and sinter plants, remodelling of the two existing blast furnaces, addition of a third BOF converter, etc. However, although approved in 1968 the

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a/ USIMINAS Report. p. 47

implementation of these additional investments for the expansion plan was slowed down by negotiations with the government backed Brazilian National Development Bank on how they would be financed, and these were only finally resolved in late 1969, so that the new installations only began entering into operation from late 1970 onwards, a/ and the main new equipment units only in fact entered production in 1973. b/

In summary, if we term the expansion of plant capacity by substantial additional equipment investments "conventional expansion", then what we have seen is that USIMINAS's own financial crisis coupled with the Brazilian Government's actual planning and financing decisions on the steel industry led to a situation whereby (a) USIMINAS's conventional expansion plans were blocked by lack of finance between 1965 and 1969, and (b) the facilities corresponding to conventional expansion only came on-stream in 1973.

Yet USIMINAS had already in 1965 realized that it urgently needed to increase sales income and reduce production costs through doubling its original capacity and production levels, so as to reduce its high debt to sales ratio.

In other words the firm already had an urgent need in 1965 to expand production and sales, but little money to invest in making this possible.

It was in these circumstances that "capacity-stretching" on the existing plant at low investment cost became a clearly attractive option and this option was then followed up consciously between 1965 and 1972.

3.3. Capacity stretching in AHMSA

Our third example is from the record of AHMSA and refers to

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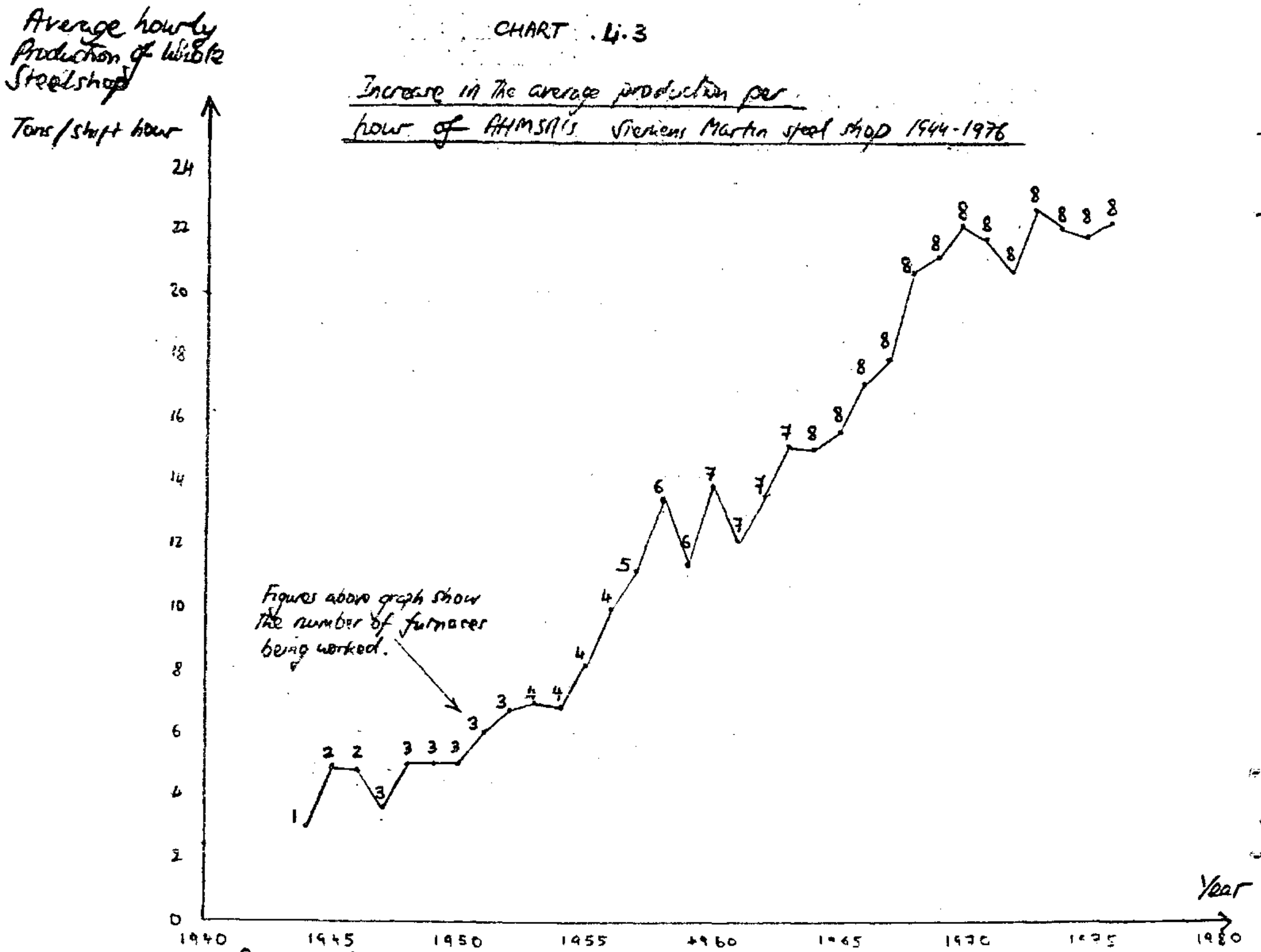
a/ USIMINAS Report. p. 120, 121

b/ Ibid. p. 123

CHART 4.3

Increase in the average production per hour of AHMSA's Siemens Martin steel shop 1944-1976



Source: AHMSA Report, p.97

capacity stretching in AHMSA's Siemens Martin steelshop. Chart 4.3 above shows that there has been a constant increase over the years in the production per hour from this steel shop. This has been to a large extent due to the installation of additional Siemens Martin furnaces, as is shown in the chart. Thus, the plant started with just one Siemens Martin furnace in 1944. A second and third were quickly added in 1945 and 1947. Then five additional, and larger Siemens Martin furnaces were added between 1953 and 1964.

However, a further effect can be noticed in Chart 5.3. This is the tendency for the output per hour to increase in successive years when the <u>same</u> number of furnaces were in use. This is particularly noticeable from 1964 onwards when all eight furnaces were working.

As we shall see, this post-1964 effect is closely related to a particular "circumstance" in the AHMSA expansion story: namely the fact that 1964 was the last year in which in an additional new Siemens Martin furnace was installed in AHMSA's steel shop - its eighth and final furnace of this type.

In the normal course of AHMSA's further expansion to meet constantly rising levels of domestic steel demand, one would have expected further new Siemens Martins to have been added during the second half of the 1960s and the early 1970s -- however this was not done because AHMSA, following world trends, decided in 1967 that the more recently developed BOF (oxygen converter) technology for making steel was more economic than Siemens Martin steelmaking, and therefore that they would instal BOF in their further capacity expansions.

As a result of this decision by AHMSA, it became apparent "that right from the planning stage for the first BOF shop the economic resources of the firm were principally directed to the future new steelshop, and the Siemens Martin shop began to get displaced so that investments in it were only directed to maintain it in operation rather than improve it". a/

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a/ AHMSA Report, p. 90, paragraph 4.

This meant that -like in the Acindar and USIMINAS cases- any improvements from 1967 onwards of AHMSA's Siemens Martin steelshop were subject to a clear investment constraint (i.e. to a regime of low, or minimal new investment).

It is interesting, therefore, to note -from the AHMSA study- that this situation of being "relegated to secondary status", a/ and being "practically condemned to disappear" a/ led to a clearly competitive response from the Siemens Martin personnel, who made increased productivity the "central objective" of their steel shop, a/ and who brought about a whole series of consequent technical changes at zero or very low investiment cost, whose principle objective was to reduce production costs. a/ b/

The authors of the AHMSA study are emphatic that this series of changes would not have been carried out were it not for the competition provided by the BOF shop, c/ and the challenge thus presented to the Siemens Martin shop to improve performance so as to survive, or survive longer. (Here there is a very clear parallel to the Acindar Rosario situation where plant personnel always knew that their plant was under "suspended sentence of execution").

A further point -which the authors of the AHMSA study surprisingly do not make- is that in the years 1967 to 1972, when the new BOF shop was being planned and built, very considerable "stretching" of capacity in the Siemens Martin shop took place. This can be seen in Charts 4.4 and 4.5. Thus, in the three small Siemens Martin furnaces, performance was boosted brom around 1.8 to nearly 3 heats per day between 1963 an 1971. In the five large Siemens Martin furnaces it was boosted from around 2.2 to near 2.8 heats per day between 1963 and 1972.

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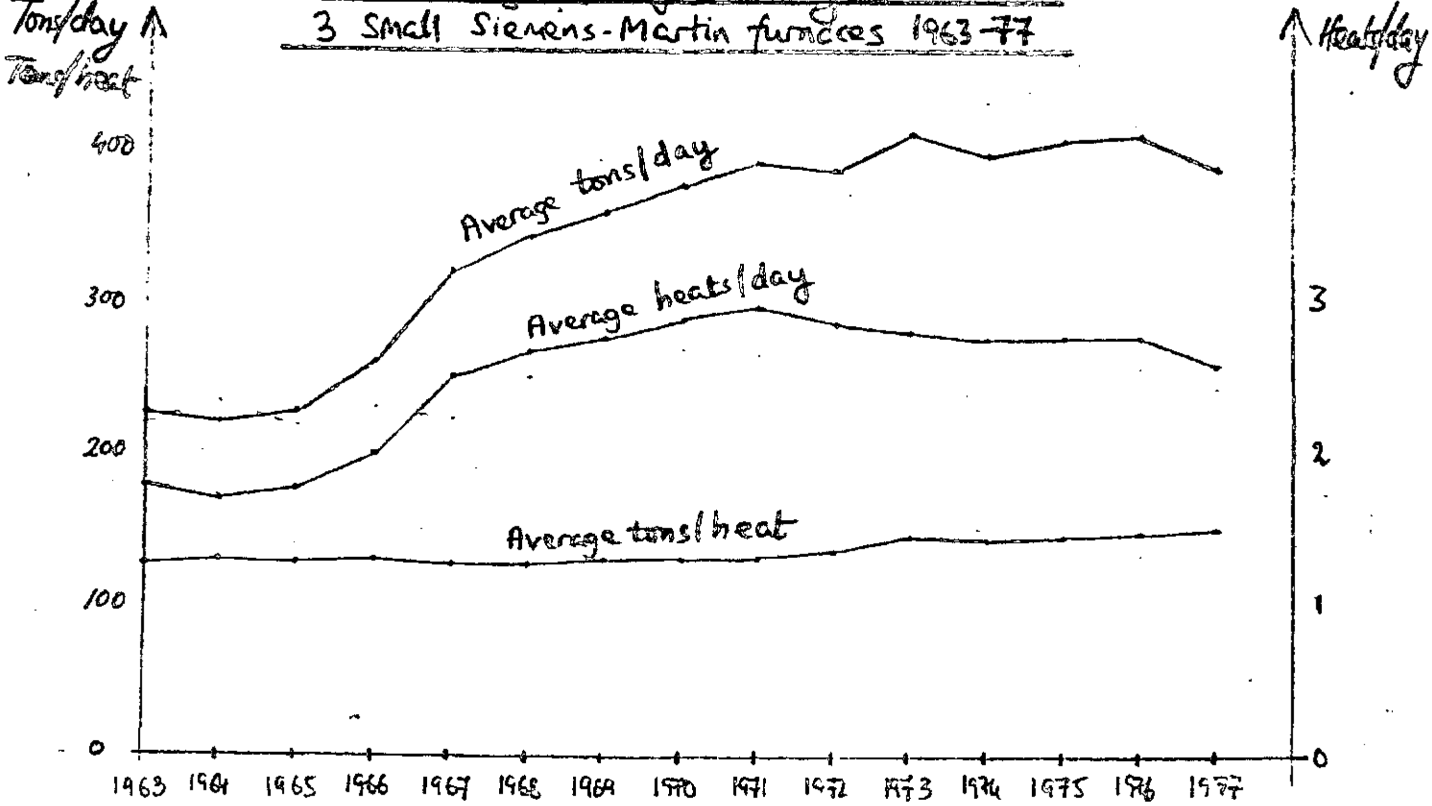
a/ AHMSA Report, p.88, paragraph 5.

b/ Ibid, p.89, paragraph 1, p.90, paragraph 5.

c/ Ibid, p.91, paragraph 4.

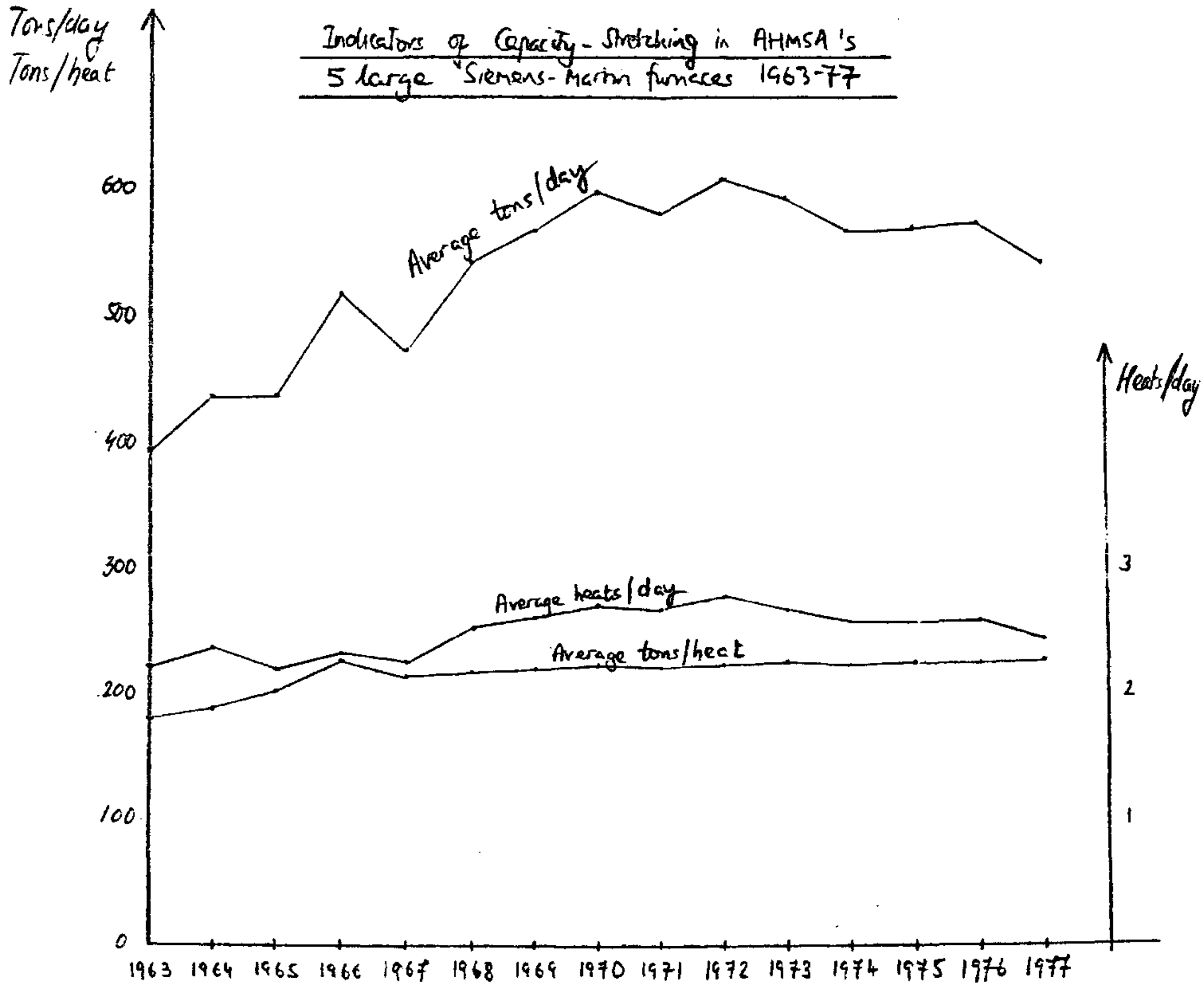
CHART 4.4

Indicators of Capacity-Stretching in AHMSA's 3 Small Siemens-Martin furnaces 1963-77



Source :- Based on figures calculated from data in AHMSA Report, pages 102 and 226

CHART 4.5



Source : Based on figures calculated from data in AHMSA report, pages 102 and 226

At the same time, in both the small and the large furnaces, an additional element of capacity stretching was provided by noticeably raising the average weight of steel produced in each heat.

The net effect of these two types of improvement was to stretch the production capacity of the small furnaces by approximately 81% between 1963 and 1973, and that of the large furnaces by approximately 54% between 1963 and 1972. a/

Our interpretation of this notable capacity-stretching is straight forward. It is that the years 1967 to 1972 represented a period when it was known that the BOF shop was being planned and would be coming on stream, but when, nevertheless, the expected output that would be obtained from it was obviously not yet available.

This must therefore have put a clear premium on squeezing the needed extra output to satisfy demand from the existing Siemens Martin units - yet at low investment cost because this increased output would only be needed from the Siemens Martin the relatively short time-span expected to intervene until the BOF shop would start up.

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a/ Furthermore these figures may well understate the true degree of capacity stretching actually achieved, because in the period 1967-72 there was also a noticeable decrease in the fraction of the load to the Siemens Martin furnaces that consisted of liquid pig iron ('hot metal') from the blast furnaces. (The fraction of hot metal charged to the small furnaces dropped from about 75% to about 50%, and in the large furnaces from about 60% to about 45%). This meant that a greater fraction of the load to the furnaces consisted of cold scrap that had first to be melted, which would, other things equal, lead to a slower working cycle and therefore to less heats per day. This was evidently more than compensated by changes in operating techniques which speeded up the overall production cycle, and produced the capacity stretching that we have observed.

In these circumstances, of clearly "present" increased demand, but unavoidable "delays" in satisfying it on the basis of the newly-to-be-installed technology, the motivation for capacity-stretching at low investment cost seems clear enough, and bears an obvious, similarity to the situations which we have described previously for Acindar's Rosario plant and for USIMINAS.

3.4. Summary

In all three cases described above, capacity-stretching was extensively resorted to as a kind of "second-best" option when the conventional expansion options that the firm would have liked to engage in were blocked or delayed.

The effects of these blocks and delays was that expansion could not -temporarily- be brought about in any other way than by capacity-stretching within a low-investment constraint.

Specificly it appears from the above cases that the following three kinds of circumstances provoked the blocks and delays to conventional expansion which in turn made capacity-stretching necessary.

(i) Rather long normal timelags inherent in the technological aspects of planning, designing, procuring, constructing, and starting-up whole new plant stages or major sections thereof. (i.e. in "conventional" expansion)

(ii) Expected and unavoidable political and bureaucratic delays in the process of securing official permission to undertake major "conventional" plant expansions, and in securing available government promotional incentives and/or financial guarantees. Plus the incidence of "unexpected" political and bureaucratic obstacles which lengthened the gestation period of the expansion project concerned and thus further delayed the date on which the desired increased output from the new plant could be expected to be available.

(iii) Investment constraints produced by financial crises in the firm -or by management's decision to concentrate most of its available resources on rival technologies or other parts of its activities.

4. EXISTENCE OF MANY OTHER INCENTIVES TO CAPACITY STRETCHING

In the previous section we emphasized the major incentive to capacity-stretching that arose when conventional output expansion was blocked or delayed because of external factors, investment constraints, or inherently long delays in the gestation period of the major capital investments required for conventional expansion.

However, the pervasiveness of capacity-stretching in the steelplants strongly suggests that incentives to it exist in a wider range of situations than merely those when it is a "second-best" option to conventional expansion plans.

Indeed it appears that pervasiveness is in large measure due to the sheer variety of different incentives that were observed in the case studies to have motivated capacity stretching projects. Without attempting to be systematic or comprehensive, the following list of incentives, all drawn from the case-studies, will be illustrative:

(i) Indivisibilities in steelplant equipment, which meant that small increments in demand could not economically be met by adding whole new units.

(ii) Disequilibrium inducements to stretch capacity caused by bottlenecks and/or imbalances in the capacities of different plant stages.

(iii) Accumulation of experience due to learning-by-doing in the daily operation of plants. This leads to the improvement of operational routines and the spotting of many minor design-defects and potential design-improvements which could raise capacity at low investment cost.

(iv) Temporary demand-peaks, which lead to efforts to raise the capacity of the existing plant, but which would not justify investing in extra new capacity.

(v) Stimulus provided by visits to other plants where capacity-stretching techniques are seen at work.

(vi) Stimulus provided by the wide diffusion in the trade literature of capacity-stretching innovations tried out successfully in other steel plants.

(vii) Stimulus provided through technical assistance contracts with a foreign steel producer or engineering firm that provide a channel for recommending innovations, including ones that stretch capacity.

(viii) The "performance-improving-instincts" of plant engineers keen to get more out of their existing equipment, which leads them to work-up and recommend capacity stretching projects.

(ix) The need for capacity-stretching as a pre-conditinn for securing cost-reduction achievable through greater output levels.

(x) The "spin-off" incentive in terms of capacity-stretching obtained "free" as a result of technical changes carried out primarily with other objectives in mind (e.g. to reduce production costs or improve product quality).

This long list of different observed incentives for capacity-stretching -in conjunction with the incentive discussed in the previous section- goes some way towards explaining the "pervasiveness" of capacity-stretching efforts that we observed in these plants; for, clearly, a very large variety of "trigger events", both external to the plant and internal to it, can -and did- activate one or more of the capacity-stretching incentives mentioned. a/

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a/ Some examples of external "trigger events" which induced capacity-stretching in our plants included: (a) severe unplanned shortfalls in competing supplies or in imports due to production or
(N.B. this footnote continues overleaf)

Furthermore the disequilibrium inducement to stretch capacity caused by bottlenecks or imbalances in different plant stages seems to act as a "multiplier" of the number of capacity-stretching projects that steelplants engage in. This happens because almost any capacity -stretching initiative in one particular plant stage (whether originally inspired by external or internal stimuli) is likely to stimulate or induce a further stream of secondary capacity-stretching adjustments to correct the new bottlenecks and imbalances that then arise. b/

So both the variety of different external and internal incentives to capacity-stretching and this "multiplier effect" help explain why capacity stretching projects were so "pervasive" in our plants, and also why their cumulative impact was so considerable.

(continuation of footnote a/ from previous page)
balance-of-payment problems -which led to temporary demand peaks for steel end products or intermediates, (b) currency devaluations, rapid inflation, and government price controls, which eroded steel firm profitability and led to investment constraints ruling out conventional expansion, (c) unusual or unexpected demand peaks caused by new government-subsidised public works programmes or by shortage of steel products on the world market, (d) changes of plans by the government which blocked or delayed conventional expansions, (e) autonomous demand increases which exceeded production capacity in different product lines.

b/ "When a single innovation is adopted within an existing system of production, it sets up pressures and open opportunities for successive 'ripples' of change in other parts of the system. Such pressures may be manifest in successive bottlenecks at different stages of production as management strives to realize the full potential of an innovation. Alternatively, the adoption of an innovation at one stage of the process may impose more severe requirements for quality and uniformity at earlier stages. As a third, and more favourable possibility, the initial innovation may create or unblock a variety of possibilities for profitable change at other points in the production process...". William S. Pierce. 7/

5. METHODS USED TO STRETCH CAPACITY

5.1 Existence of a "generic" set of capacity-stretching methods:

A further finding that emerges from comparing the steelplant case-studies is the great similarity that can be detected in the methods used to stretch capacity in the different plants.

This similarity is specially notable, as would be expected, between technologically similar units in the different plants -e.g. as between the Siemens Martin furnaces of Acindar (Rosario) and the Siemens Martin furnaces of AHMSA, or the blast furnaces of USIMINAS and the blast furnaces of AHMSA, or between the various rolling mills in the different plants.

But even more significant is that one can clearly detect a "generic" similarity between the capacity-stretching methods used across all these different technologies. In other words what appears to be underlying all the methods of capacity stretching observed is a central cluster of generic techniques - which presumably could also be applied to other metallurgical and process plants beyond the confines of the steel industry.

To make this clear, we shall now list these "generic" capacity stretching techniques, and then comment briefly on them.

The generic techniques that were used to stretch capacity in our steelplants seem to have been:

(1)	Improving the characteristics, control, preparation classification and standardization of the raw material "charge" to the process in question.	LEADS TO HIGHER OUTPUT YIELDS PER TON OF INPUT AND LESS PROCESSING DIFFICULTIES WHICH CAUSE HALTS IN PRODUCTION

(2) Increasing the usable volume of the containing vessels, in those cases where chemical reactions are involved.	INCREASES BATCH SIZE AND THROUGHPUT PER VESSEL PER DAY.
(3) Varying operational and equipment parameters so as to speed up cycle-times in each component physical, mechanical or chemical stage of the process.	INCREASES NUMBER OF 'CYCLES' AND HENCE THROUGHPUT PER DAY.
(4) Speeding up materials handling and transport between stages via improved mechanization and better layout.	INCREASES NUMBER OF 'CYCLES' AND HENCE THROUGHPUT PER DAY.
(5) More precise and rapid process-control and quality control, via improved and more intensive monitoring of process variables, and more rapid control-response-times.	LEADS TO (1) HIGHER PRODUCT YIELDS PER TON OF INPUT (2) LOWER PRODUCT REJECTION RATES
(6) Boosting the availability of processing units by incorporating more durable and reliable materials, components and accessories in those parts of the units most subject to wear out, and by developing maintenance and preventive maintenance techniques which reduce the "down-time" of units needed for their cleaning, maintenance and repair.	INCREASES NUMBER OF ACTUAL PROCESSING HOURS/DAYS PER YEAR, THUS BOOSTING ANNUAL CAPACITY
(7) Redesigning, or upgrading the numbers, capacity and reliability of auxiliary equipment units so as to match or permit faster cycle times in the main units.	FREQUENTLY A CONDITION FOR SECURING THE CAPACITY IMPROVEMENTS OF TYPES 1 to 6.

(8) Building up production experience which leads to improvements in labour operating efficiency.	CONTRIBUTES TO FASTER CYCLE TIMES FASTER AND BETTER QUALITY CONTROL AND MORE RAPID MAINTENANCE ACTIVITIES

Abundant examples of all these generic capacity-stretching techniques can be noted in the case-studies.

To illustrate, let us take just one of the methods of capacity stretching mentioned above -that of speeding up processing cycle-times. This theme appears again and again in the different equipment units in the different plants. Thus, in USIMINAS' and AHMSA's blast furnaces, cycle-timeswere raised by such steps as increasing blast pressures and temperatures, injecting oxygen into the furnaces, and more uniform operation obtained by closer process control. In Acindar's and AHMSA's Siemens Martin steelshops faster cycles were achieved by speeding up scrap-loading, by using more hot metal in the charge, by the use of higher flame temperatures and oxygen injection to speed up the refining reactions. In rolling mills in all the plants, faster operation and cycle times were obtained by rewinding motors to increase rolling speeds, superior synchronization to lower "dead times" in between successive slabs or bars being rolled, more precise roll-guides and tension guides to avoid production halts and "cobbles" etc. All these methods are also used in steelplants all over the world.

But, is this result in fact surprising? Perhaps not, if one realizes that the idea of speeding up process cycles, which in turn increases capacity, is a quite natural idea for steelplant engineers and technicians. Natural for engineers, too are such goals as minimizing production halts through better maintenance, and trying to acquire greater control over process variables, and indeed all the other goals in our list as well.

Thus, from an engineering viewpoint there is nothing actually surprising about our finding that capacity stretching projects in the categories mentioned above were found in all our plants. These are just the kind of things that engineers are trained to do.

Nevertheless, a caveat is in order. Although the generic principles of how to stretch the capacity of steelplant units are easy enough to state, and can be seen embodied in many examples in our case-studies, this does not mean they were easy to implement. There are two main reasons for this:

(1) the inherent complexity of process variables and lack of precise theoretical models to describe what is going on in blast furnaces, steel furnaces, and rolling operations mean that a great deal of empirical knowledge and experience needs to be gained so as to control and improve them successfully.

(2) the actual detailed process conditions that characterize each steelplant are highly idiosyncratic because of innumerable variations between plants in terms of different equipment and raw material characteristics, distint grades of steel being processed, different size ranges of intermediate products, variations in operating practice and end-product specifications etc. - which means that simple copying of techniques used in other plants is usually impossible.

As a result, capacity-stretching projects in our plants nearly always required a considerable input of in-plant know-how, design and experiment in addition to knowledge about those specific operational, equipment or maintenance innovations which might be suitable for the task. Also, of course, management agreement was required to invest the sums needed for modifying equipment, acquiring new auxiliary units, testing new operational methods etc.

This means that, although the generic capacity-stretching technics used were common across all our plants, the extent to which capacity-stretching potential was actually exploited in each plant was clearly dependent on (1) technical capacity of the firm, (2) its access to information about possible capacity-stretching innovations that could be introduced, and (3) the structure of economic incentives and of expected costs surrounding individual capacity-stretching projects and the way these were evaluated by the firm bearing in mind its investment policies, investment constraints and alternative investment projects.

The impact of these three sets of variables (different in each plant) means that a simple comparison of our plants on the basis of their adoption or non-adoption of certain kinds of capacity-stretching methods would tell us next to nothing about the comparative "efficiency" of the firms in exploiting the capacity-stretching potential of their plants.

Nevertheless the case-studies do provide some interesting "pointers" concerning some of the more efficient and systematic ways of exploiting capacity-stretching potential. This is the subject of the next section.

5.2 Pointers towards the systematic exploitation of stretching potential

Although a "direct" comparison of capacity-stretching efficiency in the three plants cannot be made, the case-studies illustrate two broadly different approaches to capacity-stretching, and also point towards an "evolution" from one approach to the other in each plant over time.

These two broad approaches can be characterized as

(1) The "ad-hoc, defensive" approach to introducing capacity-stretching innovations

(2) The "systematic, offensive" approach to introducing capacity-stretching innovations

To see what is meant by these two labels, we shall give some examples from the case-studies.

First of all consider the case of visits to other steelplants. In all the case-studies such visits were reported as important sources of ideas both for capacity-stretching and other kinds of technical changes. However, one gathers from the interviews carried out, and the reports themselves, that the visits to other plants were not usually systematically programmed but took place under the influence of an essentially random, hazard, and fortuitous set of factors - e.g. the impulses of senior managers to see other plants, the opportunities seized by younger staff sent abroad for training to look at plants in their host country etc. Indeed in the AHMSA Report it is clearly stated that "there did not exist an explicit and periodic programme of visits to exchange information about problems and solutions". a/

An interesting contrast to this essentially "ad-hoc" approach to gaining information by visiting other plants is provided by an experience related in the USIMINAS Report. As from 1967 USIMINAS wanted to stretch the capacity of its steelshop from 600,000 to 700,000 tons per year, so what it did was to commission a study "of how its converters compared with those of 16 U.S. plants in terms of characteristics and production" b/, - and this study showed that the increased capacity could be obtained with only minor specific changes in operating practice plus stengthening of some auxiliary units. What this example illustrates is the use of a systematic and precise scanning approach to the information available from other plants - as opposed to the essentially "random" approach implied by occasional visits. Interestingly, amongst our plants,

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a/ AHMSA Report, p. 27

b/ USIMINAS Report, p. 170

USIMINAS is also the one that most systematically scans the world steel literature a/, and also the one that appears to make the most systematic and creative use of external technical assistance. In this regard, it is not surprising that one of the most important innovations introduced by USIMINAS to stretch the capacity of its original steel-shop was the "three-holed oxygen lance" that was suggested to the company by Nippon Steel with whom USIMINAS had a ten-year technical asistance contract. b/ External technical assistance has also been important in AHMSA and in the Acevedo and Marathon plants of Acindar.

A quite different illustration of the differences between an "ad-hoc" and a "systematic" approach can be gathered from the record of capacity-stretching in Acindar's Rosario plant. In Acindar, Rosario -in contrast to USIMINAS- the sources of technical change have been almost exclusively internal to the plant. Rather than scanning the technological horizons, Rosario staff have always been concerned with "doing their own thing" and improving their technology with small resources and a lot of in-house ingenuity. In the rolling mills section, virtually all technical changes during many years were introduced as responses to particular machinery problems, breakdowns, and processing difficulties that cropped up during production and which interrupted smooth functioning - i.e.

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a/ USIMINAS's Center of Technical Information "has the best library on steel in the country and maintains permanent contact with the main information organs in the country and in the world in order to collect information of interest.... The Research Center has its own technical library staffed with 19 persons with over 5,000 books and its own subscription to 329 relevant technical journals and magazines apart from those in the main library". USIMINAS Report. p. 216.

b/ USIMINAS Report, p 172.

fundamentally an "ad-hoc" troubleshooting approach. a/

However, there was a further development, for in the period 1969 - 71 the men who had spent many years attending to the Rosario mills with this "troubleshooting" approach, had the opportunity to introduce substantial design modifications of their own into the plant's billet mill and its bar & section mill. This led to two low-cost but highly effective projects -entirely designed in house- which both had an extremely notable capacity-stretching impact. Analysis of these two projects shows that they were based on the long-experience and detailed familiarity of their designers with virtually every facet of these mills, their operation, their design problems, faults and possibilities. This enabled an extremely precise, detailed and comprehensive combination of modifications to be introduced in both cases which systematically exploited the available equipment, motor-horsepower, and space-available to the maximum extent at minimum extra investment cost. b/

The critical point in this example is the shift from an "ad-hoc" troubleshooting approach to a "systematic approach" which is made possible by the growth of familiarity with the process to be improved - this growth itself occurring due to the experience acquired in by plant staff operating the process and coping with the difficulties involved.

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a/ Indeed as experience built up, this came to be rationalized as a specific design philosophy, stated as follows: "To go along, eliminating passes, redesigning rolls so as to minimize problems, to roll with greater cross section wherever possible, to try to minimize production halts and nuisances, and if possible to withdraw men because it is pretty unpleasant type of work involving risks of getting burnt; to go along making adjustments in the elements or accessories of the mill which bring you problems".

Source: Acindar Report (Draft Thesis Version), p. 9.25.

b/ Both projects are described in detail in the Acindar Report (Draft Thesis Version) pp. 9.34 to 9.37.

This shift from an "ad-hoc" to a systematic approach based on growing process familiarity was clearly observed in <u>all</u> our steel plants. For example, in the AHMSA Report, we find the following passage which describes the sequence of events after 1971 when the firm acquired a great deal of sophisticated "best-practice" new technology (including BOF technology) for the first time:

> "The degree of foreign technological dependence increases during the guarantee period because during this time any operational problem with the technology must be directly resolved by the suppliers. Once this period is over, a period of learning is necessary so as to get to know deeply about the functioning of the process and the equipment, during which external assistance is sought sporadically. Finally, starting from this knowledge-base, a process of trial and error is begun (without having a very solid theoretical basis ex-ante, but regularly generating one ex-post) in which the aim is to incrementally improve and optimize the operational routines laid down by the foreign equipment suppliers." a/

In other words, it requires a considerable period of prior familiarization and "trial and error", before plant staff develop a good understanding of the interplays and subtleties of the complex set of equipment and process parameters and variables that they control. So it is only to be expected that <u>early</u> capacity-stretching efforts will be more ad-hoc than systematic, and that these early efforts will usually arise in the course of trying to keep the process going when it is faced with specific operational difficulties, rather than through unforced experimentation on potential improvements.

This difference between "early" and "later" capacity-stretching is also borne out strongly by USIMINAS's experience. For example, in the sinter section

> "the initial effort was devoted to learning about the basic process itself, particularly the influence of various physical and chemical qualities of the process. As these were learned,

a/ AHMSA Report, p. 24

greater efforts were directed at controlling the basic characteristics of the raw materials. In large part this involved reaction to the variations in these qualities in the raw materials received. (Reactions to external fluctuations). Third, as more experience was gained, better methods were developed, including not only changes in raw materials used, their handling, preparation, weighing etc., but also of the process itself. To do this it was necesarry to not only modify or add various pieces of equipment but to develop new organizational methods involving training, learning and studying various aspects of the process. a/

So we see that USIMINAS's experience confirms AHMSA's and Acindar's in showing why one would expect to find later capacity-stretching efforts are characterized by a more comprehensive, sophisticated - and "theory- intensive" approach than earlier ones.

A further important characteristic of "later" capacity-stretching efforts was also detected in the case-studies. This has to do with the problem that as the more "obvious" capacity-stretching steps are taken, any further stretching will often depend on extending efforts to hitherto neglected components and aspects of the process.

For example a "saturation" of this kind was detected in USIMINAS's steelshop, where if one reads through the list of measures being considered by the company for its "fourth wave" of capacity-stretching in this steelshop, what is striking is the cumulative number and range of the efforts being considered and the number of components identified for improvement. (These included changed operating practices in charging the converters, redimensioned ingot moulds, special refractory bricks for scrap and steel-run-sites, new systems of inventories of spares, increased oxygen injection, holding extra pig iron reserves to insure against production halts, and improvements in calcination.) b/ What is reflected here is that USIMINAS

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a/ USIMINAS Report, p

b/ USIMINAS Report, pp. 172-3.

apparently wanted "no stone left unturned" in their efforts to stretch capacity further and further towards inherent design limits, and therefore were prepared to systematically try to improve virtually every component of the process - a task which evidently required extensive prior familiarity with the process concerned. A similarly "comprehensive" approach to capacity-stretching -via revising literally every possible component- was also a feature of the two projects in the Acindar Rosario rolling mills mentioned earlier.

A final point worth making whilst dealing with the theme of "systematic" capacity-stretching is that neither in Acindar, nor in USIMINAS was there any clear idea beforehand of just now much they would in fact be able to stretch capacity. So far as Acindar is concerned, back in the 1950s no-one conceived it possible, or thought of planning to stretch the Rosario plant's capacity to the extent that was finally achieved. The actual cumulative stretching finally achieved was the unplanned <u>outcome</u> of a long series of efforts carried out successively given the reiterative blocking of conventional options.

As for USIMINAS, as late as 1969 its Annual Report spoke of the achieved steel production level of 790,000 tons as the "maximum probable production" thatcould be obtained with its existing installations - and then went on in succeeding years to stretch this level up to nearly 1,200,000 tons. a/

This suggests that both Acindar and USIMINAS (and quite probably AHMSA too) underestimated the terrific possibilities that actually existed for capacity-stretching. That they in fact achieved so much seems greatly due to adverse historical circumstances which made it economically urgent for them to stretch their plants to a high degree. In other words it seems that"historical jolts" (or sets of jolts) helped these firms to <u>wake up</u> to the

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a/ USIMINAS Report, p. 127

full-potential for capacity-stretching in their plants. Without these jolts (which involved mainly the blocks and delays in conventional expansion plans) it is doubtful if they would have been so systematic or successful.

This completes our survey of "ad-hoc" versus "systematic" methods of introducing capacity-stretching technical changes. Our survey has not been comprehensive -for space reasons- and, in particular, we have not mentioned several important organizational steps which our firms took in order to reinforce their internal capability to identify and implement capacity-stretching and other changes (e.g. the setting up of a "standard-cost" system, a/ and the setting up or reinforcing of several technical departments within the plants). However, enough has been said to show that our plants were able to develop a number of systematic approaches to capacity-stretching. These ranged from the systematic scanning and exploitation of information from other plants and the use of external technical assistance, through to the executing of comprehensive process modifications based on plant staff's mastery of process know-how that they acquired through experience.

So in addition to demonstrating the existence of several "generic" capacity stretching techniques common to all the plants the case-studies also demonstrate some ways in which the firms were able to exploit these techniques in a systematic way.

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a/ "Such capacity stretching (in the first 10 years of USIMINAS) was possible thanks to the implementation of a standard cost system with an elaborate organizational infrastructure to study its existing equipment, compare it to the best world performance, and then try to reach the same or higher levels." USIMINAS Report, p. 263; for details of the implementation of the standard cost-system see USIMINAS Report, p.p. 211-213.

6. SUMMARY OF THE EMPIRICAL FINDINGS

In the previous pages -Sections 1 to 5 of this chapter- we have sought to describe salient features of "capacity-stretching" observed in the steel plant case-studies.

The main points which emerged were:

1) the great quantitative extent of capacity stretching

2) the fact that its implementation at low investment cost was to a significant extent fuelled by the blocking or delaying of conventional output expansion plans.

3) there were also many other kinds of incentives to capacity -stretching, which together with the "multiplier effect" of the bottleneck-imbalance incentive, help account for the "pervasiveness" of capacity-stretching projects that we noted in the plants.

4) capacity-stretching was often the priority objective involved in carrying out technical changes, and cannot be considered as always a subsidiary objective related to cost-reduction; it has legitimate status as an independent category of technical change, though its complementarity to cost-reduction certainly deserves exploration.

5) there appears to exist a "generic" set of methods for stretching capacity, whose use was common across all the plants and technologies within the plants; this is intelligible from an engineering viewpoint; however process -complexities and marked plant idiosyncracies mean that it was not a simple matter to apply these generic methods because straightforward copying of techniques used in other plants is not viable in this industry.

6) both "ad-hoc" and more "systematic" approaches to stretching capacity were detected in the study - the latter being closely related to gaining familiarity and knowledge about process variables and how to control them; also some systematic ways of exploiting information from other plants and from external technical assistance were noted; finally it was observed that at least two of our plants had initially greatly underestimated the extent of capacity -stretching that they would be able to achieve.

Although these above results are drawn from case-studies on just a few plants, we believe that the phenomenon they describe -i.e. capacity-stretching- is a widespread one in steel-plants, which deserves to explicit recognition in the planning process.

References to Chapter 4

1/ Bela Gold, "Productivity Measurement Problems and Methods", Chapter 3 of S. Eilon, B. Gold and J. Soesan, Applied Productivity Analysis for Industry, Pergamon Press, Oxford, 1976, pp. 48,49.

2/ F. Sercovich, Design Engineering and Endogenous Technical Change: A Microeconomic Approach based on the Experience of the Argentine Chemical and Petrochemical Industries, BID/CEPAL/BA 43 (English version), October 1978. See Ch. III.

3/ J.L. Enos, "A Measure of the Rate of Progress in the Petroleum Refining Industry", Journal of Industrial Economics, June 1958.

4/ S. Hollander, The Sources of Increased Efficiency: A Study of the Du Pont Rayon Plants,

5/ On economics of scale in the steel industry, see A. Cockerill, The Steel Industry: International Comparisons of Industrial Structure and Performance, Cambridge University Press, 1974, especially Ch.VII; C.F. Pratten, Economics of Scale in Manufacturing Industry, University of Cambridge Department of Applied Economics, 1971.

6/ G. Rosegger, "On Optimal Technology and Scale in Industrialization: The Case of Steelmaking", Omega, Vol.3, N°1, 1975.

7/ W. Pierce, "The Ripple Effects of Technological Innovation". The case of Iron-Ore Pelletizing, Omega, Vol. 2 N°1 1974.

Appendix to Chapter 4.

Table 4.A.1 Production figures from the USIMINAS BOF Steel Shop N°1
1963 - 1972

YEAR	PRODUCTION	Av. TONS/HEAT	Av. HEAT/DAY	OPERATING INDEX
1963	73,417			
1964	276,248			
1965	383,124			
1966	529,323			
1967	570,052	57,8	27.0	67.6 %
1968	649,167	58.5	30.4	78.4 %
1969	790,914	65.1	35.2	84.3 %
1970	850,235	67.9	36.0	86.9 %
1971	950,040	70.2	38.2	87.1 %
1972	1,179,296	71.9	46.0	94.6 %

Source: USIMINAS Report, Vol. II, p. 136.

Table 4.A.2. Capacity increases in AHMSA Siemens Martin furnaces, 1963-1973.

	Three small furnaces a/ (Average per furnace)			Five large furnaces b/ (Average per furnace)		
YEARS	Heats/day c/	Tons/heat e/	Tons/day	Heats/day d/	Tons/heat f/	Tons/day
1963	1.79	126.93	227.2	2.20	178.43	392.5
1964	1.70	130.40	221.7	2.33	186.28	434.0
1965	1.78	128.46	228.7	2.18	200.10	436.2
1966	2.00	130.49	261.0	2.30	224.24	515.8
1967	2.51	127.47	319.9	2.22	211.70	470.0
1968	2.68	127.47	341.6	2.50	215.75	539.4
1969	2.75	130.59	358.8	2.59	218.85	566.8
1970	2.87	131.21	376.6	2.69	221.49	595.8
1971	2.95	132.24	390.1	2.64	219.31	579.0
1972	2.84	136.10	386.5	2.75	220.55	606.5
1973	2.80	146.52	410.2	2.65	222.89	590.7
1974	2.76	143.39	395.8	2.56	220.09	563.4
1975	2.77	145.90	404.1	2.56	221.80	567.8
1976	2.76	148.16	408.9	2.57	221.80	570.0
1977	2.58	150.35	387.9	2.41	223.29	538.1

Source: AHMSA Report, pages 102 and 226.

a/ These three furnaces were installed in 1944, 1945 and 1947 and their current (1977) capacities were nominally rated at 135 tons per heat. (See AHMSA Report, p.67).

b/ These five furnaces were installed in 1953, 1957, 1960, 1960 and 1964. Their current (1977) capacities were nominally rated at 255, 215, 225, 225 and 225 tons per heat respectively.

c/ Average of first three columns of Table N°9, AHMSA Report, p. 102.

d/ Average of columns four to eight of Table N°9, AHMSA Report, p.102.

e/ Average of first three columns of table in AHMSA Report, p.226.

f/ Average of columns four to eight of table in AHMSA Report, p. 226.

This chapter provides brief, mainly impressionistic, evidence on some other aspects of plant upgrading beyond the "capacity stretching" dimension discussed in the previous chapter.

Taken in conjunction with the previous chapter, it reinforces the view that plant upgrading, and the cumulation of minor technical changes which make it possible, should be considered as central, not marginal features in the techno-economics of steel plant development, in spite of the "low visibility" of individual piecemeal changes.

5.1 The Low Visibility of Plant Upgrading in the Literature

One of the curious features of plant upgrading - considering its great importance - is how little this phenomenon is explicitly recognised or dealt with in engineering or economics literature.

Engineering consulting literature, for example, typically refers only to various subdivisions of what we have called the "gestation period" and usually does not specifically identify a succeeding phase of plant upgrading or improvement during which several plant performance parameters may be improved beyond initially rated levels. In economics literature, plant upgrading has also been a rather neglected subject, though work by Enos (1958), Hollander (1965) and Katz (1973, 1976) did at least help put it on the map.[1/]

1/ "Consideration of investments at various plants suggests that relatively small investment expenditures incorporating modifications to existing plants are capable of generating large improvements in efficiency. Such improvements are sometimes sufficient to permit an older plant to produce at unit costs which are not substantially higher ... than those at a newly constructed plant embodying the latest technology". Hollander (1965)

This "low visibility" of plant upgrading in the literature is probably largely due to the fact that upgrading efforts mostly involve the piecemeal accumulation of quite minor technical changes, none of which individually seem very remarkable. This is in marked contrast to the high visibility of the changes that get introduced in the gestation period when an entire new plant or major expansion is put up.

Indeed, evidence from interviews with engineers in some of our sample of steelplants shows that sometimes minor technical changes pass unhailed and unrecorded even inside the plants themselves.

This is well illustrated in the following remark of an Acindar engineer who said that:

> "Often, with small changes - 'the ant's progress', we call it - we just try to carry them out, and very few people even get to hear of it. It's not something you'd mention to the higher-ups in the company. After all, it's not for hanging a medal on anybody." [a/]

In effect then minor "small-beer" technical changes carry little prestige - they are not "good public relations" in the same way that a brand new oxygen converter is to journalists or politicians. As a result, their great <u>economic</u> significance, of which we have been able to offer some instances in this case-study, is not fully appreciated.

Further evidence of the neglected status of minor technical changes emerges from the Altos Hornos de Mexico case-study, from which we draw the following extract:-

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a/ From an interview by the author in Acindar's Rosario plant.

> "In the plant we visited, we found a large number of incremental (minor) technical changes in each of the different sections of the plant, so much so that it would require an excessively long document to narrate each one of them and their effects on plant productivity. Nevertheless, in spite of their importance, an outstanding and surprising discovery was that on only a few occasions was there any written information on what the problem was, how it was resolved, and the results. These types of changes are generally implemented with the active participation of the plant's operations and maintenance personnel, who, on most occasions did not consider what they had done to be of special importance, and who, once the problem was resolved, considered that they had more important and urgent things to do than to sit down and write about solutions already achieved. What we wish to emphasize is the tremendous significance for our country (Mexico) of the fact that these innovative efforts are not getting duly publicised even within the firm that generates them, thus losing the benefits from diffusion of this knowledge. But even more serious are the costs which this procedure generates, because the fact that the information is embodied in physical persons means one has to start again from zero when the same problem crops up again if these people for any reasons abandon the firm concerned. 1/

Economists, too, have neglected minor innovations - as can easily be proved by consulting the economic literature on innovation in the steel industry in the last fifteen years. 2/ Legislators have paid even less attention to the phenomenon than economists. 3/

However, although minor technical changes may be individually relatively insignificant, they may be cumulatively very important. We have already

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1/ Luis Alberto Perez, A Summary of the Principal Findings of the Case-Study on the Technological Behaviour of the Mexican Steel Firm, Altos Hornos de Mexico, IDB/CEPAL Seminar, 6-10 November, 1978, Buenos Aires.

2/ The literature contains several studies of major "breakthrough" innovations such as the oxygen converter, continuous casting and direct reduction, but neglects minor and incremental innovations.

3/ "The Latin American systems of industrial property do not support, in general, the results of adaptive activities or minor inventions", Carlos Correa and Eduardo White, El Marco Jurídico de la Innovación Tecnológica en América Latina (The Legislative Framework for Technological Innovation in Latin America), Vol. 1, BID/CEPAL/BA/15, p.28.

discussed the evidence for this in regard to the stretching of the capacity of the steelplants beyond rated levels (see Ch. 4). Moreover, capacity stretching was by no means the only dimension of upgrading in the plants we studied, as will now be seen from the material presented in the next section.

5.2 The Multiple Objectives of Minor Technical Changes

A broad range of objectives were involved in the minor technical changes introduced to upgrade the steel plants, going beyond just cost reduction and capacity stretching, to include improved end-product quality, changed input quality and input mix, and diversification of the product mix. These various objectives were important both as independent priority objectives in their own right, and as secondary objectives (or spin-offs) of technical changes carried out with other priority objectives in mind.

The reader is referred back to Table 4.3, (a detailed Classification of the Objectives of 54 Acindar R & D Projects) for a clear illustration of the variety of objectives involved. Documentation of several different objectives of minor technical change is contained in the AHMSA study.[a] Also, many examples of minor technical changes involving objectives other than just cost-reduction or capacity stretching can be found in the USIMINAS study.[b]

The introduction of these minor technical changes was by no means a

a/ AHMSA Study, p. 71-86

b/ USIMINAS Study, pp. 58-65, pp. 147-182 "rare" or "marginal" activity in the plants we studied.[a/] Rather, it was a pervasive activity going on all the time in most of the plants once started up.

This evidence of the importance of minor technical changes and their range of different objectives in the plants studied gives occasion for a brief theoretical aside:

In the past, it has been conventional for economists to portray technology as being "frozen" into a world of specific techniques defined as fixed, singular points on a production function. However the world visualised by steelplant engineers is much more flexible. Engineers tend to view any particular technique or set of equipment as being capable of being operated within a rather wide margin of possible performance levels. Just how wide this margin is, will depend on (i) the particular production "mission" which the equipment is called on to fulfill (which may change), (ii) the particular working conditions to which the equipment will be subjected in normal operation, and (iii) the degree to which it may be possible to adapt the particular equipment and/or working conditions so as to obtain better performance from the equipment in the fulfillment of its existing mission. Hence, from an engineering viewpoint, a "technique" is not nearly such a fixed entity as an economist's conventional representation of it would suggest. Techniques are, on the contrary, often highly flexible and, within limits, improvable, so that it is difficult for any static, non-chronological representation to capture what to engineers is a technique's most central attribute.

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a/ In Acindar even though minor "upgrading" type, technical changes tended to involve only minor incremental investments even so, they amounted cumulatively to some 25% of Acindar's overall investments in plant and equipment. (Maxwell (1982), p. 103

5.3 The Profitability of Minor Technical Changes

Whilst we made no systematic study of profitability, some qualitative evidence from the case-studies suggested that minor technical changes introduced in both plants had been rather profitable. For instance, in Acindar's Rosario plant, considerable stretching of the plant's billet production capacity - which permitted increased sales by Acindar and higher utilisation of capacity in the Acevedo plant - was achieved by the introduction of minor technical changes at very low investment cost. In Acindar's Acevedo plant, analysis of a sample of 31 improvement phase investment projects showed short expected payback periods averaging around 2 years for most of the projects analysed.[a/] Furthermore, according to interview data, payback periods of less than 3 years and often less than 1 year were expected and considered the norm by Acindar's directors for investments involving minor improvement phase technical changes - in marked contrast to expected payback periods of 6 years or more on major new acquisition phase investments.

This is a significant finding, because if minor technical changes are very profitable, there may be a case for steelplant managements to invest more in such changes than they are currently doing. In other words, managements might be underinvesting in minor technical change in terms of their own profit maximisation objectives; this could include under-investing in absolute terms, or relative to what is invested in major new technology acquisitions.

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a/ See Maxwell (1981), Appendix 9

Apart from this hypothesis about underinvestment in minor technical changes, our case-studies also suggested some reasons why minor technical changes may turn out to be highly profitable, and in consequence deserving of special attention by steel firms. These can be seen in the situations depicted in Figs. 1 and 2. The common element in these two situations is that they involve a minor technical change which (a) is achieved by adding ΔK to the initial capital stock K_i where ΔK is small compared with K_i and (b) has the effect that the plant achieves a notable increase in its output to capital ratio as a result.

In the first case, described in Fig. 1, the output to capital ratio is first adversely affected by a situation exogenous to the plant. The cause shown is a decline in demand for an existing product line, but an equally plausible cause would have been a shortfall in the supply of a key raw material used by the plant. The minor technical change explained in the figure then has the function of restoring this ratio to something closer to its previous value.[1/]

In the second case, described in Fig. 2, a "bottleneck-breaking" minor technical change is shown which succeeds in raising the output to capital ratio from its previous value to an improved one. This kind of minor technical change is often highly profitable because the relatively small investment needed to improve the particular component or substage which represents the bottleneck then unleashes - as it were - the surplus

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1/ If we had shown the short supply of raw material case rather than the demand-decline case, then the technical change required would have been one which adapted the plant to make use of a different type or quality of raw material so as to make up for the shortfall in the previously used one.

0 to t_1 The plant is producing quantity Q_A of product A whose price is P_A, using installed initial capital K_i. Output to capital ratio = Q_A/K_i and the ratio of the economic value of output to installed capital is $Q_A P_A / K_i$.

t_1 to t_3 During this period demand for product A declines in favour of product B, which sells at price P_B (it might, for example, be a somewhat more sophisticated or higher-quality version of product A). However, we assume that the plant cannot immediately produce product B because either some adaptation is needed to one of the existing processing stages, or because the addition of an extra processing stage is required. So output during this period falls to $(1 - n)Q_A$, where $0<n<1$, and the output-capital ratio declines accordingly. Meanwhile work is started at time t_2 on the needed adaptations to produce B, and these require the addition of ΔK to the capital stock, where ΔK is quite small compared with K_i.

t_2 to t_3 At time t_3 the needed adaptation to produce product B is complete, and the plant begins producing an output mix consisting of $(1 - n)Q_A$ units of A plus Q_B units of B. The ratio of the economic value of the plant's output to its installed capital then rises sharply from

$$(1 - n)Q_A P_A / K_i \text{ to } \frac{(1 - n)Q_A P_A + Q_B P_B}{K_i + \Delta K}.$$

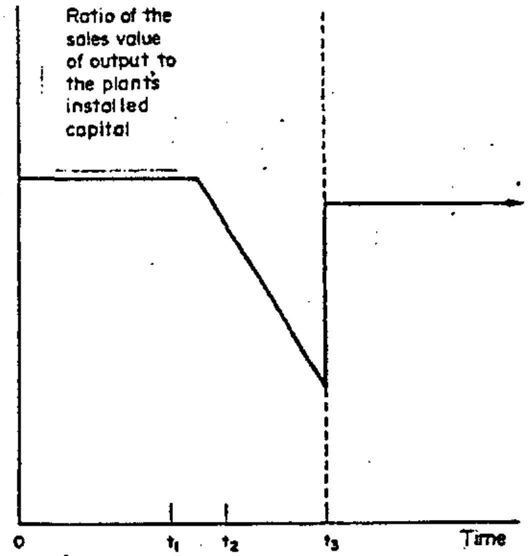

Figure 1. Technical change to counteract a demand decline for an existing product by diversifying the product mix.

0 to t_1 The plant is producing at full capacity output Q_C. Output-capital ratio = Q_C/K_i.

t_1 to t_2 Demand at t_1 is known to exceed the plant's full capacity supply, Q_C, which is limited to this value by a bottleneck in one of the plant's process stages. Work is started at time t_1 to relieve this bottleneck by a technical change involving an additional investment, ΔK, which is relatively small compared with K_i.

t_2 to t_3 At time t_2 the adaptation (i.e. bottleneck-breaking) is complete and the plant's capacity and output both increase considerably to $(1 + n)Q_C$ (where, in most cases, $0.05<n<0.5$). The output-capital ratio now rises to $Q_C(1 + n)/(K_i + \Delta K)$.

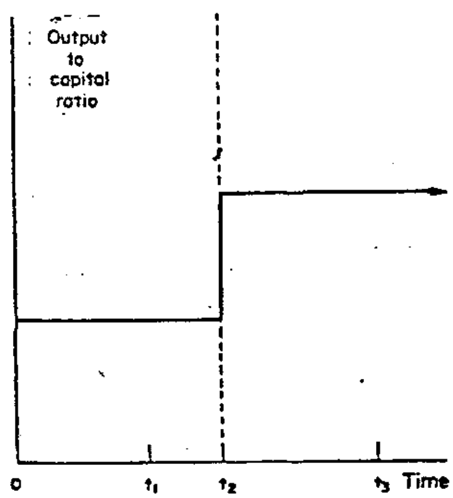

Figure 2. Technical change to stretch plant capacity by relieving a bottleneck.

capacity which is already built into the other components or stages of the process. So the incremental output to capital ratio $\Delta Q/\Delta K$ involved in bottleneck-breaking can easily be far higher than the original full-capacity output to capital ratio Q_i/K_i. Bottleneck-breaking in these circumstances is then a low-cost way of stretching a plant's capacity and hence a highly profitable means of coping with demand increases.[1/]

5.4 The Significance of Minor Technical Changes

Broadly speaking, the above-mentioned findings on minor technical changes combine into the following picture of their significance, on the assumption that one can generalise from the experience of the plants we studied.

(1) Minor technical changes seem often to permit plants to respond to adverse factor market, market and production developments by restoring output to capital ratios (capacity utilisation ratios) to values resembling those obtained before the adverse developments set in - i.e. minor technical changes can often enable plants to quite cheaply avoid the severe economic penalties inherent in low rates of capacity utilisation caused by factor market imperfections, competition, and demand changes, or production problems.

(2) In addition, minor technical changes enable firms to take

1/ The importance of bottleneck-breaking in industrial plants and processes was signalled early on by Rosenberg (1969). A pioneering paper offering an economic model of innovation to deal with bottlenecks is Teubal (1978). Bottleneck-breaking in Argentine petrochemical plants is examined empirically in Sercovich (1978b), and there is some discussion of the theme for U.S. chemical plants in Levin (1974).

advantage of the many upgrading possibilities that are "built in" to a plant's initial technological profile - e.g. surplus capacities in many production stages, flexibility to produce a wider range of products, flexibility to adapt to a wider range of raw materials, or to produce higher-quality products, etc.

We infer that a plant which can invest in, and implement, minor technological changes will be able both to respond to many adverse developments in the improvement phase and to exploit its technology's inherent upgrading possibilities so as to lower costs, stretch capacity to supply increased demand, improve product quality, etc.

Conversely, we infer that a plant with a zero or very low capacity to invest in or implement minor technical changes is exceptionally vulnerable to adverse developments which will leave it with low-capacity utilisation, poor-quality products, static or declining productivity, and an inflexible product range.

The conclusion is that since minor technical changes are apparently both necessary and profitable in steelplants so as to upgrade and adapt them, plant managements might be well advised to give explicit and systematic attention to their organisation, generation and incorporation, rather than relying on just an ad-hoc defensive approach.

Ch 6. From "Defensive" to "Offensive" Technical Change Strategy

Henceforth we shall take for granted the importance of upgrading steelplants through introducing technical changes into them. The purpose of this chapter is to present an hypothesis by Rosenberg to the effect that firms tend to introduce technical change "defensively" - as this hypothesis will be helpful in suggesting an analytical framework in which to cast our case-study results about how steelplant organizations meet the challenge involved in introducing technical change. Then we shall contrast the essentially "defensive" approach of Acindar with the more "offensive" approach of USIMINAS and draw some conclusions.

6.1 The Rosenberg hypothesis

Briefly, Rosenberg's hypothesis is that most firms do not possess anything like an "innate innovative animus" (our expression), but introduce technical changes as a defensive response when forced by circumstances into doing so. As Rosenberg puts it:-

> "It is possible.... that threats of deterioration of actual deteriorations from some previous state are more powerful attention focussing devices than are vague possibilities for improvement. (...) There may be psychological reasons why a worsening state of affairs, or its prospect, galvanizes those affected into a more positive and decisive response than do potential movements to improved states" 1/.

Expressed in other words, what Rosenberg is suggesting is a distinction between unforced i.e. "offensive" technical changes and forced i.e. "defensive" technical changes. "Offensive" technical changes represent active initiatives taken by a firm designed

1/ N Rosenberg "The Direction of Technical Change: Inducement Mechanisms and Focussing Devices", Economic Development and Cultural Change, October 1969.

to improve its position even though the firm is under no immediate pressure to do so and could quite satisfactorily remain operating with its existing practices for some time. "Defensive" technical changes, on the other hand, are those which occur when the firm is suddenly confronted with an actual or immediately threatened deterioration in its existing modus operandi (such as serious fall-offs in demand, sharply increased competition, production breakdowns, cutoffs in normal raw materials supplies etc.) which calls for an urgent remedial response to be mounted if serious economic losses to the firm are not to ensue. In such circumstances if a firm does nothing, or cannot put together an adequate innovative response, then clear economic penalties will ensue. The firm is therefore virtually "forced" into trying to introduce technical changes.

The Rosenberg hypothesis is a particularly relevant one in the context of steelplants because the enormous thermic and mechanical stresses involved in steelmaking, coupled to the synchronized, multi-staged nature of the production operations, means that steelplants are exceptionally vulnerable to breakdowns and to constantly emerging bottlenecks in production or in raw material supplies. This means that trouble is constantly breaking out in one or more parts of the line or supplies, and requires a constant task of maintenance, repairs, improvisation and modifications to keep things going. In short, the organizations that run steelplants are constantly engaged in "troubleshooting" and in the consequent "defensive" introduction of technical change.

Indeed, willy-nilly, steelplant engineers , technicians and men find they <u>have</u> to learn how to "troubleshoot" if their plant is to be kept going.

In addition to finding good corroboration in the steelplant context (because a great deal of the observed introduction of technical change in steelplants turns out to be defensive), Rosenberg's hypothesis has also suggested to us a framework for analysing steelplant organizations. This framework consists in examining a given organization's capability to introduce technical changes <u>both</u> "defensively" (when under immediate pressure) <u>and</u>

"offensively" (when the innovation represents a desirable but unforced improvement).

In such a framework one can incorporate the idea of a process of organizational maturing-over-time, indicated by the gradual shift away from a purely defensive towards an increasingly offensive capability in introducing technical changes. This in turn suggests the need to probe into what specific organizational steps, tactics and strategies made such a shift possible, and into what factors may have delayed or accelerated this process of organizational maturing.

This framework -consisting of looking at organizational maturity with respect to the defensive/ offensive dimension in introducing technical change- is the one we shall adopt below in contrasting the kinds of technical changes introduced by two of the plants in the case-studies.

6.2 "Defensive" Technical Change in Acindar, Rosario

Acindar's Rosario plant was recognised as obsolete in the mid 1950s, but it was not scrapped until 1977 because (as explained in Ch. 4, Section 3.1) Acindar repeatedly found it necessary to keep it going for security of supply reasons. The firm's alternative projects to produce billets at lower cost by "integrating" their other more modern rolling plant with billet production facilities ran into trouble with the Argentine government steel planning authorities. However, since Acindar's directors always believed that their problems with the Argentine government would be solved in fairly short order (a belief which had some rational foundations), they always believed they would soon be closing their Rosario plant down. So, from the mid 50's through to 1977 it is fair to say that the Rosario plant was always under "suspended sentence of execution". Therefore, very little investment money was spent on it (compared to on Acindar's other steel plants), even though it had a vital role to play in servicing some 30% of the company's requirements for billets.

Furthermore, whilst all the Rosario plant's staff knew that the axe was liable to fall at almost any moment in this twenty year period (from the mid 50s to 1977), the paradoxical situation occurred that because of the persisting billet shortages afflicting the Argentine steel industry, frequent demands were made on the Rosario plant to increase their billet output on several occasions, so as to squeeze as much output as possible from the plant's obsolete installations.

Furthermore the plant was also required to "upgrade" its steel output into the special(quality) steels field to a considerable extent in the early sixties, and again, to some extent in the early seventies.

So this was a plant frequently subjected to heavy exogenous (external) demands from company headquarters to introduce performance increasing technical changes, even though the plant was obsolete, under suspended sentence of execution, and subjected by HQ to a low investment regime!

One might imagine that, in such circumstances, the Rosario plant's engineers would have permanently gone about with long faces, depressed, expecting the worst , and done a kind of "engineering go slow".

But the opposite is true. There seems to have been a kind of growing local pride which had the effect that, to ward off the repeated threats to their survival, the Rosario technical team came up again and again with ingenious low-cost technical solutions to not just keep the plant going, but also to improve its performance over time by a long series of piecemeal improvements. Most notably, they cumulativey managed (as we noted in Ch. 4) to "stretch" the capacity of their original installations by 130% in the case of the billet mill, between 66% and 130% for their open hearth furnaces, and 70% for their commercial rolling mill.

In fact, there is no doubt that the Rosario case provides multiple examples of what we called earlier "defensive" technical changes, introduced under pressure, the cumulative effect of which was substantial.

Organizationally, too, there is clear evidence that some of the major changes introduced into the Rosario plant's organization were of the "defensive" variety. This clearly applied to the setting up of a greatly strengthened Quality Control division in the plant in the early 1960. What catalysed this change was the impending start up of the state steel plant SOMISA, which threatened to take away much of Acindar's market in common steels. Result: - the Rosario plant was now obliged to switch appreciably into the production of quality steels, for which a greatly strengthened quality control department was essential.

A second clear example of how the emergence of an external development catalysed a "defensive" organizational change in the Rosario plant is provided by the emergence of a cash shortage in Acindar in 1968/69. What happened was that in these years Acindar had very few funds available for investment - far less than in normal years due to some significant business losses. Now this was a situation which had occurred for reasons external to the Rosario plant. However the effects of this restriction on the Rosario plant were substantial because the cash shortage made it impossible to replace many essential worn parts and machinery. The result was that by 1969 this had led to a notably increased incidence of machinery breakdowns and stoppages of production in the plant. This in turn then provoked the urgent need to intensify preventive maintenance procedures in the plant so as to keep the machines running and avoid parts / breaking. This in turn led to far greater articulation and formal structuring of the preventive maintenance function in the plant - i.e. to an important organizational change.

So, interestingly, we find that there are not only "defensive" <u>technical</u> changes, but also "defensive" <u>organizational</u> changes in steelplants - the latter being introduced under urgent pressure which an organizational innovation is the appropriate management response.

But what about "offensive" technical change in the Rosario plant ?.

Here, the key result to emerge from the Rosario plant case-study is that there was an important connection between the exercising of defensive capability and the subsequent emergence of offensive capability.

Thus, for one thing, we noted how the strengthened quality control department and preventive maintenance department in the Rosario plant quickly became regular sources of ideas, suggestions and data for improving product quality and modifying machinery independent of particular, urgent needs to do so. In other words, although These departments got strengthened originally for defensive reasons, this very strengthening helped to equip the plant with greater "offensive" technical change capability. In fact, most of the new technical improvement suggestions made by these strengthened departments were not even thought about when the original decisions to strengthen these departments were made.

Additional evidence of a maturing process from defensive to offensive capability was gathered by looking at the 1970-71 engineering modification project on the Rosario plant's commercial rolling mill - a highly profitable, efficient, and low-cost project entirely planned, designed, and executed by the plant's own technical staff.

Here what happened is that, given their repeated historical exposure to successive survival crises, the plant's technical staff realised they ought to have something "up their sleeve" for when the next crisis came along. So they designed this engineering project for the rolling mill with one stage for immediate implementation and two further evolutive stages "standing by" for implementation at a moment's notice. Rather than simply responding to crisis, this staff had learned to engage in some active contingency planning !

But it is also interesting to ask why were the plant's technical staff able to design such an efficient low cost project (and two further evolutive stages) at that point in time? The explanation seems to be that in the course of many years of previous "troubleshooting" on this rolling mill, the technical staff had become highly familiar with every facet of these mills, their operations, design problems, faults and possibilities. They were thus equipped not merely to respond to concrete difficulties and demands, but to visualise how to extend the mill's capabilities in various new directions, without the prior need for some urgent situation to provoke their imaginations into action.

So both the repeated need for defense, and the familiarity with the technologies involved which was bred by successive defenses, helped the staff concerned to see the need for and have the tools for a more offensive approach.

In summary, whilst the Rosario plant case illustrates, prototypically, a long succession of effective defensive measures to introduce technical changes to cope with changing external circumstances and threats to its survival, it also illustrates how this long defensive process led the plant's organization to mature both in terms of strengthened departments and heightened awareness and capability to introduce technical change offensively.

6.3 From Defensive to Offensive Technical Change in USIMINAS, Brasil

In contrast to the small-scale and obsolete Rosario plant belonging to Acindar, the Usiminas case refers to one of the greatest steel plants in Latin America, as well as the most outstandingly successful amongst the continent's state-run plants.

Three main stages can be noted in Usiminas' existence

I 1956-66 Planning, construction and start-up of the 500,000 ton per annum plant, under the supervision of Nippon Steel (Japan) engineers and managers. During this stage, the Brasilians learn the ropes.

* The following description is entirely based on the findings of Dahlman (1978)

II 1966-72[a/] The Brasilians take over from the Japanese, but there is an acute financial crisis in Usiminas due to inflated construction costs coupled to the Brasilian steel market recession, and controlled low steel prices. This forces the company (a) to urgently seek export markets, for which higher steel quality, and quality control, is essential, (b) to seek to expand the plant's output by stretching the capacity of its installations at lowest possible investment cost (due to lack of funds) - the point is that expanded output will permit higher sales, and lower overhead costs. Both these goals i.e. higher quality leading to exports and greatly stretched plant output, are brilliantly achieved by Usiminas technical staff.
The latter goal is achieved via the cumulation of scores of piecemeal technical changes introduced into the plant based on operational experience and also on systematic comparison of the plant with similar plants internationally to see where Usiminas' performance could be improved.

III 1973-80 During this period the company carries through successfully a vast programme of expansion in its output from just over 1 million tons per annum up to 2.4 million tons and then over 3 million tons per annum. These expansions are based mainly on the purchase of new units to add to the plant's existing installations; very significant design and engineering contributions to these expansions are made by Usiminas' own project engineering staff, who in fact take over complete responsibility for the expansion to above 3 million tons.

Not only are Usiminas's ambitious expansions achieved on time (in contrast to the other giant Brasilian steel plants, and similar ones in the rest of Latin America), but the company also begins to offer technology and technical assistance to other Brasilian and foreign steel companies. From its dependent position on the Japanese in Stage I, the company has progressed to being an exporter of technology at the end of Stage III.

What we now do is to briefly analyse some aspects of this above record which bear on the theme of the "defensive" versus "offensive" introduction of technical change, and how the Usiminas organization matured into one capable of offensive technical change.*

a/ This period was described in more detail earlier in Ch. 4, Section 3.2

* Again, we emphasize that this present account of the USIMINAS record is entirely based on Dahlman (1978)

So far as Stage I is concerned, learning from the Japanese, two comments are appropriate. First, Nippon Steel who were Usiminas's "tutors", were later to prove themselves the worlds top steel company in terms of size and all-round efficiency. Therefore the Brasilians were lucky to have outstanding tutors-yet they must be congratulated for making what (at that time in 1956) was an unconventional choice. (For it would have been more normal to have had U.S., German or British, rather than Japanese partners). Second, Usiminas was a very active learner. Rather than just sitting back and let the Japanese run the plant, the Usiminas management was determined to make maximum use of their learning opportunities, and they did so.

Coming now to Stage II, this was a clearly "defensive" stage, when the company was, literally, fighting for its financial survival, and when the technical changes needed to improve product quality and stretch plant capacity at low investment cost were urgently, indeed desperately needed. The result was a seven year period of mainly "defensive" technical change, in which Usiminas engineers and technical staff, like in the Acindar Rosario case, proved equal to the challenge set to them. Nevertheless, it would appear that in the Usiminas case, they early on developed - even within this fundamentally "defensive" technical change strategy - a clearly more systematic, offensive approach than in the Acindar case. For, on the one hand, they organized a systematic comparison of how Usiminas's plant compared to many other similar plants internationallly to see exactly where their plant could be improved. On the other hand, they made much more systematic use than did the Acindar, Rosario staff, of outside technical assistance and outside technical information.

However it is really in Stage III, where we see the full force of Usiminas' "offensive" technical change strategy displayed. And here, the point of critical interest to our theme in this paper is that Usiminas achieved this fundamentally through the <u>anticipated (i.e. "offensive") buildup of its own technical organisation</u>.

Indeed Usiminas's management had a long term strategy for Usiminas to develop, within its own organization, strong capabilities in what was called the four sides of the "technological prism" - viz. Research, Engineering, Equipment Manufacture, and Production. It was also realised that the very fast rate of expansion planned would require a greatly strengthened organization specifically devoted to expansion, to handle it successfully.*

Based on these perceptions by Usiminas' management, the case-study records the following organizational innovations made by Usiminas, in chronological order.

Year	Technological Prism Concept	Expansion Concept
1967	Training of Personnel for Research Center begun	
1968	Center for technical information set up	"Expansion Group" set up
1970	Research Center set up and begins work	General Superintendency of Development created to coordinate development of plant expansions

* All of this is fully set out in Dahlman (1978)

Year	Technological Prism Concept	Expansion Concept
1970	A subsidiary company to manufacture steelplant machinery and other capital goods is set up	
1974	Dept of Information systems (computer) set up	
1975		Gen.Superintendency Development, Engineering wing, strengthened by sub-departments specializing in (i) Process engineering (ii) Basic engineering (iii) Equipment engineering (iv) Engineering services (v) Research and Information services

Furthermore, besides greatly strengthening its technical organization in the above ways (and others not covered in the table), Usiminas simultaneously invested unusually heavily in technical assistance contracts with leading outside steel firms, and heavily in the training and qualifying of its own technical staff.

In this way, by "taking the offensive" in terms of systematically building up the level of both its own technical organization, and its staff's qualifications, Usiminas equipped itself to successfully introduce the manifold technical changes required by its existing plants and expansions thereof, and in this way managed to become the most successful large state steelplant in Latin America.

6.4 Conclusion from the two cases

Both the Acindar (Rosario) and Usiminas cases offer interesting material on the potential efficiency of the mechanisms of "defensive" technical change and defensive organizational change when steelplants are faced by the urgent need to react to crisis conditions of one kind or another.

Psychologically this makes sense, as we all have had experiences of suddenly finding ourselves with three times our normal resourcefulness when our backs are "against the wall", or when critical deadlines approach.

But, useful though this defensive mechanism often is in ensuring that plant production can continue, and useful though a succession of defensive technical changes may be in promoting improved plant performance over time, one can hardly doubt that there are additional benefits to be gained for a steelplant which can add an anticipative and "offensive" dimension to its ability to introduce technical changes.

Progress towards this "offensive" capability is what we have called maturity in steelplant organizations. It can arise as a kind of natural result of a long sequence of defensive technical and organizational changes (the Acindar, Rosario case) - but it can evidently be accelerated by a deliberate "organization building" approach (the Usiminas case).

6.5 Further arguments for an offensive, rather than defensive strategy

Further arguments in favour of offensive strategies can be advanced. The first is, simply, that defensive strategies for investing in minor technical change are not optimal. In fact they imply underinvestment by firms in the technical change process. A main reason is that a firm which follows a purely defensive strategy will, by definition, fail to invest in any of the multiple plant upgrading and improvement possibilities which it is not absolutely forced by pressing circumstances into exploring and attending to. In other words, its technical change efforts will only be focussed on a strictly limited region of the " innovation possibility set" (improvement possibility set) with its technology, rather than choosing its projects from the whole set.

Undoubtedly one of the reasons why firms may not take advantage of the entire improvement possibility set is that they may seriously underestimate its scope and extent, and the feasibility of exploiting it through incremental technical change.

In summary our hypothesis is that most LDC steel firms - and especially inexperienced ones - will (a) not perceive the full extent and potential of the improvement possibility set with their technologies, and, (b) will therefore fail to engage, of their own accord, in the privately optimal level of investment in minor technical changes so as to exploit this potential.

6.6 Natural trajectories of technical change, and their relevance to offensive strategy

Offensive strategy implies active, systematic exploration and exploitation of the improvement possibility set with a steel plant's technology. The possibility to conduct this kind of active and systematic approach gains support from the idea due to Nelson and Winter that there may exist "natural trajectories" of technical change, appropriate to the particular "technological regime" with which a firm is working, that "focus the attention of engineers on certain directions in which progress is possible, and provide strong guidance as to the tactics likely to be fruitful in probing in that direction", and for which the "payoffs from advancing in that direction exist under a wide range of demand conditions".[1] This idea was strongly corroborated in our steel plant case-studies in AHMSA, USIMINAS and Acindar in which a good number of "natural trajectories" appropriate to technical change in steel plants were independently discovered.[2] Sixteen of these natural trajectories are listed below.

1) Resolving bottlenecks
2) Stretching the capacity of existing units through mechanization layout changes, faster loading, simplified product mix, lowered rejection rates etc.
3) Reducing process cycle times
4) Minimization of non-recuperable metallic losses and recycling of recuperable losses
5) More intensive utilization of by-products
6) Improved in-plant materials handling
7) Establishment of operating routines for the principal equipment units and process optimization
8) Minimization of maintenance and repair down-times
9) Standardization and beneficiation of raw materials leading to more successful operating routines and more consistent product quality
10) Cost reduction through altered input mix
11) Saving on energy consumption through greater thermic efficiency
12) Extending the useful like of equipment units
13) Extending the useful like of refractories, mill rolls and ingot moulds
14) More exact and intensive quality control
15) Product diversification and new product development on the basis of existing equipment
16) Organizational innovations to meet the challenges inherent in the immense scale and multi-departmental complexities of modern steelmaking.

The argument is that there is no inherent reason why all these natural trajectories should only be followed "defensively" i.e. when necessity arises. They can also be pursued "offensively" by a combination of capital investment, and in-house technical, engineering and research efforts. In this perspective, an explicitly offensive technical change policy, coordinated with investment, and aiming at rapid advance along these natural trajectories, could make a lot of sense.

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[1]For the concept of "natural trajectories", see R Nelson and S Winter, "In Search of a Useful Theory of Innovation", Research Policy (6) 1977.

[2]The researchers involved were Luis Alberto Pérez and Jesús Pérez y Peniche (Mexico), Carl Dahlman and Fernando Valadares Fonseca (Brazil), and the author (Argentina)

Ch. 7. SUMMARY AND CONCLUSIONS

Aims and Scope of the Study

This study has sought to trace out and compare the technology selections and subsequent "paths" of learning and technological evolution in five Latin American steel firms. Technology has been at the centre of the analysis. The individual case-studies carried out by different authors on the individual plants have been the empirical basis of the comparison conducted.

Throughout the analysis, our belief has been that some plants will have made a better job of technology selection and subsequent plant upgrading than others, and that a close look at the actual historical experience of selection and upgrading in our sample of plants would throw light on the nature of the criteria that make for successful or unsuccessful performance, so that lessons can be learned. In looking at the learning/technological "paths" of the various plants, what we have focussed on is relative, not absolute learning performance. What learning sequences seem to have worked better in plants, and what sequences worse? Can one detect any determinants for why some plants seemed to have chosen their technology more effectively, or improved it more efficiently, than others?

The goal of this comparative analysis has been to arrive at practical policy conclusions for steelplant managers, government steel planners and institutions providing finance for the steel industry.

This final chapter is therefore devoted to the statement and discussion of practical policy conclusions, whilst relating them to evidence and findings from earlier chapters of the study. The conclusions are presented under the following headings:- 1. Towards a realistic planning picture of steel plant learning paths; 2. Planning for technology selection and gestation; 3. Planning for minor technical change and the upgrading of technology; 4. The representativity of the findings; and 5. The need for more research to guide the planning process.

7.1 Towards a Realistic Planning Picture of Steel Plant Learning Paths

A principal finding which emerged clearly in the "synthesis" of the case-studies provided in Ch. 2 is that the traditional scheme of stages in the life of a steel plant - i.e. a planning stage, a construction stage, and then a start-up stage whilst the plant is brought up to rated capacity - is too simplified, because it leaves out important stages in the subsequent evolution of plants, once rated capacity and performance has already been attained. For one thing, the traditional scheme leaves out the impact of minor technical changes to already fully operational plants to upgrade performance beyond rated levels. These changes, made at relatively low levels of investment, involve minor, incremental technical changes, and may be considered as occurring within an "improvement stage" which succeeds the end of the start-up stage.

Furthermore in all five plants, we found that major expansions (i.e. non-incremental) had been introduced, often doubling or tripling installed capacity and sometimes causing major upheavals to pre-existing operations involving very much greater costs-of-disruption than anticipated. These successive "expansion stages" need to be considered as integral parts of the overall technological path of steelplants, in addition to the improvement stage mentioned above. (Furthermore, each major expansion stage itself can be decomposed into its own planning, construction, start-up and improvement stages).

A second key finding from Ch. 2 concerns the complex, long-drawn out, uncertain, and idiosyncratic nature of the "path" of each of the steel plants. This path was, in each case, more like what Hirschman (1963) has called a "voyage of discovery" than an assured progression down some kind of "standard" infant industry learning curve.

In other words, we found no such thing as just one "standard" path of evolution in the life of a steel plant. Rather each plant's path was notable for the idiosyncracy of the evolution of its technology, and its markedly individual character. So much so that, rather than refer to standardised steel plant evolutionary paths, or technology paths, we prefer to refer to such paths as "biographical".

Moreover, all the case-studies showed, in many respects, what a difficult, mistake-filled and unpredictable business steel plant evolution can be. In none of the plants did things work out according to plan. In two of the plants - Chimbote and Paz del Rio - the material documents what can only be described as badly mistaken initial choices of technology (at least with the benefit of hindsight), followed by long and difficult years of "remedial" efforts to try to compensate. In USIMINAS, the enterprise had to wrestle with a major financial crisis in its first years of operation, and attempt to squeeze additional output from its existing plant with minimal additional investment. Acindar, for its part, had to cope with very erratic government policies which prevented it for many years from integrating its plant. AHMSA experienced severe problems in adapting itself efficiently to run its new investment in BOF steelmaking.

Indeed all the plants had many problems in trying to select, finance and operate their technology, in trying to cope with their government sponsors and political opponents, and in seeking to adapt to major fluctuations in raw material supplies and in steel demand levels. The point is that steel plant planning, financing, construction, operation, modification and expansion involves many uncertainties and an exceedingly complex and difficult learning process in the technological, management, logistical, financial and political spheres. Few outsiders not familiar with the industry readily appreciate this. Many insiders only seem to acquire this knowledge by painful trial-and error.

The first lesson, therefore, is that Latin American steel planners need to be much more realistic about the intriinsically difficult, long drawn-out and, in some respects, non-standardized nature of the learning challenge they face when planning to build, improve or expand their steel plants.

In other words, making a success of the steel plant "learning curve" is very far from being the assured thing that project promoters and economists often seem to assume. It therefore becomes incumbent on planners to become as familiar as possible with the nature, idiosyncracies and determinants of steel plant learning paths and with the factors that make for relative success or failure in the evolution of steel plants.

In this regard, it is relevant that the synthesis of the case-studies offered in Ch. 2 pointed to a fundamentally common set of basic "influential factors" which seemed to be generating the observed "biography" of plant evolution in each case. These factors included (1) the technology initially selected, (2) "internal technical capability" factors (very different between the plants[1]), and (3) external factors - especially the role of the government (but also the impact of the nature, quality and reliability of raw material supplies to the plant, of demand conditions, and of the terms on which external finance were made available for investments in building or expanding plants).

Whatever the exact influence of these three sets of factors was, it is clear that some of the plants made better technology selections than others, some got through the gestation period more quickly and efficiently, and some subsequently made more systematic use of the upgrading potential of their plants than others, and handled their major expansions better than others, etc. Moreover the comparative analysis carried out in Chs. 2 to 6 enabled us, to some extent, to understand or to hypothesise some of the reasons for this differential performance, and to deduce some implications for planners. The next two sections take up these implications.

7.2 Planning for Technology Selection and Gestation

The topic of technology selection and the overall gestation period of major new investments is extremely important in steel plants. Its

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[1]It was obvious from the case-studies that a wide gulf in capability separated the quality of the initial teams of engineers in Acindar, AHMSA and USIMINAS from the teams in Acerias Paz del Rio and Siderurgica del Chimbote, and there were also major differences in the extent to which additional skills and capability were acquired in the different plants subsequently.

importance derives partly from the great difficulties that beset the making of satisfactory initial choices of technology, scale and suppliers for new plants and expansions in this industry, and partly from the sheer length of time involved in project gestation. We showed in detail in Ch. 1 how both these features were, in turn, due to the intrinsic technological and capital-intensive characteristics of steel plants, as well as to the extensive range of financial, political and planning factors that impinge on plant technological choices and bias their outcome.

The first half of Ch. 3 explained how the actual technology selection process in our sample of steelplants was not an "open scanning" over many alternatives followed by optimal choice. Instead it was the result of "restricted search", because several kinds of constraints meant that only a quite limited part of the techno-economic horizon was explored for selecting the technology of each plant concerned. The constraints included financial ones, political ones, planning criteria (including a bias towards large scale plants), machinery supply restrictions, and "heritage" constraints (the latter referring to the characteristics of the pre-existing plant in the case of major expansions). In some cases it was clear that the very restricted nature of the scanning of alternatives for technological choice had seriously prejudiced the quality of the choices actually made. The conclusion drawn was that planners of steelplants should be aware of the severe dangers and potential costs of "restricted search", and should aim for a broader, more open scanning of alternatives.

The second half of Ch. 3 was concerned with the empirical analysis of the duration of the gestation period, and of the determinants of this duration, both for the greenfield plants and the major plant expansions examined in the case-studies. The analysis divided up the gestation period into the "pre-investment period", the "construction period" and the "start-up period". Within our sample of plants the duration of the pre-investment period was found to range from 0 to 8 years. The construction period from 1 to 7 years; and the start-up period from 1 to 8 years. The time involved in the overall gestation period ranged from 3 to 19 years. Average overall gestation lasted 11 years for greenfield plants and 10 years for major expansions. Each of the three sub-periods was found to last, on average, about 3 to 4 years.These figures demonstrated both the sheer length of the overall gestation period in our sample of plants, and also the enormous variations as between plants in the speed of getting through the gestation stages.

What caused such major differences in gestation time? The main hypothesis developed in Ch. 3 was that the scale of a steel plant project, the complexity of the technology involved, the extent of the firms previous experience in steel plant planning, design, construction and operation, and the extent of the "jump" the firm was making from its previous experience of scale and technology would all be influential determinants of gestation time and unplanned gestation delays. (A concise statement of these hypotheses is also set out in Appendix 1).

Besides this hypothesis, some empirical evidence from the case-studies about the causes of gestation delays was also presented. In particular, long pre-investment periods appeared to be caused mainly by shortages of finance, and by political and planning obstruction. Construction period delays were caused by things such as delays by suppliers, dock strikes, problems in foreign exchange remittance, and sometimes by bad organization of construction work; long start-up periods were mostly due to problems in the specification/design of the plant, including often its insufficient adaptation to "localised" conditions; other contributing factors to prolonged start-ups were defective construction work, inadequate training of the workforces, shortages in raw materials, shortages in key services, and overoptimistic demand forecasts. It was also clear how many of the factors causing long delays in the start-up period (i.e. in achieving rated capacity) had originated in decisions made earlier on in the pre-investment period - e.g. decisions on technology specification/design and on plant sizing, overestimates of staff capability, inaccurate forecasts of raw materials availability etc. This in turn suggests that the methodology and biases prevalent in feasibility reports are not all they should be.

To conclude Ch. 3, several planning implications were then derived from the analysis of factors that had been influential on technology selections and gestation times in the plants in our sample. These will now be listed:-

First the need for a more "open scanning" of alternatives prior to selecting technology scale and suppliers for plants was re-emphasized.

A second conclusion was that planners should carefully consider building smaller plants so as to render the expansions more easily manageable, and to help ensure shorter, and more predictable gestation periods.

A third conclusion related to the need for the most careful possible examination of plant-specific factors in technology selections; (these include (a) technological factors related to the localization of the plant, (b) technological factors related to plant heritage, and (c) the need sensibly to choose the scale/complexity of any proposed expansion, bearing in mind limitations in the technical capabilities and experience of plant staff to cope with too ambitious a jump in scale or complexity.

A fourth, related conclusion was about the need for explicit consideration by planners of what level of investments in staff training and in first-class technical assistance will be needed by a steelplant to ensure that its staff's technical knowledge and capabilities will be on-par with the scale and sophistication of the technology it is seeking to acquire.

A final conclusion was that at the project planning and feasibility report stage, serious sensitivity analysis should be performed of how project profitability will fall if the gestation period for the new plant or major expansion takes longer than expected.

7.3 Planning for Minor Technical Change and the Upgrading of Technology

The main planning conclusion to emerge from Chs. 4, 5 and 6 was that minor technical changes need to be considered as a central, not a marginal feature in the techno-economic development of steel plants. Each of the three chapters described a different facet of this reality and we shall therefore briefly summarise them in turn:-

Ch. 4 was about "capacity-stretching" in the steel plants, i.e. the phenomenon whereby the capacity of plants is increased beyond rated capacity in small, incremental steps without the requirement for large new investment programmes. Empirical evidence was presented from four of the five case-studies to show (a) the great cumulative extent to which the effective capacity of the units had been stretched beyond nominal capacity, and (b) that capacity-stretching technical changes were "pervasive" in the plants, and that capacity-stretching was often the primary objective of technical changes, rather than merely a secondary or spin-off objective.

It was also shown that a principal reason leading three of the steel firms greatly to stretch the capacity of their existing plants had been the long delays experienced in being able to undertake "conventional" (i.e. capital-intensive) expansion plans. These long delays were due to various factors, which included financial problems in the firms concerned or shortages of loan finance, the inherently long planning period needed for capital intensive expansions, and the incidence of unexpected political and planning delays due to the non-agreement of government planners to each firm's major expansion plans. Because of these long delays, low-cost capacity stretching of existing plant then became a valuable "second-best" option. In addition a large variety of other incentives to capacity stretching projects were identified - helping to explain their observed pervasiveness and cumulative large impact.

Two contrasting approaches to capacity stretching were identified in the plants:- namely the "ad-hoc defensive" approach and the "systematic, offensive" approach. In general, a more systematic approach was adopted over time as a plant's technical staff developed both familiarity with - and a more scientific understanding of - the processes concerned. In at least two of the plants, capacity stretching potential was greatly underestimated. It was only the fact that the blocking of their "conventional expansion" plans had made capacity stretching so repeatedly necessary that led the men in these plants to fully discover and utilize the stretching potential that was there.

From the planning viewpoint, this phenomenon of capacity stretching is important. It seems to be a common occurrence not just in Latin American steel plants, but in industrial plants more generally. To judge from our own sample, the main planning implications appear to be (a) the need for better recognition by planners of the very long gestation delays often inherent in conventional expansion, (b) the need for better estimations by planners of the impressive extent of capacity stretching potential that exists in many steel plants, and (c) the adoption by plants of systematic methods to exploit this potential both as a substitute and a complement for conventional expansion.

Chapter 5 dealt briefly with some further aspects of plant upgrading, going beyond just capacity stretching. I.e. it tried to cover aspects relating to the introduction of any kinds of improvements in the plants that involved minor technical changes aimed at improving their performance above rated levels. Incorporation of these minor technical changes was shown to be a pervasive activity going on all the time in most of the plants. These changes were devoted not only to stretching the capacity of the plants but also to several other objectives, too, including reducing production cost, changing input mix, raising product quality, diversifying the product mix etc.

Moreover these minor technical changes often permitted the plants to respond to adverse market, production and factor supply developments by introducing needed adaptations, as well as to take advantage of the many upgrading possibilities that were built in to their initial technology. Indeed minor technical changes appeared to be both necesary and profitable in our steel plants so as to upgrade and adapt them. Our conclusion was that plant management should give explicit and systematic attention to the organisation and generation of minor technical changes in their plants rather than simply introducing minor technical changes in an ad hoc fashion, as dictated by pressing circumstances.

Ch. 6 built on Ch. 5 by further discussing and contrasting the "defensive" versus the "offensive" approach to the introduction of minor technical changes. In particular it examined and contrasted the experience of Acindar in its Rosario plant and USIMINAS as an illustration of the differences between the defensive and offensive approaches and the transition between them which plants can make as their staff gain more experience.

The suggestion was made that defensive strategy implies underinvestment in technical change. Finally attention was briefly drawn to the existence of so-called "natural trajectories" of technical change in steel plants, which could guide plant managers as to some directions in which minor technical change was likely to be worth pursuing on a systematic basis.

The main planning conclusion which emerges from Ch. 6 is to reinforce the conclusions of Chs. 4 and 5 that plant managements can, and should, organize systematically to introduce technical changes into their plants. They should not allow the build-up of their plant's technical organization to be merely implicit - i.e. a sort of evolutionary by-product of the firm's experience. Instead, this build-up should be the objective of specific management attention - e.g. through training its technical staff, setting up and strengthening technical departments, trying to advance up natural trajectories, etc.

7.4 The Representativity of the Findings

The sample of steelplants examined in the study has been small. It is based on the experience of only 5 Latin American firms, whereas Latin America has well over 100 sizeable steel firms.

Nevertheless, some of the key findings reported here do appear to hold true for steel plants more generally - and may be partly applicable to other kinds of heavy industrial plants, too.

In particular, our empirical findings about the unduly long gestation periods for our sample of steel plants correspond with what is known to be a frequent characteristic of large industrial investment projects, particularly in LDCs. For example, as Little and Mirrlees wrote in their well known book on project evaluation[1]

[1] Little, I., and Mirrlees, J., Project Appraisal and Planning for Developing Countries, Basic Books, 1974

"Despite exceptions it has been the rule in developing countries (and common in all countries) that major projects take longer to complete than is allowed for in the project report"

Secondly, the period between when a plant is finished and when the new management team and labour force are sufficiently skilled to be able to operate it at its rated capacity has usually been underestimated"

Also, our findings about difficulties and mistakes in initial technology selection (both for greenfield plants and major plant expansions) match with the findings of literally scores of case-studies of LDC industrial plants reported in the transfer of technology literature and in the literature on technical change in LDCs which have pinpointed the "lack of adaptation of the technology to local conditions" as a major difficulty in the technology selection and transfer process.

Furthermore the findings about the empirical importance of minor technical change in the plants, and the tendency of managements to underestimate the value of minor technical changes and to fail to exploit them systematically are in line with the findings of many other recent case-studies in Latin American plants (see Katz,[1] 1978,[2] 1980) and elsewhere.

A further reason for believing that the results from our small sample of plants are relevant to steel plant planners everywhere is that technology selection difficulties, long gestation periods, and the subsequent need to upgrade plants at low investment costs can be seen as intrinsic planning features of the steel industry which arise from the central technological and investment characteristics of steel plants, (as we showed in Ch. 1 in some detail).

Therefore, although the sample of case-studies (five) on which this study has been based is clearly too small for reaching firm conclusions, the study has, we believe, thrown some light and some extra evidence on planning issues which are very important and relevent to most steel plant managements, planners and financiers in Latin America and elsewhere.

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[1] Katz, J. (1978b) Technological Change, Economic Development and the Intra and Extra Regional Relations of Latin America. Working Paper No. 30, BID/CEPAL BA/36, August

[2] Katz, J. (1980b) Domestic Technology Generation in LDCs: A Review of Research Findings, Working Paper No. 35, IDB-ECLA Programme, CEPAL Offices, Buenos Aires.

7.5 The Need for More Research to Guide the Planning Process

In view of the grave problems experienced in the past three decades not only in the Argentine steel industry[1] but in major sections of the Columbian, Venezuelan and Peruvian steel industries - as well as, to a lesser extent, in sections of the Mexican and Brasilian steel industries - it seems likely that Latin American government planners and steel firm executives, as well as international financial institutions lending money to Latin American steel firms might be able to benefit from systematic retrospective analyses and comparisons of past firm learning paths and performance in the steel plants of these countries.

Regrettably, however, the past record of the Latin American steel industry is only sparsely covered by retrospective scholarly analysis. Indeed we reckoned in the Introduction that for every $1 million invested in the continent's steel plants, less than $30 on average - at the most generous estimate - has been spent on independent scholarly evaluations of how these investments have developed.

This is not nearly enough, if one considers the enormous levels of social investment that are involved and the enormous social costs incurred when these investments go wrong. Indeed, these levels of investment make it quite irresponsible for each firm and country merely to proceed by trial-and-error in project selection and planning for its basic industries. Certainly, some learning through mistakes will always be involved - but there is no good reason why this should not be supplemented by some learning from "systematically analysed and compared previous experience".

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[1]The social costs of the failure of steel industry planning in Argentina may have been especially high, because of steel's large share of the entire Argentine import bill which meant that failure of import substitution in the steel sector probably had a substantial "multiplier" effect in contribution to Argentina's persistent macroeconomic instability.

This is why <u>further research - designed to equip planners with an improved body of historical data and comparisons from which to develop better planning guidelines - would be amply justified.</u> Moreover it is independent, scholarly research that is most needed, because steel industry consultants cannot be relied on to provide a sufficiently critical view of past performance. Nor can a government's own steel planners, who are necessarily enmeshed in politics. <u>So the small investments needed for further independent scholarly studies are especially important.</u>

Such research could help to equip LDC planners with detailed historical comparative data on the outcomes of many previous steel plant planning efforts - at many different scales of plant, different technologies and under different constellations of government politics, ownership and intervention in the industry, and under different market constraints and conditions. This body of data would very likely suggest more realistic planning criteria for steel plants than have often been followed in many LDCs to date - and would give honest, realistic planners a firm point of reference in trying to defend their viewpoints against the inflated claims often made by project promoters, including their own planning colleagues.

Even if - quite realistically - one takes the view that political, not economic considerations, are often over-riding in how decisions are made on major LDC industrial projects in many countries, the existence of a body of systematically organised and widely-available cross-national comparative findings on past project performance in basic industries could help limit the extent to which political considerations dominate sound economic ones in project selection. To contribute to building that body of cross-national, comparative data - not only for steel plants, but hopefully for all basic industries is the main research challenge which has emerged from examining the technological evolution of the five plants described in this study.

APPENDIX 1 : GESTATION PERIOD DETERMINANTS AND SCALE OF PLANT

(as per hypotheses put forward in Ch. 3)

The following symbols and discussion summarise what was suggested in Chapter 3 of this study, and may provide a starting point for improved formulations:-

Let:-

S_o = Scale of pre-existing plant

T_o = Index of the "complexity" of the technology of the pre-existing plant

E_o = Index of previous experience of steel firm in steelplant design, construction, and operation

S_1 = Scale of new/expanded plant

T_1 = Index of the "complexity" of the technology of the new/expanded plant

I_{EE} = Investment in training/education/qualification of plant's own staff for specifying, constructing, operating new/expanded plant

I_{TA} = Investment in technical assistance in connection with entire gestation of new/expanded plant

θ = Expected overall gestation period

$\Delta\theta$ = Unexpected gestation period delays

$$T^* = \frac{T_1 - T_o}{T}$$

$$S^* = \frac{S_1 - S_o}{So}$$

$$E^* = E_{incr.}(E_o, I_{EE}, I_{TA})$$

incr = Signifies an increasing function of the variables in the brackets

Next, denote 'f' as the "scale economies benefit function", which describes the traditionally expected capital cost benefits and operating cost benefits to be derived from building larger plants.

Denote 'g' as the "scale diseconomies function", which describes the extra costs that arise from building larger plants as a result of both longer expected gestation periods than in smaller plants and longer "unplanned" gestation lags as well.

Net benefits Π of building larger plants are given by

$$\Pi = \text{'f'} - \text{'g'}$$

$$\Pi = f_{incr}(S_1, T_1) - g(\theta + \Delta\theta) \qquad (2)$$

According to our gestation period hypotheses,

$$\theta + \Delta\theta = h_{incr} \left(\frac{S^*, T^*}{E^*}\right) \qquad (3)$$

So $$\Pi = f\left[S^*, T^*\right] - g_{inc}\left[h_{inc}\left(\frac{S^*, T^*}{E^*}\right)\right] \qquad (4)$$

For the scale economies benefit function, it is normal to expecy that

$$\frac{\partial f}{\partial s} > 0 \qquad \frac{\partial^2 f}{\partial s^2} < 0$$

However, for the scale diseconomies function, we are inclined to believe that

$$\frac{\partial g}{\partial s_1} > 0 \qquad \frac{\partial^2 g}{\partial s_1^2} > 0$$

based on the hypothesis of more than proportionally longer gestation periods as the scale built rises higher and higher.

However apparently gestation periods and hence scale diseconomies are also very sensitive to E*.

If the problem is to choose the profit maximising scale of plant to build, with given technology T_1, and with a budget limit, then our hypotheses suggest there is a trade-off between expenditures on capital equipment I_C which rise with the scale of the plant built, and investments I_{EE} and I_{TA} which augment the "experience" with which the plant can specify, construct and operate its proposed expansion, and thus reduce gestation periods and scale diseconomies. This trade-off also depends on how much experience, E_o, the plant has already accumulated previously. The less previous experience it has, the more "economies" will be purchased by buying one dollars worth more of I_{EE} and I_{TA} and one dollars worth less of I_C.

The problem with many feasibility reports, in the light of the above discussion, is that they simply assume that gestation will occur smoothly in a definite period of years (often optimistically underestimated), and also do not perform sensitivity analysis with respect to unplanned gestation lags - i.e. they underestimate or ignore the scale diseconomies arising from longer expected gestation periods and unplanned gestation lags caused by building larger plants.

APPENDIX 2 : GESTATION PERIOD OVER-RUNS AND PROJECT COST OVER-RUNS

One main effect of long project gestation times is to make projects more vulnerable (i) to inflation in the costs of domestic inputs to the investment, (ii) to inflation in the costs of the foreign inputs to the investment - mainly equipment and engineering services, and (iii) to local currency devaluations which increase the burden of the project-promoting firm's hard currency debts. These inflationary effects played a central role in causing hugely increased capital investment burdens to SOMISA and USIMINAS in their greenfield plants. Also the sharp 1976 devaluation of the Mexican peso had a grave effect in increasing AHMSA's investment costs in their second oxygen steelshop mentioned in Tables 1 or 2. Though we do not have exact figures to quote, investment cost over-runs in all three cases were large.

A second effect is that long project gestation periods increase the financing charges on the money borrowed to plan, construct and start-up plants, and so inflate project investment costs.

A third effect in boosting investment costs arises when long gestation times are caused by start-up periods which get prolonged by the need for "remedial measures" to be taken, i.e. design changes, modifications, and extra installations must be added to the plant as originally planned to get it working properly. (This is what happened notably in the Acerias Paz del Rio greenfield plant and in the AHMSA and SOMISA expansions). The effect is that capital investment costs get inflated by the costs involved in the remedial measures.

One more interconnection between long gestation times and inflated project investment costs has already been cited earlier. This is that unexpected project cost inflation (for reasons unconnected to gestation time) may put project owners in great difficulties to raise the extra finance needed. This may then in turn cause delays in securing this extra finance, thus prolonging the pre-investment period (e.g. the Acerias Paz del Rio and SOMISA greenfield plants), thus further extending the period during which inflation can swell up project investment costs.

Inflated capital investment costs in turn help cause higher fixed costs per unit of output. This is in addition to the contribution to higher fixed costs per unit which occurs when capacity utilization is slow to build up to expected levels either bacause of lower-than-expected demand, or because there is an insufficient supply of raw materials or services to the plant.

Variable production costs can also be negatively affected by prolonged plant gestation periods, to the extent that slow start up involves a period of lower than planned labour productivity and raw materials productivity.

Higher than planned fixed and variable costs, translated into higher than planned steel product prices, can in turn have a feedback effect on demand, and may reduce final demand below planned levels (even though the actual "state of demand" was correctly forecast in the market studies). The consequent low capacity utilization level helps reinforce the high steel product prices, and a vicious circle effect is present.

It is true there can also be some favourable effects on investment and production costs of long gestation times:- thus, in some circumstances taking somewhat longer in construction may enable the job to be accomplished cheaper and more reliably (crash programmes can be very risky) and may permit more time for recruitment and suitable training; also when a plant gets going later than expected, the demand for its products may be higher and firmer than if it had started up earlier. As Marglin has noted - if not only plant construction but also its associated construction costs can be postponed, then this will reduce the size of the present value of construction outlays (so long as their absolute cost does not increase over time and the interest rate is positive, so

> "the loss in the present value of benefits from postponement may be more than offset by the savings in the present value of cost" 1/

This kind of situation envisaged by Marglin is more likely to occur (a) the lower the expected initial capacity utilization level (for demand reasons) of the "unpostponed" plant would be, and (b) the greater the rate at which the demand curve is currently shifting outwards. Nevertheless - whilst the situation envisaged by Marglin is certainly an important variant to be considered - we shall not explore it further here.

The main thrust of our above discussion is simply that the problems of avoiding prolonged gestation times, inflated project investment costs and inflated production costs are significantly related. It follows that under-estimated gestation time will, in many circumstances, lead to <u>overestimated project profitability</u> in steelplant investments. Hence a more explicit consideration of steelplant gestation times and their determinants should be a valuable input to the planning process.

1/ S. Marglin, <u>Approaches to Dynamic Investment Planning, North Holland, Amsterdam 1963</u>.

Gestation time and economies of scale:

The most significant planning implication of the gestation lags observed in our steelplant sample is - to our way of thinking - the need to look closely at the way in which "economies of scale" concepts are used (or perhaps one should say manipulated) in the pre-feasibility and feasibility reports, and other project evaluations, on steelplant projects which are performed during the pre-investment stage.

The reason is that, whilst the capital cost savings and operating cost savings obtainable from bigger and bigger plants have received much attention in the industrial economics literature on the steel industry, and get endlessly repeated by consultants, banks, and government planners, far less attention gets paid to the dis-economies of scale which may also attend the building of bigger and bigger plants, and which may turn out to be greater than the economies.[1/]

1/ There is nothing new about this:- "biting off more than one can chew" is a familiar situation.

APPENDIX 3 : THE RISE OF THE LDC'S IN WORLD STEEL PRODUCTION

Steel is a primary input to such industries as capital goods, armaments, construction, the automobile and consumer durables sectors, etc., and this fact has long given rise to the view that steel is a "strategic" industry, vital for a country's security, essential for its future development.1/

As a consequence of steel's importance, all the world's traditionally industrial countries, and most of the newly industrializing less-developed countries have sought to promote their steel industries so as to accompany their economic growth aspirations, and this is reflected in the continuous growth of steel production that can be observed since 1950 in all the regions of the world. (See Chart 1.)

Of course, as can be observed in Chart 1, the growth rate in output has not been identical

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1/ The Ruhr steel centres fed German military might, whilst it was Pittsburgh, U.S.A., that produced the steel for America's guns and tanks and planes. Britain's Labour party nationalised steel on the grounds that it was one of the "Commanding Heights" of the Economy. The Soviet Union emphasized its steel industry right through the days of Lenin, Stalin and Khruschev - and Mao's China made steel production its priority target in the bold days of the "Great Leap Forward".

CHART WORLD STEEL OUTPUT BY REGION, 1950 -1975

(thousands of ingot tons)

Region	1950 Production	1950 %	1960 Production	1960 %	1970 Production	1970 %	1975 Production	1975 %	Average annual rate growth of output 1950-1975 %
Western Europe	52,100	27,5	108,769	31,5	161,521	27,1	155,043	23,8	7,54
Eastern Europe	8,100	4,3	21,181	6,1	40,082	6,7	51,850	8,0	7,71
USSR	27,300	14,4	65,294	18,9	115,886	19,5	142,000	21,8	6,82
Northamerica (1)	90,900	48,0	95,337	27,6	130,340	21,9	118,987	18,3	1,08
Latin America	1,400	0,7	4,316	1,2	13,181	2,2	18,611	2,9	10,40
Africa	800	0,4	2,199	0,6	5,326	0,9	7,773	1,2	9,52
Middle East	-	-	40	0,01	525	0,1	1,225	0,1	-
Asia(i) Japan (2)	4,839	2,6	22,138	6,4	93,322	15,7	102,313	15,7	12,98
Asia (ii) Non Japanese(3) Asia	2,661	1,4	22,539	6,5	28,347	4,8	45,939	7,0	8,92
Oceania	1,300	0,7	3,753	1,1	6,996	1,2	8,054	1,2	7,57
WORLD TOTAL	189,400	100,0	345,666	100,0	595,526	100,0	651,795	100,0	5,07

Principal Source: International Iron and Steel Institute and U.N. Statistical Yearbook, as quoted in Instituto Chileno de Hierro y Acero <u>Estudio sobre Tecnología en la Siderurgia Latinoamericana</u>, BID/CEPAL/BA/14, Comisión Económica para América Latina, Buenos Aires, December 1976.

(1) Mexico is included in Latin America.

(2) The figures for Japanese production are derived from "Nippon Steel News", Nippon Steel Corporation, Tokyo, No. 80, December 1976.

(3) The figures for "non-Japanese" Asia were derived by the author by subtracting the figure for Japanese output from the figure for "Asia" appearing in the principal Source referred to above.

in all regions. In particular, there are two striking features in the Chart to which we wish to draw attention.

The first relates to the astonishingly rapid emergence of Japan as a first-rank steel power producing more than 15% of total world output.

The second is the rapid growth rate of steel output in less developed regions, i.e. in "non-Japanese" Asia (which includes India, Korea, and Taiwan) in Latin America and in Africa.

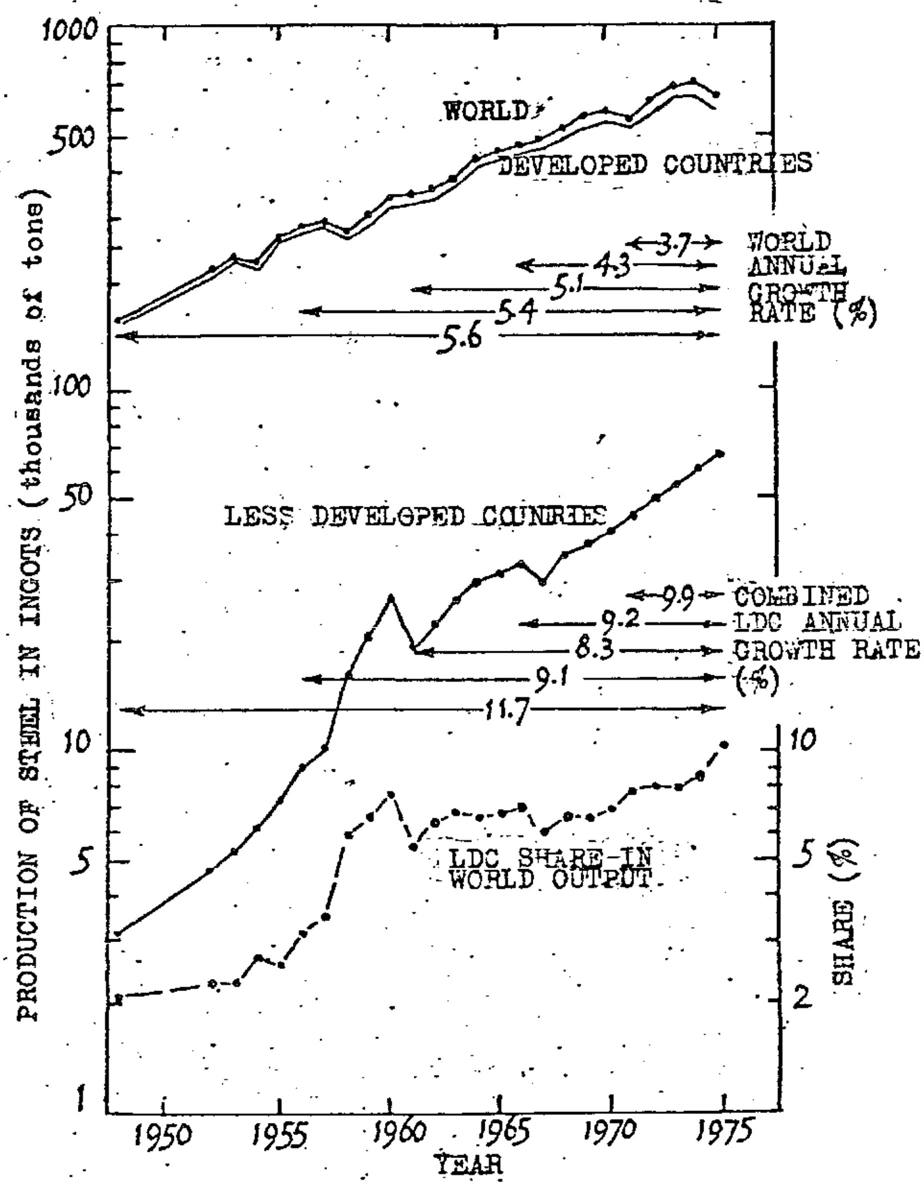
In fact, if we consider less developed countries as a group, their growth performance in steel output since 1950 has been far more rapid than the growth performance of the developed countries considered as a group. This can be seen clearly in Chart 2 below.

Chart 2 shows an 11,7% annual growth rate in LDC steel production between 1950 and 1975 compared to only 5,6% annual growth rate in developed country steel production in the same period.

This chart also shows that by the mid seventies, LDC production of steel had climbed to the 60-70 million tons per year mark, representing roughly 10% of total world steel production, which was in the region of 650 to 700 million tons per year.

So far as future projections of world steel output are concerned, the LDC share of world steel output is expected to go on rising rapidly in the next few decades. This is largely because LDC

CHART 2: THE EVOLUTION OF LDC COMPARED TO DC STEEL OUTPUT



Source: UNIDO Consultants report, Dec. 1976, reproduced in "Primera Reunión de Consulta sobre Siderurgia", Siderurgia Latinoamericana, No. 202, Febrero, 1977.

policies aim at steel self-sufficiency, which means the progressive elimination of current steel imports from DCs in favour of local steel production which is favoured by promotional incentives and tariff protection.

There are, moreover, some further reasons going beyond the drive to self-sufficiency which reinforce the prediction of a continued rapid build up of LDC steel output compared to DC steel output.

First of all, some LDCs - such as Brasil, South Korea and Taiwan - are actively planning to export steel on a sizeable scale during the 1980s. Second - and related to this - some LDCs have immense potential for further exploiting some very significant comparative advantages which they have in steel productic compared to many of the more traditional steelmaking countries. Such comparative advantages include proximity to cheap sources of iron ore and energy, relative freedom from pollution problems, cheaper real wages, etc.

Thirdly, - in spite of some current (1977) indicators that a newly protective trend is underway in advanced countries - the political notion promoted by the United Nations that a greater share of the world's industrial output should be located in less-developed countries could well have some influence on international negotiations and growth targets in the next few decades.

So far as the announced targets of LDCs are concerned, the LDCs gathered within the forum of UNIDO are officially on record as projecting to achieve at least 25% of world steel output by the year 2000[1/], and they have actually set 30% of world steel output as their official target[2/].

If this target is to be achieved, and if a figure of 3-4% annual growth in world steel demand until the end of the century is accepted as reasonable, then LDC steel output would have to quintuple from around 100 million tons in 1977 to over 500 million tons in the year 2000, whilst DC output would merely double from around 600 million tons in 1977 to around 1200 million tons at the end of the century.

In practice, however, there are some factors that could upset this forecast of how world steel output will evolve. To begin with, there is currently (1977) a large volume of excess steelmaking capacity in developed countries, particularly in the United States, Western Europe, and to a lesser extent Japan, and there are also some major steel capacity expansion plans still in the pipeline, particularly

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1/ This 25% target for LDCs in steel is in line with the target for LDCs of 25% of all industrial production by the end of the century adopted in the "Declaration of Lima", resulting from the 2nd UNIDO Conference on Industrial Development held in Lima in March 1975.

2/ The 30% target was set by the First Consultancy Meeting on the Steel Industry held by UNIDO in Vienna in February, 1977, as part of the follow-u to the Lima conference.

in Japan.[1]

This situation has already made the world export market for steel extremely competitive so far as prices are concerned and is leading to very strong pressures in the USA[2] and the Common Market to protect their domestic markets from the low-priced steel imports of more efficient producers (especially Japan). These protective pressures are reinforced by the enormous employment and regional economic problems that would be involved for U.S. and Common Market producers in winding down their steel industries by closing down their many obsolescent plants.

1/ For example, Japanese capacity of around 140 million tons per year in the mid 70s is scheduled to reach over 160 million tons in 1980.

2/ Steel imports amounted to 14% of U.S. steel consumption in 1976, and there are very real worries that imports could rise to capture 30% of the U.S. market. This prospect has generated fierce pressures for protective measures. Much use is being made of the "strategic" argument for not becoming dependent on foreign sources of steel supply. Another, much less convincing, argument being used by the American steel industr is the prospect of world shortages of steel "which could occur at any moment after 1980", according to the Putnam, Hayes and Bartle Consult report prepared for the American Iron and Steel Institute. Source: "El comercio internacional del acero y sus implicancias en la siderurgia norteamericana" (International commerce in steel and its implications for the North American steel industry), Siderurgia Latinoamericana, No. 208, Agosto 1977.

If these protective trends gather force and continue, then logically the perspectives for sizeable LDC exports of steel products to DC markets would not be so good.

Another important obstacle to raising LDC steel output as high as 30% of total world output by the year 2000 is the enormous volume of investment finance that would be required-greatly exceeding the budgetary possibilities of LDCs on their own. On the basis of $1,000 investment per annual ingot ton which steelmakers use as a rough rule of thumb for new integrated plants (1977), one can see that roughly U.S. $400 billion would be required to instal the new capacity needed to boost LDC output to over 500 million tons of steel per year by the end of the century, i.e. an average of over $17 billion per year for the next twenty three years. Even if LDCs can finance half this total, there is some doubt that the other half will in fact prove to be available from the international aid and export finance market.

Another possible perturbing factor is that the managers, technologists and skilled labour needed to make the new steel investments operate efficiently may not be available from LDC educational institutions and industry in time or in sufficient numbers to match such a rapid investment programme. In that case, the growth rate of LDC steel output could lag very considerably behind the steel investment programme and thus prevent the output targets from being achieved on time.

All these factors, then, cast serious doubt on whether LDC output will in fact quintuple by the year 2000. Equally, these same factors suggest that DC output may well do more than just double in magnitude by then.

Nevertheless, what can hardly be doubted is that LDC steel output will grow much more rapidly between now and the end of the century than DC output and nowhere is this more true than in Latin America, which, of all the LDC regions, is the one whose current steel programme and forecast steel plans are the most expansive.

APPENDIX 4 : LATIN AMERICAN STEEL PRODUCTION, PROSPECTS AND EXPERIENCE

Latin American production of steel in 1978 stook at around 24 million ton per mark [1/], having grown at over 10% compound per annum since 1950. Consumption, however, was nearly 30 million tons [2/] and some 20% of steel consumption was still imported.

Given that self-sufficiency is the broad goal, the future targeted growth of steel output must not only aim to keep up with the projected rapid growth rates of steel consumption in Latin American economies but must also exceed those rates so as to cut into the remaining proportion of imports in total steel consumption. According to Dr Argenis Gamboa, President of the Corporacion Venezolana de Guayana, the minimum predicted average annual growth rate in Latin American steel consumption between today and the year 2000 is 6%, the most likely rate is 7.5% and the maximum forecast is 9.5%. Any of these figures - even the minimum - necessarily requires a strong expansion of the steel industry given self-sufficiency goals.

A further important spur to the growth of steel production is the existance in Latin America - e pecially in Brasil and Vene uela - of nearly 30% of world iron ore reserves (in terms of recuperable iron content). In 1977, the region p duced 113 million tons of which 84 million were exported. The incentive to convert a higher proportion of this ore into steel both for internal consumption and export is therefore a strong one. [3/]

1/ Source ILAFA: Siderurgia Latinoamericana No. 229, Mayo 1979, p.21

2/ Source ILAFA: Siderurgia Latinoamericana No. 226, Febrero 1979, p.25 (From a speech by Dr Dario Vallejo Jaramillo, President of ILAFA, during its 19th Annual Congress: His estimate for 1978 consumption was 29.5 million tons).

3/ As the President of the British Metals Society has succinctly explained:- "The Third World does not wish to go on forever exporting its iron ore at $15 a ton so that the old world can convert it into steel and sell it at 300 a ton". Cited by L Garcia, Siderurgia Latinoamericana No. 229, Mayo 1979, p.51.

Plentiful reserves of gas, hydroelectricity and petroleum in some Latin American countries also make the setting up of steel plants economically attractive in these countries.

These factors, plus the considerable confidence developed in the Latin American steel industry as a result of their experience so far, have led to very ambitious expansion plans being set underway.

According to forecasts made by ILAFA (the Latin American Iron and Steel Institute) in 1976, based on Latin American governments' and firms' announced expansion plans, it was calculated that Latin American steel making capacity would rise to 51 million tons by 1980 and to 90 million tons by 1985 - an incredible rate of expansion when compared to the 1976 production of around the 19 million tons mark.[1/]

More recent forecasts, also by ILAFA, have revised these figures downwards very considerably - so that now steelmaking capacity is scheduled to reach only around 60 million tons by 1985, and 90 million tons by 1990[2/] - yet this still represents an extremely rapid expansion rate.

Furthermore, these are not merely paper plans. In recent years, Latin American steel investments have been running at over U.S.$2.5 billion per year, representing some 15-20% of total world investments in the steel industry in this period.[3/]

1/ These forecasts were published in ILAFA, La Siderurgia Latinoamericana en 1975-76 y sus perspectivas a 1985, (The Latin American Steel Industry in 1975-76 and its perspectives for 1985), ILAFA, Santiago de Chile, 1977.

2/ The exact figures forecasted are 59.6 million tons capacity by 1980 and 91.6 million by 1990. ILAFA, "Panorama de La Siderurgia Latinoamericana y Mundial", Siderurgia Latinoamericana, No. 229, May 1979

3/ Source: ILAFA

Even with the more "conservative" expansions now forecast, the additions to installed capacity in the near future involve a very rapid overall growth rate of the industry in Latin America. For the leading four Latin American steelmaking nations, Brasil, Mexico, Argentina and Venezuela, the figures are as follows:-

Table A.4.1 Production Capacity Growth in Latin America's Four Leading Steelmaking Countries

Country	Capacity in 1973-75 (millions tons) 1/	Forecast Capacity in 1975 (millions tons) 2/	Implicit Annual Growth rate (%)
Brasil	9	28.3	12.1
Mexico	7.5	11.1	4.0
Argentina	4.5	8.0	5.9
Venezuela	1.5	7.7	17.8
4 Countries Combined	22.5	55.1	9.4

This table makes it clear that policy for the Latin American steel industry will be profoundly affected by the challenges and problems which derive from seeking to grow at very rapid rates.

It is true that Japan managed to grow its steel industry at the astonishing compound rate of nearly 15% per year between 1950 and 1973,[3/] yet this was very

1/ Data drawn from the International Iron and Steel Institute, reporduced in ILAFA, La Siderurgia Latinoamericana en 1975-76 y sus Perspectivas a 1985 (The Latin American Steel Industry in 1975-76 and its perspectives for 1985), ILAFA, Santiago de Chile, 1977.

2/ ILAFA, "Panorama de la Siderurgia Latinoamericana y Mundial", ILAFA, Siderurgia Latinoamericana, No. 229, May 1979.

3/ This compound rate - actually 14.9% - was calculated by the author from figures originally supplied by "Nippon Steel News", quoted in " Treinta años de continuo progreso en la Siderurgia Japonesa", El Informativo, No. 5598, 28 Febrero, 1977, Santiago.

much the exception on the international scene. Can Brasil grow its steel industry at 12% compound from now on? And can Venezuela succeed in growing its steel industry at over 17% compound? These are important questions for the future.

However, from our own viewpoint in this book, we are naturally more interested in the historical experience that has been accumulated up until now by the Latin American steel industry - in particular the experience in matters having to do with technological learning and technological change.

This historical experience is, by any standards, quite considerable, as is indicated by the following Table A.4.2 which shows the dates of the start of production and the initial and recent steelmaking capacities of Latin America's 15 biggest steel producing firms.

Table. A.4.2:- THE FIFTEEN LARGEST LATIN AMERICAN STEEL PRODUCING FIRMS LISTED IN THE ORDER OF THE YEAR OF START-UP OF THEIR ORIGINAL PLANT */

Name of Firm	Location of Plant	Country	Year of plant start up	Initial Plant Capacity Ingot tons	Approximate plant capacity 1976 Ingot tons
Fundidora de Monterrey	Monterrey	Mexico	1903	90,000	1,000,000
Compañía Siderúrgica Belgo Mineira	Monlevade	Brasil	1937	50,000	720,000
Altos Hornos de Mexico	Monclova	Mexico	1944	60,000	2,500,000
Compania Siderurgica Nacional	Volta Redonda	Brasil	1946	300,000	2,000,000
Hojalata y Lamina	Monterrey	Mexico	1946	20,000	1,000,000
Compañía de Acero del Pacífico	Huachipato	Chile	1950	300,000 (est.)	1,000,000
Acesita	Itabira	Brasil	1951	-	300,000
Companhia Siderurgica Mannesmann	Minas Gerais	Brasil	1954	60,000	600,000
Acerias Paz del Rio	Paz del Rio	Colombia	1955	150,000 (est.)	300,000
Tubos de Acero de Mexico	Veracruz	Mexico	1955	50,000	350,000
Siderperu (Sogesa)	Chimbote	Perú	1958	50,000	500,000
Somisa	San Nicolás	Argentina	1960	600,000	2,500,000
Sidor	Ciudad Guyana	Venezuela	1962	700,000	1,200,000
Usiminas	Vale do Rio Doce	Brasil	1962	500,000	2,400,000
Cosipa	Santos	Brasil	1965	600,000	1,300,000

SOURCE: Author's compilation based on diverse sources, the two most important of which were Instituto Chileno de Hierro y Acero, Estudio sobre Tecnología en la Siderurgia Latinoamericana, BID/CEPAL/BA/14, Comisión Económica para América Latina, Buenos Aires, December 1976; and B. Leuschner, The Transfer of Technical Know-how in the Steel Industry in Brasil, United Nations Economic and Social Council, E/CN.12/922, October 1971, English (original Spanish).

*/ These firms were the largest in terms of their capacity to produce steel ingots in 1976. Note that quite a few firms (including Acindar S.A. of Argentina which is examined later on in the case-studies) would enter into the list of the top 15 firms if the size of their rolling operations was the criterion.

This chart shows a length of production experience ranging from one to seven <u>decades</u> for the 15 plants mentioned, and makes it clear that there is a rich fund of technological learning and experience which empirical studies on Latin American steel plants could explore.

This is particularly so in Mexico, Brasil and Argentina, the three Latin American countries with the longest steel-making tradition.[1/]

1/ Argentina' long steel tradition appears considerably under-represented in the Chart because it has at least two large private firms which in 1976 had much bigger steel finishing capacities than steelmaking capacities, and which therefore did not enter into our Chart of the top 15. These firms are Acindar (start-up in 1943), and Dalmine Siderca (start-up in 1954), both of which are now fully integrated plants in the top 20 if not the top 15.

Argentina was also in the lead, together with Brasil and Mexico, in the formation of state steel companies. Thus, Altos Hornos Zapla in Jujuy, Argentina, started production in 1945 but has not grown fast enough to be included in the top 15 steel producers in 1976. Also Argentina's SOMISA was formed in 1949, but for reasons did not start production until 1960.

Finally, although Chile, Colomiba and Peru appear ahead of Argentina in our Chart in terms of years of experience of their biggest steel producing firm, it should be noted that Argentina's SOMISA is a bigger firm than the biggest firms of the other three put together, and in addition, none of these three countries have "second-string" firms of either experience of size comparable to Acindar or Dalmine, in Argentina.

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