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TECHNOLOGY AND THE GESTATION PERIOD IN LATIN AMERICAN STEEL PLANTS

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- "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 foros are sufficiently skilled to be able to operate it at its rated capacity, has usually been underestimated".

In this paper, we report some empirical findings about the duration of project gestation in the sample of steelplants which we examined. Some illustrations are then given which throw light on some of the factors which influenced the length of project duration.

A preliminary effort is also made at the end of the paper to suggest some hypotheses about the determinants of gestation time, and some planning implications of the findings presented.

1. The Sample of Steel Plants and Expansions Analysed

The "gestation period" refers to the period involved in planning, constructing and starting up new steelplants or major expansions of existing ones.

The sample of technology gestations which we analyse in this paper is listed in Table 1 (for new plants), and Table 2 (major plant expansions).

Our source of information, in most cases, was the set of case-studies on five Latin American steel plants carried out in the BID-CEPAL-PNUD Research Programme 3/ to 7/; however information on SOMISA came from Savio 8/, Castineiras 9/, and SOMISA's Annual Reports; and information on Acindar's expansion project to build a direct-reduction plant (Table 2), came from Acindar's Annual Reports.

3/ P. 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.

4/ 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.

5/ G. Puerta, El Desarrollo Tecnológico en la Industria Siderúrgica en Colombia, (Technological Development in the Colombian Steel Industry), Working Paper 26, BID/CEPAL/PNUD, April 1979, Spanish.

6/ L.A. Pérez Aceves & 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 24, BID/CEPAL/PNUD, October 1978, Spanish.

7/ J. Gianella, "Empresa Pública, Política y Gestión Tecnológica: El Caso de Siderperú", (State Firm, Policy and Technological Management: The Case of Siderperú), Part I: 1956-67, unpublished. In this paper the plant which later became Siderperu is referred to as Siderúrgica de Chimbote.

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

9/ P. Castineiras, Esto lo hicieron los Argentinos, available through SOMISA, Buenos Aires, 1972.

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 plata and sheet.	100,000	1940-50
Acindar, Villa Constitución (Mexico)	Rolling plant, chiefly for non-flats	215,000	1947-54
Acerías 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 platas, 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

2. Framework for analysing the gestation perios

In what follows, we classify the gestation period into three distinct, successive, chronological periods. The division adopted is :

1. "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.

2. "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.

3. "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 prior to this point, the plant's staff had already learned to operate the plant on a sustainable basis at its nominal rate 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.

4. "IMPLEMENTATION PERIOD"

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

5. "OVERALL GESTATION PERIOD"

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

3. Evidence on the Duration of the Gestation Period

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:

3.1 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.

3.2 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 followedin 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 Acendar'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.

3.3. 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.

3.4. 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 remedial

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, there were construction weaknesses in the coke-washing plant, the blast furnace and steel-shop. In fact 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, several major intrinsic design errors were made by the German suppliers of this steelshop, including errors arising from the inappropriatenses of the supplied equipment to local conditions. The AHMSA case-study lists 11 main 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 required remedial measures by AHMSA in the course of the start-up period.

* --- In SOMISA's $2\frac{1}{2}$ million ton expansion plan, some major design and construction errors appear to have been made by the British

suppliers of the large new blast furnace constructed as part of the expansion. Right from the beginning of start-up of the blast furnace in March 1964 serious operating problems were encountered, which could not be righted by the suppliers. Normal functioning was not achieved, and after $2\frac{1}{2}$ 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.

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:

* --- 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 is that the factors causing start-up delays which were mentioned above mostly originate in decisions which were made earlier during the pre-investment or construction period (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).

4. Some Hypotheses about the Determinants of Gestation Time

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 [10/] 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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10/ 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.

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, [11/] and also by Cartwright,[12/] 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.

11/ In large-seze 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, A Comparative Study of the Capacity Decision Process in the Steel Industry: The U.S. and Europe, Ph.D, Harvard University, 1973.

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

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,[13/] 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

13/ R. Eckhaus, op.cit.

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 acceptance of a poor basic design from the German 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.[14/]

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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14/ M. Nicodemo "Los Nuevos Altos Hornos en Argentina", (The New Argentine Blast Furnaces), Siderurgia Latinoamericana, N°211, Noviembre 1977.

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 "junp" 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 so 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.

5. Conclusions

This last section states some topics for planners that might be suggested in view of the evidence presented earlier about the gestation period.

1) Underestimates of gestation time made at the pre-investment stage (i.e. when pre-feasibility and feasibility reports are being evaluated) are likely to lead to overoptimistic forecasts as to the financial rate of return on the capital that will be invested in a project. Possibility: insist on feasibility reports including sensitivity analysis to gestation period delays.

2) Whilst the capital cost savings and operational cost savings obtainable from building bigger and bigger plants have received much attention in economics literature, and are much used by

consultants, banks and government planners to justify big plants, less than adequate attention has perhaps been paid to the diseconomies of scale which may attend the building of bigger plants due to longer gestation periods, and longer gestation over-runs.

3) It may be helpful for planners conducting feasibility reports to engage in explicit considerations as to whether the "jumps" in scale (and technology) recommended, might be excessive in relation to previous plant experience and in relation to the possibilities which the plant's management has to invest in augmenting its experience in time to handle the proposed expansion.

4) In a similar vein, it may repay effort for planners to consider the trade-off that appears to exist between (a) expenditures on capital equipment which rise with the scale of the plant built, and (b) investments made by the plant in augmenting the "know-how" and experience which the firm and its staff can bring to bear on the specification, construction, and operation of a proposed expansion, so as to reduce the gestation period and accompanying scale-diseconomies. Expressed simply, paying more attention to this trade-off would probably mean building somewhat smaller plants and expansions, but investing more money in plant design, plant staff training and qualification, and first-class technical assistance during start-up.