TECHNOLOGICAL DEVELOPMENT AND STATE INTERVENTION:

A STUDY OF THE BRAZILIAN CAPITAL GOODS INDUSTRY

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D. PHIL THESIS
THE UNIVERSITY OF SUSSEX
1977

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~~[illegible]~~ September, 1977.

ACKNOWLEDGEMENTS

During a work covering many years, such as this, one accumulates debts to many people. During my stay at the University of Sussex, I became deeply indebted to P.L. Cook, who was my supervisor and to Charles Cooper, who participated in the supervision committee, for their help and dedication. I also benefitted considerably from discussions with members of the Science Policy Research Unit (SPRU), especially from William Walker.

I received useful comments from the participants of the Brazil Seminar at the University College, London, especially from Eduardo Guimaraes and Francisco Biato.

Marie Martha Cassiolato gave me great help with the bibliography. Sylvia Richards typed the thesis at record speed at the most improbable hours, and Jose E. Cassiolato helped to revise the typescript. I am also thankful to Jackie Fuller for the administrative support received from SPRU.

While I was in the U.K., I was helped by many people in Brazil. I wish to thank especially Jose Tavares de Araujo Jr., Leonidia G. Reis and Antonio L. Barbosa from FINEP and Amilcar Ferrari from the CNP for the information sent and Roberto Erber for the general help he gave me.

I am thankful to the Secretaria de Planejamento da Presidencia da Republica (SEPLAN), to the Banco Nacional do Desenvolvimento Economico (BNDE), to the Conselho Nacional de Desenvolvimento Cientifico e Tecnologico (CNPG) and to the Ford Foundation for the financial help received.

My period of work at the Research Group of FINEP was very fruitful and I am thankful to those who contributed to it, especially my colleagues of the Group - Sergio Alves, Jose Tavares de Araujo Jr., Leonidia G. Reis and Myrian Redinger - who participated in the study of the capital goods industry.

I renew here my thanks to the entrepreneurs interviewed and to the staff of the BNDE, and Tecnometal who contributed to the study.

I am especially grateful to Jose Pelucio Ferreira who, as President of FINEP, made possible the creation and operation of the Research Group and, as a friend, encouraged and supported my efforts.

My wife, Ana Maria, and my children Paula, Renato and Claudia, gave me the support of their affection, without which this experience would have been considerably poorer, To them and to Pelucio this thesis is dedicated.

In no way are the persons and institutions above-mentioned responsible for the opinions here expressed.

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MAIN BRAZILIAN ABBREVIATIONS USED IN THE TEXT

MAIN BRAZILIAN ABBREVIATIONS USED IN THE TEXT

ABDIB	Associacao Brasileira para o Desenvolvimento das Industrias de Base (Brazilian Association for the Development of Basic Industries)
ABNT	Associacao Brasileira de Normas Tecnicas (Brazilian Association for Standards)
BNDE	Banco Nacional do Desenvolvimento Economico (National Bank for Economic Development)
	EMBRAMEC - Mecanica Brasileira S/A (Brazilian Mechanics S/A)
	FINAME - Agencia Especial de Financiamento Industrial (Special Agency for Industrial Financing)
	FUNTEC - Fundo Technico-Cientifico (Technico-Scientific Fund)
BRDE	Banco Regional do Desenvolvimento do Extremo Sul (Regional Bank for the Development of the South)
CACEX	Carteira de Comercio Exterior do Banco do Brasil (Foreign Trade Department of Banco do Brasil)
CDI	Conselho de Desenvolvimento Industrial (Industrial Development Council)
CESP	Centrais Eletricas do Estado de Sao Paulo (Sao Paulo's Electricity Company)
COBRA	Computadores Brasileiros S/A (Brazilian Computers S/A)
COSIPA	Companhia Siderugica Paulista (Sao Paulo's Steel Company)
CNPq	Conselho Nacional de Desenvolvimento Cientifico e Tecnologico (Scientific and Technological Development National Council)
CPA	Conselho de Politica Aduaneira (Customs Policy Council)
CSN	Companhia Siderurgica Nacional (Natinnal Steel Company)

CTA	Centro Tecnologico da Aeronautica (Air Force Technological Centre)
	IFI - Instituto de Fomento Industrial (Institute of Industrial Development)
	IPD - Instituto de Pesquisas e Desenvolvimento (Research and Development Institute)
	ITA - Instituto Tecnologico da Aeronautica (Air Force Technological Institute)
CVRD	Companhia Vale do Rio Doce de Mineracao (Vale do Rio Doce Mining Company)
Digibras	Empresa Digital Brasileira S/A. - Brazilian Digital Enterprise
Eletrobras	Centrais Eletricas Brasileiras S/A (Brazilian Electricity)Power)
EMBRAER	Empresa Brasileira de Aeronautica (Aircraft Brazilian Enterprise)
FINEP	Financiadora de Estudos e Projetos (Financial Agency for Studies and Projects)
FNDCT	Fundo Nacional de Desenvolvimento Cientifico e Tecnologico (National Fund for Scientific and Technological Development)
ICM	Imposto sobre Circulacao de Mercadorias (Tax on the Value Added in the Enterprise)
IPI	Imposto sobre Produtos Industrializados (Sales Tax)
IPT	Instituto de Pesquisas Tecnologicas (Technological Research Institute)
MIC	Ministerio de Industria e Comercio (Ministry of Industry and Trade)
	STI - Secretaria de Tecnologia Industrial (Industrial Technology Secretariat)
	INPI - Instituto Nacional da Propriedade Industrial (National Institute of Industrial Property)
Nucleobras	Empresas Nucleares Brasileiras S/A (Nuclear Brazilian Enterprise)
ORTN	Obrigacoes Reajustaveis do Tesouro Nacional (Indexed Treasury Bonds)

Petrobras	Petroleo Brasileiro S/A (Brazilian Oil Company)
	Petroquisa - Petroquimica Brasileira (Brazilian Petrochemicals Company)
RFFSA	Rede Ferroviaria Federal S/A (Federal Rail Network)
SUMOC	Superintendencia da Moeda e Credito (Money and Credit Superintendence)
Telebras	Telecomunicacoes Brasileiras S/A (Brazilian Telecommunications Company)
Usiminas	Usina Siderurgicade Minas Gerais (Minas Gerais' Steel Company)
PBDCT	Plano Basico de Desenvolvimento Cientifico e Tecnologico (Basic Plan of Scientific and Technological Development)
PND	Plano Nacional de Desenvolvimento (National Plan of Development)

CHAPTER I:

INTRODUCTION.

This dissertation is addressed to the discussion of the problem of the development of a local design capacity in the capital goods industry in a less developed country (henceforth LDC) in the light of the possibility of using licensing from the more advanced countries (henceforth ACs) and to the relationship of such development to State policies, focussing on the Brazilian case.

It is often suggested that scientific work has the nature of puzzle-solving, in which research unearths problems leading to further research (Popper, 1972). This is not an exception to this pattern.

This dissertation is intimately linked to my involvement with science and technology studies for policy-making in Brazil, especially to my work as Coordinator of the Research Group at FINEP - Financiadora de Estudos e Projetos. FINEP is a public enterprise, a financial agency of the Federal Government in Brazil and it acts as the Executive Secretariat for the National Fund for the Development of Science and Technology, the main source of funds for science and technology in the country, besides being deeply involved in the overall policy-making and execution of the science and technology policy, including the preparation of the Basic Plan for the Development of Science and Technology. Its Research Group (now a Research Centre) is an interdisciplinary group in charge of making policy-oriented studies with the purpose of suggesting policy measures to FINEP and to the Planning Secretariat (formerly Planning Ministry) of the Federal Government. I was responsible for originally setting up the Research Group, establishing its main research programme and coordinating the main projects from 1971 to 1974.

One of the basic assumptions that guided the work of the Group was that in order to reduce the amount of trial-and-error that inevitably goes with policy-making we should try to understand the motivations of the economic agents whose actions we would have liked to influence.

One of the first groups we decided to study were the producers of capital goods. There were several reasons for this choice. Firstly, there was the role played by the capital goods industry in the processes of capital accumulation and of technical diffusion in the economy; as it is largely in capital goods that technical progress becomes embodied and then is diffused throughout the other branches of industry through their purchases of machines and equipment. Moreover, the capital goods industry has traditionally been the locus of development of engineering skills which are then used by other industries too (Rosenberg, 1963).

In Brazil, at the time of the study, 1972, production of capital goods accounted for about 13% of the manufacturing industry production,[1] (see Tables I-1 and I-2), but such figures underestimate their importance in terms of industrial growth, especially in the recent previous period. In fact, Sugigan et al (1974) estimate that the capital goods industries were responsible for 27.8% of the industrial growth in the period 1970/1973 (see Table I-3).

1/ My estimate, using data from MPCG (1969) and Suzigan et al (1974). The industries producing capital goods are the mechanical industry, the transport industry and the electrical industry. In 1966 it was estimated that the whole production of the first was of capital goods and that, respectively, 18% and 55% of the latter two were for capital goods (MPCG, 1969). Table I-1 shows a disaggregation of the production of those three industries for 1968. See also Table II-4 in Chapter II for a breakdown of value of production and value-added for the whole Brazilian manufacturing industry according to Kamrany et al. (1976) for the period 1950/1970.

11.2% ... 1970; 15.1 ... 1973
(F2 - B.a.E)

TABLE I-1:- BRAZIL - INDUSTRIES PRODUCING CAPITAL GOODS[1/] - SHARE OF VALUE OF PRODUCTION AND VALUE-ADDED OF MANUFACTURING INDUSTRY - IN PERCENTAGE - 1949, 1970.

Industry	Value of Production 1949	Value of Production 1970	Value-Added 1949	Value-Added 1970
Mechanical	1.6	5.7	2.1	7.1
Electrical	1.4	4.8	1.6	5.4
Transport	2.3	8.3	2.2	8.1
Total	5.3	18.8 *	6.0	20.6 **

NOTE:- 1/ Electrical and Transport industries produce also consumer durable goods. In 1966 it was estimated that 18.3% of the production of the former and 55% of the production of the latter were for capital goods (MPCG, 1969).

SOURCE:- Table II-4

* 11.2 - KG

** 12.6 - KG

6

TABLE I-2:- BRAZIL - INDUSTRIES PRODUCING CAPITAL GOODS - VALUE OF PRODUCTION - IN PERCENTAGE - 1948.

Industry	%
A - MECHANICAL	100.0
Non-Electric Motors (boilers, steam generators, etc.)	10.5
Transmission Equipment	4.8
Non-Electrical Machines and Equipment for Hydraulic Instalations, heating, freezing, etc.	19.4
Machine Tools	24.8
Components and Sub-Components	5.4
Agricultural Equipment and Machinery	9.8
Machinery and Equipment for Work-Shops and Domestic Use	4.4
Machinery and Equipment for Offices	10.3
Others	10.6
B - TRANSPORT EQUIPMENT	100.0
Maritime Engines and Vessels	4.8
Vehicles	58.8
Parts and Accessories for Vehicles	25.1
Road-Building Machinery	0.4
Others	10.9
C - ELECTRICAL AND COMMUNICATION EQUIPMENT	100.0
Generators, Motors, Convertors, Transformers	11.4
Electrical Equipment for Vehicles	6.9
Instruments	10.3
Electrodomestics	40.0
Others	34.4

SOURCE:- Suzigan *et al.* (1974).

TABLE I-3:- INDUSTRIAL GROWTH IN BRAZIL - 1966/1973 - PARTICIPATION OF THE INDUSTRIAL GROUPS IN THE RATE OF GROWTH

Categories of Goods	Partic. in the Growth Rate	
	1966/1969	1970/1973
Capital	8.8	27.8
Consumer Durables	18.5	15.6
Consumer Non-Durables	28.8	17.5
Intermediaries	43.9	39.1
Total	100.0	100.0

SOURCE:- Suzigan *et al.* (1974).

TABLE I-4:- BRAZIL:- IMPORTS 1967/1972 - PERCENTAGE OF FOB VALUES; US $

Categories of Goods	1967	1968	1969	1970	1971	1972	Yearly Growth Rate
Capital	31.9	33.7	37.0	37.7	38.9	42.2	31.2
Intermediaries	52.6	53.1	49.5	47.5	54.3	42.7	18.9
Consumer Non-Durable	3.8	4.0	4.4	5.3	6.3	6.6	38.6
Consumer Durable	10.4	9.2	8.1	8.1	8.8	7.7	16.9
Others	1.3	0.0	1.0	1.4	0.7	0.8	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	24.0

SOURCE:- Von Doellinger *et al.* (1974).

Moreover, in an economy where the scarcity of foreign exchange has traditionally been one of the main obstacles to economic growth,[1/] imports of capital goods had increased at a rate of 31.2% p.a. in the period 1967/1972, accounting for 42.2% of total imports in that last year (see Table I-4). In terms of exports, the industries producing capital goods accounted for a small, but increasing, share of total Brazilian exports - circa 2.6% in 1967 to 5.2% in 1972. In this period, 1967/1972, they were responsible for about 18% of the Brazilian exports of manufactured products[2/] (see Table I-5). Furthermore, Fainzylber (1971), in his extensive study on Brazilian exports of manufactured products had suggested that in mechanical machinery, especially machine tools and equipment for processing agricultural products, Brazil had some comparative advantages which could be exploited for exports. On the other hand, the literature on licensing indicated that such agreements normally lead to restrictions on exports by the licensee (e.g. Vaitsos, 1970).

Secondly, it is an industry in which competition is largely based on the quality of the products, i.e. on the quality of their design and of the techniques with which they are manufactured. Such quality is highly dependent on the experience the enterprises have of designing and producing such goods (see Chapter II).

1/ The economic history of Brazil is well documented, inclusive in English. On the specific point see, for instance, Baer (1965), Gudin (1972). See also Chapter V.

2/ Exports of manufactured products represented 15.1% of total Brazilian exports in 1967 and 25.9% in 1972. However, the bulk of those products had suffered few transformations from their primary stage. The capital goods exported were generally simple machines, such as pumps, universal machine tools, etc. (Von Doellinger et al., 1974).

TABLE I-5:- BRAZIL - 1967/1972 - EXPORTS FROM THE MECHANICAL, ELECTRICAL, AND TRANSPORT EQUIPMENT INDUSTRIES1/ - AS PERERCENTAGE OF TOTAL BRAZILIAN EXPORTS AND OF MANUFACTURED EXPORTS

Industries	Percentage of Total Exports						Average Participation in Manufactured Exports - 1967/1972
	1967	1968	1969	1970	1972	1972	
Mechanical	1.78	1.66	1.92	2.37	2.65	2.50	11.40
Electrical	0.30	0.32	0.43	0.59	0.98	0.97	2.98
Transport	0.56	0.21	0.30	0.54	0.94	1.72	2.41
Total	2.64	2.19	2.65	3.56	4.57	5.19	17.79

NOTE:- 1/ The percentages shown above are probably an overestimate of the exports of capital goods, as they probably include durable consumer goods produced by the electrical and transport industries.

SOURCE:- Von Doellinger et al. (1974).

Thirdly, and related to the former, it is an industry in Brazil where there is a strong participation of local entrepreneurs which have been active in the sector for a considerable time - the experience of local production, dates back to the end of the last century, mainly in terms of repair shops for agriculture and transport equipment 1/ as well as supply of military equipment, especially for the Navy. In fact, in the late 1940's the domestic industry, at the time composed mainly of local enterprises, supplied already over 60% of the market for capital goods in Brazil (Leff, 1968). In 1972 the ten largest Brazilian enterprises had an average experience of circa 38 years and a wider sample, covering 84 enterprises, the main producers of capital goods, indicated that 60 of those had been founded before 1950 (Erber et al., 1974).

Such Brazilian enterprises were competing not only with imports but also, internally with foreign subsidiaries.

Analysing the ownership of net assets in the industries producing mechanical and electrical products with data related to the largest 500 corporations in Brazil, Fainzylber (1971) estimated that in 1968 Brazilian enterprises controlled, respectively, 44 and 32% of the net assets in those industries, the rest being controlled by subsidiaries of foreign firms. 2/

1/ A similar role was played in the US through the development of the railway system, which spawned several capital goods firms (Rosenberg, 1972).

2/ The State at the time held the equity control of an important producer of capital goods, especially of railway equipment, through the BNDE, but such control was rather loosely exercised. Since then it has set up an enterprise with the purpose of producing equipment for steel production, a subsidiary of one of the steel State Enterprises. The share of national enterprises increases when more corporations are included in the sample, reflecting the relatively small size of capital goods enterprises in general and the concentration of foreign enterprises among the biggest firms of the sector. For instance, analysing the data for the largest 5,113 non-financial corporations in Brazil, the share of net assets of national private enterprises in the mechanical industry increases to 53% and in the electrical industry to 39% (see Table I-7. See also Table I-4).

A similar picture emerges from a study of the firms producing custom-built capital goods (Tecnometal, 1971) covering practically all the main producers of such goods, where local enterprises controlled circa 44.5% of the capital and were responsible for circa 52% of the sales, in 1970 (see Table I-6). Among the most dynamic branches of the Brazilian industry the mechanical industry had one of the highest participations of Brazilian private enterprises (see Table I-7).

We knew from previous studies (MPCG, 1968; Leff, 1968; Tecnometal, 1971) that to compete with imports and with the foreign subsidiaries the Brazilian enterprises relied heavily on licensing but I expected that they would also be very interested in developing an independent design capacity. During the interviews we found that, with some exceptions, they were not. The "falsification" of such expectation led me to study the problem again, trying to understand better the rationale of choice of design strategy by capital goods enterprises and its relationship to State policies, which play an important role in such choice.

In fact, another reason why we chose the capital goods industry was because of the role the State plays in its development, especially in Brazil. Such role, is examined in detail in subsequent Chapters and has a double interest: from the point of view of policy-making it offers the opportunity of effectively influencing the decisions of the capital goods entrepreneurs and, from the point of view of political economy, the opportunity of understanding better the relationship between private enterprises and the State. It is hoped that the present discussion contributes to the on-going debate about the relationship between Brazilian enterprises, the State and foreign enterprises.

TABLE I-6:- CAPITAL GOODS INDUSTRY IN BRAZIL - PARTICIPATION OF FOREIGN AND NATIONAL ENTERPRISES

A - ENTERPRISES INCLUDED IN THE 500 LARGEST CORPORATIONS IN BRAZIL - 1968 - AVERAGE NET ASSETS; PERCENTAGE OF NET ASSETS AND NUMBER OF ENTERPRISES

Industry	National			Foreign		
	Number	Av. NA	%	Number	Av. NA	%
Mechanical	11	22.8	43.9	10	32.1	56.1
Electrical Products	12	17.6	32.1	9	49.6	67.9

B - TEN LARGEST ENTERPRISES OF THE SECTOR - 1972 - PERCENTAGE OF NET ASSETS AND NUMBER OF ENTERPRISES

Industry	National		Foreign		Total	
	Number	% of NA	Number	% of NA	Number	% of NA
Electrical & Communcications Equipment	3	38.7	7	61.3	10	100
Machinery	3	28.0	7	72.0	10	100

C - ENTERPRISES PRODUCING CUSTOM-BUILT EQUIPMENT - 1970 - PERCENTAGE OF CAPITAL AND VALUE OF PRODUCTION AND NUMBER

	Number	% of Capital	% of Value of Production
National	29	44.5	51.8
Foreign	20	55.5	48.2

NOTES:- (A) and (B) include enterprises which are producers of durable consumers' goods in the electrical industry.

(A) Average Net Assets in CR$ millions in 1968.

SOURCES:- (A) Fajnzylber (1971)
(B) Baer (1973)
(C) Tecnometal (1971)

TABLE I-7:- BRAZIL: PATTERNS OF ASSET OWNERSHIP OF THE INDUSTRIAL ENTERPRISES INCLUDED AMONG THE LARGEST 5,113 NON-FINANCIAL ENTERPRISES, 1974. AVERAGE GROWTH RATE OF PRODUCTION OF INDUSTRIAL BRANCHES - 1966/1972

Industry	Total Net Assets (million Cr.$)	%	Share of Public Enterprises	Share of Foreign Enterprises	Share of National Private Enterprises	Yearly Growth Rate 1966/1972 (%)
Manufacturing Total	161,571	100.0	0.20	0.29	0.51	10.3
Non-metallic	7,551	4.67	0.02	0.35	0.64	11.3
Metallic	27,711	17.15	0.34	0.12	0.54	10.3
Mechanical	8,293	5.10	0.01	0.46	0.53	16.2
Electrical	6,476	4.01	-	0.61	0.39	14.7
Transport Equipment	15,155	9.38	0.04	0.63	0.33	14.7
Wood	8,782	5.44	-	0.09	0.91	n.a.
Furniture	577	0.36	-	-	1,00	n.a.
Rubber	1,834	1.14	0.06	0.61	0.33	12.1
Leather	685	0.42	-	0.11	0.89	n.a.
Chemicals	40,162	24.86	0.55	0.23	0.22	12.6
Textile	12,411	7.68	-	0.13	0.87	3.7
Food	16,910	10.47	0.01	0.31	0.68	8.3
Beverages	3,571	2.21	-	0.14	0.86	5.4
Tobacco	2,095	1.30	-	0.99	0.01	5.8
Printing	2,143	1.33	-	0.02	0.98	8.0
Miscellaneous	8,211	5.08	-	0.47	0.53	n.a.

SOURCES:- Bacha (1977) and Suzigan et al. (1974).

We began the study by discussing the problems of the domestic (i.e. nationally and foreign-owned) capital goods industry with members of the staff of the BNDE, of the IPEA and of some State enterprises and by analysing the studies previously made about the sector: Leff (1968), the planning documents such as MPCG (1967 and 1968) and, especially, Tecnometal (1971), which dealt with custom-built equipment, and the preliminary results of a study conducted for the IPEA by the same firm (Tecnometal) and by the Italian concern Italconsult on the metal-mechanic industries, which covered the non-custom-built equipment.

At the end of this preliminary phase, we found that although there were clear indications that the most important source of technology for the Brazilian entrepreneurs were licensing agreements, there was much less reliable evidence on what led them to rely on such agreements. Although economic theory and international evidence suggested some plausible hypotheses, there seemed to be a case for discussing the problem directly with the entrepreneurs, who would, after all, be taking the relevant decisions, in order to better understand what were the main characteristics of the present sit ation and so to choose the most appropriate instruments of policy to change it, reducing thus the margin of trial-and-error in policy-making.

Implicitly, there was the judgement, which is a political as well as an economic judgement, that a strengthening of the design capacity of the Brazilian capital-goods producers was desirable. I return to this, in more detail, in Chapter III.

Because of the nature of the questions we wanted to discuss, which included Government policies and the relationship of the enterprises with their licensors, we discarded the possibility of a mail-sent questionnaire and we decided on a series of interviews, which, although necessarily restricted in number, would compensate this restriction by the depth of the answers.

Moreover, the capital goods industry in Brazil is fairly concentrated. In the Tecnometal study (1971) less than a third of the enterprises controlled between 65% and 75% of all the industries, whichever indicators were used - capital, labour force, built-up area, electric power consumption, or value of production. Table I-8 shows the participation of the four largest firms in the value of production and employment for the four-digit classification of the IBGE, but such data has to be treated with great caution, as the IBGE does not guarantee representatively at that level of disaggregation. 1/

Therefore, by interviewing a relatively limited number of enterprises, we were still "covering" the bulk of the local production. The same rationale probably underlies other studies of the sector in Brazil, such as Leff's (1968) where he interviewed 20 enterprises in the heavy-engineering field.

Having decided on interviews, we then elaborated a questionnaire in which the questions contained a list of probable answers suggested by the theory and by the international and local experience, but which were kept open-ended in order to incorporate alternatives not foreseen. In fact, during the interviews, only the researcher had the list of alternatives, which were used as a guide and a check-list.

The questionnaire emphasised the questions related to licensing agreements, as we already knew that this was the main source of designs for the enterprises.

1/ There are also substantial problems of classification involved. As several capital goods enterprises are to some extent backwardly integrated, having foundries of their own, they are often classified in the "metallurgy industry", instead of "mechanical" or "electrical".

TABLE I-8:- CONCENTRATION IN THE BRAZILIAN CAPITAL-GOODS INDUSTRY - SHARE OF THE FOUR LARGEST ENTERPRISES IN THE VALUE OF PRODUCTION AND EMPLOYMENT - IN PERCENTAGE - 1968

IBGE Classification	Industry (Products)	Prod. (%)	Empl. (%)
12.11	Boilers for steam generation	53	45
12.18	Equipment for electrical transmission	69	67
12.21	Non-electrical machines and equipment for hydraulic installations etc.	20	16
12.31	Machine tools and other industrial machines and equipment	23	16
12.32	Tools, parts and accessories for industrial machines	21	13
12.41	Production and assembly of machines and equipment for agriculture	54	25
12.42	Machines and equipment for rural industries	37	29
12.48	Tools, parts and accessories for rural industries	76	62
13.11	Generators, engines, convertors and transformers	31	33
13.51	Equipment for telephoning, telegraphs and signalling	95	93
14.11	Maritime engines and shipbuilding	81	74
14.21	Railway vehicles, including parts	67	46
14.62	Earthmoving equipment, including parts	99	99

NOTES:- See text about limitations of data above.

SOURCE:- Fajnzylber (1971).

Poderia ser substituído por Tab 8 p.32 BeF

It enquired, for instance, about which lines of production used such agreements, the difficulty of obtaining licenses and, especially about the main features of such agreements (e.g. continuity of flow of technology, export restrictions, etc.) and about the reactions of the entrepreneurs to those features.

We enquired also about the lines of production which were based on designs developed by the local enterprises, as well as about the use of possible alternatives sources of technology, such as the research institutes and engineering companies and about related matters such as the role played by national standards and patents.

Finally, we asked about some characteristics of the Brazilian market for capital goods which we thought might affect the decisions of the local entrepreneurs, such as competition from imports, fluctuations in demand and the diversification of production. In the end we asked for suggestions of policy measures from the Government needed for increasing or beginning R&D activities.

Parallel to the elaboration of the questionnaire we proceeded to select the enterprises to be interviewed. This selection followed a two-step procedure.

First, because of the policy-orientation of the study, we selected the industries in which we knew there was a strong nucleus of local producers and in which the State's influence was greater, as direct purchaser and/or as a financing agency. Table I-9 shows the industries from which enterprises were finally interviewed and the respective number of enterprises interviewed. The classification there follows a "purchasing-industry" approach, adopted also to clarify the role of the State, but, of course, some of the products (machine tools, for instance) are of common use and are presented in a separate category. In the same Table it is indicated whether the demand in those industries is predominantly for custom-built or series-produced products.(see also Table IV-5 in Chapter IV). Because of the diversification of production that characterises the sector (see Chapter II) we often found an enterprise producing for several of the industries, as reflected in Table I-9.

From those industries we then chose the enterprises to be interviewed, using as a basis the universe studied by Tecnometal, for which we had substantial information. Using this information and in consultation with the staff of the BNDE and Tecnometal we selected local enterprises so as to have for each industry as least two enterprises of different size and different level of technological sophistication. Nevertheless, the sample is biased towards relatively big enterprises - not only does it include the main Brazilian producers of custom-built equipment and machine tools at the same time, but also the other enterprises are relatively big: none has less than a hundred employees. As can be seen in Table I-10 the great majority of industrial establishments in the Brazilian mechanical and electrical and communications equipment industries has less than a hundred employees. Probably the firms interviewed are not small even in international terms: in Germany (FRG), for instance, 62.4% of the firms in the mechanical industry had less than 100 employees, in 1972 (Braunling et al., (1976).

At the end of this process we chose 25 enterprises out of those studied by Tecnometal (equivalent to 66.7% of the value of production of that universe and including the ten largest Brazilian enterprises), to which we added ten more, producers of standard goods, to a total of 35 enterprises.

TABLE I-9:- DISTRIBUTION OF THE ENTERPRISES INTERVIEWED BY PURCHASING INDUSTRY; TYPE OF PRODUCT AND ROLE OF THE STATE

Industry	No. of Enterp. Nat.	For.	T	Type of Prod. CB	S	Role of S. P	F
Sugar & Alcohol	2	1	3	x			x
Railways (*)	4	1	5	x		x	
Steel (*)	2	-	2	x		x	
Mining (*)	3	-	3	x		x	
Cement (*)	3	1	4	x			x
Petrochemicals (*)	5	1	6	x		x	
Oil Extraction	2	-	2	x		x	
Paper & Cellulosis (*)	2	1	3	x			x
Shipbuilding (*)	3	1	4	x		x	
Electric Power (*)	3	4	7	x		x	
Road Building	2	1	3		x	x	
Agricultural Equipment (*)	3	1	4		x		x
Of Common Use:-							
Handling of Materials(*)	5	1	6	x		x	
Machine tools	5	1	6	x	x	x	
Electrical Machinery (*)	2	1	3	x	x	x	
Pumps & Compressors	-	1	1	x		x	
Industrial Electronics	2	-	2		x	x	

NOTES: N - National Enterprises; F: Foreign Subsidiaries

CB - Goods predominantly custom-built; S - Goods predominantly produced in batches, standardised.

P - State acts as a purchaser and financing agency; F - State acts only as the financing agency.

(*)- Enterprises which produce capital goods for those industries also produce for other industries as well.

TABLE I-10:- DISTRIBUTION OF INDUSTRIAL ESTABLISHMENTS IN THE MECHANICAL INDUSTRY AND ELECTRICAL AND COMMUNICATIONS EQUIPMENT INDUSTRY IN BRAZIL ACCORDING TO NUMBER OF EMPLOYEES - 1970

	Industrial Establishments - in Percentage	
Number of Employees	Mechanical	Electrical & Communics. Equipment
Less than 10 persons	34.2	31.3
From 10 to 50 persons	45.3	41.5
From 50 to 100 persons	10.6	12.7
From 100 to 500 persons	8.5	13.0
From 500 to 1,000 persons	0.9	1.2
More than 1,000 persons	0.5	0.3
Total	100.0	100.0
Total Number of Establishments	3499	1648

SOURCE:- IBGE (1974).

Because of the purpose of the study, the majority of those enterprises (27) were Brazilian-owned and it is on their behaviour that the following analysis concentrates. 1/

The interviews, conducted in the period from October to December 1972, were normally made with members of the Board of Directors of the enterprises and their technical staff, that is, people at the decision-making level. They often lasted a day long, being accompanied by visits to the plants.

A report of the research was written in 1973, and, after internal discussion, published as a book by FINEP (Erber, Alves, Araujo Jr., Reis and Redinger, 1974 ;henceforth referred to as Erber et al., 1974). It comprised, besides a description of the procedures, a brief analysis of the development of the capital goods industry in Brazil, the major findings of the study and a suggestion of a "package" of policies for increasing the degree of self-reliance of the Brazilian capital goods industry in terms of technology.

This set of suggestions was later used in drafting the policies of support to Brazilian enterprises incorporated in the First Basic Plan for the Development of Science and Technology. More immediately, the study spawned

1/ The foreign enterprises interviewed presented a very homogeneous behaviour, fully consistent with the literature for other countries. They relied practically exclusively on foreign technology, mainly from their parent companies and their associates, introducing minor modifications in this technology in order to adapt it to local conditions, especially size of the market and raw materials. Their main complaints about policy measures was, predictably, about the difficulty of paying the parent companies for patents and trademarks, which they cannot do, according to the Brazilian law (see Chapter V, Section 6).

a credit line in FINEP for financing local technological development by Brazilian firms (which is analysed in detail in Chapter V) originated by one of the cases found during the research.

For this dissertation, I have re-analysed 1/ all the reports of the interviews, drawing from them previously non-used material and comp ementing them with additional information I was able to get about the firms interviewed.

The structure of presentation is as follows:

In Chapter II, I discuss the choice of design strategy by the capital goods enterprises - developing its own design or using another enterprise's design - from the point of view of the firm.

Although the economic literature on technical progress has progressed substantially in its treatment of techno ogy from the "residual factor" approach, a considerable part of it still treats technical progress as a product of an R&D "black box" without specifying the activities and resources which are required to achieve such technical progress. This is apparent, for instance, in the lumping together of industries such as chemicals, drugs and machinery as "research-intensive" although the activities, information and personnel required in these industries are substantially different.

Such "black box" approach is not only analytically deficient and even sometimes misleading, as it implies an homogeneity of the "R&D factor" which

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1/ The analysis of the questionnaires when the FINEP report was written was made mainly by Sergio F. Alves.

in practice does not exist, but it is also troublesome in terms of policy-making, as it provides scarce indications for policy-makers about priorities and resources necessary if they want to achieve technical progress in specific industries, a selection which is critically necessary in the case of the LDCs, given their scarcity of resources.

Chapter II analyses first the different requirements which the design of capital goods have to satisfy, indicating the main trends in such requirements, based on an extensive reading of engineering literature and discussions with engineers. It then analyses the different stages of the design process and the resources needed for each stage, comparing licensing with the development of designs by the firm (which I will call, for short, self-reliance). It is an attempt, albeit limited, to open the "black box" for the case of capital goods.

The same Chapter compares the different implications of the two strategies in terms of survival and growth of the firm, arguing for a "mixed strategy" in which both are combined. Finally, it shows the support given by the State in the ACs to local design activities of their capital goods enterprises.

Chapter III presents a theoretical discussion of the reasons why the State may support design actixities in the capital goods industry, developing first the general arguments from the economic literature on R&D (e.g. Nelson, 1959; Arrow, 1962) for such support, and then discussing the licensing alternative in cmmparison with local development, focussing specifically on the case of the LDCs.

Chapter IV analyses the results of the interviews, interpreting them in the light of the arguments developed in the second Chapter.

Chapter V discusses in detail the main economic policies affecting the choice of design strategy of the Brazilian capital goods enterprises and the policy-making for the industry, covering the period from the mid-'fifties when the main features of the present structure of the industry were established, until approximately 1976; that is, including also the important changes in policies which were introduced after the interviews, some of which have the aim of stimulating local design in the Brazilian capital goods industry. Besides using secondary sources, this Chapter draws also on a study made at FINEP on the purchasing policies of State Enterprises in Brazil, presenting original material, as well as from my experience at FINEP and at the National Development Bank (BNDE).

Finally, Chapter VI presents an interpretation for the State policies and the strategy of the enterprises interviewed, based on the comparison between the reasons for State intervention discussed in Chapter III and the main traits of the Brazilian pattern of development. It concludes with a discussion of the possible implications of the recent policies adopted for the development of design capacity in Brazil.

Two appendices are included. In the first (Appendix A to Chapter II) I discuss the importance of re-design and copying for the capital goods industry. In the second (Appendix B, to Chapter V), I present two programmes of development of new industries in Brazil (mini-computers and aircraft engines) which are of considerable interest in terms of their technological strategy and institutional support.

As a conclusion to this Introduction, it is worthwhile to comment on the limitations of the following discussion that I perceive, intrinsic to the approach and the data used.

First, there are limitations related to the data used about the Brazilian capital goods enterprises. The sample used is, as already mentioned, relatively small, and it does not include small enterprises. Moreover, because of the somewhat ad hoc manner in which it was selected, an operational necessity, it is biased in favour of enterprises which tend to concentrate on custom-built equipment. Nonetheless, more recent studies on standard equipment such as machine tools (e.g. Bastos, 1976) corroborate our findings about the use of licensing and local development of design.

The choice of enterprises and the focus of the study on the State, as well as data availability, may have also given a too great emphasis to the policies of the State Enterprises in comparison with other purchasers of capital goods. Although the State Enterprises play a critical role for the development of the capital goods industry in Brazil and the data available indicate that, as regards the choice of design strategy by the capital goods producers, the influence of the other large companies (mainly foreign companies) is similar to that of the State Enterprises, a detailed study of the policies of other purchasers of capital goods, not done yet to my knowledge, would be of great interest. Where I had data available I have indicated the policies of other purchasers of capital goods besides the State Enterprises (see Chapter IV).

Therefore, the generalisation of the data from the interviews to the capital goods industry as a whole should be taken with caution, although the main trends observed about the use of licensing and development of local design can probably be generalised.

Turning to more general questions of approach, first, the following discussion concentrates on capitalist countries, that is, countries where there is a decentralised private ownership of the means of production and where enterprises take their decisions based on their assessment of the conditions of the market.

This relative independence of decisions remains true even if the State plays the important role it does in the Brazilian capital goods industry, although in such case the concept of "market determination" is only partially significant, in the sense that some of the main determinants of the decisions of the enterprises have to be sought at the level of the determination of the actions of the State.

The more centralised control implicit in a socialist economy, would pose different problems, which are not discussed here.

Also, a capitalist country is inevitably committed to a relative freedom of international movement of capital and commodities. Although this is often more honoured in theory than in practice, the problems involved in restricting such freedom, if necessary, would be much less in a socialist economy.

Finally, and most important, a socialist society, in order to develop new forms of organisation of production, may present the capital goods industry design requirements very different from those prevailing internationally, especially a socialist LDC. This is an important area of research which we shall not discuss here.

Second, the discussion is relevant especially to those LDCs which have achieved a stage of development which allows for a local production of capital goods, although, as pointed out before, in the discussion of the experience of the Brazilian capital goods industry, this probably tends to occur earlier than the literature on economic development normally suggests. Also the relevance will be greater for those situations where there is a well-developed State apparatus and especially where there are important State enterprises. Nevertheless, I hope that a similar analytical scheme might be useful for the study of other industries too.

CHAPTER II:

THE CHOICE BETWEEN DEVELOPING ITS OWN DESIGN AND USING ANOTHER ENTERPRISE'S DESIGN BY THE CAPITAL GOODS PRODUCERS

II.1: Introduction

In this Chapter the focus is at the enterprise level, analysing the main elements which bear on the choice of design strategy by a capital goods producer.

An important point to make from the outset is that the capital goods industry is characterised by a high degree of product differentiation and that firms within the industry tend to produce a wide range of products. A firm may combine the two strategies in its product mix for different products. Moreover, under certain conditions, it may use licensing as a basis for learning how to develop its own designs (a point which is further developed in Section 5). The analysis below is, in fact, especially concerned with this "strategy mix" of the firm.

Using an approach suggested by Jones (1966), we see the design process as a process of matching three sets of constraints (or "structures", to use his expression): (1) the demand, or "situation structure", i.e. the pattern of needs which the design must satisfy; (2) the "solution structure" - the physical structure of a possible machine, and (3) the "resources structure" - the availability of materials, manufacturing processes and their respective costs. In other words, design is essentially an exercise in compromise between considerations of technical, economic and social conditions.

In the following Section, we examine the main trends in "user's needs", showing the different requirements capital goods design has to meet, the differences between capital goods as regards such requirements and the implications of those differences for the choice of strategy.

In the next two Sections we analyse first, the design activities performed by the enterprise in the two strategies (Section 3), and then the different resources such activities require from the firm and its environment, (Section 4).

In our research on the methods used by capital goods enterprises to develop their own designs, we found the importance of re-design and copying-and-adaptation. Such methods have important advantages and limitations which deserve analysis in some detail. In order to preserve the focus of the discourse on the comparisons between the two strategies such analysis is included as an Appendix to the present Chapter. (Appendix A).

In Section 5, we discuss the probable outcomes of the two strategies for the enterprise and, bringing together the results of the preceding Sections, we analyse their different implications in terms of survival, growth and control of decisions for the enterprises, giving special emphasis to the strategy mix.

Finally, in Section 6, we discuss the role played by the State in the choice of strategy by the enterprise.

Although the strategy of using another enterprise's design normally involves more than a permission to use the latter's proprietary and non-proprietary knowledge (see Chapter IV for the Brazilian case), we shall call, for short, this a "licensing strategy" (LS). The strategy of developing its own designs we shall call "self-reliance strategy" (SRS).

II.2: Trends in Design Requirements - Differences Between Products.

In this Section we analyse first, the main trends in design requirements of capital goods in capitalist economies, and, in the last part discuss the differences between capital goods as regards the different weights of such requirements in their design.

(i) Quantity and specification of the final product:

A machine will be required by its purchaser to produce a given range of quantity of products with given characteristics. This will inform the specifications of the machine itself.

As regards quantity, there has been a marked trend towards larger scales of production in most branches of industry [1/] which has required an increase in capacity of capital goods. [2/]

1/ In metallurgical industries, for instance, the larger alluminium plants have grown since the Second World War from a capacity of less than 100,000 tonnes per annum to more than 300,000 t/a and in the steel industry new integrated steel works of more than 10×10^6 t/a capacity are no longer unusual, where pre-War capacities of 2×10^6 t/a were considered large (Feilden, 1973). In the chemical industry, increases have been even more dramatic. Perrin (1976) shows that for several products, such as estyrene, phenol and ethylbenzene, minimum size plants have increased over tenfold in the period 1960/1970-1975. (See Table II-1). Power generation and distribution systems all over the world have also shown a tendency to increase their capacity and the area covered (Surrey and Chesshire, 1972). Similar developments are observed in consumer goods industries.

2/ See (iii) below.

TABLE II-1: MINIMUM SIZE PLANTS FOR PETROCHEMICAL PRODUCTS - 1960 - 1970/72/75 ('000s TONS/YEAR).

	1960	1970/72/75	Coefficient
U.S.			
Ethylene	150	450	3
EUROPE	40	400	10
Vinyle chloryde	135	450	3
Ethylene oxide	45	150	3
Acrylonitrile	45	135	3
Phtalique Anhydride	15	45	3
Ethylbenzene	45	500 - 600	12
Estyrene	45	450	10
Phenol	25	315	12
Cyclohexane	60	150	2,5
Cumene	50	150	3
Isopropanol	50	220	4
Butadiene (extraction)	50	100	2
Steam-cracking	25	500	20
Ammoniac	80	500	6

SOURCE: Perrin (1976).

Concomitant with this increase in size, there has been an increasing emphasis on accuracy of operations reflecting stricter specifications for the final products.

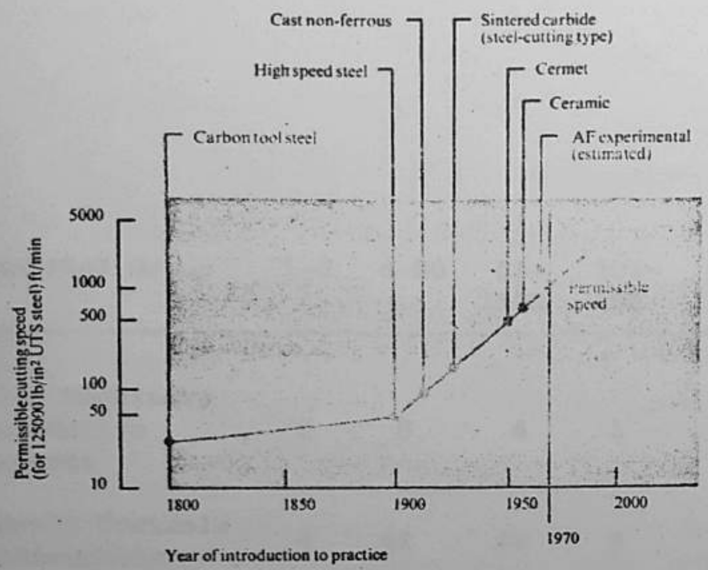
The trend towards an increase in capacity and accuracy of performance is not limited to heavy machinery - in lighter equipment, such as machine tools and handling equipment it is also observed. For instance, in machine tools there has been a great increase over time in the requirements for more power and higher speeds. Figures II-1 and II-2 illustrate the historical evolution of permissible cutting speeds and accuracy from 1800 to 1970. Recent reports, of the important machine tool exhibition held in Paris in 1975 (I EMO) indicate that the trend towards bigger, faster and more powerful machines continues (The Engineer, 28/8/75).

(ii) Versatility:

In many industries, reflecting product differentiation, there has been a trend also towards requiring greater versatility of the machines, so that they can produce a wide range of products. This is especially important in the metalworking industry, which is characterised by production in relatively small series. In the U.S., for instance, 75% of the production is of batches of less than 50 pieces (Merchant, 1973) and a similar situation is observed in the U.K., especially in the production of capital goods (see Table II-2).

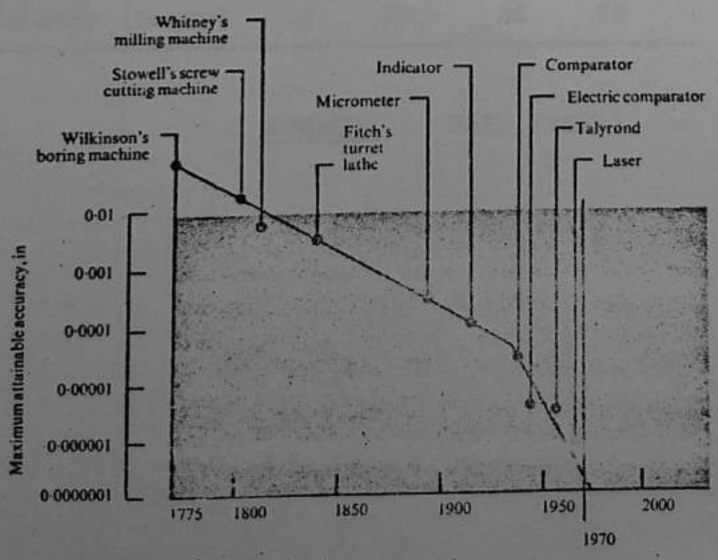
In fact, there is an increasing demand for flexibility in the performance requirements of machines (Merchant, 1973; The Engineer 15/5/75, 30/10/75), and it has been suggested that the trend in production is towards reducing the size of batches even further (Merchant, 1973).

igure II-1: Improvement of Tool Materials and Permissible Cutting Speeds



Source: Bell (1972)

Figure II-2: Improvement of Accuracy of Metal Removal



Source: Bell (1972)

TABLE II-2: RELATIONSHIP BETWEEN INDUSTRIAL GROUPS AND DISTRIBUTION OF WORK ACCORD NG TO BATCH QUANTITY.

Industrial Group	1-5	6-20	21-100	101-200	201-500	501-1000	1000	Total % age	Median Value
Office Machinery & Automotive Equipment	0	0	4	1	14	20	71	100	1200
Aircraft Controls & Instruments	4	42	46	3	2	0	3	100	23
Reciprocating Machinery (medium)	2	1	31	27	20	7	2	100	150
Rotating Machinery	41	22	32	0	5	-	-	100	9
Machine Tools	28	31	35	3	2	0	1	100	15
Reciprocating Machinery (heavy)	17	33	21	12	13	1	3	100	20

SOURCE: Bell (1972).

The most important development in the capital goods industry for the combination of high performance standards, automation and versatility has been through the use of electronic controls, especially numerical control (NC)[1/]. Such development has broken the link observed in the past between automation and large-scale production.[2/]

The application of NC to machine tools is especially important as those are the "machines which produce machines". As a trade journal has put it, "NC has been to batch manufacture what the transfer line was to mass production" (The Engineer, 30/10/75, p. 25). In the recent machine tools exhibition (I EMO) the "clearest trend" observed was the increase in

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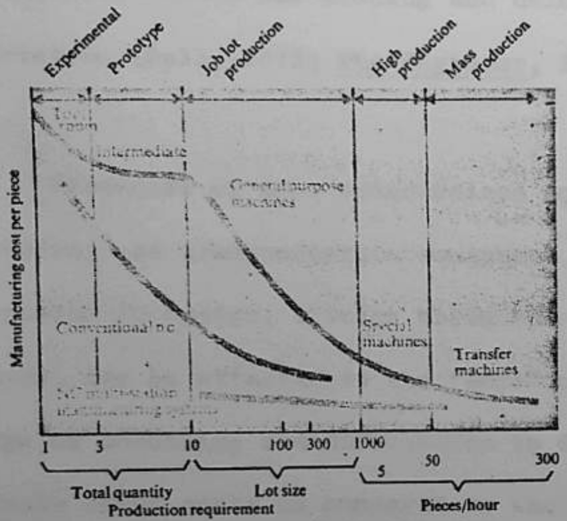
1/ Such controls cover nowadays a wide range, from "plug-board" systems, which have a relatively limited memory capacity and where information is usually fed manually, to "direct numerical control" systems, where the machines are directly linked to a computer, with almost infinite memory capacity, but they were called, generically, numerical control (NC).

2/ Almost up to the end of the 1960s machines in which the control system is automated, as it is in NC, were mainly special-purpose machines, where the memory of the control is built-in into the operational mechanism of the machine, so that changes in the memory were restricted and costly, involving changes in the operational mechanism. Such machines, because of their cost and inflexibility, were only usable for large-scale production, such as in durable consumer goods. Hence the link above-mentioned between large-scale, automation and special purpose (Bell, 1972). With the development of NC machines operating even in small batches can be automated and produced at competitive costs. Figure II-3 illustrates this, relating cost to number of pieces, but it should be remarked that the more complex the parts, the more advantageous is the operation of the numerically-controlled machine in comparison with conventional machines, as the process is not only more continuous but also more accurate (Bell, 1972).

However, it should be noted that NC machines still represent a minute proportion of the number of machines used - in the U.S., where they were first introduced, they accounted for circa 1% of the total stock of machines in use in the beginning of the '70s (Merchant, 1973) and in theU.K. the proportion was even smaller (circa 0.3% in 1970, according to Bell, 1972). However, in terms of value of the machines and of the output produced, their participation was much higher (circa 33% of the latter in the U.S. at the same time - Merchant, 1973) and, as discussed in the text, their participation tends to increase. In Brazil the local production of NC machine tools is beginning (see Chapter IV). The importance that conventional machine tools still command illustrates the heterogeneity of the demand for capital goods. This is an important feature of the market for the producers of the less developed countries, which may not be able to compete at the "frontier" of the technology.

Figure II-3: Manufacturing Costs, Obtainable with Numerically Controlled Multi-Station Manufacturing and Other Systems, Plotted Against Production Requirements



Source: Bell (1972)

the use of NC, with an increase in its complexity, with a shift from point-to-point controls to contouring controls, which are becoming the "norm" (The Engineer, 15/5/75).

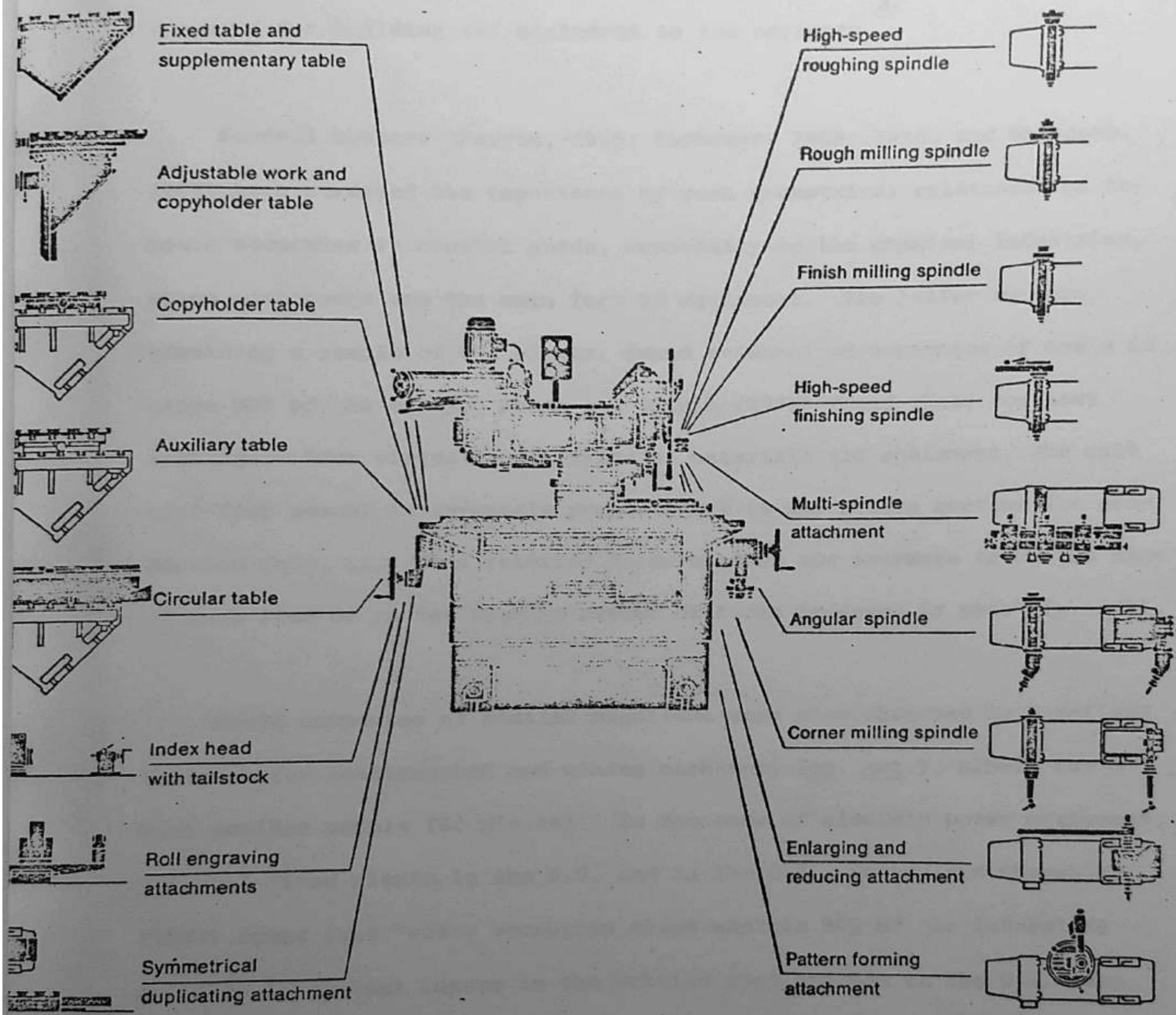
A similar development, in the direction of increased automation, higher technical performance and greater flexibility through electronic controls is observed in the materials handling industry, notably the developments in industrial robots for loading and unloading and in conveyors for transportation (Bell, 1972; The Engineer, 27/11/75).

Producers of more standardised equipment, such as machine tools, handling and transportation equipment, have also resorted to a "modular" approach in design, through which specific features, responding to specific needs, can be attached to the "core" of the machine. This has the advantage of combining standardisation in design and production (i.e. relatively lower costs as compared to wholly custom-built equipment) with versatility. The fact that the main development in this type of capital goods has been in the automation of their controls, helps this approach, as shown, for instance at the Paris exhibition, where many machine tools which featured numerical control, had not been designed from the outset for NC (The Engineer, 15/5/75). Figure II-4 gives a good illustration of modular approach in machine-tools.

(iii) Costs - Economies of Scale, Materials and design concepts:

Alongside with increases in the markets for the goods produced by the industries which demand capital goods and the processes of concentration which occurred in some of those industries, the trend towards greater sizes has been stimulated by economies of scale in the cost of capital goods, i.e. by the fact that the costs of the capital goods has increased proportionately less than their capacity.

Figure II-4: Example of Modular Approach in Machine-Tool Design - The Deckel KF System



Source: Deckel, 1977 Catalogue.

Such economies of scale in capital goods are related to the increase in the size of the capital goods enterprises (solving thus, problems of indivisibility of machinery and manpower); to learning factors 1/ and to a family of geometric relationships which relate the material and labour required for building the equipment to its capacity. 2/

Several authors (Perrin, 1976; Hufbauer, 1966; Haldi and Whitcomb, 1967) have stressed the importance of such geometrical relationships for scale economies in capital goods, especially in the chemical industries, where containers **are the main form** of equipment. The latter authors, examining a sample of 662 plants, found evidence of economies of scale in circa 90% of the cases. Fraas and Ozisik (1965) found that, for heat exchangers "for virtually all types of materials and equipment, the unit cost (per pound) is inversely proportional to the square root of the production rate. ... This relation holds whether the increase is in the size of each item or in the average number of items produced by year" (p. 141).

Scale economies of similar magnitude were also observed by Haldi and Whitcomb for construction and mining machinery (<u>op</u>. <u>cit</u>.), albeit for a much smaller sample (25 plants). In the case of electric power equipment, for coal-fired plants in the U.S. and in the U.K., Surrey and Chesshire (1972) found that "scale economies alone explain 60% of the interplant variance in capital inputs in the British case and 63% in the U.S. case. The really important scale variable in both cases is the size of the turbine generator". (p. 162).

1/ Learning results in increased productivity and it is the outcome of accumulated experience (Arrow, 1962b). It is more fully discussed, with special reference to the design activities, in Sections 3 and 4 and in the Appendix to this Chapter (see Appendix A).

2/ The most important seems to be the relationship between the surface and the capacity of containers (tanks, furnaces, pipes, etc.). While capacity increases with the cross-sectional area (πr^2), the material and labour requirements depend on the circumference of the container ($2\pi r$), i.e. the latter increases proportionately less than the former.

Economies in capital costs present a powerful incentive to the customers of capital goods to commission bigger and more powerful units. But it should be noted that higher performance requirements often tend to push up the construction costs of capital goods, counteracting, to some extent, the effects of economies of scale.

For instance, more complex materials, often needed for special functional requirements, are frequently very expensive, especially if they have to be submitted to accurate quality controls (as an example, the cost of a plate fin and round tube radiator for a nuclear power plant is about ten times as much per square foot as the value for aluminium fins on plain carbon-steel tubes- Fraas and Ozisik, 1965).

Therefore, there is a great economic pressure for a careful search for materials and components that will be as cheap as possible and still fulfill the technical requirements.

Similarly, the more parts a machine which is subjected to tight performance requirements has, the more it will cost to manufacture and the higher will be its probability of failure. So, there will be a pressure for simplicity in the design concept, trying to reduce the number of parts, structuring the machine in such a way that their repair or replacement is as easy and quick as possible and specifying the parts so that maximum standardisation and minimum risk are achieved.

The trends previously noted in automation and accuracy of operations serve also the purpose of reducing the operational costs of the machines, reducing down-time and wastage of materials. In metal-working, for instance, 2,000 MW power station project of L. 350 m. would cost the Board between L. 59 m., and L. 84 m., not including the cost of replacing the missing electricity from older and less efficient plants, which would cost from L. 30 m. for fossil fuel to L. 110 m. for a nuclear plant. Similar estimates of the consequences of delays in equipment delivery are presented by The Engineer (15/5/75), especially for chemical plants.

It is important to note that although capital goods sales often include clauses of performance guarantee and delivery date, with fines attached in case of non-compliance by the capital goods suppliers, those elements of insurance are often insufficient to compensate the purchaser for its losses, especially in case of prolonged interruptions of production and long delays in delivery (The Engineer, 15/5/75).

(v) Labour Use ~~and Capital~~

Special mentinn should be made to the manpower requirements and the economies resulting from the developments previously analysed, because of their wider implications.

Metal-working has traditionally been a stronghold of highly qualified manpower, inclusive at the shop-floor level (Landes, 1972), demanding considerable skills and often relatively extended formal training and apprenticeship, lasting several years (seven years is not unusual for a toolmaker in the U.K. - Financial Times, 3/4/76). In the U.K. for instance, in the mechanical engineering industry, craftsmen in skilled occupations represented over a third of the manpower employed in 1970 (EDC, 1971).

The discussion of the results of automation in terms of manpower (Bright, 1966; Bell, 1972; Braverman, 1974) shows that the trend is ultimately towards a reduction of the overall number of skilled personnel and a concentration of the more skilled in the management, conception and control functions (including R&D and design activities) and away from the shop-floor.

Therefore, for the user of the machines, the increase in automation will result in higher productivity of the remaining work-force at the shop-floor, whi nh, as shown by Bright (1966) and Braverman (1974), will only in part , be offset by higher maintenance costs.

For the owner of the machines, automation has also the concomitant result of reducing the control exerted by workers upon the labour process, a result of important political consequences, which it is not possible to discuss here in detail. 1/

In contrast with the requirements previously analysed, this is seldom made explicit. As Braverman (1974) points out, "the design which will enable the operation to be broken down among cheaper operators is the design which is sought by management and engineers, who have so internalised this value that it appears to them to have the force of natural law or scientific necessity" (p. 200). It is a useful example of how technical considerations are constrained by economic and political determinants.

Nonetheless, the reaction of workers to developments in machinery as regards employment, safety intensity of work, etc., are often taken into consideration in the advanced countries, as shown for instance by the observation of The Engineer (30/10/75) that "an interesting bonus of multiple-spindle machines has been that they are often acceptable to trade

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1/ Dickson (1974) put in a "modern" parlance - "machines might therefore be looked upon as the means by which the capitalist class reduced the entropy - or tendency to disorder of the whole productive system" (p.81) what Ure (1835) had stated in a blunter way, when celebrating the introduction of Roberts' spinning machine; "this invention confirms the great doctrine already propounded, that when capital enlists science in her service, the refractory hand of labour will always be taught docility" (quoted in Dickson, 1974, p. 80).

unions as a method of increasing productivity. Apparently, three spindles to one machine is easier to swallow than three machines to one operator" (p. 29).[1/] In this sense, the producers in the more advanced countries are at a disadvantage compared with their competitors in the less developed areas, where, by and large, the work-force is much less organised.[2/]

(vi) Differences between industries and products:

The emphasis given to the different requirements above discussed varies considerably according to industries and the success of a specific design depends heavily on the capacity of the capital goods producer to establish a compromise appropriate to its customers characteristics.[3/]

As shown by the BIPE (1972) study, where the demand is concentrated in a few enterprises with considerable financial resources available and with high performance requirements (e.g. power generation, aircraft, automobiles, steel, chemicals, armaments), the cost constraint tends to be

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1/ Such constraints on design are often embodied in legal norms. Other legal constraints bear upon the design process such as norms on environment protection and protection of property rights (patents etc.).

2/ Some authors, such as Gambino (1972) and Palloix (1975) have recently stressed the importance of worker's resistance to changes in machinery and especially to automation. The latter suggests that such resistance may lead to a drastic change in the division of labour within the capitalist system, with more directly productive (shop-floor) activities being shifted to the less developed countries, where the labour force is less organised, while the activities of conception of commodities (research and development and product and process engineering) would be retained in the advanced countries. The realisation of detailed design activities in the less developed countries would be consistent with Palloix's suggestions, which include the manufacture of capital goods in some of the more advanced of the less developmd countries (e.g. Iran, Brazil).

3/ The importance of "appropriateness to users' needs" in the success of innovations has been stressed by several studies, covering, among others, some capital goods industries (e.g. textile machinery, metalworking machinery). Such studies are analysed and compared in Freeman (1974) and Rothwell (1976).

reduced and the main concern will tend to be with the technical characteristics of the product - especially its performance and reliability - and with the capacity of the manufacturer to design and produce it with the required characteristics and in due time.

Products of this type of industries, particularly those which constitute the core of their productive processes, are normally custom-built i.e. especially designed and manufactured for a specific customer, normally as individual units (one-off) or in small batches. Being non-standard goods, there is a close identification of the product with the producer (i.e. the technology is highly firm-specific).

Partly in order to minimize risks of performance and delivery, assessment of the producer is normally based on past performance of similar products and often a privileged relationship is established between a customer and its supplier, which is often maintained for long periods (Surrey and Chesshire, 1972), so that new producers operating with their own designs face an important barrier to entry in such markets. As orders for such products tend to be irregular in time and limited in most national markets, producers often have to operate on an international scale, which heightens further the problems of entry. Policies of "buy natinnal" are often found for such products (Palloix, 1975; Surrey and Chesshire, 1972) and also make entry to new producers more difficult.

Even in the advanced countries, the capital goods produced for the industries which stress quality above costs[1/] represent a relatively small portion of the total production of capital goods (this is shown in Table II-3 for the mechanical industry in France, Germany and the U.S.). Never-

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1/ The BIPE (1972) calls them "industries of intensive demand", and the related capital goods are usually known as heavy engineering products.

TABLE II-3: MECHANICAL MACHINERY 1/ IN THE ADVANCED COUNTRIES - ACCORDING TO THE CHARACTERISTICS OF THE DEMAND - IN PERCENTAGE OF VALUE OF SALES - 1966.

Type of Demand/Branches	France	US	FRG
1) Branches of "Intensive Demand" 1/	24.5	21.5	16.4
Products for Electric Power Generation	4.5	2.8	2.1
Specialised Heavy Equipment	9.6	10.8	9.9
Railway Equipment	10.4	7.9	4.4
2) Branches of "Extensive Demand" 1/	75.5	78.5	83.6
General Industrial Equipment	11.0	8.9	10.0
Speciali ed Industrial Equipment	19.2	18.7	31.0
Metalworking	15.3	15.9	19.2
Equipment for Public Works	8.3	13.5	7.1
Agricultural Equipment	17.8	13.6	13.8
Precision Equipment	3.9	7.9	2.5
Total	100.0	100.0	100.0

NOTE: 1/ Excludes machinery for domestic use.

SOURCE: BIPE (1972).

theless, they play a crucial role in the process of technological development of the industry, as often the most radical innovations are introduced first in those products and later on are diffused to other branches of the industry (e.g. NC machine tools which were originally developed for the aircraft industry).

Where the demand for capital goods is characterised by a diversification of users, from different industrial sectors and especially where such users tend to be medium and small enterprises, there will be more emphasis on cost constraints and versatility in design, allowing for multiple use of capital goods (BIPE, 1972).[1/] Although trademarks are often important (e.g. in agricultural machinery) and experience plays an important role in reducing costs via learning, the barriers to entry to new producers with their own designs tend to be smaller than in the group of products examined above, especially if the products present a relatively low cost.

Such products, among which we find a substantial part of machine-tools, handling equipment, transportation equipment, agricultural machines, etc., (see BIPE, 1972 for list, pp. 29 & 30), constitute the main part of the production of the mechanical industry in the advanced countries (see Table II-3).

From the discussion above, we see that the general structure of the industry (its distribution by branches) and its pattern of growth have a deep influence on the degree of self-reliance which a capital goods industry can achieve. Where in the industrial structure predominate the industries of "intensive demand" the degree of SR that can be achieved in an LDC is

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1/ Called "industries of intensive demand" by the BIPE (1972), they can be equated to "medium" and "light engineering" consumers.

reduced, especially when the purchasers of capital goods have traditional links with capital goods suppliers from abroad or which operate with licenses. In such cases, SR may be even totally precluded by the unwillingness of purchasers to take the higher risks (performance, reliability, delivery) implicit in the use of an untried (or less tried) design.[1/] As the risk assessment is to a considerable extent subjective, the customers of capital goods usually have considerable room for exerting their eventual prejudices and vested interests in the continuation of the use of imported technology (see Chapter V on State Enterprises in Brazil).

In the Brazilian case, it is worth noting that in the Post-Secnnd World War period, there was a marked shift in the industrial structure, from "traditional" (mainly non-durables) consumer goods to intermediary products, durable consumer and capital goods (see Table II-4),[2/] therefore tending to to increase the complexity of the capital goods required. The participation of foreign subsidiaries is especially strong in the most dynamic sectors (see Chapter I). In manufacturing industry as a whole, there was a trend towards increasing the size of industrial establishments, especially through the reduction of the importance of establishments with less than 20 employees (see Table II-5).

II-3: Activities of Design Performed in the Two Strategies

3.1) Stages of design:

It is generally accepted that a design passes through three main stages:- feasibility, preliminary design and detailed design and that designing is a decision process demanding analysis, synthesis and

1/ As seen above, even in the advanced countries, the purchasers of the capital goods bear most of the risk.

2/ Such aspects are well examined in MPCG (1969) and Suzigan *et al.*, (1974) for the periods of, respectively, 1949/1966 and 1966/1972.

TABLE II-4: DISTRIBUTION OF OUTPUT AND GROSS VALUE-ADDED IN MANUFACTURING INDUSTRY - 1949, 1959, 1970 - IN PERCENTAGE, IN BRAZIL.

	OUTPUT			VALUE-ADDED		
	1949	1959	1970	1949	1959	1970
Traditional Consumer Goods	**63.9**	**47.6**	**39.5**	**56.5**	**41.4**	**35.2**
Textiles	18.6	12.5	9.4	19.6	12.0	9.5
Clothing & Footwear	4.3	3.4	3.3	4.3	3.6	3.3
Food	31.9	24.1	19.7	20.5	16.4	13.1
Beverages	3.2	2.4	1.9	4.5	2.9	2.3
Tobacco	1.4	1.1	1.0	1.4	1.3	1.3
Printing & Publishing	2.8	2.3	2.5	4.0	3.0	3.7
Furniture & Fixture	1.7	1.8	1.7	2.2	2.2	2.0
Intermediate Goods	**29.5**	**37.3**	**40.1**	**36.1**	**42.0**	**42.1**
Non-Metallic	4.5	4.5	4.1	7.1	6.6	5.8
Metallurgy	7.6	10.5	12.6	9.4	11.8	11.7
Wood	3.4	2.6	2.2	4.2	3.2	2.4
Paper	2.0	2.0	2.5	2.2	3.0	2.6
Rubber	1.6	2.5	1.7	1.9	2.9	2.0
Leather	1.5	1.0	0.7	1.3	1.1	0.6
Chemicals & Plastics	5.4	9.6	12.7	5.6	9.5	12.1
Pharmaceuticals	1.9	2.0	2.2	2.8	2.5	3.4
Perfumes	1.7	1.5	1.4	1.6	1.4	1.6
Capital Goods E Durable Consumer Goods	**5.3**	**13.6**	**18.8**	**6.0**	**15.0**	**20.6**
Machinery	1.6	2.8	5.7	2.1	3.4	7.1
Electrical	1.4	4.0	4.8	1.6	4.0	5.4
Transportation Equipment	2.3	6.8	8.3	2.2	7.6	8.1
Miscellaneous	1.2	1.3	1.6	1.6	1.8	2.1
Total Manufacturing Ind.	100.0	100.0	100.0	100.0	100.0	100.0

SOURCE: IBGE, Censo Industrial 1950, 1960, 1970

in Kannay et al (1976)

TABLE II-5: NUMBER OF FIRMS AND PARTICIPATION IN TOTAL.

Firm Size	1959		1970		Share In Value-Added		Share In Employment	
	Number	Percent	Number	Percent	1959	1970	1959	1970
5 to 9 employees	20,381	48.6	27,529	44.0	5.7	4.0	7.5	7.7
10 to 19 employees	9,951	23.7	15,382	24.6	6.8	6.2	8.1	8.9
20 to 49 employees	6,398	15.3	10,972	17.5	10.4	11.6	12.3	14.3
50 to 99 employees	2,467	5.9	4,331	6.9	9.4	12.1	10.6	13.1
100 to 249 employees	1,572	3.8	2,752	4.4	15.4	20,9	15.3	18.5
250 to 499 employees	654	1.6	1,027	1.6	15.2	17.9	14.6	15.7
500 and more	468	1.1	634	1.0	37.1	27.3	31.3	21.8
Total	41,899	100.0	62,627	100.0 1/	100.0	100.0	100.0	100.0

NOTE: 1/ The 1970 census does not provide information of 40 establishments which belong in the last interval.

SOURCE: Kemreny *et al*. (1976).

evaluation. Asimow (1962) has suggested a widely accepted presentation of the design process, combining the two dimensions; he further subdivides the three main stages of design into 25 stages and each stage is an iterative loop into which is fed the outcome of the last stage together with new information or an appropriate mode of analysis. Within each loop there is a stage of synthesis followed by a stage of evaluation. Figure II-5 reproduces his scheme.

Despite the complexity of the design process due to feed-back and revaluation, the discussion is based on the simple three-stages categorisation, as this is sufficient for the analysis of the activities and resources needed by each of the two strategies.

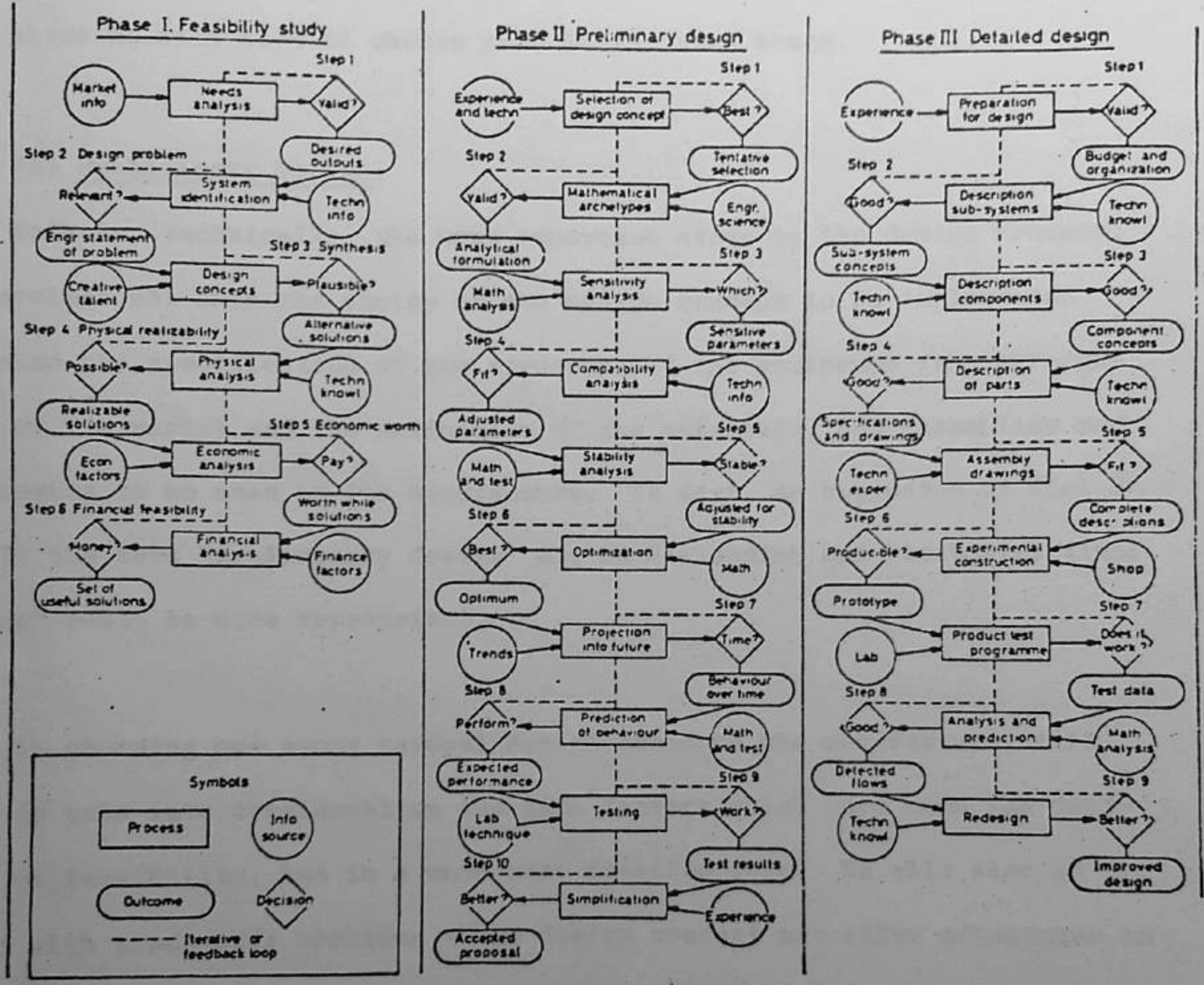
(a) Feasibility Stage:

At this stage, the manufacturer is likely to treat the design problem, from the technical point of view, as a "black box" (Leech, 1972) - i.e. as a non-detailed activity which mediates resources and constraints (inputs) and a desired outcome. The needs [1/] - the "sponsor's requirements" in the design jargon - will be submitted to a preliminary analysis in order to determine the essential functions the equipment must perform (the output of the black box). [2/] Such functions will have to be considerably disaggregated and specified, transforming the "needs" into specific performance requirements (e.g. speed of transformation or transfer, capacity of containment and support), which are further constrained by other requirements (delivery times, safety conditions, etc.), previously examined.

1/ The design process invariably starts from a need recognition. In the case of capital goods, this is often a result of customers' requirements (often one specific customer, as in the case of special purpose-built goods) or it may originate from sources inside the firm, such as the R&D Department or the sales personnel. It may be prompted by new technical opportunities opened up by research efforts, innovations introduced by competitors or difficulties found by customers in the operation and maintenance of equipment previously manufactured by the enterprise.

2/ Gregory (1966) suggests that all engineering functions can be classified as either systems functions (transformation or transfer), container

Figure II-5: The States of Design



Source: Asimow (1962)

If, by confronting the resources available (the inputs to the black box) with the above-mentioned requirements and restricting factors, the manufacturer decides that prima facie the equipment is feasible for his company, he may end up with a set of several feasible design concepts, from which he will have to choose one, in the next stage.

(b) Preliminary Design:

This is, technically, the most important stage in the design process. It involves not only the choice of the design concept to be implemented but also the specification of the structure of the equipment (the arrangement of its parts) and the definition of the materials, sub-assemblies and components to be used in its manufacture. In fact, as suggested by Edel Jr. (1967) the term "preliminary design" may be misleading and "tentative final design" would be more appropriate.

In choosing one among several design concepts the manufacturer will have to take into consideration the same factors which bore upon the decision on feasibility, but in a much more detailed form. He will also be faced with trade-offs problems - one design concept may offer advantages in one respect which have to be set against different advantages of alternative concepts.[1/]

At this stage, the manufacturer becomes commited to one specific concept. Generally, abandoning that concept for another at a later stage of the design process, entails considerable costs, not only in terms of expended

1/ For example, numerical control machine tools have the advantage over conventional machines of greater precision and reduction of operational costs by using less skilled operators, but on the other hand, they tend to increase pre-production costs because of programming, as well as maintenance costs (Bell, 1972).

labour and capital, but also in terms of delivery time and lead time over competitors.

The preliminary design stage is also critical because, following the choice of the design concept, it is at this stage that the major components of the equipment will be defined. Accurate layouts and three-dimensional models of the equipment will be produced in order to specify the structure of the equipment and each of the main components will be tentatively specified as regards their functional requirements and their physical and chemical characteristics. [1/] Standard and smaller hardware items, which are assumed to be available and able to be fitted into the proposed design, are normally left for the detailed design stage.

The specification of the main components determine not only their performance but also their costs (defining the material of which they are made and, in many cases, their manufacturing process) and their delivery time (e.g. specification of non-con entional shapes or materials and components may imply more testing, or more search for different suppliers of parts or materials).

Therefore, the main elements which will determine the competitive possibilities of a capital good - technical performance, cost and delivery time - are defined at the preliminary design stage, even if there are some feed-back loops from one stage to another.

Tests on scale models and, when possible, full-size prototypes are normally made and, after the preliminary design has been modified accordingly, the project is ready for the detailed design.

1/ Such as, for instance, strength factors (bending, torsion, tension, compression, fatigue strength, impact strength, creep and temperature properties), stiffness factors, corrosion resistance, frictional characteristics, etc.

(c) Detailed Design:

Here the main consideration is to provide information for production as each part is drawn in detail in order to be manufactured. Emphasis will then be placed upon dimensions and tolerances [1/] (Edel Jr., 1967; Lent, 1951). The greater the availability of standard parts in the economy (a result of the division of labour and size of markets) and the less the restrictions placed by the preliminary design on the use of such parts, the easier will be the work at this stage. In the advanced countries, where extensive and detailed standards have been codified and are widely used throughout industry (BS in the U.K., ASA in the U.S., DIN in Germany) the detailed design is rendered easier by reference to those standards. The designer must consider also, the other subsequent stages of production, such as inspection and assembly. Moreover, he must bear in mind that the component is part of a system, so that if changes are introduced in the preliminary design, they have to be so as not to jeopardise the overall performance of the system (Edel Jr., 1967).

(d) Comparisons between the Stages

The relative importance of the three stages of design will depend o largely on the novelty of the product for the enterprise. Whereas with innovative design or completely new designs feasibility is of primary importance, [2/] when the product is wellknown to the enterprise, the emphasis is on optimisation of the characteristics of the product, at the preliminary design stage.

As in the capital goods industry there is a considerable use of re-design (see Appendix A) the preliminary design stage is often the most important stage in the whole process.

1/ When drawing and production are integrated in one unit within the enterpris, the drawing specifies the tools and operations; when they are separated the part is described by its dimensions, tolerances, surface finish, etc and the tools and operations are decided by the shop in charge of producing the parts (Lent, 1951).

2/ As Gregory (1966b) aptly puts it: "where the design is highly developed there is usually little formal questioning of feasibility and the stress is on optimisation. On the other hand, with innovative design or completely new design, optimisation is almost impossible....

The three stages of the design process above discussed, require different skills and information. At the feasibility stage the decisions taken must be informed by the product requirements vis-a-vis an overall picture of the enterprise, of its product mix, of its resources and those of its competitors. The upper levels of management are normally involved in this decision.

Although the same elements must still be considered at the preliminary design stage, the emphasis there is on the definition of the characteristics of the product. Compared with the detailed design stage, the former requires skills of analysis and conceptualisation far superior to the latter, as well as a broad range of information of scientific and technical nature, including the availability of materials, components, etc.; in contrast with the more restricted concentration of detailed design on more specific manufacturing problems, normally related to the manufacturing possibilities of the firm itself and of its suppliers.

This implies that, notwithstanding the iterative nature of the design process, the capacity to perform detailed design does not imply the capacity to produce preliminary designs - moving from the former to the latter requires the enlargement of the skills available and a greater capacity for gathering and processing information.

In many firms, especially the larger organisations, the detailed design work is carried through by a different group from that which elaborated the preliminary design - the production engineering group. Reflecting their much more restricted degree of freedom as regards the definition of the main characteristics of the equipment and the more routine type of work, detailed design work is often assigned to sub-professional personnel, under the guidance of engineers.

(e) Stages of Design and the Two Strategies

The main difference between the two strategies as regards the performance of design activities lies at the preliminary design stage, which the firm which follows a licensing strategy, delegates to its licensor. In both strategies the firm must go through the feasibility stage, although in the licensing strategy the analysis tends to concentrate more on the economic and financial aspects as it is assumed that the licensor can solve the main technical problems involved. Although licensing may include the realisation of the detailed design by the licensor, this stage is often performed by the licensee, especially in international transfers, 1/ because of the need to adapt the specifications to local conditions of production (raw materials, components, standards, etc.)

The division of labour between licensor and licensee combined to the difference in skills used for the stages of design each party performs - preliminary design by the licensor only; detailed design by the licensee eventually - has two important consequences. First, the licensor retains the technical control of the design process; second, if the licensee wishes to use licensing as a basis for achieving SR, it must develop its own preliminary design capacity independently from licensing and use the latter in a process analogous to reverse engineering (see Appendix A). In the absence of such independent development of preliminary design capacity the licensee will continue to be dependent on the licensor for any important changes introduced in the product. The implications of the points above for a comparison between the strategies are further disuussed in Section 5 of this Chapter

1/ If the conditions of the two countries are very distinct, adaptation (which may be costly) is almost inevitable as shown, for instance, in the case of the transfer of technology for the aircraft industry from the US to Japan (Hall & Johnston, 1970), which is worth quoting; especially as Japan was at the time (mid-'fifties) already an advanced industrial country, with widespread general and firm-specific knowledge:

"The blue-prints, design drawings and similar data transferred had to be adapted because of the differences between manufacturing practices in the two countries. First, they had to be 'up-graded', that is, made more detailed, because US tool-makers and machinists are expected to surmise more than are their European and Japanese counterparts. Second, the data and drawing in the early programs had to be translated into Japanese and into the metric system" (p. 318).

"The revision of US drawings to make them compatible with Japanese shop practices required a considerable fraction of the US technical assistance efforts" (ibidem).

"The point is obvious but vital. Sophisticated technology can seldom be transplanted without adaptation to local practices and skill levels. The costs of such adaptation are often significant". (Hall&Johnson, 1970, p. 317)

3.2) Design and R&D:

In terms of the categories of R&D more often used in the literature on innovation, according to the international definitions, as long as the design is for a new product, the feasibility and preliminary design stages should be included in "development"[1/] and detailed design excluded, although it is worth noting that according to the OECD's Frascatti Manual, "possibly the greatest source of error in measuring R&D lies in the difficulty of locating the cut-off point between experimental development and other technological activities" (Freeman, 1974, p. 322). This is especially important in the case of the capital goods industry, where design and development are often part-time activities, due to their incremental nature, (see Appendix A), and where detailed design should be excluded from R&D.

In the OECD countries, the bulk of R&D expenditure in the electrical and non-electrical machinery industries is related to "development" instead of "research". This is shown in Table II-6 where R&D expenditures for the main four countries in the OECD are broken down according to basic research, applied research and development. In both groups[2/] development is the main component - in no case less than two-thirds of the expenditures and, in the U.S. case, above 80%. Design activities correspond to a considerable, although not possible to identify precisely, part of development expenditures.

1/ Strictly speaking, in the feasibility stage, only the preliminary analysis of requirements should be included. Economic and financial feasibility studies should be excluded.

2/ There are considerable problems of aggregation involved in such data as several countries present data for electrical machinery together with electronic equipment and components, and sometimes (e.g. in the U.S. case) include in "machinery" R&D expenditures those expenditures related to computers ("office machinery") and those related to instruments.

TABLE II-6: BREAKDOWN OF R&D ACTIVITIES FOR THE MAIN OECD COUNTRIES - 1971.[1] IN PERCENTAGE OF TOTAL EXPENDITURE ON R&D.

Country	Basic Research	Applied Research	Development
A - MACHINERY			
US	1.1	13.7	85.1
UK	8.1	16.3	15.6
Japan	5.8	21.0	73.2
FRG	2.5	97.5 (Applied Research + Development)	
B - ELECTRICAL MACHINERY [2]			
US	3.2	14.9	81.9
UK	2.0	25.3	72.7
Japan	7.7	23.5	68.8
FRG	7.3	92.2 (Applied Research + Development)	
C - DRUGS			
US	19.7	35.9	44.3
UK	6.0	55.8	38.1
Japan	29.4	24.9	45.7
FRG [3]	11.8	88.2 (Applied Research + Development)	
D - TOTAL MANUFACTURING			
US	3.4	17.5	79.2
UK	4.0	20.2	75.7
Japan	9.4	26.5	64.1
FRG	7.3	92.7 (Applied Research + Development)	

NOTES: 1/ UK data for 1963. 2/ US & FRG include Electronic Equipment & Components. 3/ Includes chemical

SOURCE: OECD (1975).

Therefore, to label the capital goods industries as research-intensive, as is often done, au pair with industries such as chemicals and drugs, is probably misleading, as regards the type of activity and resources necessary for their technological development. "Development-and-design" intensive would probably be more accurate.

In this respect, the emphasis of the economic literature on innovation on R&D has probably been unfortunate, especially since it has tended to treat R&D as "black box", as an undifferentiated set of activities. Even where differentiation has been introduced, the emphasis has normally been laid on research. Although this may be appropriate to the industries which have often served as a "paradigm" for the literature (mainly chemicals and electronics), it is not appropriate for the machinery (electrical and non-electrical) industries, as well as probably for many other industries.

In fact, the capital goods industry is not an industry which is directly and immediately science-based, as presently are, for instance, electronics or chemicals, in the sense that new scientific information is a necessary and continuously sought after input for the development of the industry.[1/]

Even where the design of equipment does need scientific inputs, such as for electrical equipment, and equipment for chemical industries, in the majority of the cases such knowledge (as Fourier and Newton's equations for the design of heat exchangers (Horsley, 1970)) does not require the realisation of basic (and even applied) research by the companies using it. The

1/ Bernal (1965) goes as far as to say that "the basic engineering products, even the relatively novel automobiles and aeroplanes, and the methods used in constructing them ... still remain based on the science of the nineteenth century rather than on that of the twentieth century." (p. 725).

case of the electrical industry is, to use Bernal's comment, "an ideal example of a purely scientific industry depending on skill and ingenuity in using a limited set of principles for the solution of an ever-increasing range of practical applications" (Bernal, 1965, p. 616, my emphasis).

A similar point is made by Vickers (1966), that most branches of engineering "move in regions where only one or at most two aspects of their design are on the fringes of knowledge" (p. 48), and he adds the important consideration that too often in the capital goods industry, "development" activities are just concerned with the correction of poorly done previous design.

This feature of the capital goods industry is one of the roots of the extensive use of re-design in the industry (see Appendix A), - if new scientific inputs were continuously being introduced, changing the basic concepts of capital goods, such practice would be more difficult. As it is, "skill and ingenuity", which derive largely from experience, are still the main factor in the design of capital goods.

Nevertheless, there is a consensus among analysts of the design process, that the present trend is towards a reduction of empiricism and greater reliance on scientific information, inclusive for the re-design of machines, although this information is not necessarily, nor often, the result of recent research, requiring only the use of a "limited set of principles".

Despite their conceptual and statistical limitations, R+D data are the only ones that are systematically collected, so that we shall use them, with the reservations already expressed.

Table II-7 presents data on the "R&D intensiveness" of the electrical and non-electrical machinery industries, in terms of the ratio of R&D expenditures to value added, for ten OECD countries in the period 1967/1971, covering three Internatinnal Statistical Years (1967, 1969, and 1971). The Table shows also the ranking of those two industries in terms of research-intensiveness among 15 industrial groups, their participation in total manufacturing R&D expenditures and the extent to which R&D expenditures are company-financed.

The data in Table II-7 confirm that the electrical machinery (plus electronic equipment and components) is considerably more R&D intensive than non-electrical machinery, as well as accounting for a greater share of manufacturing industry's R&D expenditures. Electrical machinery, in fact, ranks high among all industries, in terms of R&D intensiveness while, except in the U.S. (but see preceding footnote) non-electrical machinery has an R&D intensiveness below the average of total manufacturing industry and its ranking is normally on the middle-range.

Another important implication of the data shown in Table II-7 is the great international concentration of R&D expenditures - for both groups of industries, the "big four" (U.S., Japan, Federal Republic of Germany and the U.K.) account for over 80% of the ten countries' R&D expenditures (almost 90% in the case of machinery plus instruments). (See Table II-8[1].)

1/ Again, it should be stressed the statistical problems involved in this sort of comparison. Besides the problems already mentioned there are the thorny problems of differing international R&D costs (especially labour costs) and the problems of converting those costs to a common denominator. I have used Walker's (1975) estimates, which are based on Freeman and Young's (1965) R&D-exchange-rates, estimates for 1962 and the only available. (See Walker, *op. cit.*) for a full discussion of the procedures adopted.

Nevertheless, the order of magnitude of the concentration is unmistakable, and it is unlikely that it would be greatly altered by more precise estimates.

Industry	R&D Intensity	USA	Belgium	France	FRG	Italy	Netherlands	UK	Sweden	Japan	Canada
Electrical machinery, electronic equipment and components	a	7.09	6.60	7.05	7.85	5.05	8.28	7.35	9.33	6.48	5.14
	b	15.68	7.13	13.39	9.03	6.98	9.16	11.85	10.75	6.33	7.34
	a/b	0.45	0.93	0.53	0.87	0.72	0.90	0.62	0.87	0.98	0.70
	c	2(3)	4(5)	2(3)	2	3	5(6)	2(3)	2	2	2
	d	1272	29.2	191	429	71.5	90.4	377	64.4	587	76
Machinery	a	2.96	1.86	1.01	1.98	0.45	5.11	2.25	3.76	1.39	1.18
	b	5.02	1.92	1.69	2.56	0.66	5.65	2.77	3.92	2.08	1.51
	a/b	0.79	0.97	0.60	0.77	0.68	0.90	0.81	0.96	0.91	0.78
	c	6	8	8(10)	7(8)	9 9	8	7	6	7	8(9)
	d	1136	10.1	72	208	20.9	52.9	238	45.8	257	15.7
Total Manufacturing	a	3.01	1.95	1.73	2.51	1.66	4.06	2.36	2.54	2.57	1.14
	d	6046	136.4	770	1664	412	372	1472	210	2321	231
	e	21.04	21.41	24.81	25.78	17.35	24.30	25.61	30.67	25.29	32.90
	f	18.79	7.40	9.35	12.50	5.07	14.22	16.17	21.81	11.07	6.80

NOTES:

1/ R&D intensity - measured as the ratio of R&D expenditures per value-added in the industrial group, in percentage. Average of the years indicated.

a/ R&D intensity using only company-funded e penditures.

b/ *Idem* using total expenditures.

a/b/ Participation of company-funding in total R&D expenditures.

c/ Ranking of group within manufacturing industries (15 groups), using total R&D expenditures intensity. When ranking usi company expenditures is different, it is indicated in parentheses.

d/ Company-funded expenditures in 1967 (in US $ 1963 prices). For machinery it includes also the expenditures on instrumer

e/ Participation of electrical machinery in total manufacturing industry's R&D expenditures (company-funded).

f/ *Idem* for machinery industry. Source: Walter (1975) Tables A 4 and A 5

TABLE II-8: CONCENTRATION OF R&D EXPENDITURES IN THE MAIN OECD COUNTRIES - PERCENTAGE OF TOTAL.

Industrial Group	US	Japan	FRG	UK	Sub. Total	Others [1/]	Total
Electrical Machinery, Electronic Equipment and Components	39.81	18.42	13.46	11.83	83.62	16.38	100.00
Machinery and Instruments	55.24	12.50	10.11	11.57	89.42	10.58	100.00

NOTE: 1/ Belgium, France, Italy, Netherlands, Sweden, Canada.

SOURCE: Table II.7.

II.4) Resources used for Design

This Section examines first the resources used for design activities: the manpower and equipment used and the sources of information from outside the firm (points 4.1 and 4.2). In Part 4.3 we examine the differences between the two strategies as regards the use of such resources.

The cost of production of design is given mainly by the payment for such resources and in Part 4.4 we discuss the relationship of this cost of production to the cost of licensing.

4.1: Manpower and Equipment:

We stressed, in the two preceding Sections, the importance of experience in the capital goods industry - in its role as determining the competitive position of the capital goods enterprises vis-a-vis their customers and the possibilities of entering markets and in its role as the basis for their capacity for self-reliance in design (see also Appendix A). In licensing the licensee relies on the experience of the licensor (especially of preliminary design) and, in fact, this experience is one of the main criteria by which licensors are chosen (see Chapter IV).

In recent years 1/ there have been attempts to make this experience

1/ Engineering industries, especially those producing capital goods are often regarded as industries in which technical progress comes through "tinkering", in which innovations are introduced as a result of a blend of mechanical ingenuity, craftsmanship and some luck. This type of process certainty played an important role in the beginning of the mechanical industry, for instance in the development of the steam engine and of textile machinery in the XVIIIth century and in the early development of machine tools in the last century (Landes, 1972; Rosenberg, 1972). In the electrical engineering, even at the beginning it was of much less importance, as from the outset, this was a "laboratory-based" industry (Bernal, 1965).

"Cut and dry" methods, even if applied to relatively simple problems, with considerable amount of ingenuity, tend to be very expensive in case of failures. Moreover, their application is largely dependent on skills embodied in persons, frequently at the shop floor, Therefore, as a means of ensuring that the process of introducing innovations became more systematic, less risky technically and less dependent on workers' skill (reducing thus their power), design activities soon became a specific activity, performed by people with higher technical and scientific qualifications and organisationally (and socially) closer to management.

"objective knowledge", in the Popperian sense (i.e. knowledge which is independent of the persons which have produced it - Popper, 1975).

In terms of the design process, this has taken the form of studying in detail the decisions taken at each design step and devising methods through which such decisions are recorded, becoming, possibly, reproducible independently of the original designer (Asimov, 1962; Eder, 1966a; Gregory, 1966b).

Such approach has been aided by the development of information storage-and-retrieval systems, especially through computers. Presently, the use of computers is affecting mainly those activities which are of a more routine character, mainly the stage of detail design (Parton, 1966; Bell, 1972). In fact, Eder (1966b) claims that numerical control is rendering detailed component drawings obsolete. However, special programmes, "synthesis programmes", are already in use for the design of large electrical machines (such as large alternators and transformers) in order to obtain first sets of likely dimensions, at the stage of preliminary design (Parton, 1966). With the development of more flexible software, reducing thus the cost of programming, the use of computers is likely to spread.

Nevertheless, design, especially for custom-built equipment, retains a craftsmanship quality, remaining to a considerable extent, "subjective knowledge", property of the designers 1/ and the substitution of machines for designers will probably never be complete, in as much as creative processes are needed, i.e. especially at the stages of feasibility and

1/ The situation found by Fraas and Oxisik (1965) for heat exchangers, "that not only the companies generally consider their basic cost data proprietary - an understandable point of view - but cost estimators as individuals usually guard their "secrets" jealously" (p. 14), (my emphasis), is probably not untypical, especially for custom-built equipment, where standardisation of the basic design is almost impossible, each case being different from the other.

preliminary design; but the efforts of design theorists seem to mirror, possibly unwittingly, with some fifty years of lag and using more modern techniques, the process of breaking down activities, simplifying them, and then introducing automation, started in the 1890's by Taylor at the shop-floor level.

In fact, even in the more advanced countries, where presumably the use of machinery and equipment for R&D is more widely spread, labour costs amount to approximately half of the total R&D costs. This participation is higher in mechanical engineering than in electrical engineering, which requires more complex equipment, both for research and for development (see Table II-9). However, it is worth stressing again the heterogeneity of the sector, not only between mechanical and electrical engineering, but also within the industries, as shown in Table II-10 for the U.K.

Those activities require a high participation of highly qualified manpower - in the F.R.G. scientists and engineers represent more than one-third of the labour employed for R&D purposes and in Japan their participation is even higher, almost half of the labour force (see Table II-11).

Although normally grounded on formal training (mainly engineering) the experience of design is developed through learning-by-doing over the course of years. Even in the advanced countries, good designers, especially those capable of developing new products, are not an abundant commodity. For example, Bright (1966), in his analysis of the consequences

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1/ As shown in Table II-12, the numbers of scientists and engineers employed by the capital goods industries for R&D purposes are considerable, not only in terms of the quantity of people employed but also as a participation in total manufacturing industry.

To the scientists and engineers previously mentioned, one should add the technicians too - see Table II-10.

TABLE II-9: BREAKDOWN OF TOTAL R&D COSTS FOR THE FOUR MAIN O.E.C.D. COUNTRIES - IN PERCENTAGES, 1971. 1/

<table>
<tr><th>Countries</th><th>Labour Cost of all R&D Staff</th><th>Other Current Costs</th><th>Land & Buildings</th><th>Instruments & Equipment</th></tr>
<tr><td colspan="5">A - ELECTRICAL MACHINERY 2/</td></tr>
<tr><td>US 3/</td><td>48.2</td><td>51.8</td><td>..</td><td>..</td></tr>
<tr><td>UK</td><td>56.6</td><td>34.2</td><td>0.6</td><td>8.5</td></tr>
<tr><td>Japan</td><td>40.0</td><td>46.5</td><td>2.5</td><td>11.0</td></tr>
<tr><td>FRG</td><td>54.4</td><td>36.3</td><td colspan="2">9.3</td></tr>
<tr><td colspan="5">B - MACHINERY</td></tr>
<tr><td>US 3/</td><td>56.1</td><td>43.9</td><td>..</td><td>..</td></tr>
<tr><td>UK</td><td>52.1</td><td>41.4</td><td>1.5</td><td>5.0</td></tr>
<tr><td>Japan</td><td>46.8</td><td>39.5</td><td>3.2</td><td>10.4</td></tr>
<tr><td>FRG</td><td>58.9</td><td>31.3</td><td colspan="2">9.8</td></tr>
<tr><td colspan="5">C - TOTAL MANUFACTURING</td></tr>
<tr><td>US 3/</td><td>49.6</td><td>50.4</td><td>..</td><td>..</td></tr>
<tr><td>UK</td><td>50.1</td><td>40.3</td><td>2.9</td><td>6.7</td></tr>
<tr><td>Japan</td><td>43.6</td><td>38.3</td><td>4.8</td><td>13.3</td></tr>
<tr><td>FRG</td><td>54.3</td><td>32.8</td><td colspan="2">13.0</td></tr>
</table>

NOTES:

1/ For the UK, 1969.

2/ For the US and FRG, electronic equipment and components are included.

3/ For the US capital expenditures data are not available. Depreciation is, however, included, although not separated, in "Other Current Costs".

SOURCE: O.E.C.D., 1975.

TABLE II-10: UK - R&D EXPENDITURES AS PERCENTAGE OF TOTAL EXPENDITURES BY INDUSTRY, BY TYPE OF COSTS - 1968.

Industry	Current Expenditures			
	Wages & Salaries	Materials & Equipment	Total	Capital Expenditure
Mechanical Engineering (Total).	2.5	0.9	3.4	2.8
Machine Tools	3.4	1.2	4.6	5.8
Industrial Engines	7.8	5.0	12.8	10.7
Other Mech. Engineering	2.2	0.7	2.9	2.2
Electrical Machinery	4.9	1.9	6.8	8.5
Total Manufacturing	3.9	0.7	4.6	3.7

NOTES: 1/ Capital expenditure participation is somewhat upward biassed as the R&D figures are gross acquisitions and the industry total is acquisitions less disposals of assets.

2/ Current expenditures do not include depreciation.

SOURCE: Economic Trends (1974).

TABLE II-11: MAIN O.E.C.D. COUNTRIES - RATIOS BETWEEN SUPPORTING STAFF AND SCIENTISTS AND ENGINEERS - FRG AND JAPAN 1/ - 1971.

	FRG	Japan
Machinery		
Technicians	0.9	0.5
Workers & other Supporting Staff	1.0	0.7
Electrical Machinery		
Technicians	0.7	0.6
Workers & other Supporting Staff	1	0.6
Manufacturing Industry		
Technicians	1.1	0.6
Workers & Other Supporting Staff	1.5	0.8

NOTES: 1/ US and UK not available.

2/ Includes electronic equipment and components.

SOURCE: O.E.C.D.,(1975).

TABLE II-12: MAIN OECD COUNTRIES [1/] - SCIENTISTS AND ENGINEERS EMPLOYED IN R&D (FULL-TIME EQUIVALENT) - NUMBER AND PERCENTAGE OF TOTAL MANUFACTURING - 1971.

		US	Japan	FRG
Machinery	N	40,000	9,754	7,670
	%	11.4	9.27	14.3
Electrical	N	95,200 [2/]	14,430	20,573 [2/]
	%	26.8	13.7	38.3

NOTES: 1/ UK not available.

2/ Includes electronic equipment and components.

SOURCE: O.E.C.D. (1975).

of automation in the U.S., notes that

> "plants that build their own automatic machinery have a greater requirement for the peculiar talents needed for machinery development, and they are the main source of complaints about the shortage of adequately skilled people. Not only is technical training needed, but some kind of skill in visualisation, imagination and mechanical creativity. The last was by no means obtainable simply by hiring more engineers, according to several experienced managers." (p. 215) 1/

Moreover, because of the interface role played by design activities, of matching specific sustomers' requirements to the specific manufacturing facilities of the firm, the design experience is also firm-specific - in other words, it takes time, even for an experienced designer to get "geared" to a firm. Therefore, after it has set up a design department of some might, a firm can ill-afford to disband it at times when the demand is slack, on the assumption that it is easy to assemble an equally productive team quickly when demand picks up again.

This implies that the decision to set up one's own design department represents a long-term financial commitment - and more than that. Once such department is set up, the firm's strategies will be affected, not only by its existence as a consumer of resources, and a supplier of productive services but also as a group of interests within the enterprise, pressing for a higher "engineering" content in the products the enterprise makes, which, if successful, will increase their importance within the enterprise and so their power and other, more material, benefits. In this sense following a strategy of self-reliance on design is to some extent an endogenously generated process, a kind of self-fulfilling prophesy.

1/ If this is observed for an economy with a pool of technical resources as wide as that of the United States, it is clear that the conditions facing producers in the less developed countries are much more difficult.

Although, as we said above, the experience of design is, to some extent, firm-specific, a capital goods enterprise can use the experience gained by its designers in other enterprises; not only because the skills involved in designing different products are similar but also because there is a substantial amount of design of capital goods performed in enterprises which do not specialise in their production.

Table II-13 shows this for the U.S. in terms of R&D expenditures. There, the interdependence between electrical and non-electrical machinery industries is strong; but it is worth noting that the other user sectors account for circa one-fourth of the total R&D funds used for electrical equipment and one-fifth in the case of non-electrical machinery (including computers). A finer breakdown is shown in Table II-14, where we can see that this varies considerably from product to product, a major factor being probably the technical 'affinity' of the user industries to the machinery industries and the size and degree of backward integration of the demanding firms. As an example, the "machinery industry" is responsible for only one-third of the R&D expenditures for "engines and turbines", less than the participation of "motor vehicles and related equipment" industry, while, on the other hand, 72% of the R&D for "office machinery" is funded by the industry which specialised in its production.

As discussed in detail by the literature, the movement of technical personnel plays a key role in the process of diffusion of technical knowledge (see Pavitt <u>et al.</u>, 1974, for a survey and Freeman, 1974). In the experience of the designer who moves from one firm to the other is incorporated the knowledge of how other firms work, learned through on-the-job training, which he/she transfers to the other designers of the new employer.

TABLE II-13: R&D FUNDS FOR ELECTRICAL AND NON-ELECTRICAL MECHINERY BY INDUSTRY. - US - 1973 - IN PERCENTAGE.

Industry	R&D For Machinery (%)	R&D for Electrical Equipment & Communications (%)
Food & Timber Products	0.4	- 1/
Paper & Allied Produce	0.4	- 1/
Chemical & Allied Produce	1.4	0.5
Primary Metals	0.8	0.1
Fabricated Metal Produce	0.8	0.2
Machinery (Total)	62.3	9.9
Office, Computers & Accounting Machinery	37.9	7.6
Electrical Equipment & Communications (Total)	18.2	65.7
Radio & T.V. receiving Equipment	..	1.1
Electronic Components	0.2	6.9
Computer Equipment	12.1	43.0
Other Electrical Equipment	5.9	14.7
Motor Vehicles & Equipment	7.8	8.5
Aircraft & Missiles	2.6	11.1
Professional & Scientific Instruments	1.7	1.0
Non-Manufacturing Industries	2.2	2.2
Non-Specified Industries	1.4	0.8
Total	100.0	100.0
Total (US $ Millions)	2,225	4,347

NOTE: 1/ Included in "Non-Specified Industries"

SOURCE: N.S.F. (1975).

ndustry	Engines & Turbines	Farm Mach.& Equip.	Construc. Mining & Met. Handling Mach.	Metalwork Mach. & Equip.	Office, Comp. & Accounting	Other Mach. excl. Electr.	Total	Electrical TRANSM. & Distrib.	Electrical Industrial	Others	Total
ood & Kindred roducts						2.8			2.		
aper & Allied roducts						2.1					
hemical & A llied Prods.			3.4	2.7		6.7			2.4		
rimary Metals	1.7			2.7		2.8					
abricated Metal roducts				12.3		2.8			1.6		
achinery	33.1	69.2	78.4	54.8	72.0 1/	44.0					
lectronics Comp.								23.1	18.1		
ommunic. Equip.		4.3	1.3	11.0	20.1	6.7		1.4	6.7		
ther Electrical quip	20.0	3.4	3.9					64.0	36.6		
otor Vehicles Equip.	36.0	16.2	9.0								
ircraft & Missiles	4.6	4.3				11.3		2.4	12.6		
nstruments					2.6	2.1					
ther Manuf. Inds.						3.2					
on-Manuf. Inds.	4.0				1.9	3.9		6.2			
on-Specified Inds.	0.6	2.6	4.0	16.5	3.4	1.6		4.7	22.0		
otal	100.0	100.0	100 0	100.0	100.0	100.0		100.0	100.0		
articipation in otal Prod. Expend. %	15.8	5.3	10.4	3.3	52.4	12.8	100.00	25.4	30.6	44.0	100.00

NOTE: 1/ Of which 99.6% performed by the office, computing and accounting machinery industry itself.

SOURCE: N.S.F. (1975).

Although part of such benefits to the new employer are probably reflected in higher salaries for experienced designers, there is also an element of externality, of a benefit not paid for, for the recipient firm, as well as a relative loss of the enterprise the designer leaves, in terms of the training invested for the latter. Although theoretically conceivable, no compensation schemes exist in practice for this situation, except from the general circulation of manpower, through which an enterprise which loses designers also receives designers from other enterprises (see Chapter III).

Firms which develop their own designs also benefit from informal and untraded exchanges of information between their design staff and technical staff of other firms of the sector, customers, suppliers and engineering firms (see below and next Chapter).

In the LDCs, partly because of their relative scarcity, engineers and other technical personnel tend to be relatively highly paid not only in comparison with other groups within their countries, but also in comparison with technical groups in the advanced countries. A rough comparison between gross pay of engineers in Brazil, U.K., F.R.G., and France (Table II-15) suggests that such costs are roughly equivalent,[1/] although, presumably, in the latter engineers are more experienced.

1/ The limitation of such comparison should be noted. Apart from problems of coverage of the original sources and problems of exchange rates, the data presented, deal only with gross pay - i.e., in terms of the costs to the enterprise they do not include either fringe benefits nor social security payments and both costs can be relevant: in the U.K., for instance, it was estimated that the former epresented circa 20% of the pay, in 1973 (CEI, 1973) and, in Brazil, the latter amount to circa 50%.

TABLE II-15: GROSS PAY OF ENGINEERS - BRAZIL, UK, FRANCE, GERMANY - 1970 - £s PER ANNUM.

Country	Job	£ p.a.
UK	Chief Engineer	4480
	Head of R&D	4406
FRG	Chief Engineer	3413
	Head of R&D	3735
France	Chief Engineer	6136
Brazil	"Average" 1/ Chemical Engineer	3577

NOTE: 1/ Average salary of 1.189 Mechanical Engineers working in Sao Paulo in 1970.

SOURCES: UK, FRG and France:- Fores and Bonrgers, (1975).
Brazil - Pasbra (1972).

4.2) Information from Outside the Firm

(a) Supplying industries

Metals and metal-products are the traditional materials used in the capital goods industry for the fabrication of the machines and their components, to the extent that the industry is normally referred to as a "metal-working industry". In recent times this association has weakened. Besides the important use of electronic components for the cantrol and automation of capital goods already mentioned, the other main developments seem to be in the large-scale use of plastics for components, the large-scale use of advanced composite materials (especially carbon-fibre composites and their near relations) and in the use of specialised new metals, alloys and ceramics (Bell, 1972; BIPE, 1971 and 1972). In fact, most of the radical innovations recently introduced in the capital goods industry originate from their supplying industries.1/

Such dependence puts a high premium on keeping a close contact with the supplying industries, not only through a close monitoring of technical literature but also through personal contacts, in order to better understand and use the technical characteristics of the new products, to induce the suppliers to produce goods which are most appropriate for the needs of the capital goods enterprise, as well as to better assess future trends and forestall competitors.

Moreover, higher performance requisements imply stricter design specifications, especially if they are concurrent with requirements for

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1/ The use of new material and components in the machine tool industry has been such that Rosenberg (1972) has suggested that "just as metallurgy is giving way to materials science, so the machine tool industry seems on the way to becoming the materials-forming industry" (p. 156). Nevertheless, metals, especially steel, are still the main material used for machine building.

higher reliability and durability, as the present trend seems to be.

Smaller tolerances imply that the search for material and components with the necessary specific characteristics must be increased. This means, at the same time, widening the field of possible suppliers, in the sense of using new materials and components which may have the desired characteristics, and narrowing it by excluding those suppliers which cannot produce materials and components of the desired quality.

(b) Engineering firms

The need for a capacity of obtaining and processing a greater amount of information at the design stage is reinforced by the increased demand for machinery embodying special features for specific customers which we have previously discussed.

For this purpose the capital goods firms have been greatly aided by the development of engineering contractors as an autonomous activity (Perrin, 1976), which function as a channel of communication between the customers and the equipment producers, supplying the latter with the functional requirements of the equipment already in accordance with the rest of the system into which they have to fit. The ease of access and communication with such engineering firms represent an advantage for the producers of the advanced countries, where practically all the main engineering firms have their basis of operations.[1/] Several authors (Perrin, 1976; Roberts, 1973)

1/ Although the role of engineering firms as a conveyor to sales of local capital goods, often in special conditions, has come into attention of the development literature rather recently, it is in fact an old pattern in the industry as shown by the complaints of railway equipment producers in the beginning of this Century in Britain that "their costs were being raised by the consulting engineers' practice of forcing them to obtain bought-out parts from specified firms which took advantage of their position to "inflate prices" (Saul, 1970, p. 150, my emphasis).

have argued that this advantage goes further - as the engineering firms are more aware of the possibilities offered by the capital goods producers in their advanced countries, they tend to specify equipment that can be more easily supplied by these producers than by their competitors from the less developed countries, even when those would be able to supply it and the plant is being set up in their own country.

(c) Research institutions

Even for research and development, the role played by research institutions is relatively small in the capital goods industry. As shown in Table II-16 for the U.K. and the U.S., the expenditures for R&D contracted out are negligible in comparison with in-house expenditures and well below the average for manufacturing industries. However, such figures probably underestimate somewhat the role played by research institutions in a supportive capacity, performing basic research which may eventually be incorporated in future designs as well as their use by the industry for ad hoc information, often done informally and without payment.

In fact, the capital goods enterprises benefit indirectly from the research conducted for its supplying and using industries, 1/ and directly from the scientific investigation in academic institutions, for an example, on factors such as vibration (Arnold, 1971) and lubrication (tribology) (Scott, 1967), new control processes, such as fluidics (Linford, 1971) and new machining processes (Bell, 1972). Moreover, in some countries like the U.K., Research Associations, like the MTIRA for machine tools, perform an important advisory and supportive role.

1/ Here one could ask whether the capital goods industry would commission such research if the others did not.

TABLE II-16 : R&D CONTRACTED OUT - UK AND US.

- UK - R&D CONTRACTED OUT AS A PERCENTAGE OF R&D PERFORMED IN-HOUSE.- 1968.

Industry	%
Mechanical Engineering (Total)	2.49
Machine Tools	3.85
Industrial Engines	1. 9
Other Mechanical Engineering	2.51
Electrical Machinery	2.38
Total Manufacturing	5.71

TABLE II-16B: R&D CONTRACTED OUT - UK AND US

- US - R&D CONTRACTED OUT AS A PERCENTAGE OF TOTAL COMPANY-FUNDED R&D EXPENDITURES - 1973.

Industry	%
Machinery, including office Machinery	1.11
Electrical Equipment & Communication	0.90
Manufacturing Industry	1.91

SOURCES: A:- Economic Trends (1974).

B:- N.S.F. (1975).

As regards the development of new machining processes (chemical milling, electro-chemical machining, electrical discharge machining, ultrasoning machining, and laser beam machinery), they represent a departure from the pattern previously discussed in the sense that they are much more research-intensive than the "conventional" processe and they imply radically new concepts of equipment. However, their use is still quite restricted, either to very tough, heat-resistant materials, such as used in the aerospace industry, or to very small and intricate machining patterns required by the electronics industry, sectors for which they were developed. It is still doubtful whether their use will spread considerably in the future, besides those special applications. Some, like the last two mentioned, are still at an experimental stage. 1/

As regards design activities proper, because of the type of information needed for such activities, especially at the stages of easibility and preliminary design, it is highly unlikely that the enterprises could or would delegate such decisions to a research institute, as this would require the disclosure of strategic decisions of the firm, which could "leak out" to its competitors, undermining its potential lead over them (see Section 3.1). Moreover, in many enterprises, such decisions are often based on non-explicit assumptions and result from compromises between conflicting interests within the firms, making their delegation even more difficult (Freeman, 1974; Lindblom, 1968). Finally, it is unlikely that academic

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1/ It is interesting to note, as a reiteration of a pattern of development common in the industry, that the most widely used of those processes, electrical-discharge machining, is not a new concept - it was first introduced in 1946, in Russia; but only when there was a demand for that type of technical performance, from the aero-space industry in the second half of the 'sixties, was the process more widely adopted (see also Appendix A for the case of NC).

institutions would be as able as enterprises to achieve the necessary compromises that make a design not only a technical but also a commercial success.[1/]

This has important technology policy implications as there seemed to be the hope in several Latin American countries that the limitation of innovative activities by local entrepreneurs could be compensated by the activities of the research institutes, supported by the State. As far as the production of design goes, this is probably wishful thinking, although the research institutions, at least in Brazil, do play a role (which could be increased) at the end of the productive process - for quality control - and could probably play an even more important role at the other end - in research activities strictly speaking, as they do in the advanced countries. In Chapter IV we discuss in more detail the use of the research institutions by the Brazilian capital goods enterprises.

(d) Other capital goods enterprises

Besides the movement of personnel and informal exchanges of information previously discussed (see 4.1) there are also institutional channels of communication used by enterprises in the industry, such as patent pools and cross-licensing agreements, where several enterprises participate.

Such coordination is easier to achieve when the producers are few - in the capital goods industry it is more notable in the electrical machinery field than for mechanical machinery (Surrey and Chesshire, 1972; Sercovitch,

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1/ Of course, enterprises do delegate decisions about design, as in the case of licensing agreements, where the enterprise that receives the design implicitly places its trust on the original producer of the designs. However, it is important to stress that such trust is placed not only on the technical capacity of the other enterprise, but also on its acumen of judgement about profit-making and, most often, only after the enterprise and the product have shown profit-making potential.

1974), although it has been observed in the latter too, in concentrated branches such as diesel engines (Vaitsos, 1973).

Such agreements reduce costs for the enterprises participating in them via sharing their experience and, also, (probably more important), reduce uncertainty, giving each participant in the agreement a fair amount of knowledge of what its potential competitors are doing.

They also constitute a barrier to entry of newcomers to the markets, excluded from such agreements, as such exclusion raises their costs and increases the uncertainty involved in developing new designs. In this sense, it can be said that there is a threshold to being admitted to such coordination - only when a firm by virtue of its development presents a threat to the position of the firms already established is it likely to be co-opted by including it in the agreement. Firms which rely exclusively on licensing are unlikely to present such a threat as they can be controlled by their licensors (see next Section).

Therefore, where such agreements exist, the capacity to develop successfully one's own designs becomes a pre-condition to reduce the costs of future developments through sharing the results of other enterprises' work.

It is however, important to stress that for firms entering a market, the presence there of competitors with a technology already developed may preclude the use of an SRS if customers have a marked preference for "traditional" suppliers (see Section 2) and/or if delivery times are short (see Section 5). In such cases, collusion between the established producers simply heightens the barriers to entry.

(e) Other sources of information

Besides the sources above-mentioned, the capital goods enterprises exchange information also with their customers, directly, and use inputs from the scientific and technological information system, in which, for the purposes of design, standards bureaux and patent services are especially important (see Section 3).

4.3) Resources used in Licensing and SR

Whichever strategy the firm follows, it will use some of the resources described in the two preceding parts. However, their importance for the firm will vary according to the strategy. For its own development of designs the firm will require more and more qualified manpower than for licensing, as in the latter its manpower will be occupied mainly with detailed design, (see Section 3.1). Similarly, in licensing most of the information will come from the licensor - in some cases the whole "technological package", from the preliminary designs to marketing know-how. 1/

The diversification of resources used in a strategy of self-reliance imply that it is easier for a firm to pursue such a strategy if it operates in an environment where the technical division of labour has been considerably extended, so that the firm can have access to specialised knowledge. Because of the role played by person-embodied knowledge and informal exchange,

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1/ If licensing is international, this implies that local resources are not developed. This may be important for the firm, depending on the importance attached to having a national supply of resources, independent from abroad - a point more fully treated in the next Chapter.

physical and cultural proximity make this access considerably easier.[1/]

For the same reasons, pursuing a strategy of self-reliance in such an environment is not only easier but cheaper for the firm - not only will there be more possibilities of externalities, but also resources will be more cost-effective.

Such advantages apply, of course, more intensively to the more complex products - those requiring higher performance and reliability standards and those composed by a multiplicity of sub-systems.

It is also important to note that the process we have been discussing is one of reciprocal stimulation: if the capital goods producers benefit from the activity of their suppliers, engineering firms, etc., the latter benefit also from the developments introduced by the capital goods enterprises.

If the participants in such process are, in general, following strategies where SR plays an important role - i.e. they are all investing in their own SR capacity, the result, through this mutual stimulation, will probably be a higher general level of SR - in other words, it probably results in what some authors have called "collective work" and others "sinergy"[2/] - a total effect that is greater than the sum of its parts.

1/ Geographical concentration of engineering activities is often observed - e.g. the Midlands in the U.K., Sao Paulo in Brazil. Freeman (1974) has suggested that a considerable advantage enjoyed by the American electronics industry vis-a-vis its European competitors lay in its much wider net of information and physical proximity.

2/ "It is a question of not only expanding the individual productive forces but to create through the cooperation a new force that functions only as a collective force" - Marx (1963) p. 864 (my translation).

"Sinergy ... embraces a wide range of elements which ultimately result in a 2 + 2 = more than 4 effect. Synergy results from complementary activities or from the carry-over of managerial capabilities" - Weston (1970), p. 309.

It is probable therefore that the external economies previously mentioned are subject to scale effects, increasing more than proportionately when the general investment in SR increases.

On the other hand, the same process of reciprocal stimulation applies to licensing: for example, the use of foreign specifications by capital goods producers may lead their suppliers to use licensing too (or to be required to do so) and this, in turn, complicates the work of capital goods producers trying to develop designs locally, as the suppliers do not have an independent capacity to feed into this process.

This implies that for self-reliance it is necessary not only to have an extended division of labour, but also a division of labour in which there is a widespread investment in SR. It is possible to envisage, in fact, an industrial structure fairly developed, where the enterprises interact at the level of the production of commodities but not at the level of the generation of the knowledge for producing such commodities, being all dependent on knowledge generated abroad. Such a "scenario" closely corresponds to the situation presented by the more industrialised LDCs, which have, through their process of industrialisation, "re-defined their terms of dependence" (Cardoso, 1973).

In fact, in many LDCs what we may call their "structural weakness" in terms of the supply of resources available to firms used for a strategy of self-reliance - the limited division of labour, the lack of trained personnel, the undevelopment of the technical and scientific information structure, etc. - has often been compounded by a pattern of industrialisation which placed an overall high degree of reliance on the use of imported technology, rendering more difficult the efforts of self-reliance of the national enterprises. We return to this point in the next Chapter.

4.4) Cost of Production of Design and Cost of Licensing

The conditions of licensing are normally established through a bargaining process (Vaitsos, 1970, 1974; Sercovitch, 1972) depending on the opportunity costs of the two parties. The cost of production of design of the two parties are normally only one element in such bargaining and often not the most important.

From the point of view of the licensor, its own cost of production of design will play a different role depending whether the product is custom-built or standard. In the first case, its cost of production will probably set the lowest limit of revenue from licensing it is willing to accept.

In the second case, however, assuming that the designs are already available, their cost will probably have already been covered by he sales of the products.1/ The costs of transferring such designs to the licensee will normally be negligible since adaptation costs are borne by the latter. In such cases, therefore, the role of the cost of production of the design by the licensor is relatively small.

Such opportunity cost will vary from product to product and from licensee to licensee depending on the importance of the licensed product for the licensor, on the alternative uses of its technical capacity (in the case of custom-built equipment) on the availability of other licensors and on the technical capacity of the licensee.2/

For a potential licensee its cost of producing the design instead of licensing may set the highest limit it is willing to pay for licensing but

1/ Licensors are normally chosen on the basis of the success of the sales of their products. See Chapter IV.

2/ In the next Section we examine in more detail the role played by the technical capacity of the licensee in the conditions of licansing. Such conditions are also discussed in more detail in that Section.

only under the rather restrictive assumptions that the risks and incomes involved in the two strategies are the same and that no better alternatives investments are available. If such assumptions are dropped the importance of the cost of production of design per se, as a determinant of the bargaining position of the licensee is considerably reduced.

The conditions actually established for the licensing will probably lie between the opportunity costs of the two parties. In most cases, there will be an element of rent paid to the licensor corresponding to the difference between its opportunity cost of licensing and its ncome received from such licensing.

Such rent is normally explicitly paid through a percentage on the sales of the product plus the payment of a lump-sum. However, it may also be paid through the purchase of materials and components from the licensor (see next Section).

II.5) Implications of the Strategies for the Survival, Growth and Autonomy of the Enterprise

As capitalist enterprises are based on the private ownership and control of the means of production, we begin by analysing the implications for the licensee of the use of a means of production of critical importance, the designs, owned and controlled by another firm. In fact, in the licensing relationship the licensor retains the legal property of the knowledge transferred, so that, as Sercovitch (1974) has pointed out, the licensee is a leasee of such knowledge. Moreover, by retaining the production of the preliminary design, the licensor controls the production of the design, unless the licensee has an independent design capacity which allows him to use the designs transferred to understand their rationale. The points described below are examined in detail in Chapter IV for the Brazilian case.

The negative implications [1/] for the licensee of this double control are

i) Free transfer of improvements on the product to the licensor - as a leasee, the licensee is obliged to ask the permission of the licensor to modify the product. As the goodwill of the licensor is normally linked to the performance of its products, especially in a "technology intensive" industry as the capital goods, [2/] there is a clear rationale

1/ Such negative implications are normally treated in the literature as the "restrictive clauses" imposed by licensors on licensees and their occurrence has been widely documented, for LDCs of all continents by UNCTAD (1974), by Vaitsos (1973a + b; 1974) for Bolivia, Ecuador, Columbia, Peru and Chile, by O'Donnel and Linck (1973) and Sercovitch (1974) for Argentina, by Wionczek (1973) for Mexico, and by Fung and Cassiolato (1976) for Brazil. What the literature sometimes neglects is the fact that such restrictions are inherent to the logic of licensing, as discussed in the text, and that they often have an important counterpart in the concession of special privileges to the licensee - notably its monopolistic position, a fact recognised by the licensees (see Chapter IV).

2/ Failures of a product to comply with required specifications may lead to negative consequences in terms of future orders, not only for the party which produces them (the licensee) but also to the originator of design itself, as it is often very difficult to identify the precise origin of the fault (whether at the design or the manufacturing stages) and the two parties become tightly linked in their responsibilities.

for this control, which, nevertheless, reinforces the controls above-mentioned. Adaptations in capital goods are very common (see Section 2 and Chapter IV) and while the licensee bears their cost the licensor retains their property.

ii) Control of supplies - Licensors often impose purchases of materials and components from specific suppliers, especially if the latter belong to the same group. Vaitsos (1970; 1974) has shown that in some industries (pharmaceuticals, electronics, textiles) such supplies are often overpriced in international terms.

iii) Control of markets - Market sharing is inherent to licensing. The licensee normally receives the monopoly of the license for a certain area (normally the country in which it operates) - one of the great advantages of licensing - but is, as a counterpart to that, normally restricted from competing in other markets, reserved by the licensor for itself or other licensees.

iv) Risk of entry of the licensor as a competitor - For the licensor, licensing may be an alternative to exporting. In fact, Walker (1975) has suggested that licensing may be a reason for the weak correlation found between exports and R&D intensity for the mechanical industry in the OECD countries. Our results (see Chapter IV) indicate that licensors consider licensing a second-best to exporting.

Licensing may also be used by the licensor as a preparation for setting up a subsidiary, using the licensee to test the market and establish its trademark among customers.

In both instances, the licensee is in a weak position to retain its position in the market, unless it has its own technical capacity or is able to switch to another licensor and to convince its customers that the quality of the product will not suffer. Especially in the case of custom-built equipment, where the technical capacity required for designing them is high and the suppliers of licenses tend to be few, the entry of the licensor, especially through a subsidiary, may lead the licensee to abandon that market.

v) Risk of entry of licensor as a partner. Control of decisions - The control of knowledge by the licensor often "overspills" into other decisions (product-mix, marketing, etc.) (Sercovitch, 1974). Such controls are probably increased when the licensor receives as its payment a share in the equity of the licensee.

vi) Sharing the profits with the licensor - The granting of exclusive rights to the licensee offers the latter the possibility of monopolistic profits on those lines of production, especially in an industry with the marked degree of product differentiation as the capital goods industry. However, it has been remarked, especially by Sercovitch (1974), that the licensor, through the rents he charges (see Section 4) and through the sale of components can appropriate part or even all the monopolistic profits of the licensee.

If the licensor becomes a partner of the licensee, by capitalising the value of its future rents, it obtains a share of the total profits of the licensee.

The conditions of licensing are established through a process of bargaining and, when established between firms of similar technical capacity and similar access to markets, the conditions above will be less stringent.

Two factors seem to determine this result (Hufbauer, 1966). The first is the fear of the licensor that if it sets too harsh conditions the prospective licensee may develop its own designs. Between firms of similar technical capacity in an industry which uses re-design so widely, the possibilities of catching-up are strong. That is, the original possessor of the design sacrifices part of its potential profits in the markets that will be occupied by the licensee in exchange for the assurance that the licensee shall not interfere in the markets it has already established or thinks it has strong possibilities of capturing. Therefore, for the licensor, licensing represents not only an additional source of income, but also an important instrument for defensive purposes.

Second, between firms of similar capacity, with a similar range of products, there is the possibility of reciprocity in licensing, so that it is to the common advantage not to set too stringent conditions.

Finally, it is worth noting that between firms of similar experience not only the communication is easier but also the firm that provides the design is more sure that the quality of the product manufactured will remain the same. This is especially important in an industry where the demand is so quality-conscious as in the case of capital goods.

Therefore, in the interest of regulating present and future competition the firm which owns designs will probably be willing to accept "softer" conditions for releasing such designs from a stronger licensee than a weaker one.[1/]

1/ Licensing is probably one of the best examples of the application of the Biblical "Matthews Principle", "To who hath .....".

A critical element in this strength is the licensee's capacity for self-reliance.

The limitations above-described, which a licensing strategy may impose on a firm, do not exist in a strategy of self-reliance, as they spring from the ownership and control of design by another firm. Against them, one has to pose the advantages presented by licensing, which spring mainly from the technical division of labour in design between licensor and licensee, where the latter relies on the experience of the former to produce appropriate preliminary designs.

Briefly, such advantages are:

a) Entry in some markets - In some markets licensing may be a condition sine qua non for entry, e.g. imposed by the purchasers of capital goods, be it for reasons of very high performance and reliability requirements or because of traditional links with some suppliers, which act then as licensors (see Section 2).

b) Reduction of delivery time - The development of designs is a very time-consuming process (see Section 3), especially when the product is new for the enterprise and more so in the case of capital goods subject to high performance and reliability requirements. In the case of standard goods, where the licensor has the designs ready, licensing can shorten the delivery time considerably. Even in the case of custom-built equipment the greater experience of the licensor abridges the delibery-time.

In cases when the lead-time is short, licensing may be, in fact, the only solution; especially when the firm is competing in new products with others which have either the design ready, or access to licenses, as is the case of producers in the LDCs competing with foreign subsidiaries or with local licensees.

Moreover, quicker delivery times imply quicker incomes' receipts, so that firms with a high time discount rate may for this reason favour licensing (see also (c)).

(c) Learning - Although the licensor has no interest that the licensee learns how to produce the preliminary design of the licensed products, he has all interest that the licensee knows how to make detailed design and masters the manufacturing techniques needed for the licensed product, as on them depend the sales, and, consequently, the licensor's revenue. Therefore, licensing agreements often involve learning of detailed design and manufacturing techniques by the licensee,

However, detailed design skills and the manufacturing techniques used for capital goods (see Duggan, 1970 for a good description of the latter) can be used for several products, so that the learning achieved through licensing contains, in fact, an externality for those lines based on the firm's own designs.

Furthermore, if a firm has an independent technical capacity it can use the designs and skills transferred via licensing to develop its own capacity of producing the <u>preliminary</u> designs of the licensed products, in a process analogous to reverse engineering (see Appendix A). Therefore, although licensing does not transfer the preliminary design skills, it may serve as a basis for learning how to produce the preliminary design of the licensed products, provided the licensee has its own preliminary design capacity, and invests in the latter - that is, a mixed strategy is essential for this type of Learning.

d) Risk-reduction - Probably the most strong deterrent of a strategy of self-reliance for new products is the technical and economic uncertainty about the appropriateness of such goods to users' needs (Freeman, 1974). If a firm concentrates a substantial part of its resources on one (or very few) products, it may approach bankruptcy end-point 1/ in case they fail and, even if they are successful, the timing of expenditures and incomes may lead to to gambler's ruin, 2/ especially since gamblers ruin is more probable when events are co-related along time, as in the case in learning curves, as shown by Reutlinger (1970), who shows that the standard deviation of the present value of streams of costs (or benefits) in such cases are three to four times larger than when they are uncorrelated.

In fact, while in licensing most of the costs the firm has to bear are subsequent to the sale of the product 3/ in a SR strategy the costs antecede the sale, so that the possibility of bankruptcy end-point or gambler's ruin are much greater in the latter.

In most countries, especially the LDCs, such risks for the firm are increased by the lack of risk-capital from other parties, except

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1/ The closest a firm comes to bankruptcy, the more difficult in a stocastic sense it is to escape from it, e.g. for credit reasons (Balch and Wu, 1974).

2/ The possibility that while the average return of the firm may be satisfactory, fluctuations in the average return may give rise to a series of losses or negative cash flows causing bankruptcy.

3/ Except lump-sum payments, often charged as a "disclosure fee".

when the State intervenes (see next Section).[1/]

The timing of expenditures and receipts above-mentioned also imply that firms with a high present-time preference will tend to favour licensing.

A product-mix which combines old (safe) and new (risky) products is the traditional p tfolio solution to the problem above. Licensing provides an alternative solution as, by relying on a tried product (or, at least, an tried producer) the firm reduces the technical and economic uncertainty involved in new products.

Moreover, if the firm has some lines of production based on its own technology, by using licensing for another part of its product range, it can concentrate its resources on its own products, reducing thus the overall risk of failure of its whole product range.

1/ Even in advanced capitalist countries, at a time in which there was a relatively abundant supply of financial capital, the OECD has reported that credit for R&D projects was particularly scarce (OECD, 1963).

However, it should be noted that the evidence from the literature on the problem of lack of funds for more innovative (and risky) projects is far from conclusive and often contradictory. Grabowsky (1968) and Scherer (1965), for instance, studying the same industries (drugs, chemical petroleum) in the same country (U.S.) came to unexplained opposing conclusions as regards the effect of the availability of funds on R&D projects - the fommer claims that such availability was an important factor for the realisation of such projects, while the latter fonnd no evidence of this importance.

Other authors, such as Eads and Nelson (1971), have suggested that even small firms in the advanced countries can find appropriate risk capital in the market, if they show probable high rates of return, an assertion which is far from validated by the survey made by Bean et al. (1975) of the practice of venture capital firms (also in the U.S.), which "apparently plays little direct role in the early stages of technological innovation, but rather funds the production and distribution of relatively well-developed innovations" (p. 405), preferring also to concentrate operations in firms which are already growing rather than on start-up projects.

However, it is important to stress that the discussion briefly mentioned above is related to a context in which there is a highly developed capital market. In countries like the LDCs where the capital market is poorly developed, especially the risk capital market, it is much more probable that the funds for developing one's own designs have to come mainly from the firm's own resources or from its general credit on the existing capital market, except in the case of direct State intervention.

Therefore, if a firm has an SR capacity, by combining it with licensing it can increase the benefits and reduce the disadvantages of SR. At the same time, as we have discussed above, an SR capacity allows the firm to obtain better conditions from licensing, reduce its disadvantages and profit more from it in terms of learning and risk-reduction. In other words, the two strategies, when combined, interact, so that the effect of a mixed strategy is different from the summation of the effects of the two strategies separately.

For a firm with a diversified range of products, as tends to be the case in the capital goods industry, a mixed strategy with a predominance of SR is probably that which offers the best prospect in terms of combining survival, growth and self-control of decisions. A "pure" SR strategy will present such characteristics only if the firm concentrated its production on a rather narrow range of products, which may, however, raise problems of cyclical demand and, therefore, of growth and survival. A "pure" strategy of licensing will inevitably raise at least problems of control of decisions, especially if the licensor is only one (or very few) and, probably, restrictions on growth (especially because of (ii), (iii) and (vi) above) and uncertainty of survival (especially because of (iv) above).

However, it is important to note that the two strategies present features of a cumulative, self-reinforcing process. In SR there will probably be spin-offs, new developments originated either from the internal development of design or from learning from licensed products (which the capacity for SR permits to develop). Moreover, there will probably be an internal pressure, from within the enterprise for greater SR (see Section 4.1). Its main checks are probably the costs and risks of diversification.

In licensing, we have argued, the learning process normally does not lead to SR, unless the firm invests in SR too. Moreover, if the enterprise does not try to expand its experience of preliminary design (i.e. invests in SR), as it changes its product range to cope with new needs its dependence on licensing will tend to increase and, in some cases, may cover its whole production (see Chapter IV).

Therefore, a mixed strategy as the one suggested above, requires a continuous investment in SR. However, it is possible that, past some threshold of SR, because of the cumulative effects above-mentioned, this investment may become marginally decreasing in relation to total production.

Comparing the situation between LDCs and ACs, the main difference does not seem to be, as the literature sometimes seems to suggest, in the use of licensing by the enterprises in the former and SR in the latter, but mainly in the proportions used in the strategy mix.

In fact, in the advanced countries, capital goods firms have traditionally used licensing - in 1867 John Platt told a Parliamentary committee, that "it is the custom among machine makers in England to purchase inventions from the Americans and adapt them to use in this country" (quoted in Burn, 1970, p. 83). A hundred years later, license payments by the mechanical engineering industry amounted to 60% of the R&D expenditures (see Table II-17). The experience of the U.K. is not unique - the use of licensing agreements, played a critical role in the development of the Japanese mechanical industry too (Ozawa, 1968).[1/] Although data on licensing payments is

1/ In Japan the industries producing mechanical machinery and electrical machinery were responsible for, respectively, 35.0% and 19.3% of the number of contracts for import of technology (Fajnzylber, 1971).

generally scarce, it is also known that in the electrical machinery industry licensing is widely used too, even by the large producers, as shown in detail by Surrey and Chesshire (1972, pp. 24 & 25).[1/]

The main differences with the situation found in the LDCs, of which the Brazilian situation seems to be typical (see Chapter IV), is that in the advanced countries licensing is coupled to a strong capacity in SR, reinforced by a continuous investment in such capacity (see Table II-17), so that the firms are able to develop their own designs for new and complex products, as well as to maximise the benefits from a mixed strategy, while in the LDCs such ability for SR applies mainly to old or simple products, reflecting and reinforcing a predominant reliance on licensing for new products.

Finally, to conclude this Section, bringing together also the results of the analysis of the preceding Sections, we can suggest how the main characteristics of the enterprises affect their choice of strategy:

1) The evolution (structure and timing) of the product-mix - If the enterprise changes the composition of its product-mix considerably, introducing many new products, SR will be more difficult, especially if the changes are made over a short period of time (see especially Section 3 and above).

2) Time-Preference - We have previously argued (Section 4 and above) that a high present time-preference runs against SR for new products.

3) Financial resources - We have also argued that, because of the differences in timing of the streams of incomes and outlays, SR requires

1/ See also Table II-17 for U.K. data.

TABLE II-17: UK RELATIONSHIP BETWEEN R&D PERFORMED IN-HOUSE AND LICENSE PAYMENTS - 1968.

Industry	In-House R&D	Licensing Payments Payments
Mechanical Engineering (Total)	100	60.04
Machine Tools	100	19.23
Industrial Engines	100	2.78
Electrical Machinery	100	9.06 1/
Total Manufacturing	100	17.09

NOTE: 1/ Includes "Other Electrical Engineering".

SOURCE: Economic Trends, (1974).

greater availability of financial resources than licensing (Sections 4 and 5).

4) Evaluation of different types of outcomes and uncertainties - For new products, in licensing the firm exchanges the risk of technical and economic failure for the risk of having its decisions controlled and having its growth limited. In SR the firm takes the possibility of higher growth and autonomy but also a greater possibility of failure (see above).

The evaluation and comparison of such different outcomes and uncertainties will be dependent on the characteristics above (1 to 3), but also on the evaluation of the entrepreneurs of the importance of retaining control of their decisions: a point which we discuss in more detail in the next Chapter.

II.6) The Role Played by the State

The focus in this Section is on how the State affects the market forces and the characteristics of the enterprises previously examined which shape the choice of strategy by the enterprise. The form of such interference and its intensity will, of course, vary from country to country. Nevertheless, we can take as general feature of modern capitalism a substantial interference of the State in economic interrelations between enterprises, often acting as an entrepreneur itself through the State Enterprises (Schonfield, 1970). The Brazilian State policies are examined in detail in Chapter V.

In fact, through the State's powers of:

1) interfering on the access which enterprises of different sectors and different ownerships (e.g. foreign vs. nationally-owned) have to the means of production, financial resources and customers located in the geographical area over which it has national sovereignty as well as on the prices paid for such resources and commodities (e.g. through credit policies, foreign investment policy, import policy, etc.);

2) Interfering in the appropriation and distribution of profits by different enterprises (e.g. through fiscal policy, monopoly laws, etc.);

3) acting as a direct supplier of services and commodities (e.g., through the State Enterprises, through parts of the science and technology system and the education system,eetc.);

the constraints above examined - users' needs, the resources need for the design activities, the structure and experience of the capital goods industry, and the availability of financial resources - may be deeply affected.

In the advanced capitalist countries, the policies implemented by the different national States have generally favoured the development of a capacity for self-reliance in their natinnal capital goods enterprises, through:

1) The funding of the education system (especially engineering education) by the State - a normal feature in many countries (e.g. the U.K., France, F.R.G., etc.);

2) The funding of universities, reseεrch centres and other sources of information, such as standards systems and centres for technological

information (e.g. the SBA in the U.S. and the Rationalieserung Kuratorium der Deutsche Wirkschaft in the F.R.G.);

3) The support given by the State to the technological innovation in the ppstream and downstream services and industries (see Table II-18), through the funding of R&D projects and through State purchases. In the advanced countries, electronics is the prime example, but other results of the funding of the other "high-technology" sectors' R&D (aircraft, space, and nuclear power) are also important such as the development of ceramics and highly resistant materials. 1/

4) The preservation of the rights of monopoly of the designs to the enterprises which develops them, including the right to obtain compensation from those who try to appropriate such information without due payment. 2/

Such legal framework is provided both by national laws, such as patent laws, and by the agreement of national States to international procedures, as those of the Paris Convention. The ACs' States have not only relatively efficient legal systems but have also always strongly upheld the internationalisation of such rights.

5) Provision of financial resources for the technological development of the capital goods industry - As we have seen (Table II-7), Government

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1/ The case of electronics deserves to be stressed in view of its role in the technical progress of the capital goods industry (see Section 2) and of the role played by the U.S. State in its development - as shown by Freeman (1974) and Schnee (1976), the U.S. State demand, especially for defence purposes, was critical in sustaining the semi-conductors industry throughout its learning period, which allowed it to achieve the enormous cost reductions that spawned its diffusion later on.

2/ Demsetz (1969) goes as far as saying that "appropriability is largely a matter of legal arrangements and the enforcement of these arrangements by private or public means, The degree to which knowledge is privately appropriable can be increased by raising the penalties for patent violations and by increasing resources for policing patent violations" (p. 170).

TABLE II-18: GOVERNMENT R&D EXPENDITURES IN MANUFACTURING INDUSTRY IN SELECTED OECD COUNTRIES - IN PERCENTAGE - 1971.

Industry	US	UK	Japan	FRG
Electrical Machinery	31.8	1.1	13.3	23.7
Machinery	4.0 4/	3.8	67.0	8.3
Electrical Equipment & Computing	5/	23.0	6.2	5/
Metallurgy 1/	0.2	0.5	2.1	1.7
Aircraft	54.5	67.4	n.a.	58.5
Chemicals 2/	2.8	0.8	4.2	1.7
Others	6.7	3.4	7.2	6.1
Total Manufacturing	100.0	100.0	100.0	100.0
US $ Value of Total Manufacturing 3/	7213.0	519.2	510.7	346.2 6/

NOTES: 1/ Ferrous metals; Non-Ferrous; Fabricated Metal Products.

2/ Chemicals; Drugs; Petroleum Refining.

3/ US $ Millions. Converted at official exchange rates.

4/ Includes "Instruments".

5/ Included in "Electrical Machinery".

6/ Inclusive since 600 million DM. for which no breakdown by industry branch is available.

SOURCE: O.E.C.D. (1975).

funds account for a substantial share of the industry's R&D expenditures. Such funds represent an important part of the total allocation of total Government funds to R&D in manufacturing industry especially in Japan and in the F.R.G. (see Table II-18).

State resources for technological development are normally provided in very generous conditinns and often cover the majority of the costs of the projects to which they are allocated.

In the F.R.G., for instance, in the "Programme to Support Key Technologies", Federal Government grants cover 83% of the total project costs in the mechanical engineering industry and 48% in the electrical engineering industry. In another programme ("Programme for Important Innovations") directed mainly to smaller enterprises (the majority in mechanical engineering), up to 50% of development and pre-production costs can be covered by Government grants, which have to be repayed only if the project proves to be commercially successful within ten years (Braunling <u>et al</u>., 1976).

In other cases, they are provided as risk-capital to the enterprises, normally in exchange for equity participation, as in the case of the SBICs in the U.S. (Bean <u>et al</u>., 1975) or to be covered by a levy on future sales, as in the case of the NRDC in the U.K. (Walker, 1976).

In some cases, such funding is linked to purchases from the State. In the U.S., for instance, the role of military purchases has been especially pronounced and has increased over time, as can be seen in Table II-19, by the participation of the NASA and DOD in the Federal funding of R&D expenditures in the capital goods sector (circa 80%, in 1973). It is estimated that circa 90% of the DOD contracts are negotiated so as to ensure that the firms recoup all their R&D and design costs (Neppy, 1976).

TABLE II-19: US - NASA AND DOD PARTICIPATION IN FEDERAL UNDS FOR R&D - 1963, 1968 AND 1973.

Industry	1963			1968			1973		
	DOD[1/]	NASA	Total	DOD	NASA	Total	DOD	NASA	Total
Machinery	59.2		59.2	51.3	27.9	79.2	64.4	18.9	83.3
Electrical Equipment & Communications	64.9		64.9	65.5	18.4	83.9	71.8	8.1	79.9

NOTE: 1/ Includes NASA.

SOURCE: N.S.F. (1975).

It is important to note that through policies such as those mentioned above, the State reduces not only the costs, but also the uncertainty for the capital goods enterprises.

6) Protection in the National Market. The profits accruing to a firm which develops its own designs will be greater the longer it can maintain its lead over its competitors and the State, in actice, can affect this lead by its policies related to entry in the market.

Such policies cover a wide span of instruments. In the advanced capitalist countries, States have often restricted the entry of products of competitors from abroad through explicit measures such as "buy national" acts (see below) and, less often, through measures such as import controls as tariffs and quotas and, more indirectly, through the exchange policy. Competitors from abroad have also been deterred to enter the market through the policies related to foreign investment, such as the selection of sectors in which this investment is allowed, remittances provisions, fiscal incentives, etc. The Japanese case presents a good example of the careful use of the above-mentioned measures, coupled to State financial support to local design efforts (see Table II-7) and the selective use of licensing to achieve considerable SR in a relatively short period (Jequier 1970 ; Barrio , 1974).

Among the policies above-mentioned probably the most important for the capital goods industry in the advanced countries has been the policy of local purchases ("buy national") of the State Enterprises and agencies.

Although in the advanced countries, State purchases of capital goods cover a wide range of products, they are especially important for those products which have to fulfill high-performance and reliability requirements, because of the important role played by the State in those sectors (see Section 2).[1/]

Apart from armaments, in some industries (electric power, railways, telecommunications) the State is often the sole purchaser, (e.g. in France, in the U.K.). As a monopsonist it sets not only the size of the demand but it also bargains with the enterprises the price and conditions of purchase (Machlup and Taber, 1970).

Even where the State is not the sole purchaser its purchases have played an important role providing the enterprises with a minimum market with which to cover the costs of design and allow for learning effects and in setting a precedent for purchases by private enterprises, both in terms of conditions of sale and as a demonstration of the value of the equipment. The role played by the State's purchases in early stages of innovations has been more studied in the U.S. for electronic products such as semi-conductors and computers (Freeman et. al. 1963; Schnee , 1976) where learning effects have been remarkably high, Such role is very important also in industries where learning factors are not so dramatic, but where the costs of the equipment are so high that national markets are usually not sufficient and the firms must operate on an international scale, as is the case for electric power generation equipment, where the national markets act as a "platform" for international sales (Surrey and Chesshire, 1972).

1/ As it is known, the State in capitalist countries has tended to concentrate its entrepreneurial activities in sectors where capital investment is high and pay-back periods long, which serve as suppliers of essential inputs to the other economic activities (e.g. electric power generation, railroads). From such sectors come a high proportion of the demand for heavy engineering products (BIPE, 1972).

In other cases, such as for NC machine tools, the action of the State in OECD countries extended beyond initial purchases and demonstration effects, including also active encouragement of purchase by private enterprises through special depreciation rates and low interest rates loans for purchase (OECD, 1970).

Also, in its capacity of purchaser of goods and services the State has played an important role through the support given to local engineering firms which will tend to favour local producers and thus represent an important marketing outlet for the local capital goods industry's products and designs (see Section 4).

Therefore, in the advanced countries, the State has often acted in the sense of guaranteeing and widening the national market for the local capital goods enterprises, especially for the more complex products, reducing thus the risks of a strategy of self-reliance; a policy often coupled to the direct support of the costs of such self-reliance.

Moreover, through the diffusion of some of the innovations developed especially for the State, the other enterprises of the industry have benefited too, especially since some of the most important technological developments have been originally introduced in products purchased by the State (see Section 2).

7) Protection in the International Market Export credit provided by the State, often backed up by diplomatic efforts, is presently, one of the main instruments in the international competition for sales of capital goods, to the ex ent that several of the more advanced States have recently begun a process of coordination in order to avoid

mutually disruptive competition in this area (Financial Times, 10/2/76).[1/]

Sales on an international scale are often necessary to warrant production of some capital goods, especially the more complex ones and those which are produced over a wide range of models, even if local markets are protected. In turn, because of the nature of the competition, in terms of the quality of the products, and because of the restrictions on international operations imposed by licensing, an SRS is often necessary to sell such products internatinnally.

8) Reduction of time-constraints - We have previously stressed the importance of time-constraints in design costs. Where the capital-goods enterprises face customers which operate with long-term investment plans, such constraint can be reduced and the capital-goods enterprises can also improve their production planning reducing thus the probability of excessive diversification.

This is an aspect in which the procurement policies of the State play an important role in many advanced countries (e.g. France, the U.K.) although often, as in the case of wrong planning, with counterproductive effects, as seen recently in the case of electric power in the U.K. Such role could be enhanced if there was a co-ordination between the several State agencies, but in most capitalist advanced countries, the most that has been achieved so far is the financial coordination of the Government expenditures through the budget, often exluding the nationalised industries (see Chapter V for the Brazilian case).

1/ The international competition in credit raises, in turn, the importance of the credit mechanisms for local sales as an instrument of protection, a point often overlooked in the trade literature (see Chapter V).

In short, one can say that in the advanced countries, the favourable conditions for SR we previously saw as the result of the greater development of the division of labour and the social conditions of production (Section 4), are, in part, reinforced by the action of the State (e.g. the provision of technical information) but also, in part, are created by State action (e.g. the provision of R&D funds).

Although the social conditions of production and the action of the State are closely enmeshed in practice, it is nonetheless important, analytically and empirically, to retain their distinction. In the same way as we cannot say that the conditions of production result from the action of the State - which would imply a different mode of production - we also cannot say that the action of the State is given by the conditions of economic development. While the latter is the result of the individual processes of accumulation of many capitals, the action of the State, although it reflects indeed the material conditions of production, is mediated by political processes and, because of its role of providing cohesion to the system, must retain a certain distance from individual processes of accumulation.

In fact, it should be stressed that the policies we have examined above are mostly permissive and not mandatory of self reliance, i.e. they provide the capital goods enterprise with more favourable conditions for SR but they do not oblige them to follow such a strategy, except in some cases of coupling State purchases with self-reliance.

Nevertheless, the State action in the advanced countries in favour of greater technological self-reliance in the capital goods industry imply that even in such economies, with their favourable economic conditions, there is a degree of sub-optimality in the SR provided by the market, which licensing does not replace either, as in such countries there are normally no restrictions to licensing. In the next Chapter, discussing the social (as opposed to private) implications of the two strategies, we return to this point in more detail.

Finally, to conclude this Chapter, let us consider the relationship between the State policies and the risk-propensity and time-horizon of the enterprise.

Apart from instinctive and imponderable "animal spirits", the attitudes of the firm as regards its time prospective and risk propensity are probably shaped through a learning process based on their experience and on the observation of similar enterprises. Such experience forms, and, at a subsequent point in time, is perceived through what the literature often terms "the interpretative filter" (Balch and Wu, 1974). The experience of psychologists and psychoanalysts suggests that once this interpretative filter is constituted it tends to act in a self-reinforcing way, i.e. to interpret reality in such a way as to confirm the basic ideas of the "filter".

If the actions of the State play the role we have previously argued, they do, the enterprise will have to take them into account, and, after some time and experience, it will form an expectation about such actions, which will be part of its interpretative filter and contribute to the shaping of its time-horizon and risk propensity. In fact, the predictability of the action of the State becomes one of the cornerstones of the risk-propensity and time-horizon of the enterprise.

It is worth emphasising the self-reinforcing nature of the interactions between State policies and enterprises' expectations. If the State's policies have had for some time a "direction" that makes one strategy, say, licensing, more attractive than the others, the enterprise will tend to commit its resources to that strategy. It will probably act upon the expectation of the continuation of that "direction" and therefore it will tend to resist sudden changes and probably press the State for the continuation of the same type of policies as before. That is, the self-reinforcing features of the strategies, previously observed at the level of the firm, are mirrored at the political level too, which constitutes one of the main obstacles to introduce substantial changes in the general orientation of the State policy.

APPENDIX A: RE-DESIGN AND COPYING IN THE CAPITAL GOODS INDUSTRY

A.1) The Importance of Re-Design

Although in recent years there has been a considerable effort by design theorists and educators to develop and teach design methods[1/] that free the designer from reliance on past practice, re-design is still the most prevalent approach in the capital goods industry.

In fact, Eder (1966a), who strongly recommends the new methods, in his survey (Eder, 1966b) of the application of design techniques in several capital goods industries (machine tool production, tool making, powered manual equipment, electronics, heavy electrical engineering, hydraulic engineering and chemical engineering), found that, in the majority of cases, formal methods of approaching the design problem of capital goods, were relatively little used, with overwhelming emphasis being placed on more intuitive and incremental tehhniques, through the use of previous designs and past experience. The main exceptions to this pattern were electronic equipments and, to a less extent, some equipments where electronics play an important role, such as numerically controlled machine tools, where systems-approach to design were found to predominate.

More recent surveys of present design practice (Weaver, 1976), as well as studies of the technological development of the capital goods.

1/ By making explicit the steps and decisions involved in the design process and by recommending the use of systematic approaches to the design problem, such as decision-trees and systems-search (see Eder, 1966a for a good discussion of the methods proposed) design theorists hope not only to increase the efficiency with which designers operate but also to widen the scope for creativeness by enabling (and impelling) the designers to look for different alternatives than those suggested by past experience.

industry (Burstall, 1963; BIPE, 1972) and analyses of design practice in specific capital goods industries, confirm Eder's findings that, in the majority of cases, new designs represent improvements of the preceding designs, with rare radical departures from established practice.

This is the case, for instance, for machine tools (Shigley, 1956; The Engineer, 30-10-75), presses (The Engineer, 19/6/75), electric power generating equipment (Surrey and Chesshire, 1972), heat exchangers (Fraas and Osizik, 1965), gas turbines (Vickers, 1966), compressors Engineering, March 1974) - a pattern confirmed by the evidence presented by the specialised journals, such as Engineering, The Engineer and American Machinist, in terms of case studies of enterprises and products.

There are considerable economic and technical advantages in this extensive use of re-design, both for the customer and the producer of capital goods, as well as some important limitations. As advantages, first, costs will be reduced, as less resources have to be invested in the feasibility and detailed design stages. The design and manufacturing processes will also benefit from learning effects, as the repetition of similar tasks increase their productivity. The importance of the latter, generally acknowledged under the heading of "experience", have been specifically analysed by Hirsch (1952, 1956), by Surrey and Chesshire (1972) and by Sciberras (1974) in the cases of, respectively, machine tools, electric power equipment and semi-conductors, and all of them agree on the importance of learning in design and manufacturing as an element of cost reduction and competitiveness.

Second, delivery times will be reduced, which also implies a reduction of capital costs. Third, and most important, the equipment delivered will benefit both in terms of more accurate performance (as relatively more time is spent on optimisation) and in terms of risk reduction, as well-proved concepts are used.

Alongside with its advantages, re-design has also some important limitations.

We previously characterised design as a process of matching "structures" (needs, resources and technical solution - see Chapter II). When there is a substantial departure from the past "norm" in one of those structures, re-design may prove inappropriate.

Probably the most flagrant examples of such inappropriateness are found when the sponsors' requirements are substantially different from the usual, as was the case in the demand from the American Air Force which led to the development of numerical control. It is well to remember that the sponsors' requirements may come from the capital goods enterprise itself, pursuing an aggressive policy of innovation, as shown, for instance, by some of the cases studied by Rothwell for textile machinery (Rothwell, 1076).

Other striking examples are suggested by the development of the supplying industries, whose importance we have already discussed in Chapter II.

Finally, a possibly less conspicuous origin of new concepts may be the re-design process itself. As a machine constitutes a system and re-design is often applied to specific parts of such a system (e.g. the power sub-system) there are often situations in which an improvement in part of the system may lead to such an imbalance in the total system that the improved part cannot be fitted into the latter, obliging the company to abandon the old concept and search for a new one, sometimes radically different.[1/]

Nevertheless, drastic changes have tended to be rare in the industry (NC has probably been the main breakthrough in a long period).[2/] Moreoever, after such changes have been made, a process of important improvements through re-design has followed suit, as shown by the case of numerical control.

It is worth pointing out that the re-design process is not necessarily a slow moving process in technical terms. In fact, the experienee of the capital goods industry indicates that it can be quick as well as effective. This is worth stressing, especially since the literature on innovation shows a considerable bias in favour of "radical" innovations.

Re-design, as we have treated it here, relates to improvements on designs previously produced by the firm itself (i.e. it is an activity pertinent to a strategy of self-reliance). However, the enterprise may use as a source of "inspiration" the product of another enterprise and adapt it to its own requirements. In fact, finding a machine which

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1/ As an example from machine tools, higher metal-removal rates lead to larger cutting forces and higher spindle speeds. But the latter excite vibrations which, in turn, may require changes in the structure of the machine tool (Metalworking Production, Sept. 1976).

2/ In fact, NC has been termed "probably the most significant new development in manufacturing technology since Henry Ford introduced the concept of the moving assembly line" (Lynn, 1966, p. 89), which dates from the beginning of the century. Still in this context, it is noteworthy that the concept of NC as applied to other industries than metalworking is quite old - it was applied in the XVIII century (1728) by Falcon to a knitting machine controlled by perforated cards and later on (1804) by Jacquard, in the same way, to a knitting and weaving machine. Moreover, even in the application to metalworking the concept is not new - a patent for its use for the control of machine tools was taken in the US already in 1930 (Braverman, 1974). It is indicative of the complex interplay of demand conditions and technical and industrial possibilities that only when the demand and finance of the US Government were combined with private (John Parsons Co.) and academic (MIT) expertise and with the industrial possibilities opened up by the development of the electronics industry, was the concept finally implemented for the machine tool industry (Ray, 1969; .

performs a similar function and using it as a "model" is an approach often recommended in design (see, for instance, Fraas and Ozisik, 1965, p. 139).

Although copying and re-design require similar skills, especially when adaptations of the product are involved, copying has some specific limitations especially in the conditions of the less developed countries which are discussed in more detail in the next part.

A.2.) COPYING

Copying another firm's products is a traditional form of "catching up" with technological developments in the engineering industry. Saul (1970) writes of the "American development to 1900 as the combined result of original thinking and copying from the British, ... of the traditional American way of catching up in this technology-purchasing British machines through a third party, copying them minutely and advertising them as such" (p. 144).

Copying and adaptation played an important role in the Japanese development and, more recently, it has been reported to have been widely used in less developed nations, especially in China (Haymann Jn., 1975). As we have seen in Chapter IV copying has been a prime source of technical knowledge for the Brazilian capital goods manufacturers.

Copying shares with licensing the reliance on the development of a product by another enterprise but, in practice, because of the skills involved, it is a strategy closer to re-design, as we shall see from the discussion below, which also shows some of the limitations of such strategy.

Copying, or, as it is sometimes called, "reverse engineering", involves a complex set of activities.

Briefly, first the equipment or machine to be copied must be obtained. In some cases, it is purchased directly by the enterprise or through agents but sometimes it is supplied by the client which wants to have "another of the same". (see Chapter IV)

The equipment is then pulled apart, 1/ and its parts analysed and measured, the measurements then being translated into detailed design specifications for the purpose of manufacturing.

From the technical point of view, the main problem of the copier is that it is faced with a finished product, without knowing the information that was used for its realisation, nor the criteria which presided over the several compromises that were involved in such realisation. In other words, the copier knows only <u>what</u> has been produced, not <u>why</u> it was produced in that way. If the copier has some experience of designing similar machines he probably will not face major difficulties in understanding the new one, even if it is for different uses. 2/

A machine can be divided into three basic sub-systems - power, transmission and controls and the transformation system. The first two are often commissioned from suppliers, although of course the producer of capital goods must understand their basic principles and how they articulate with each other and with the transformation system.

Assuming for the moment that the copier can commission the two first sub-systems from suppliers that are in conditions of solving

1/ In some cases, the original machine can be re-assembled and productively used but in others it may become inutilised. In the latter example the cost of purchasing the machines are of course to be included in the costs of copying or, better, the present value of the probable net earnings of the machine.

2/ In fact, finding a machine which performs a similar function and to draw "inspiration" from it, is a recommended approach even when the firm develops its own designs. See. for example, Fraas and Ozisik their own specific technicalities (but see below), there are important differences between products as regards understanding the functioning of the transformation system.

In fact, some of those systems are highly "visible" - that is the case for instance, of most metal-working machines, or, more generally, of those transformation systems where the operations are of mechanical character. However, in those systems where the transformations are essentially chemical, i.e. where modifications of the atomic or molecular nature of the material being transformed are involved, the understanding of their operation requires a knowledge that must be given a priori, that cannot be inferred from observation, as it can in the first case. This makes the copying of machines that perform chemical operations more difficult than copying those that perform mechanical operations.

The use of standardised parts, components and materials by the original producer may help the copier to recreate the specifications - provided that it has the appropriate knowledge of the standards of the original producer, and is able, if the case may be, to translate them into the prevailing standards of its own country. However, in other cases, the reproduction of the specifications may require materials analysis (such as metallurgical analysis), testing, experimentation, etc. Such procedures are not only costly in terms of time and labour costs, but they, like self reliance, require material and human infrastructure of laboratories, qualified personnel, etc., which are often beyond the possibilities of a single firm, especially in the less developed countries.

Therefore, the use of more standardised parts and materials in the advanced countries (see Chapter II), makes easier the copying of such products, even in the less developed countries. However, the lack of development of the suppliers may be an important obstacle to copying, especially when the productive structures of the countries in which the copier and original producer operate are widely different, as is the case of producers of less developed countries copying products from the advanced countries. This gap may oblige the capital goods producer to be more self-sufficient, integrating its production backwards.

In this sense, the trend towards using parts and components and materials embodying the latest advances in technology from other industries, (e.g. in electronic controls), is a deterrent of copying in the less developed countries from the advanced countries.

Copying contains also an element of additional risk which has to be borne in mind when comparing it with other alternatives: the risk of legal action by the original producers, who, based on the legal protection of patents, may sue the copier and impose on him high costs for the copying, preventing its production and therefore wasting the reverse engineering costs already incurred.

Another deterrent to copying may be the fear of reciprocal action by competitors, leading in some cases to an apparent "paradox of copying" - the easier it is to copy, the less frequent it may become.

Retaliatory action by competitors will probably be proportional to the degree in which the copier threatens their position in the market while the probability of legal action will be further dependent on the existence of appropriate legal instruments and the effectiveness of their use. On the other hand, the uncertainty of technical feasibility is less in the case of copying than when developing original designs, provided, of course, a good copy can be made.

Bearing in mind the limitations on the range of copiable goods mentioned above, copying may be a starting point for the development of its own designs by the firm. But if the firm limits its activities to strict copying, even assuming that it can turn out efficient copies, it is implicitly taking a rear-guard strategy in technical terms, with the added risk of retaliatory action by the original producer.