OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

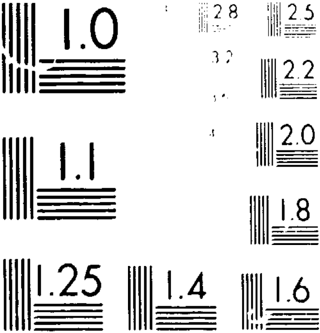
FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org


1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

09990

Distr.
LIMITED
ID/WG.324/4
19 September 1980
ENGLISH
Original: FRENCH

United Nations Industrial Development Organization

Global Preparatory Meeting for the First
Consultation on the Capital Goods Industry

Warsaw, Poland, 24 - 28 November 1980

TECHNOLOGY
IN THE SERVICE OF DEVELOPMENT *)

Prepared by the
Sectoral Studies Branch,
Division for Industrial Studies

*) This document relates to discussion subject No. 2 on the agenda: Types of technologies in the service of the development of the capital goods industries.

This document has been reproduced without formal editing.

80-43753

CONTENTS

I. THE MANAGEMENT OF A COMPLEX OPERATION : GROWTH IN EQUIPMENT GOODS IN THE DEVELOPING COUNTRIES

Growth in respect of equipment goods in the developing countries necessitates the management of a complex operation. This complexity arises not only from the diversity of the sector, which covers millions of products, but also from the diversity of the situations and objectives of the various developing countries. In order to assist these countries in defining and implementing strategies an attempt has been made, as an initial approach, to formulate what may be termed the "laws" of the composition and change of the equipment goods sector.

These "laws" of technological development in capital goods are located at the interface of the laws of nature and of economics. In order to identify them it was necessary to construct a new tool : the analysis of technological complexity (A.T.C.).

Discussion of the results observed and of these "laws" of complexity and change is essential for an understanding of the situation in this key sector. It is this sector which can provide the guiding lines for industrial strategies designed to utilize technology in the service of development.

The general objective of the Lima Declaration and Plan of Action is clear. The contribution of each sector of industry still has to be determined. The target becomes a moving one. It depends on the rate of industrial growth of the developing countries between now and the end of the century. The possibilities open to the developing countries are unequal: the challenge comes not only from nature but also from the contradictory interests. Organization involves many power centres, and the resultant activities are a mixture of conflicts and cooperations.

The resultant complexity is much greater, its organization involves the complex combination and intrincate scheduling of many activities and closely programmend events. The industrialization of the "Third World" requires a methodology of action similar to that which the specialists in systems analysis call "the management of complexity".(1)

Establishing a programme for the production of capital goods in the developing countries falls within this category. Firstly because this sector covers more than 30% of the manufacturing industry, because it is at the heart of the process of industrialization, because it involves several million products, types and models in which various technological ages coexist, and finally because it is simultaneously the manifestation as well as the cause of the fundamental imbalances between under-development on the one side and the industrialized world on the other. The capacity, by way of the manufacture of equipment goods, to reproduce a complex production apparatus - or at the least the greater part of such an apparatus - remains the privilege of the most advanced countries.

The point of departure of the developing countries, taken all together, is only of the order of 5% of world production. The inequality between them is very considerable, ranging from the absence of equipment goods industries in about fifty countries to the existence of established industries, where the essentials are concerned, in a few of the larger developing countries which will soon be able to claim admittance to the "industrial club", and also including many semi-industrialized countries.[2]

This diversity of situations is mirrored by the diversity of the machines.

The world of machines and items of equipment is extraordinarily complex. Each generation has created new machines which are then added to the stock of the means of production of humanity. The number of these has increased prodigiously during recent decades, so that there are now probably of the order of 4 million products. The machines result from the association of multiple production processes and thousands of technologies in specific combinations. Unfortunately we do not have the major intellectual tools which are needed if this complexity is to be dominated, and which thus constitutes a typology of technologies,[3] a mechanology and a general organology.[4]

The technological "order" of machines has not been the subject of systematic descriptions.

Whilst numerous historical surveys of machines exist their technological "order" has not been the subject of any systematic analysis.[5]

Research on technological order in the Western countries has mostly been carried out by philosophers.[6][7][8]

In the European socialist economy countries the laws of the development of technology seems to be an important subject of research in the various Academies of Sciences.[9]

It follows from this that the analysis of machines and equipment, being the principal vectors of technical progress, is essential for understanding technological order and the relationships between man and nature.

The man-machine pair is at the very heart of evolutions in society. It is therefore necessary to attempt to penetrate into the arrangement of the machines and equipment goods system.

In order to make progress in the analysis of the sector a method had to be developed : the analysis of technological complexity (A.T.C.).

The analysis has taken as its point of departure the realization of a threefold deficiency:[10] the absence, as already noted, of an operational typology of technologies, the absence of systematic structural descroptions of the evolution of machines, and the concentration of the existing literature on technological transfer on its trading value rather than on the content of the usage values which are transferred. It therefore seemed to be essential to forge an instrument which would make it possible to identify and to measure the technological content of capital goods. This instrument is the analysis of technological complexity (A.T.C.).

The methodology used is summarized below.[11] The products are measured in terms of the coefficient α, being the value in dollars per kilogramme, and of the coefficient β, its speed of innovation, that is to say the rate of change in products in terms of years (more than 50 years, 50 to 35, 35 to 25, 25 to 15, 15 to 10, less than 10 years). The limits of significance of the coefficient α are discussed in the technical annex.

The analysis was centred on the production function and the identification of inputs.

Measurement of the complexity of machines was therefore carried out by measuring the complexity of their manufacture.

The method comprises 4 successive operations.

This involves four operations: firstly the identification of the variables, that is to say the inputs which are needed to manufacture each group of machines; secondly the technical definition of each complexity level variable; thirdly the choice of a grading scale for complexity and the calculation of an index; fourthly the classification of these variables into sub-assemblies or "blocks" which describe the structure of the production of capital goods.

First operation: identification of the necessary inputs.

i) The variables which were retained were 80 in number. A list of them is given in the technical annex to this document, together with the definitions which have been retained for each of the six levels of complexity.

In reality the identification of the variables is a question of fact: it is either necessary or not necessary to have recourse to this or that means of production, this or that type of casting or forging, to carry out metal fabrication or stamping operations or to incorporate or not electrical, electronic or optical components. The only exception to this is when the manufacture of a machine can be carried out by way of a combination of variables. In this analysis account is therefore taken of the production paths (technological routes) which are most frequently used in industry.

Second operation: fixing the levels of complexity for each input.

ii) Defining the levels of complexity for each variable is a combination of technical analysis with a historical reference. The technologies belong to different generations which can be historically dated.

The six levels correspond to six stages of development of the capital goods industry, briefly described as follows :

1. Embryonic industrial infrastructure in the form of small and medium sized workshops, employing skilled workers, often from countries which have already developed an industry. These workshops have rudimentary equipment, but can supply a new-born industry. This level does not exist in all the countries.

2. The industrial infrastructure develops and is enlarged towards the supply of various technical services and components. The activities must take into account quality standards, even if the technology remains simple.

3. A wide variety of capital goods and infrastructure installations exist at this level. Semi-finished products and components are of increased weight and performance. This level is clearly reached when a true mechanical and electrical engineering industry is established with technology of a high level.

4. This is the stage of maturity of industrial development, observed for example in many of the OECD countries. The industrial fabric is enlarged towards heavy and precision engineering activities. The semi-products and finished products are of high complexity and quality. The research and development capacities are considerable and creative. In most of the capital goods sectors level 4 constitutes the peak point of development.

5 and 6. These two levels correspond to specific industries, armaments, civil aviation, space and other high-technology advanced industries.

These six stages coexist, therefore, in contemporary reality and the developing countries are divided up - in addition to level 0 for about a hundred of them - between classes 1, 2 and 3. Some developing countries have reached class 4.

It has therefore been possible, as has been pointed out, to define in a concrete manner each of these six complexity levels (see technical annex).

It will be seen that, in order to pass from one complexity level to another, time is required: one of the objects of international cooperation is to facilitate the passage from one level to another and to reduce the time needed.

iii) The establishment of quantified indices of complexity

Third operation: calculating the indices of complexity.

The absence of criteria and of an available methodology to quantify the weight of the variable considered has led to having recourse to a conventional grading system.

The convention used is as follows: level 1 of each factor has been given the value 1. It is then assumed that the increase in complexity between the various levels is of the geometrical type, with a ratio which varies according to each factor. This can have the values 1.19, $\sqrt{2}$, 1.68 or 2. The value chosen for each factor is given in the technical annex. It is justified by an empirical appreciation based on experience of the sector. In default of objective measurements this conventional scale can obviously be the subject of criticism, as can any subjective appreciation. It is similar, in its philosophy, to the methods used for quantifying job ratings. Sensitivity tests have been carried out to see to what extent the results would be affected by the choice of other scales.

A "technical data sheet" has been drawn up for each product: an example of such a sheet is given in the technical annex. Each square in this grid is given a "weighting", using the conventional values given above.

The total complexity C_t of a capital goods product is the arithmetical sum of the weights of the various production factors used from amongst the 80 variables.

Since the elements studied are, in fact, homogeneous "products groups" the complexity of any technical factor can have either a minimum or a maximum value for any group of products studied. In this way it is possible to obtain a maximum index of total complexity and a minimum index of total complexity, the mean of these giving the mean index of total complexity.

Because of the exogenous character of the components, which may be imported and which are rarely manufactured locally in the initial stages of development, an index of complexity WITHOUT COMPONENTS has also been calculated, so excluding from the calculation of the index the influence of those factors relating to the components.

Fourth operation: To manufacture equipment goods it is necessary to have : a final production apparatus (the central production units), an infrastructure (all the semi-finished inputs and the technical services) and the components. The 80 variables have been divided up between these assemblies and into sub-assemblies.

iv) Classification of the variables into "sub-assemblies" in the structure of the production of capital goods.

The 80 variables can be divided up into three assemblies :

A. The central production unit,

B. The production infrastructure,

C. The components incorporated in the capital goods.

Diagram 1 shows this arrangement.

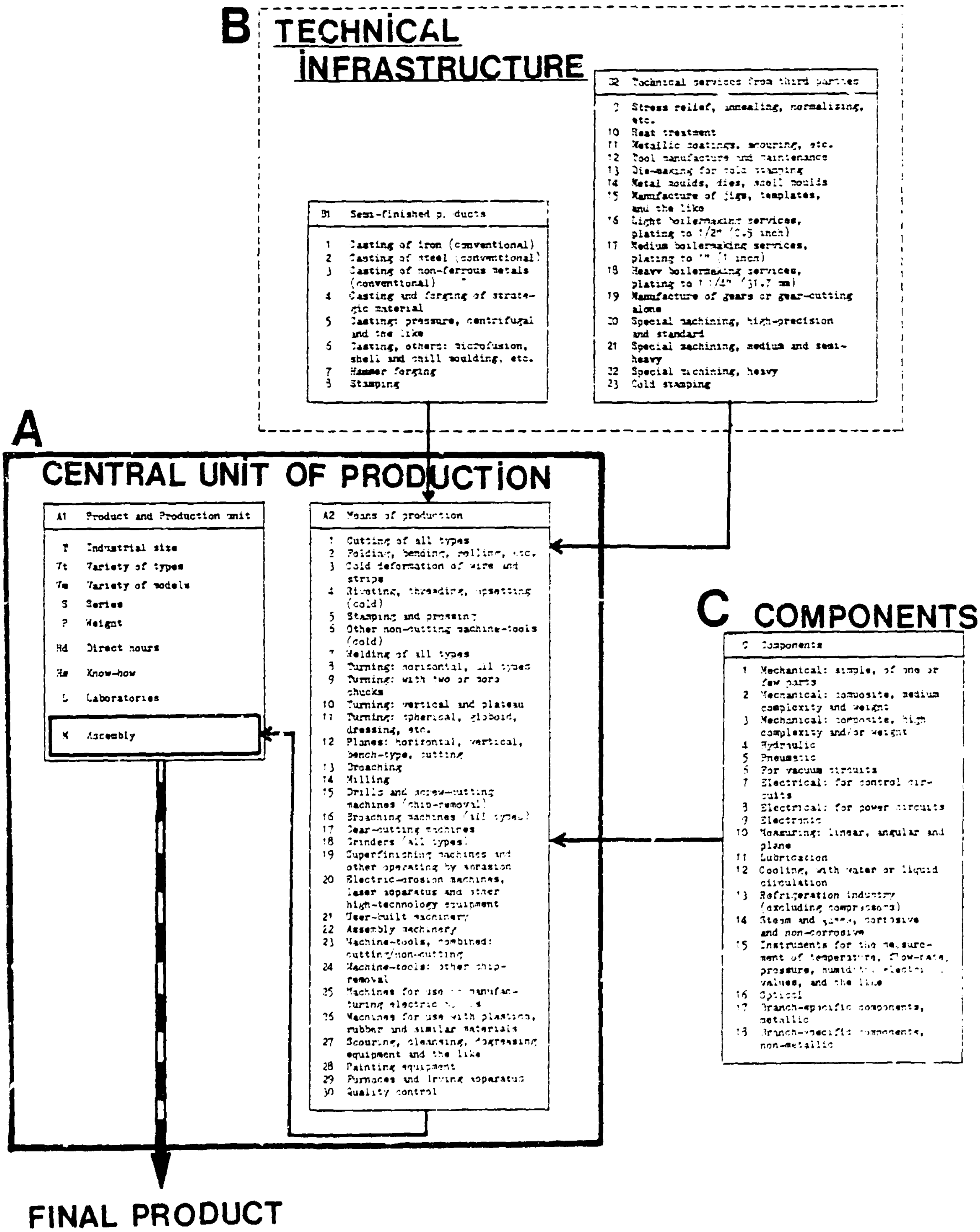
a) The central production unit is the block which supplies the completely assembled product to the client.

It necessarily includes both men and the means of production.

It can therefore be divided into two sub-assemblies, A1 and A2. The first, A1, consists of 8 variables centred on management of the size of the enterprise, on the variety of types, models and economic production runs, and on direct labour and the necessary know-how.

Diagram No. 1

Assemblies and Sub-Assemblies of the Techno economic Factors in the Structure of the Production of **Capital Goods**



The sub-assembly A2 consists of the means of production, that is to say the machinery which is essential for the functions of the central production unit. It comprises 30 variables (subsequently termed the ϕ factors).

b) <u>The infrastructure</u> consists of the semi-products and technical services sub-assemblies.

The sub-assembly B1, "semi-finished products" covers the principal activities of the "first converting of metals" activity, that is to say foundry work, forging and stamping: 8 factors have been retained for this.

The sub-assembly B2, "technical services", covers all the normal sub-contracting work in the engineering industries (annealing, heat treatment, metallization), the supply of manufacturing equipment (tools, dies and moulds, gears, etc.), and also the manufacturing processes which are characteristic of metal fabrication and engineering construction (boilerwork, machining and stamping). It consists of 15 factors.

c) <u>The components</u> are an assembly where 16 types have been considered. They belong to the simple or complex engineering industry (ball bearings, for example) or the electrical or electronic industries, or specialities such as hydraulics, pneumatics, measuring instruments, etc.

The significance of this grouping into "assemblies" and "sub-assemblies" will be further considered later.

In order to measure the complexity of capital goods a sample of 318 groups of machines has been studied.

The analysis of technological complexity has been effected by means of a <u>sample of machines and other items of equipment</u>.

An attempt has been made to constitute this sample in such a way that it would be significant of the whole. The selection involved 318 groups of machines (see the list in the technical annex), all belonging to the group of "fabricated metal products, machinery and equipment" (group 38 of the international ISIC nomenclature).

The products selected represent "groups of goods" with homogeneous characteristics and representative more of a type of industrial manufacture of capital goods than the manufacture of a single product.

In its proportions the sample is a reduced image of the sub-assemblies in the capital goods sector as it can be observed in the developing and developed countries.

In order to study more particularly the situation in the less developed countries and that in the more advanced industrialized countries the sample must be enlarged "downwards", that is to say towards machines of simple technology, and also "upwards" towards the field of high complexity. With this proviso it corresponds to an observable mean.

A first result is the construction of a system of information on the technological complexity of capital goods.

It can be seen that, on the basis of this sample, a system of information on technological complexity has been constructed, the combinatory possibilities of which are very high.(12) With 318 groups of products, 80 variables and six levels of complexity, the system has a recording capacity of 152,640 items of data. As compared with this theoretical capacity the analysis of the 318 groups of machines has effectively mobilized about 35,000 items of data.(13) The magnitude of this figure has justified the processing of the information by computer, and the results of this are set out below.

Notes to Chapter I

(1) For example in the report made to the Ministers for Science of the OECD we read : "The 'management of complexity' calls for a new outlook and approach to overall policy-making". Science and technology in the management of complex problems - OECD, 1976.

(2) See the document "Capital goods in the developing countries (a digest of the world-wide study on the capital goods industry)" ICIS/SEC - July 1980.

(3) The need to establish a typology of technologies has been perceived for a long while and emphasized by all those who have come up against the intellectual and practical obstacles which its absence constitutes.
For example in 1867 Karl Marx deplored the absence of a critical history of technology. In 1965 Miss Joan Woodward pointed out that research workers needed a natural history of industry, rather in the nature of a botanical flora. Leslie Holliday feels that we need to do, for the development of technologies, what Mendeleef and Darwin did for the understanding of chemistry and biology. (The integration of technologies - Hutchinson, London 1966). For his part Hasan Ozbektan has put forward the concept of establishing a periodical table of technologies (noted by Erich Jantsch - Design for evolution - International Library of Systems Theory and Philosophy - G. Braziller, New York 1975.
The starting point on very simple typologies is found in the works of G.R. Hall and R.E. Johnson - Transfers of US aerospace technology to Japan - NBER 1979, and James D. Thompson - Organization in action - McGraw Hill Book Co. 1967.

(4) Mechanology seeks complete technical individuals, general organology the elements which are generally the vectors of technical progress - See G. Simondon - Du mode d'existence des objets techniques, Aubier-Montaigne, 1969.

(5) The fundamental work of J.P. Usher : A history of mechanical invention - Harvard University Press, 1959, opened up the way to a structural analysis of the genesis of machines.

(6) Notably Jacques Ellul : La technique (1954); Le systèmе technicien - Calman Levy, 1977.

(7) G. Simondon : op. cit. (Ref. 4)

(8) Jean Ladrière : Les enjeux de la rationalité - Le défi de la science et de la technologie aux cultures - Aubier - UNESCO, 1977.

(9) A. Zvorikine : Ideas of technology - Technology and the laws of its development in the technological order. Proceedings of the Encyclopaedia Britannica Conference, edited by Carl F. Stover with a foreword by William Benton. Detroit, 1963 - Wayne State University Press.

(10) At least at the level of the information which the Secretariat has been able to assemble.

(11) The methodological questions relative to the analysis of capital goods will be the subject of a subsequent publication.

(12) The 80 variables considered give an effective combinatory variety of 2^{80}.

(13) The Division for Industrial Studies takes this opportunity of expressing its gratitude to Mr Franco Vidossich for his contribution to this original work.

II. AN APPROACH TO THE "LAWS" OF COMPOSITION AND CHANGE IN CAPITAL GOODS

The enormous variety and complexity which characterizes equipment goods gives an impression of overwhelming disorder. However it can be seen, after this first impression, that there are relationships of order and a non-arbitrary arrangement in the world of machines.

An attempt has been made to identify the "laws" which control the composition and change of the sector.

This has been done in the form of "propositions" so as to facilitate discussion.

In total, and where the "laws" of composition are concerned, 8 principal propositions have been put forward, with subsidiary propositions. In the case of the "laws" of change 7 principal propositions are put forward. These are underlined in the text to facilitate an initial rapid reading.

The existence of a "technological order" is a very controversial subject[(1)]. Definitions of "technique" and "technology" are far from unanimous[(2)]. These questions are important, and the fact that they are the subject of debate is, in itself, significant. However, and despite their interest, care has been taken to avoid discussing the principle involved. Attention has been directed towards observing the results of the research work, and an attempt has been made to examine its significance.

This has led the Secretariat to formulate, with great caution and modesty, the following propositions. These are not definitive conclusions, still less matters of revealed truth, but initial deductions which are submitted for discussion*, limited by the representativeness of the sample of machines analysed, and also by the novel character of the undertaking.

These propositions have been classified into two categories: those concerned with the "laws" of the composition of the sector and those which appear to characterize change within it.

---

* It will be recalled that discussion of the "Introductory Document" at the Algiers Seminar facilitated subsequent research work. The present paper, which will be presented to the Warsaw meeting (24-28 November 1980), should make it possible to prepare more fully for the First Sectoral Consultation on Equipment Goods.

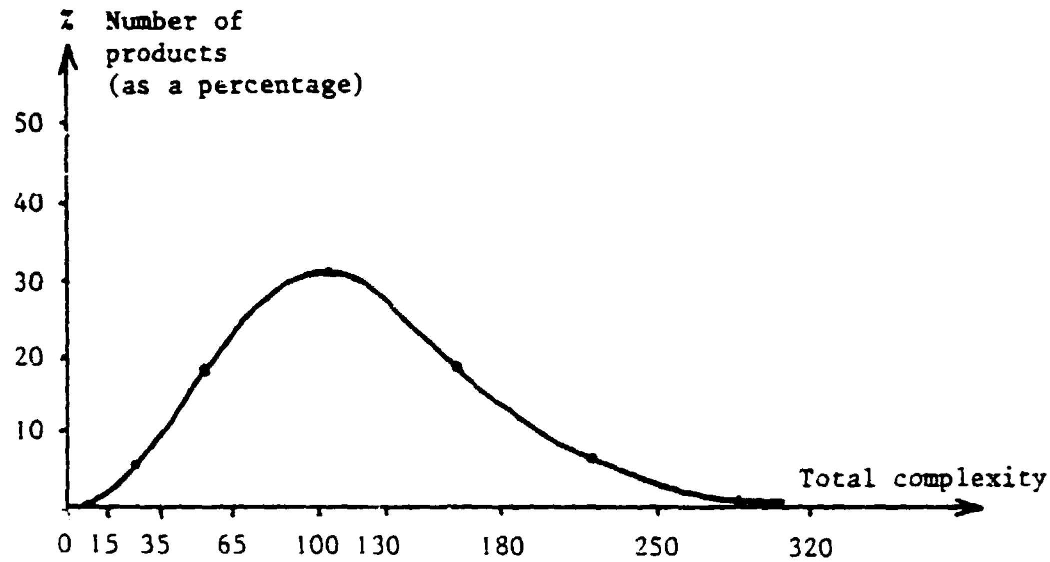
A. THE "LAWS" OF COMPOSITION

- Proposition 1(*): Capital goods are characterized by the considerable heterogeneity of their technological contents and, consequently, by their complexity

The capital goods analysed show a technological complexity ranging from 1 to 40.

The observed dispersion in the results for total complexity shows a ratio of 1 to 40, from a minimum of 15 points for simple metallurgical products to more than 600 for twin-jet aircraft in the aerospace industry.

The distribution of the results is shown in the following graph:



The concentration of the results can be seen from the above graph. About 85% of the products in the sample fall within the range of 35 - 180, which represents a dispersion of 1 to 5, and 33% fall between 60 and 100, a dispersion of 1 to 3. At the two extremities only 6% of the products have a complexity less than 35, with 9% greater than 180.

(*) The principal "propositions" are accompanied by subsidiary propositions: these are related to the principal propositions by having the same number, followed by a distinguishing letter.

Observation of the sample shows another phenomenon: the importance of the weight of components (assembly C) in the total complexity.

Graph 1 shows the mean weight of components in the total complexity is situated at around 30%[(3)]. For products of very low total complexity (up to 35 points) this rôle is small. By contrast in the upper part of the sample their weight represents 45%[(4)], leading to the following subsidiary proposition (SP):

SP 1a : complexity due to components increases with total complexity.

It is therefore important, in the analysis, to compare the results with and without components.

The complexity ratio is never greater than 1 to 20 when components are eliminated.

The dispersion of the results without components is 1 to 20 (as against 1 to 40 with the components); whilst the minimum of 15 points does not change the maximum is reduced to 336.

The concentration of the results is also considerably different. For example 95% of the products have a complexity without components which is between 15 and 130, and 85% fall between 15 and 100 - a dispersion ratio of 1 to 6.

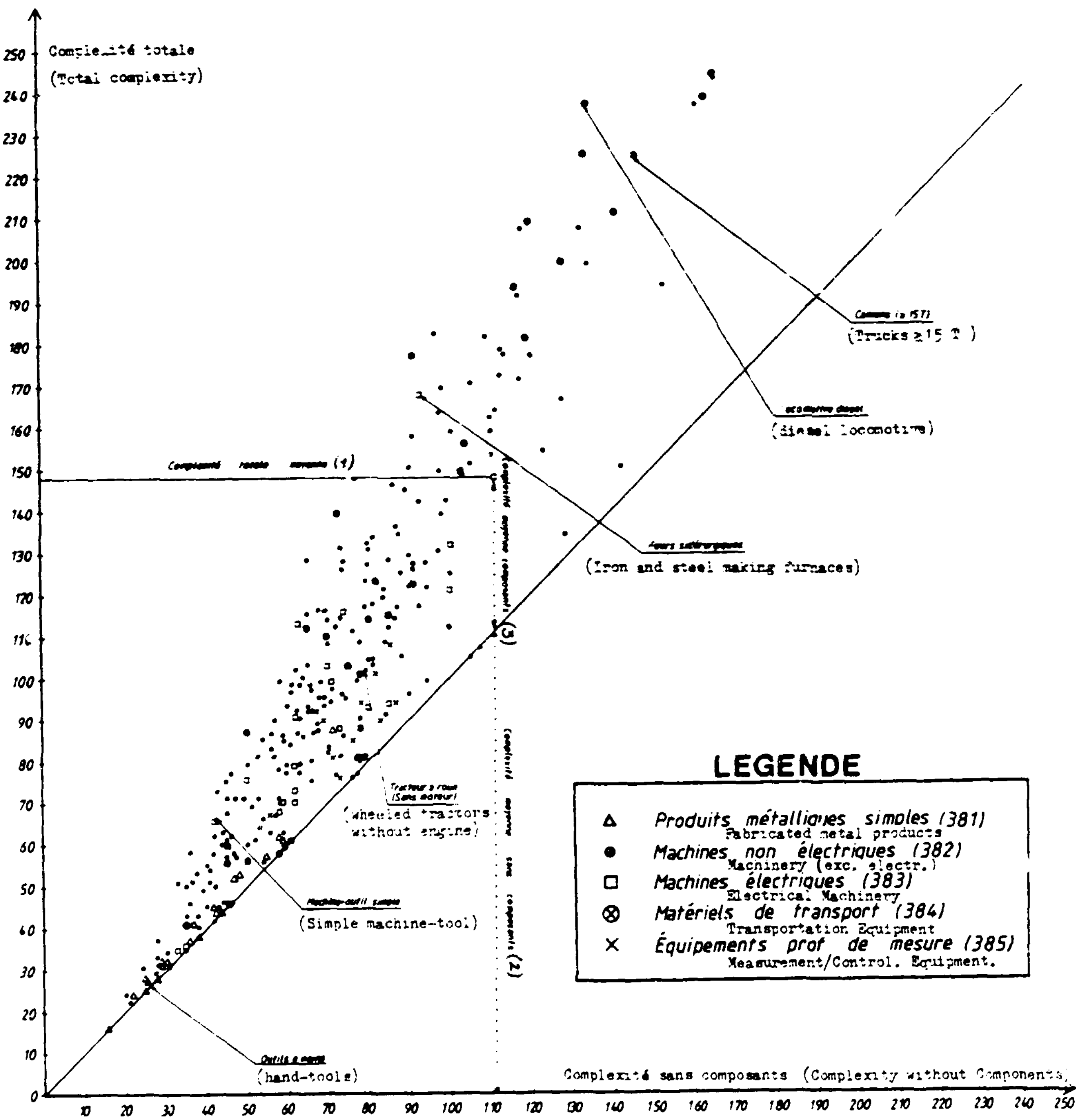
At the extremities the zone of very low complexity is scarcely modified, but by contrast only 5% of the products are found above a value of 130 (as against 25% with components)[(5)]. More than one-third of the products fall within the complexity class 35 - 65, and hence within a dispersion ratio which is less than 1 to 2, whereas the same proportion of products observed with components fall between the values 60 to 180 and hence show a dispersion ratio of 1 to 3.

It can be seen that, where complexity without components is concerned, about 40% of all the capital goods considered fall within the region of 60 - 70.

GRAPHIQUE No 1

DISPERSION DES COMPLEXITES TECHNOLOGIQUES DES BIENS DE CAPITAL

(DISPERSION OF TECHNOLOGICAL COMPLEXITIES OF CAPITAL GOODS)



1) Average of total complexity
2) Average of complexity without components
3) Average of complexity of components

It follows, therefore, that it is important to identify the levels of the productive apparatus which consists of assembly A (central production unit) and B (technical infrastructure) and which make it possible to manufacture various assortments of machines.

SP 1b: the dispersion of production complexity for capital goods without components is smaller, although it still remains large.

*

* *

The changes have been studied at the level of groups of machines.

The general appearance of Graph 1 gives an impression of continuity in technological complexity, and does not make it possible to identify groups of homogeneous products, the typical levels of complexity, or the discontinuities in the latter. It is necessary to carry out stratifications in the sample to identify these phenomena. This is why an analysis by groups of capital goods has been carried out.

These groups can be considered from various points of view.

According to the conventional international classification.

The various categories of machines can be classified according to a principal characteristic (e.g. international classification). Within class 38 the metal products are simple (sub-class 381), non-electrical (382), electrical (383), transport (384) and measurement and monitoring (385). It will be seen that, conceptually, this classification is a mixture of the characteristics of the production and use of the machines. To take one example, if we consider all the machines and tools used in agriculture these are broken down into various categories of the international classification.

A functional and technical classification.

Another classification involves considering the machines according to their functions in the process of industrial production. In this way certain capital goods are semi-finished products (and hence intermediate products, such as stamped components), whereas others are parts which are used in other machines where they constitute sub-systems (e.g. clutches, speed variators, etc.), others are autonomous finished products (e.g. engines, turbines), whilst others are finished but integrated products (equipment for petrochemicals, for example). This leads to a functional classification.

According to the final demand ...

From the point of view not of the supply of machines, but of the demand, it is possible to distinguish those capital goods which serve all branches of activity (e.g. universal machine tools), those which are common to several branches (e.g. industrial furnaces, steam condensers), and those which are specific to a final industry (e.g. textile equipment, equipment for the extraction of minerals, agricultural machinery).

Within this framework it is important to distinguish those capital goods which are used for the reproduction of consumer goods from those which are used for the reproduction of means of production (the machines which make the machines)[6].

Graph 1 shows the products classified according to their principal characteristic.

The same applies to Graph 2 where two other classifications have been represented, related to function and to demand.

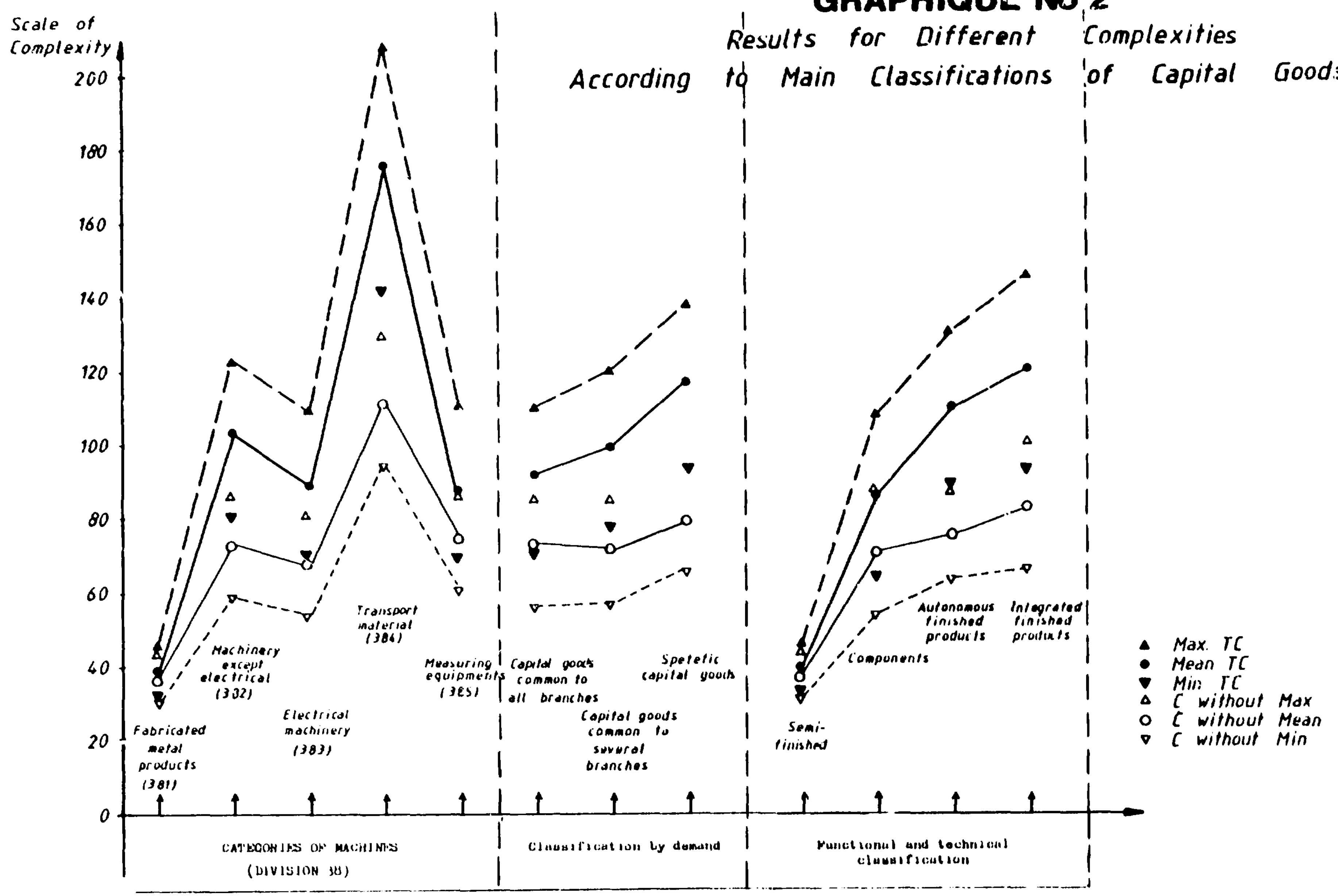
and according to a progressively more detailed breakdown.

This breakdown is carried still further in Graph 3 where capital goods common to several branches of activity have been divided into sub-groups: machine tools, engines of all types, pumps, compressors and boilers, parts and sub-systems for machines, small parts and simple mechanical components, steel components for building, storage and handling equipment, miscellaneous equipment, electrical components and parts, office equipment and road transport equipment.

The same applies to Graph 4 which shows the distribution of complexity of the machines specific to various sectors.

GRAPHIQUE No 2

Results for Different Complexities According to Main Classifications of Capital Goods

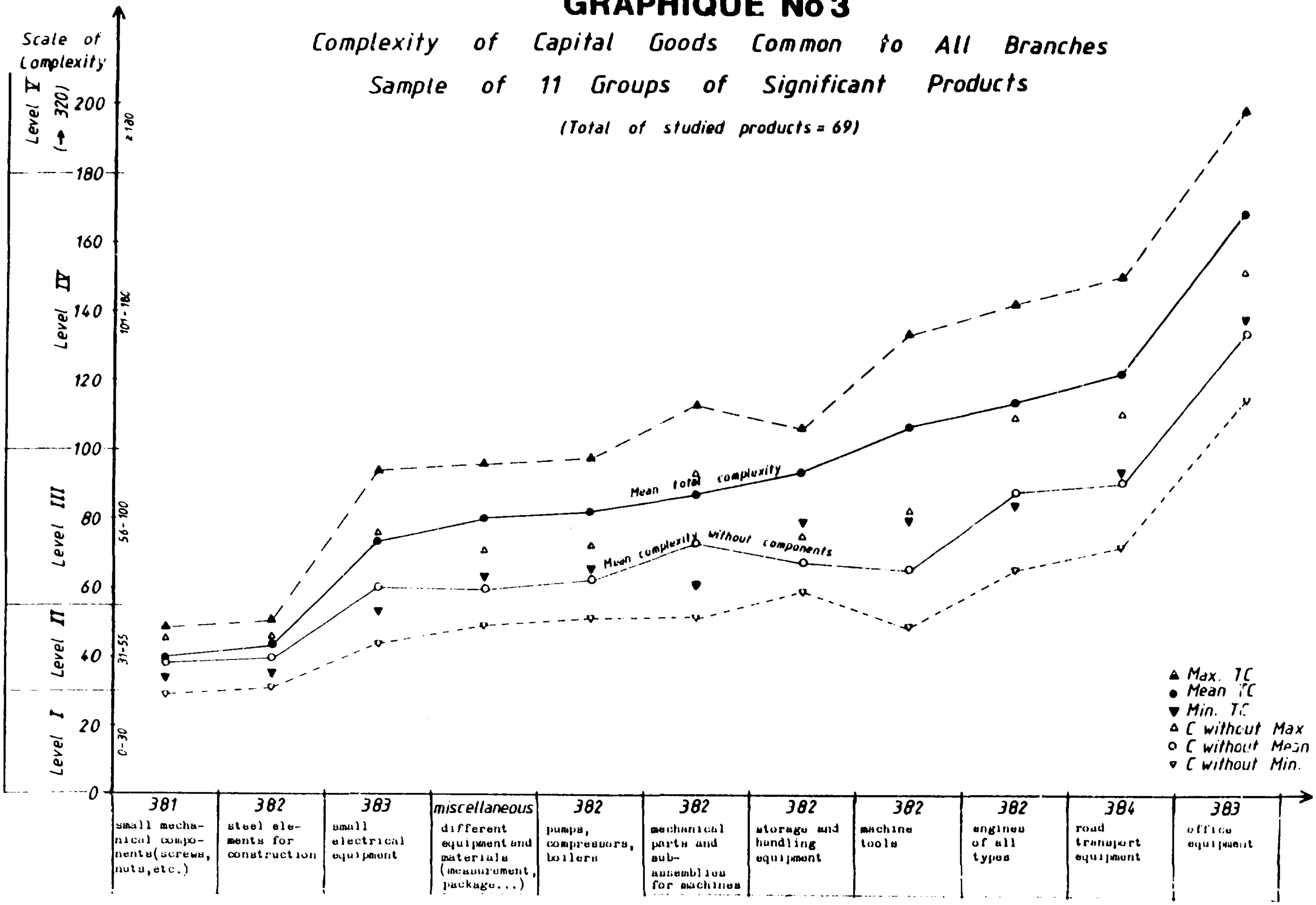


GRAPHIQUE No 3

Complexity of Capital Goods Common to All Branches

Sample of 11 Groups of Significant Products

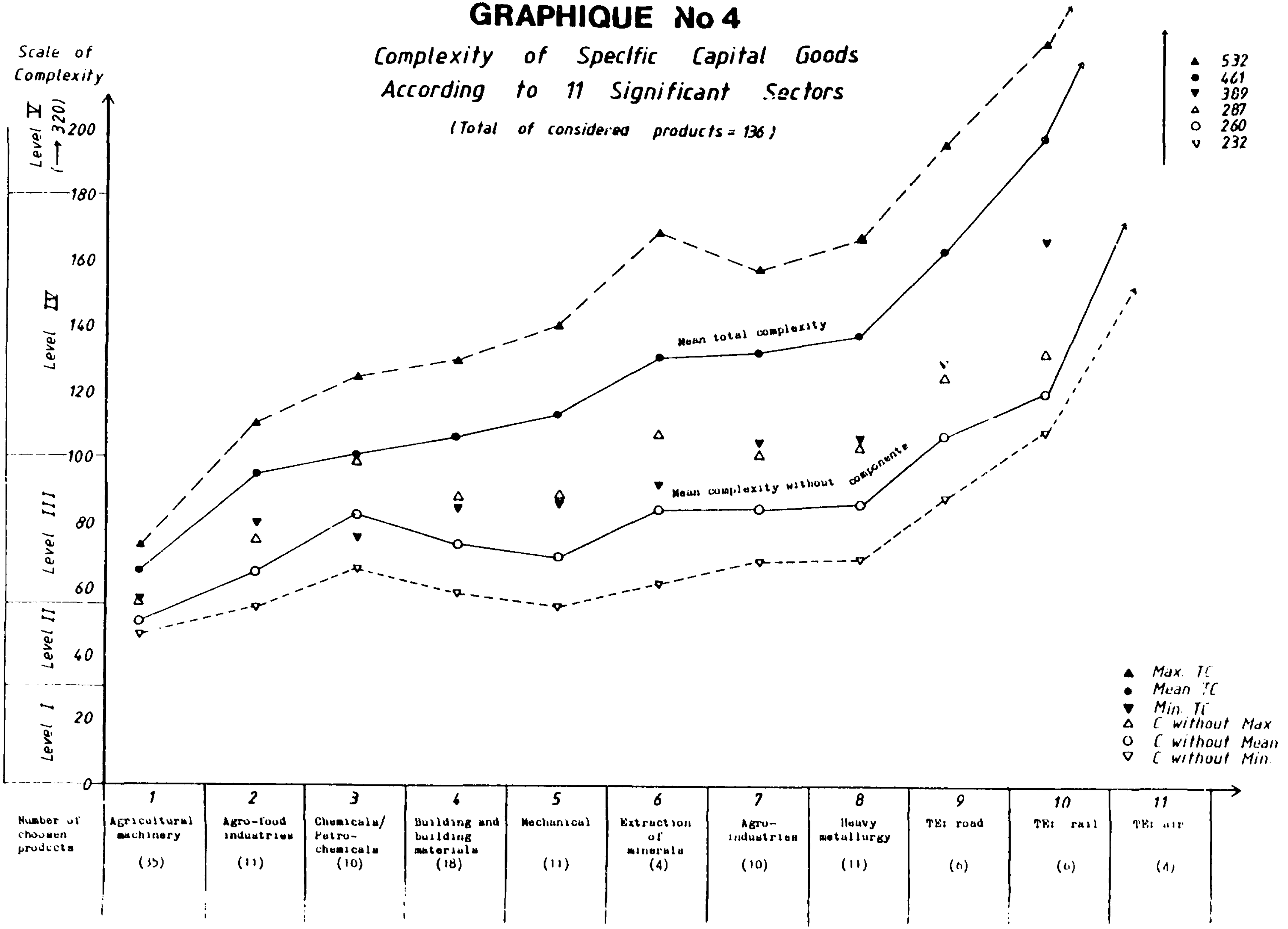
(Total of studied products = 69)



GRAPHIQUE No 4

Complexity of Specific Capital Goods According to 11 Significant Sectors

(Total of considered products = 136)



The examples cover agricultural machinery, equipment goods for building and building materials, the agricultural industries and the agricultural and food industries together with the basic industries: extraction of minerals, heavy metallurgy, the chemical and petrochemical industries, and the converting industries: mechanical engineering and the manufacture of transport equipment.

These various clarifications make it possible to identify the following propositions:

- Proposition 2:

These analyses make it possible to classify groups of machines by complexity ...

. Considered as products (international classification) the machines show great inequality of complexity. The mean complexities are arranged in the following order: simple metal products < electrical machines < measurement and monitoring instruments < non-electrical machines < transport equipment[(7)].

This mean order of complexity with components does not vary when calculated without components; however the dispersions vary.

. Considered from a functional and technical point of view, the machines have the following order of mean complexity: semi-finished products < parts < autonomous finished products < integrated finished products and sub-systems.

. Considered as goods intended for other branches of activity the machines have the following order of mean complexity: goods common to all branches ≤ goods common to several branches < specialized equipment.

Tables 1, 2 and 3 (see technical annex) amplify Proposition 2 concerning capital goods considered as products. They show that, below 35 points, the products are simple metal products - essentially simple agricultural machines - and some non-electrical machines. The range of complexity 35 - 65 contains 20% of the sample. Apart from the remaining simple metal products one finds non-electrical machines. The items of transport equipment present are of little significance in this category[8].

In the range 65 to 130 are concentrated the majority of the sample (more than 50%), in particular mechanical engineering (55% of category 382 is produced at this level of complexity), electrical engineering[9], and transport equipment. Beyond the figure of 130 the remainder covers about 20% of the sample. These are non-electrical machines of high complexity and transport equipment.

Table 4 (see technical annex) amplifies Proposition 2 when capital goods are considered by functions[10]. The order observed corresponds closely to a process of successive integration of the components of the machines in order to arrive at the final products.

Table 5 (see technical annex) also justifies Proposition 2 concerning capital goods considered as goods intended for other branches of activity.

Capital goods designed and produced for a single user branch (iron and steel or textiles, for example) have been distinguished from capital goods which are used in several economic sectors (e.g. the heavy industries) and goods common to all branches (e.g. conventional machine tools).

Analysis of this table leads to the following subsidiary proposition:

SP 2a: the total mean complexity of capital goods increases with the specific character of the demand for these goods.

.... and to begin to detect interesting phenomena.

For example the "common goods" are, on average, less complex than specialized goods by 30%. These groups include, as will be seen, high disparities within themselves. Elimination of the components effectively compresses the mean complexities of the three groups: the overall divergence is no more than 10%. The influence is considerable in the group of specialized goods, where the mean complexity is reduced by a third (from 116 to 79 points). This leads to the following subsidiary proposition:

SP 2b: the mean complexity, without components, of capital goods considered according to the nature of the demand, does not seem to vary significantly within the three groups considered.

By contrast the divergences between the minimum and maximum mean complexities are considerable for each of the groups (55% in respect of the mean value for goods common to all branches, 42% for goods common to several branches and 36% for specialized capital goods). This leads to the following subsidiary proposition:

SP 2c: within each group of capital goods there exist technical alternatives which make it possible to modify the levels of complexity downwards or upwards.

Goods common to all branches of activity, which represent 40% of the value of capital goods, are the subject of special analysis.

- Proposition 3: The mean complexity of goods common to all branches is less than that of the mean of all capital goods. The weight of the components is less, but the dispersion of complexity is considerable. There is a technological gap between the products of low complexity and the others.

It is of value to study this group in greater depth since, a priori, it could constitute a way of entry into the capital goods industry for certain developing countries. This sector is important from another point of view. It is capable of providing employment and of exercising a multiplying or encouraging effect on the downstream industries, particularly the mechanical sub-assemblies or semi-products. It is also capable of raising the levels of integration during technological transfers, for example by integrating structural metalwork and general technical equipment. Finally it will be recalled that it represents about 30% of the total production of mechanical and electrical goods (40% if one considers only capital goods). Metal products alone account for 10% (structural steel components, containers, cables, screws, bolts, tools, etc.), non-electrical machines for 14% (engines, data processing, machine tools, pumps, compressors, etc.), electrical and mechanical engineering for 7% (engines, electronic components, other appliances, etc.). By contrast the machine tools, working by metal removal - despite their essential importance in production - account for only about 1% in terms of value.

Graph 5 and Tables 6 and 7 show the results of this analysis which covers 69 products.

From this it can be seen that very few products have a complexity higher than 120 points (scarcely 15% of the sample).

All categories in class 38 are represented.

Simple metal products dominate the bottom end of the complexity range, together with some machines (air conditioning, fans, etc.).

Electrical machines are widely dispersed within the sample.

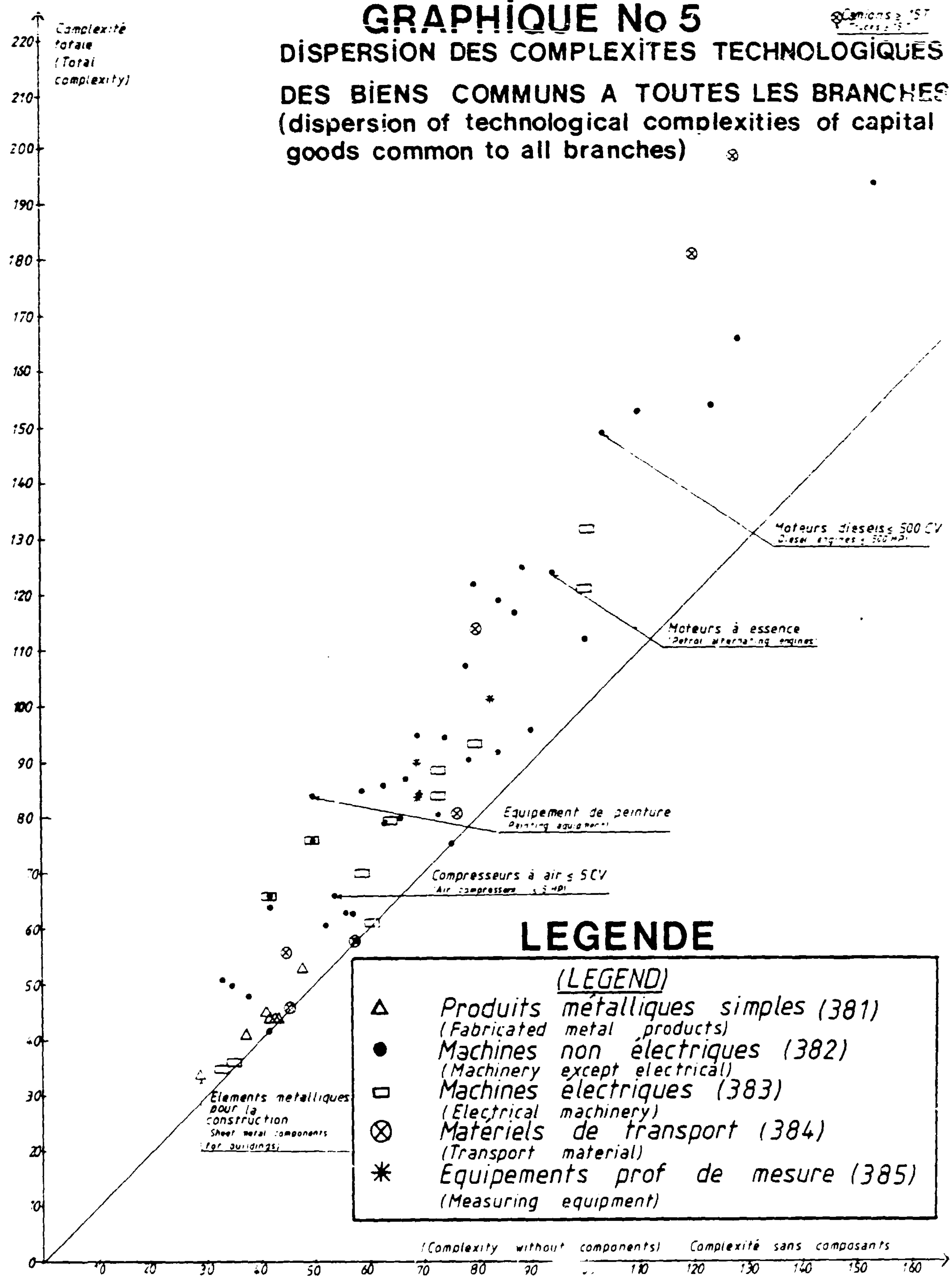
Measuring equipment is found between values 80 and 120, together with autonomous machines.

Very powerful engines, road transport equipment and calculators and computers constitute the upper end of the range above complexity 120.

GRAPHIQUE No 5

DISPERSION DES COMPLEXITES TECHNOLOGIQUES DES BIENS COMMUNS A TOUTES LES BRANCHES

(dispersion of technological complexities of capital goods common to all branches)



The influence of components is more restricted than in the general sample - with the exception of the top of the range. The small reduction in the index of complexity when the components are re-divided approximates the complexity of manufacture of goods common to all branches to that of the other categories of capital goods (see Table 5), leading to the following subsidiary proposition which supplements SP 2b:

SP 3a: The mean complexity of manufacture without components is at the same level as that of the other major classes of equipment goods. It is not therefore easier, a priori and in general, to produce them.

However since the category is a large one it is necessary to break down the group into finer categories. To do this all the common goods have been regrouped in 11 families of products which correspond in regard to their degree of sophistication and also the functions which they fulfil. Graph 3 and Table 8 show the results of this analysis. The groups have been classified in order of increasing mean total complexity.

This leads to the following subsidiary proposition:

It is possible to establish the order of complexity of manufacture.

SP3b: The order of complexity of the groups of products which constitute the class of capital goods common to all the branches is as follows: small mechanical components < elements for construction in steel < small electrical equipment < miscellaneous hydraulic control and monitoring technical equipment < pumps, compressors, boilers < mechanical sub-assemblies and parts for machines < storage and handling equipment < machine tools of the universal type < engines of all types, petrol, diesel or electric < road transport equipment < office equipment, typewriters, calculators, computers.

SP 3c: The order of complexity without components in those groups of components which constitute the class of capital goods common to all branches is as follows: small mechanical components < elements in steel for construction < miscellaneous technical equipment < small electrical equipment < pumps, compressors, boilers < universal machine tools < storage and handling equipment < mechanical parts for machines < engines of all types < road transport equipment < office equipment.

The order without components therefore has obvious differences between the 3rd and 8th positions.

With components the dispersion of the complexity ranges on average from 1 to 4, without components from 1 to 3.5.

The majority of products is concentrated between the values 70 to 100 of total complexity, that is to say a relatively high level. In fact the two first groups (small mechanical components and elements for steel construction) are products of low complexity. It is necessary to increase the variety by 70% to reach the third group (small electrical equipment, the complexity of which is 75 - 80 points). There is a technological gap at the bottom end of the range.

Products of medium and high complexity involve the groups of autonomous non-electric machines such as pumps and compressors, storage and handling equipment, and metal sub-assemblies such as reducers, clutches and gears (between 80 and 100 points). Products of relatively high and very high complexity within the common goods involve universal machine tools, engines of various kinds, road transport equipment and office equipment (above 100 points).

Finally one sees (Table 8) that the gap between the minima and the maxima is fairly wide, particularly for the last four groups, leading to the assumption that alternative technologies exist. However the minima are found at a relatively high level, and this leads to the conclusion that the common capital goods remain relatively complex in manufacture, even without the components.

The order of complexity of manufacture has also been established for capital goods specific to certain final demand sectors.

- Proposition 4: As a function of the final demand in the sectors for which they are intended the order of complexity of specific capital goods is as follows: agricultural machinery < agro-food industries < chemicals and petrochemicals < building and building materials industry < engineering construction < extraction of minerals < agro-industries, tobacco, leather, textiles < heavy metallurgy, iron and steel, forging, foundry < road transport equipment < rail transport equipment < air transport equipment.

Without components the order of complexity becomes: agricultural machinery < food industries < mechanical engineering < building and building materials industry < chemicals and petrochemicals < extraction of minerals < agro-industries < heavy metallurgy < road, rail and air transport equipment.

The order with or without components therefore only changes between positions 3 and 5.

Obviously these classifications, like the previous ones, must not be interpreted rigidly. The gaps observed are sometimes too small to lead to any conclusion concerning a definite order. The conventions of the notation and the consistency of the sample obviously influence the observations. Taking these provisos into account appreciable differences appear to exist, in the case of the total complexity, between the first and second positions, whereas between the second and fifth positions the differences are not considerable; the same does not apply from the 6th position onwards, and whilst the difference is small between the 6th and 9th positions it is more clearly shown with positions 10 and 11.

Graph 4 and Table 9 show these results.

Within the 136 products which are represented a high level of heterogeneity can be seen. The mean dispersion between the extremes ranges from 1 to 7, and this is reduced to 1 to 5 without components.

As observed above various thresholds of complexity can be seen:

. there is a major gap between agricultural machinery and capital goods for the agro-food industry.

. there is a threshold around the 100 point involving capital goods for the chemical and petrochemical industries, the building and building materials industries and mechanical engineering.

. a new threshold occurs around 130-140 for capital goods for mining, the agro-industries and heavy metallurgy.

. finally the last threshold, shifted somewhat upwards, covers transport equipment.

The weight of the components is more important there than in the common goods, being of the order of 30%. It is lower for equipment intended for the chemical and petrochemical industries (less than 20%).

The line of the minima with components (see Graph 4) is similar for the 8 first groups at about 70 points.

One finds a phenomenon analogous to that of the common goods: without components the mastery of level 70-90 makes it possible to manufacture most of the specific equipment, with the exception of transport equipment.

It may be provisionally concluded that the value of 70-90 (without components) appears to be a true barrier.

This breaking down of the groups of machires can obviously be continued. For this reason a summary is given below of an analysis of the "agricultural machinery", "agricultural and food", "building and building materials industries" groups which are particularly important groups to the developing countries, and which belong to all the capital goods specific to the sectors in the final demand.

As far as these three groups are concerned the following subsidiary proposition can be formulated:

The complexities of the sectors upstream and downstream of agriculture, agricultural machinery and the capital goods necessary for the agro-food industries have been compared. The same has been done with equipment for building.

SP 4a: The mean complexity of agricultural machinery is lower than that of the capital goods intended for the building industry and the building materials industry. The mean complexity of equipment goods intended for the agro-industries is higher than the previous one. These three categories of equipment goods have a complexity which is lower than the mean of capital goods specific to final demand sectors.

The idea of comparing the technological complexity of these three sectors arises from the following findings: all the developing countries have an agriculture which, for several of them, constitutes the almost unique if not the principal activity. As a consequence it seems to be of value, in relation to agriculture, to study the complexity of the upstream industries, agricultural machinery, and the downstream agricultural and food industries, together with capital goods intended for the building and building materials industries, every developing country also having to face up to the problems of building and town planning.

Tables 9 and 10 show the results of this analysis. They confirm the classifications set out above.

The gap in complexity without components between agricultural machinery and building is reduced and suggests - because the principal technological routes are the same - the possibility of joint production.

By contrast the gap is greater with capital goods intended for the agro-industries: the ratio is 1.9 with components. Without components the mean complexity of agricultural machinery falls by 10%, and by more than 3.5% in the case of the agro-industry; this has the effect of reducing the complexity gap between the two sectors to 1.5.

It will be seen that these 3 sectors have a mean complexity which is lower than that of all the special capital goods (116 points).

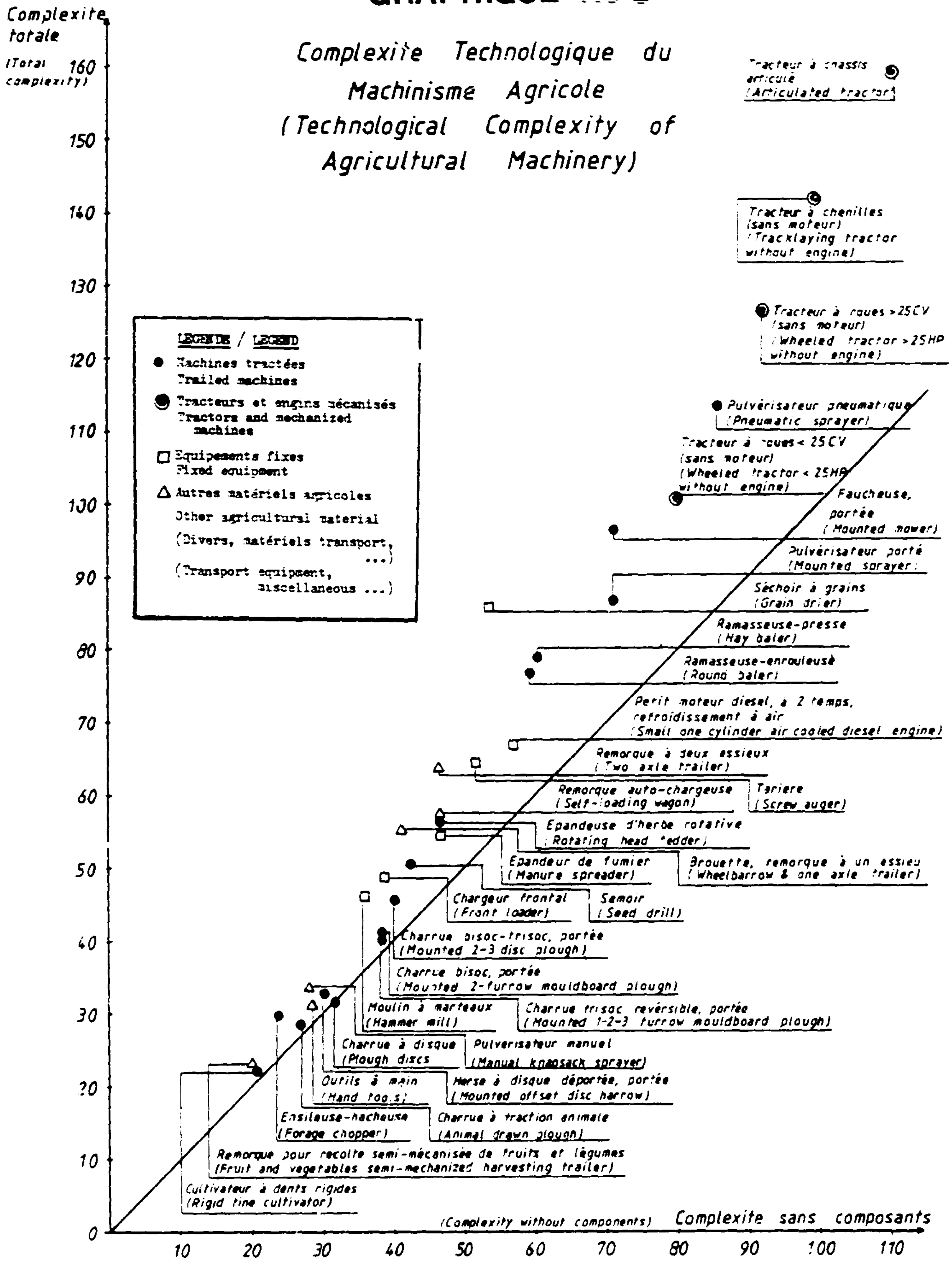
This analysis has been continued at a more detailed level, within each of these groups, as an example, and this has led to the following subsidiary propositions:

SP 4b: Although on average of low complexity the group of agricultural instruments and machines is characterized by a high level of dispersion, the weight of components being very low for simple machines and instruments but becoming important for sophisticated or multi-purpose trailed machines.

Graph 6 shows the 35 agricultural machines and items of equipment which form part of the sample, and these have been positioned according to their complexity, with or without components, in 4 categories: trailed equipment, tractors and self-propelled machines, fixed equipment and other agricultural equipment.

GRAPHIQUE No 6

Complexité Technologique du Machinisme Agricole
(Technological Complexity of Agricultural Machinery)



One can however see the high dispersion between the machines which range from 1 up to nearly 8. Trailed machines alone have a dispersion of 1 to 5.

. At the base one finds 8 products with complexity of less than 34 points for which the weight of components is very much reduced. These are the very simple trailed machines and miscellaneous items of equipment such as hand tools, single-axle trailers and manual sprayers.

. At a higher level of complexity (between 40 and 68 points) are found trailed machines and fixed equipment, together with trailed transport equipment. The sample is diversified in the graph with 13 products. The size of the components is, in general, greater, at equal complexity, for the fixed equipment.

. At another level (on the graph approximately between 75 and 100 points) one finds the sophisticated or multi-purpose trailed machines, together with the first self-propelled machine in the sample (the engine not being taken into account) and one item of fixed equipment, a grain dryer, where components represent 40% of the total complexity.

. At a higher level are found tractors and self-propelled machines where the complexity ranges from 100 to 160 points.

Special attention has also been given to capital goods for the food industries ...

SP 4c: The group of equipment goods for the agricultural and food industries has a wider complexity than that of agricultural machinery, and a wider dispersion. The weight of the components is relatively high for the more complicated products. The simplest consist of equipment goods with a mechanical predominance for the traditional agricultural and food industries. The most complex consist of equipment goods linked to the operations of packaging and production processes with a predominantly bio-chemical character.

Graph 7 takes into account the phenomena observed. The higher mean complexity of capital goods for the agro-industry, as compared with agricultural machinery, arises partly from the fact that the mean minimum level of complexity is higher and secondly that relatively more products are found in the zone of higher complexity. The difference in the complexity observed in the higher level is not significant. By contrast the dispersion between the extremes ranges only from 1 to less than 4 as against 1 to 8 for agricultural machinery.

At the bottom of the scale one finds simple equipment, grinders and mixers for animal feeding stuffs, and other equipment which is dominantly mechanical - to which may be added the specific components: refrigeration rooms, equipments for fruit juice, ice creams and ovens for bread. It will be noted that even for these simple products the weight of the components is important, being of the order of 20 to 30% of the total complexity.

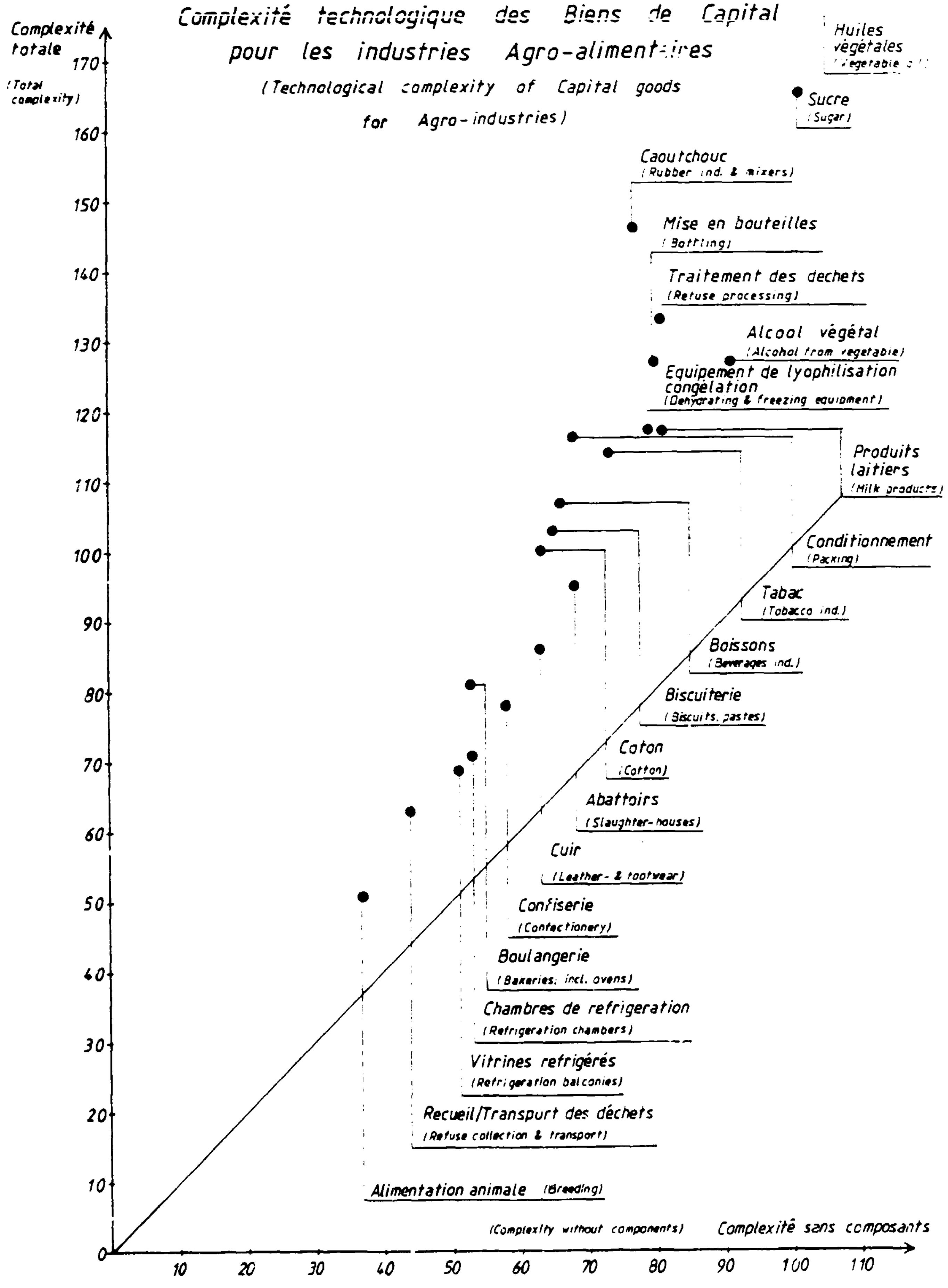
In the middle of the scale one finds equipment intended for the traditional leather, cotton, biscuits, pasta and drinks industries. The weight of the components is of the order of 30 to 40%.

Finally, at the top of the scale, one finds equipment goods for packaging, tobacco and cigarettes, dehydration processes, freeze-drying and deep freezing, bottling, and those industries where chemical processes are today dominant: rubber, alcohol, sugar and vegetable oils. The increasing "chemical" content of the agro-food industries is accompanied by increases in the complexity of their equipment goods. The weight of the components there is of the order of 50% of the complexity.

GRAPHIQUE No 7

Complexité technologique des Biens de Capital pour les industries Agro-alimentaires

(Technological complexity of Capital goods for Agro-industries)



... and those for the building industry

SP 4d : The group of equipment goods for the building and building materials industries has a complexity and a dispersion which is higher than that of agricultural machines and goods for the agricultural and food industries. The weight of the components is also higher. However the simplest part of these equipment goods is of a complexity similar to that of the lower part of the sample of agricultural instruments and machines.

Graph 8 makes it possible to visualize these observations.

In this way hand tools, portable screens, equipment for asphalt factories and for the preparation of concrete and earth, compressors and compactors are in a position comparable to the lower range of the agricultural machines. The other classes of equipment for carrying cement, for producing ceramics and asbestos, coatings, cranes, grinders, components for bridges, and trailers have positional analogies with other groups of agricultural machines (see SP 4b).

This is therefore an encouragement for subsequent research into these various products which come from comparable production routes.

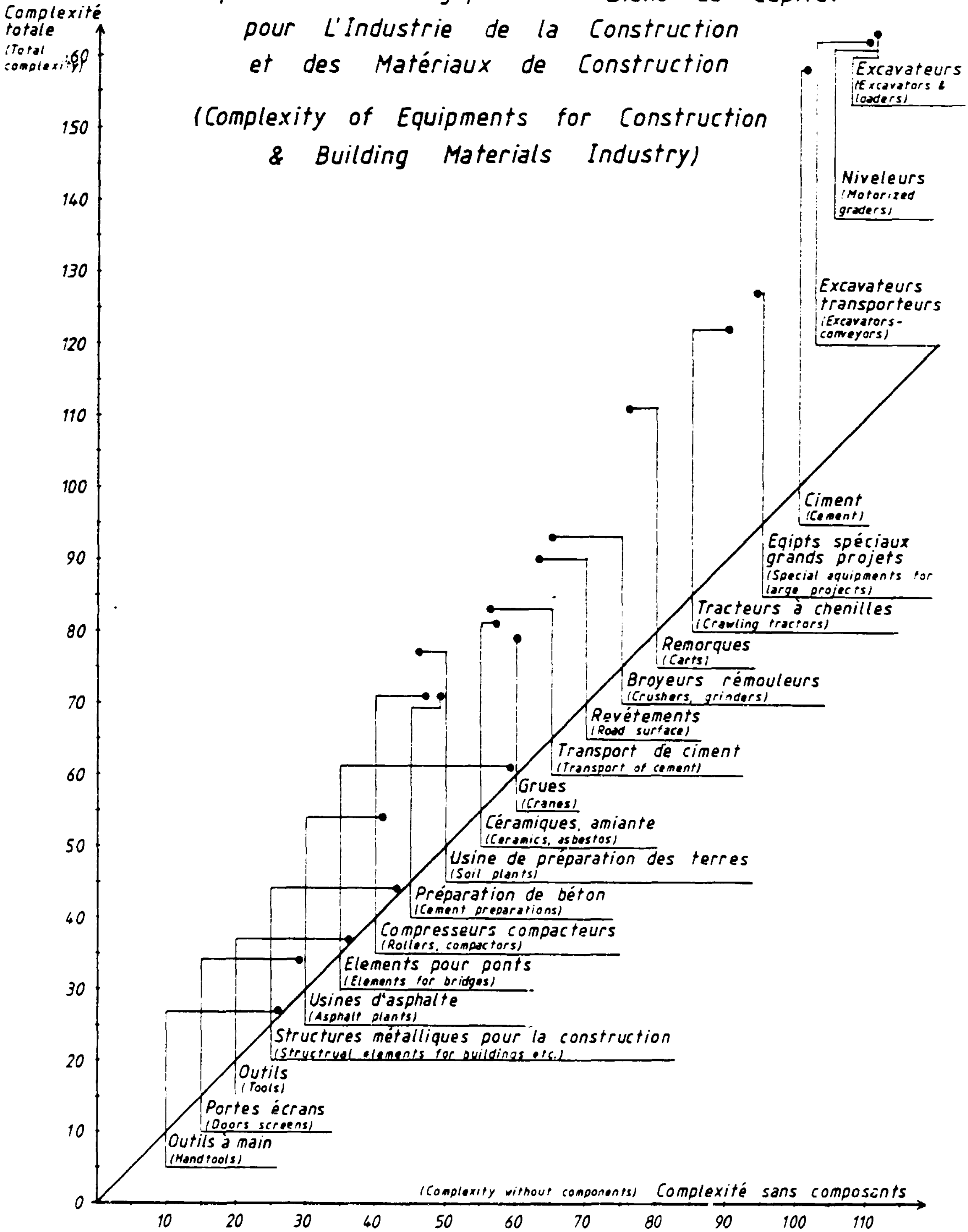
- Proposition 5 : The size of companies in assembly A is an important stratification in the distribution of production of the various groups of capital goods.

Table 11 gives the results of the analysis of the breakdown of equipment goods according to the size of the company of the production unit A, corresponding to 6 levels measured by the number of employees < 100 < 250 < 500 < 1000 < 3000 and > 3000.

GRAPHIQUE No 8

Complexite Technologique des Biens de Capital pour L'Industrie de la Construction et des Matériaux de Construction

(Complexity of Equipments for Construction & Building Materials Industry)



The conclusion which can be drawn from this table is that only 15% of the capital goods would seem to be capable of being produced in companies with less than 250 employees.

Practically 75% of the products can be manufactured in companies with 250 to 3000 employees.

If we consider Class 38 more than half the simple products can be produced by companies with 100 to 500 employees.

For non-electrical machines more than 50% of them also could be produced, but in companies with 250 to 1000 employees.

The production of electrical machinery does not seem to begin before the level of 250 employees, and more than 65% are concentrated in the classes of 500 to 3000 employees.

In the case of transport equipment the same lower limit is observed, but practically 70% of the products involve companies with more than 1000 employees.

The manufacturing of measuring and monitoring equipment is located between 250 and 3000 employees, companies with 500 to 1000 employees accounting for nearly 50% of the total.

If we consider capital goods from the functional and technical point of view, the production of semi-sophisticated products is located between the classes of 100 to 500 employees. That of parts and sub-assemblies is spread throughout all the classes, but companies with more than 500 employees provide more than 70% of the products. The same situation is observed for the autonomous machines, but a concentration of 70% is observed between companies with more than 250 but less than 3000 employees. Finally for integrated process equipment the concentration towards the top of the scale is even greater: practically 65% involve companies with more than 1000 employees.

If we consider capital goods from the point of view of the final demand of the sectors 60% of the goods common to all branches of activity are located between 250 and 1000 employees. More than 80% of the goods common to several branches are divided between 250 and 2000 employees. The concentration is lower for specialized machines and is less than 70% between these classes. The remainder is divided almost equally between companies with less than 250 or more than 3000 employees.

If we recapitulate the possibilities for manufacture in small companies with less than 100 employees (the limit which, in most of the developing countries, is that of the already large companies) it can be seen that they appear to be limited - at least under the conditions of the reference technological model: no manufacture of electrical machinery, transport, measurement and monitoring, or semi-sophisticated products, of integrated process equipment, of the order of 2% of the products for non-electrical machines, parts and sub-assemblies, autonomous equipment and machines, capital goods for some branches and special machinery. It is only for simple products in class 381 that the small company shows a higher percentage (8.7%).

It will be recalled that this analysis concerns the central production unit (A) and not companies in assemblies and sub-assemblies B1, B2 and C. In particular the production of semi-finished products (forging, casting, etc.) and technical services can accommodate the existence of small companies which give more flexibility to the system.

- Proposition 6 : The rate of innovation of capital goods varies considerably according to the products.

Out of 268 products which have been analysed 22% have a very slow cycle - a rate of innovation of 50 years or more - 19% have a cycle between 35 and 50 years, 32% between 25 and 35 years, 21% between 15 and 25 years, 4% between 10 and 15 years whilst less than 2% have a cycle of less than 10 years.

In other terms between now and the end of the century, if the rate of technical progress is not fundamentally changed, between 75 and 80% of the existing capital goods will continue to be produced fundamentally in the same way.

Amongst the most stable products are the following:

- agricultural hand tools
- air compressors (up to 5 HP)
- ironmongery
- conventional metal building components (doors, windows, etc.)

Amongst those where the rate of innovation is the highest are:

- computers
- hovercraft
- small calculators for industrial use
- calculators for personal use.

- Proposition 7 : The great majority of capital goods are concentrated at levels 3 and 4 of total complexity.

The dispersion of complexity was analysed with Proposition 1. The results were then broken down within the six classes of complexity defined in Chapter I. The conventional values which were given to them were as follows: class 1 = 0 to 30, class 2 = 30 to 55, class 3 = 55 to 100, class 4 = 100 to 180, class 5 = 180 to 320, class 6 = more than 320. These classes therefore allow a first classification of products as a function of the levels defined by hypotheses (11).

Table 12 summarizes the results in relation to total complexity. Practically 75% of the products belong to classes 3 and 4, 40% of them being in class 3.

SP 7a : *The groups of capital goods are concentrated at specific levels of complexity.*

. If one considers Class 38 80% of the simple metallurgical products (Class 381) are situated at levels 1 and 2.

. Of the non-electrical machines (Class 382) 80% are in levels 3 and 4, and the same applies to 73% of the electrical machines.

. Of the transport equipment 85% is divided between levels 3, 4 and 5, mainly in the latter two classes, and nearly 10% are at level 6.

. Control and monitoring equipment is 100% at levels 3 and 4, 85% being at level 3.

Towards the top of the complexity ranges the simple metallurgical products stop at level 4, whilst electrical machines and equipment and those involved in control and monitoring stop at level 5[(12)].

Towards the bottom of the complexity ranges electrical machinery and equipment does not begin until level 2; the same applies to transport equipment, whilst control and monitoring equipment and apparatus begins at level 3.

. If one considers capital goods from a functional and technical point of view it can be seen that:

- all the semi-finished products are in classes 1 and 2

- practically 80% of the parts and sub-assemblies are at levels 3 and 4, with 50% at level 3

- more than 70% of the autonomous equipment and machinery falls within the same ranges, with more than 40% at level 3

- more than 85% of the equipment integrated into a complex process are also at levels 3 and 4, with more than 55% at level 4.

Towards the top of the complexity range semi-finished products stop at level 3. Parts and sub-assemblies stop at level 5, integrated equipment at level 6.

. Finally if we consider capital goods from the point of view of the demand:

- more than 90% of goods common to all the branches are contained in classes 2, 3 and 4, class 3 accounting for 50% of these

- more than 80% of the goods common to several branches are found in classes 3 and 4, mostly in 3

- less than 70% of the specialized goods are also in these classes, but the remainder occupy all the other levels. This is the only case where this phenomena is observed.

. Concerning goods common to all branches:

- towards the top of the complexity range they do not go beyond level 5

- towards the bottom of the range their production only appears to begin at level 2[13].

Graph 3 shows that, at level 2 of total complexity, one finds, in the goods common to all branches, small mechanical components and the steel elements for building.

At level 3 one finds small electrical equipment, miscellaneous equipment and materials, pumps, compressors and boilers, mechanical parts and sub-assemblies and storage and handling equipment.

At level 4 are the universal machine tools, engines of all kinds, road transport equipment and office equipment.

. In the case of the specialized equipment goods Graph 4 shows that one finds:

- at level 3 of total complexity agricultural and food industry machinery and, at the limit of levels 3 and 4, capital goods for the chemical and petrochemicals industry

- capital goods for the building and the building materials industries, the engineering industry, the extraction of minerals, agricultural, and heavy metallurgy industries and road transport equipment at level 4.

- rail transport equipment at level 5

- air transport equipment at level 6.

This proposition is, to some extent, a general conclusion of the analysis of the technological complexity from the point of view of output, that is to say the distribution of the machines manufactured according to the level of complexity.

The analysis has been re-examined below from the point of view of inputs by level of complexity, and this leads to the following proposition:

- Proposition 8 : The production apparatus for manufacturing capital goods is integrated by cumulative complexity levels which represent various technological generations. Enlargement of the range of products necessitates recourse to production factors of higher degrees of complexity.

This poses the question of knowing what equipment goods can be produced with the production apparatus, characterized by the 80 factors of analysis, and at the same level of complexity.

We will return later to the importance of this question and the significance of the replies which can be given to it.

A simulation exercise was therefore carried out. The number of equipment goods which could be manufactured were identified when all the factors were raised at the most to level 1, then to level 2, and so on. From this it was possible to deduce, at each stage, the gains obtained by a uniform increase in the levels of complexity. It will be noted that in this simulation no note was taken of the complexity of the machines produced but only of the levels of complexity of the production factors.

Table 13 sets out the results of this simulation.

At the general level of the sample it will be seen that possession of level 1 for all the factors makes it possible to produce only two items of equipment goods, agricultural and domestic hand tools. Even if one then has all the factors at level 2 only 6 items of equipment goods can be manufactured. The gain in passing from "stage 1" to "stage 2" is therefore small.

By contrast the possession of factors at levels 1, 2 and 3 results in a substantial change. In this way 72 items of equipment goods, or nearly 23% of the sample, can be covered. This is even more marked when moving to level 4, where nearly 45% of the equipment goods are potentially producible.

It will be noted that even the possession of all the factors at levels 5 or above only makes it possible to manufacture 60% of the products. The possession of level 6 for certain factors is a permissive condition for increasing the variety of the production.

If one now distributes these gains within the principal groups of the ISIC 38 division the gaps can be seen to be clearly marked and to occur at different stages according to the groups:

- For 381 (simple metal products) and 382 (machines - non-electrical) the gains show a jump (absolute and relative) in passing from 2 to 3. At this latter stage coverage of group 381 is almost complete. In the case of group 382 the gains are spread fairly uniformly between levels 3 and 5. Then there is a sudden jump between levels 5 and 6. This jump makes it possible to produce nearly 40% of the machines in this class.

- For 383 and 384 the change occurs when passing from 3 to 4. It will be noted that mastery of transport equipment requires level 6 for a certain number of factors.

- Finally group 385 (control instruments) cannot really be effectively dominated except beyond level 5 for all the factors.

Clearly these observations depend upon the theoretical hypothesis that all the factors are at the same level of complexity. The results obtained therefore lead to the following subsidiary propositions:

SP 8a : In order to produce capital goods it is not only the presence of production factors which are necessary but also that the latter should have a specific index of complexity and, as a consequence, that different generations are mobilized within the technological stock.

In order to produce machines, even simple ones, not only the existence of the production factors are necessary but the fact that certain of these are of a higher level of complexity than that of the machine which they make it possible to manufacture.

The permissive condition for the production of capital goods at a significant level appears to be that certain production factors have at least an index of complexity of 3. In other terms this means that the developing countries which wish to construct an equipment goods industry must not only introduce the necessary variables but also raise the discriminant variables to a sufficient level.

These analyses obviously have an operational application. They may lead to the better utilization of existing capacities and the multi-purpose nature of the production apparatus, to envisaging the design of investment projects in a broader approach rather than micro-economic or mono-sectoral narrowness, and to having a selective view of the variety of the factors which it is necessary to increase.

Continuing to consider the production factors, the previous analysis was extended by measuring the frequency of utilization of the variables according to the level of complexity. In this way one can observe, for each variable, the "profiles" of their entry and their disappearance.

These profiles of entry and of halting of variables by levels of complexity are shown in Tables 14, 15 and 16 for the three groups of capital goods common to all branches, those common to several branches, and the specialized machines.

Comparison of the profiles for these 3 groups of machines does not show any substantial differences, but these would possibly be shown with more detailed splitting.

It will however be seen that the frequency of utilization of the B1 variables (semi-finished products) of levels 1 and 2 are higher for the production of common capital goods than in the case of specific machines. However in the case of the latter that of components at levels of 5 and 6 is higher.

In fact these observations confirm the previous proposition by showing the importance of recourse to the variables at different levels of complexity.

Analysis of the production factors was extended to evaluate the frequency of their utilization within assemblies A and B. This leads to the following subsidiary propositions:

SP 8b : Within sub-assembly A1 of the central production unit, no significant differences are observed in the rate of utilization of variables which define it as a function of capital goods common to all branches, to several branches, or specific goods.

Table 17 shows this fact.

The 30 variables of the means of production sub-assembly A2 were grouped into 4 "blocks": production by deformation, welding, working by removal of metal chips, and others. This grouping leads to the following conclusions:

SP 8c : Within sub-assembly A2, the frequency of utilization of the means of production φ evolves parallel to, or diverges in relation to, the specialization of the machines which they make it possible to manufacture.

Table 18 shows this phenomenon.

- "Metal-working by deformation" block. As the equipment goods become more specialized so greater call is made on operations involving the deformation of semi-finished metallurgical products (bending and drawing of sheets and plates, etc., or cold working of wires, tubes, etc.).
- "Welding" block. Welding operations evolve in the same direction.
- "Working by removal of chips" block. Here the operations evolve in the opposite direction. Whilst the use of certain machine tools increases as the specialization of the goods produced increases (particularly in the case of vertical lathes, planing machines and machines for cutting gear teeth) one observes, on the contrary, that the importance of others is reduced: this is particularly true of all the multi-head lathes, drilling and rectifying machines and all machines specific to the manufacturer.

  It seems therefore, particularly when considering this latter factor, that specialization of the goods manufactured and the means to produce them operate in opposite directions. This can be explained by the fact that the production of goods common to all sectors is generally carried out in long production runs and in this way justifies "ad hoc" machine tools. Conversely highly specialized goods result in much shorter production runs, and for this reason the manufacturer needs to ensure some multi-purpose character in his means of production so that he can cover a wider range of products with greater flexibility.
- For "miscellaneous" sub-blocks, apart from the operations of painting, which occur in all three sub-groups concerned, the other factors are reduced in importance as specialization increases.
- Finally, quality control shows the same level of utilization amongst the groups.

SP 8d : As the specialization of machines increases so the frequency of utilization of semi-finished products of sub-assembly B1 becomes greater.

Excluding the working of strategic materials and non-conventional processes (pressure casting) it seems that, as the specialization increases, so there is greater recourse to semi-finished products. (see Table 19).

This finding has an important consequence on the "encouraging" effect. It confirms the fact that the manufacture of goods common to all branches results in this "encouraging" effect on semi-products at low levels of complexity, the specialized goods then taking over at the higher levels.

SP 8e : Within sub-assembly B2 the frequency of utilization of technical services evolves parallel to, or diverges from, the specialization of the machines which they make it possible to manufacture.

Table 20 shows these links.

One can see evolutions in the opposite direction. Whereas metallization by deposition, the construction of dies (for cold stamping and forming) and the construction of moulds (for injection) in particular have a lesser relative importance when the specialization of the goods increases, in the opposite way the other technical services have a tendency to maintain their position or to increase their importance. This is particularly so in cold stamping, special machining, the manufacture of gears, light boilerwork and heat treatment operations.

SP 8f : For each of the components as the specialization of the machines increases so recourse to components becomes greater.

Table 21 confirms, for each component, the previous propositions which relate to the finding on the mean of assembly C.

It follows from this that the available data constitute a reserve of information, the possibilities of which are far from being exhausted. It is necessary, in particular, to re-establish with accuracy the production routes(14), their frequencies and, as a function of these, the analogue groupings of products, to go into greater detail in the influence of production runs and the correlation of the coefficients α and β with the variables by groups of machines, the pairings between men and machines, the evolution of the complexity of work in the other sub-assemblies, etc. There are, therefore, other relationships in the "composition" to be identified.

B. THE "LAWS" OF CHANGE

It is necessary to study the dynamic of the "laws" of change in capital goods

The previous analysis concerns the kinds of rules which appear to exist in the static arrangement of the capital goods system. It is necessary to supplement this with the dynamism of the evolution which is suggested by the existence of different levels of complexity. These levels are observed today, but they have a history, and time was necessary for them to be established. In a general study one cannot, at least within the framework of the UNIDO study, reconstitute this history. Case studies by countries (Bulgaria, Spain, Poland) make it possible to compare the reality of the respective national developments with the propositions of this research. But what is already possible is to analyse the conditions of passage from one level to another. This does not mean that it is essential for a given country, which today is at a certain level, to follow exactly the same path. There is no one best way. This does not mean, either, that the same time is needed to advance from one level to another as that taken by other countries in the past. This time could be shorter or longer. At the present moment it is necessary to seek the most favourable "entries", to seek the shortest possible paths, and those factors the domination of which is essential to open up the way to the future most effectively. International cooperation is one of the essential factors for reducing the time needed to advance from one level to another.

The analysis of technological complexity cannot, by itself, describe this evolution, but it makes it possible to analyse the conditions of moving from one level to another.

Analysis of the "laws" of change is not, therefore, an invitation to fatalism and a requirement for an immutable order. It is an encouragement to active realism, active in the sense that the understanding of the order of things is also the means of acting on them and of accelerating change, realism in the sense that all policies must start from an objective basis.

This analysis forms part of the long-term trends of technical progress.

This analysis requires, furthermore, to form part of the major trends of technical progress in equipment goods, trends which can be summarized as follows[15]:

- Software activities, linked to the consumer goods and intermediate goods industries, are transferred towards the equipment goods industries. The principal vector of this transfer is automation and in particular the recent development of microprocessors.

Automation also leads to integration in machines, to "crystallizing" part of the activities for work preparation and organization. This leads to changes in work, not only in the reduction of direct work but also in the development and shifting of collective work towards the functions of design, organization, control and marketing. Automation also leads to the transformation of batch production processes into continuous processes. The design of these industrial units has become too complex and has resulted in the creation of engineering consultancy structures which are either autonomous or linked with the manufacturers of capital goods, the dominant trend being a reinforcement of these latter forms. Maintenance activities have become increasingly complex under the influence of automation and of the increase in the number of components in the manufacturing process.

These trends certainly concern the highest levels of technological complexity, and it is probable that they will contribute towards creating the upper part of the supply of machines and the systems of organization by the year 2000. The question is therefore posed of knowing whether, and to what extent, these trends are capable of "destabilizing" the lower levels of complexity and accelerating the decrease in the coefficient β . The present research carried out by UNIDO does not make it possible to answer this question, but it can indicate some "laws" of past and present change.

Table 22 (see technical annex) contains the results of the indices of complexity by levels and shows the contribution of the assemblies and sub-assemblies A1, A2, B1, B2 and C to the total complexity. From these observations it is possible to deduce the following propositions:

Changes in the industrial fabric are analyzed by level of complexity.

- Proposition 1 : The rise in the total complexity is accompanied by changes in the industrial fabric constituted by assemblies A (central production unit), B (technical infrastructure) and C (components). At levels 1, 2 and 3 A dominates, at level 4 B and C become equally important whilst at levels 5 and 6 the influence of components (C) in the total complexity becomes preponderent.

This general proposition is demonstrated below, and the analysis also leads to the following subsidiary propositions.

SP 1a : At level 1 the influence of means of production (sub-assembly A2 of the central unit) on the total complexity is dominant. Then comes the influence of the sub-assembly A1, which is centred on the management of this central production unit. The technical infrastructure and components have a smaller influence.

This influence is 50% for the ϕ factors (sub-assembly A2) and 30% for management (sub-assembly A1). The central production unit A, with 80% of the complexity, is the essential part of the industrial fabric. The infrastructure accounts for 14%, components for 6%.

SP 1b : At level 2 the influence of means of production in the total complexity remains high, as does also that of management. The influence of the technical infrastructure and of components increases.

The ϕ factors still represent 40% of the complexity and management 28%. With 68% of the central production unit A continues to be the pivot of the industrial fabric. However the weight of the infrastructure begins to be felt with 19%, whilst components account for 13%.

SP 1c : At level 3 the influence of the sub-assemblies is equalized, the Φ factors and management are balanced and their influence remains slightly higher than that of the infrastructure and the components.

The Φ factors and management each account for 27% of the complexity. The central production unit A continues to exercise the greatest influence with 54%. However the infrastructure with 24% and the components with 22% tend to have an influence which is equal to that of the means of production and of management.

SP 1d : At level 4 components take over the majority influence, infrastructure is balanced with management in the total complexity, whilst the influence of the production apparatus is relatively reduced.

Components account for 32% of the complexity, the infrastructure for 24%. Components outside assembly A therefore become of greatest importance and the central unit, with 44%, loses its pivot role. Within the latter the influence of management falls slightly to 23.5% whilst that of the means of production is considerably reduced to 21.5%. However at this level the management factors (A1) and components together represent more than 55% of the total complexity.

SP 1e : At level 5 the trends shown at level 4 are amplified: components, and to a lesser extent the infrastructure, increase in importance, that of management is stabilized, whilst that of the means of production falls.

Components with 37% and infrastructure with 25% means that assemblies outside the central production unit exercise the decisive influence. Assembly A represents only 38% of the complexity. Within this management represents 23%, means of production 15%.

SP If : At level 6 components increase markedly in importance, whilst the relative influence of the technical infrastructure on complexity is reduced. That of management increases appreciably, whilst that of the means of production falls considerably.

Components finally account for 46% of the total complexity, management of A2 for 25%, infrastructure for 19% and means of production for 10%. The total of the influences of the central production unit (35%) continues to fall as compared with level 5 (38%); at the same time B + C increase (65%) whilst the distribution in the sub-assemblies A1 and A2 and assemblies B and C are modified. C and A1 increase considerably and account for 71% of the complexity, suggesting an important change between levels 5 and 6.

The changes in assemblies and sub-assemblies which form the industrial fabric are then analysed.

The components

- Proposition 2 : The influence of components, which is negligible at level 1 of complexity and small at level 2, becomes appreciable at level 3. This influence is reinforced at levels 4 and 5 and at level 6 it becomes dominant.

Their respective weight is, on average, 6% of the complexity at level 1, 13% at level 2, 22% at level 3, 32% at level 4, 37% at level 5 and 51% at level 6.

Between levels 1 and 2 the complexity due to components increases 3.9 times, between levels 2 and 3, 3 times, between levels 3 and 4, 2.4 times, between levels 4 and 5 twice and between levels 5 and 6, 2.8 times.

The repercussions of this change are considerable: with the increase in the weight of the components the problems of management of the central production unit increase when managing the supply of components and their assembly and maintenance, at the same time as the necessity for an international division of labour, international trading and cooperation are accentuated.

The means of production.

- Proposition 3 : The means of production (φ factors of the central production unit) have a dominant influence on complexity at levels 1 and 2. This influence remains considerable at level 3 but then relatively declines at levels 4, 5 and 6.

Their respective weight is, on average, 50% of the complexity at level 1, 40% at level 2, 27.5% at level 3, 21.5% at level 4, 15% at level 5 and 11% at level 6.

Between levels 1 and 2 the complexity due to the means of production φ increases 1.5 times, between levels 2 and 3 1.25 times, between levels 3 and 4 also 1.25 times, between levels 4 and 5, 1.2 times and between levels 5 and 6, 1.5 times.

The technical infrastructure B.

- Proposition 4 : The technical infrastructure B has an influence on total complexity which increases from levels 1 to 3, is relatively stabilized at levels 4 and 5, and is then reduced at level 6.

Its weight is on average 14% of the complexity at level 1, 19% at level 2, 24% at levels 3 and 4, 25% at level 5 and 19% at level 6.

However these relative percentages must not be allowed to obscure the importance of the increase in the complexity when passing from one level to another. In fact between levels 1 and 2 the variety of assembly B is increased 2.5 times, between levels 2 and 3, 2.2 times, between levels 3 and 4, 1.7 times, between levels 4 and 5 1.8 times and between levels 5 and 6 1.7 times.

The semi-finished products sub-assembly.

SP 4a : Sub-assembly B1 (semi-finished products) increases its influence up to level 3, and this is maintained up to level 6.

Its weight is very low at level 1 (about 2%) and this increases to 6% at level 2: it is then maintained at about 10% (10% at level 3, 11% at level 4, 12% at level 5 and 10% at level 6).

Between level 1 and level 2 the complexity of B1 increases 4.4 times, between levels 2 and 3 3.8 times; the increase is then maintained at about 1.8 times for each change of level.

The technical services sub-assembly.

SP 4b : The sub-assembly B2 (technical services) has a relatively constant influence from level 1 to level 5, but falls at level 6.

Its weight is initially 12% at level 1 and this then scarcely changes: 13% at level 2, 14% at level 3, 13% at levels 4 and 5, but falling to 9% at level 6.

However this relative stability assumes sustained rates of increase of 1.9 times between levels 1 and 2, 2.0 times between levels 2 and 3, 1.5 times between levels 3 and 4, 1.7 times between levels 4 and 5 and 1.5 times between levels 5 and 6.

The management sub-assembly.

- Proposition 5 : The sub-assembly A1 represents to some extent the management, in the central production unit, of men and machines (φ factors). Its influence on the total complexity is considerable at the first three levels. It has a tendency to fall, relatively, at levels 4 and 5 and to increase at level 6. However the rates of increase have a tendency to rise with the increasing level.

Its weight is initially important: 30% at level 1; this is maintained at 28% and 27% at levels 2 and 3. It declines relatively at levels 4 and 5, being 23.5% and 23% respectively, and then rises to 25% at level 6.

The rates of increase are considerable: 1.5 times between levels 1 and 2, 1.6 times between 2 and 3, 1.5 times between 3 and 4, but then increases 1.8 times between 4 and 5 and twice between 5 and 6.

It follows from this that, if the integration of production is of the vertical type and covers in whole or in part the components of assembly B (technical infrastructure), then the management of the combined assembly A + B becomes that much more complex. We will be returning later to this question but, already, it can be seen that this is one of the management complexity barriers.

- Proposition 6 : Amongst the production factors more than 50% are necessary at level 1 of the total technological complexity of machines. In order to advance to level 2 the presence of 80% of these factors is necessary; at level 3 practically 100% are necessary.
(These propositions are independent of the level of complexity of the factors).

For example at level 1 the presence of 43 factors are necessary: to this have to be added 27 at level 2, 19 at level 3 and 1 at level 4.

To the 27 factors introduced at level 2, 10 relate to the means of production - 1 belongs to A1, 3 to B1, 5 to B2 and 8 to components.

By contrast out of the 9 factors introduced at level 3 6 relate to components and only 3 to the infrastructure B.

This may be interpreted as the fact that the essential industrial fabric is constructed at level 1 and 2 and that it is subsequently made more dense.

From level 3 onwards the structure of the production apparatus is therefore "made" from the point of view of the existence of the necessary variables. This means that, from level 3 onwards, the variety of the system is increased almost solely by the increased complexity of the constituent variables. It is possible, if not probable, that this type of progress is not linear and that there are jumps, as the whole of the analysis suggests.

This finding is to be compared with Proposition 8 of the "laws" of composition. We encountered the phenomenon that the possession of variables at levels 1 and 2 of complexity of factors does not make it possible to produce more than a very limited number of machines, and that it was only from level 3 onwards that a jump was possible. Another condition for advancing is now added. This time, in order to achieve level 3 of complexity of machines, it is necessary that practically all the variables are introduced.

Reaching level 3 of the complexity of capital goods makes it possible to manufacture 40% of machines (see Chapter III - Proposition 5). However to do this it is necessary firstly to introduce practically all the variables and secondly that these should be of complexity 1, 2, 3 and 4 (at level 4 45% of the machines are potentially producible - see Proposition 8 of the "laws" of composition).

Tables 23, 24, 25, 26 and 27, relating to the frequency of utilization of the variables within the blocks A, A2, B, B2 and C, make it possible to identify the entries of new variables and their frequencies. These analyses lead to the following general conclusion:

- Proposition 7 : The basis of the industrial fabric is constructed at levels 1 and 2. It is the first accumulation at these levels which allows a considerable "gain" in the number of machines produced, and in complexity, at level 3. From this level onwards the increasing complexity of the variables makes possible the increase in the number of the more complicated machines, according to a non-linear process.

SP 7a : It follows that the difficulties of primary accumulation at levels 1 and 2 make international cooperation essential, and that the modes of this favour self-sustaining progress to levels 3 and above.

SP 7b : Expressed in times from the entry into the level 1 up to mastery of level 6 the process of development in the capital goods industry is undoubtedly very long.

It is also one of the essential functions of international cooperation to assist in shortening this period at all levels.

Notes to Chapter II

1. See: The technological order - Proceedings of the Encyclopaedia Britannica Conference, edited by Carl F. Stover with a foreword by William Benton, Detroit, 1963 - Wayne State University Press.

2. Sherman Gee: Technology transfer in industrialized countries - Sijthoff & Noordhoff, Alphen aan den Rijn, Holland, 1979.

3. The reader can visualize, on the graph, the average role played by the components by considering the progressive divergence of the points representing the products in relation to the line bisecting the two axes.

4. This phenomenon appears when considering the upper line on the graph which determines a limiting zone with the bisecting line.

5. The most complex products without components are specialized equipment for oil exploitation and printing, diesel engines of over 500 hp, gas turbines and engines, many items of transport equipment, hovercrafts, diesel locomotives, trucks of more than 15 tonnes and all aerospace construction.

6. This distinction by sections of the capital which is conceptually clear comes up against difficulties of classification: for example machine tools can be used for their own reproduction and also for the production of consumer goods and for the maintenance of installations. Paradoxically, whilst they can be analysed concretely they cannot give rise to a theoretically satisfactory classification. (See the work carried out in Peru and in Guatemala by Mr. C. Gillen).

7. Subject to the undoubtedly inadequate representation of complex electrical machines and measuring and monitoring instruments in the sample as compared with the universe of machines. However the sample is centred on those most capable of being produced in the developing countries.

8. Transport equipment includes small motor bicycle engines and cycles, wheels, springs and axles which are the metal components for automobile or rail equipment.

9. A reservation must be made as to the representativeness of the sample in regard to electrical machines. This does not, at the present time, include sufficient products of electrical engineering and advanced technology. Their inclusion would undoubtedly lead to incorporating products of class 383 in the groups of higher complexity.

10. It will be noted that the dispersion of the means ranges from 1 for semi-finished products with components to 3 for finished products integrated into a manufacturing process. This ratio falls to slightly above 2 without the components.

11. As can be seen the results have confirmed this hypothesis of classification with the exception of class 6, which seems to be clearly more differentiated from class 5, as would have been expected. However it is necessary to enlarge the representativeness of class 6 in the sample if this finding is to be confirmed.

12. It will be recalled that the sample has been largely centred on the developing countries, so that taking into consideration electrical equipment and complex control instruments would raise the flattening out which has been observed.

13. Undoubtedly with a larger sample some entries would appear at level 1.

14. The production routes are the subject of an initial description in the document "Capital goods in the developing countries", August 1980.

15. These are analysed in more detail in the document in Annex 1: Some aspects of technological transfer and engineering in the capital goods industry. See also J. Perrin: Work processes - Productive sections and the International Division of Labour, IREP, University of Grenobles, 1978.

III. THE TECHNOLOGICAL STRATEGIES

A. THE GENERAL SIGNIFICANCE OF THE ANALYSIS OF TECHNOLOGICAL COMPLEXITY FOR THE DEVELOPMENT STRATEGIES OF THE CAPITAL GOODS INDUSTRIES

Planners in the developing countries generally have information and methods to determine the demand for capital goods necessitated by the investment plans.

Another task of the planners is to determine what machines it is possible and desirable to produce locally. The planner generally has restricted operational information for making these choices, whether he is working under conditions of poor information or whether he suffers from giddiness in the face of the excessive complexity of the supply of existing machines. It is to overcome this gap in the information, and to assist in mastering the essential strategic options of the policy-makers and national decision-makers in the developing countries, that the method of analysis of technological complexity was created.

It uses the concepts of systems analysis, particularly that of "variety".

In fact to master these strategic options it is necessary to reduce the "variety" of the system, defined in cybernetics as the number of "states" that a system can take.

Systems analysis allows an interesting approach. It is known, from the work of Ashby, that one system cannot control another unless its "variety" is at least higher (law of required variety)[1][2]. The "variety" of the supply system of "capital goods" is enormous. If the "demand" system is to dominate that of the supply it is necessary that national policy-makers should also be of a higher variety.

This result can be achieved by two means:

1. increase the "variety" of the decision-makers, by means of information;
2. reduce the "variety" of the supply system. This reduction can itself be carried out by two routes:

- reduce the "variety" of the system by significant information; this implies simplifying the complexity by arriving at a significant representation of the reality of the groups of capital goods. This is what has been attempted, and what is described in Chapter II;

- to reduce the complexity which is itself contained in the machines. This question will be considered later.

In fact the structuring of information is an organizational response to the challenges of the complexity of the environment (in this case the supply of machines)(3).

Technological complexity is a complex social process. It expresses the laws of nature, particularly physical and chemical.

A system is a "physical" and "social" grouping.

A.T.C. (Analysis of Technological Complexity) concerns the "physical" representation of the capital goods system. It is a necessary, but not a sufficient, part of it. A "system" does not consist solely of a grouping of inter-related technical variables, physical variables and technological routes concerning the input-output process. The relations are also social relations. Technology acts as a mediator in the relations between the laws of nature and those of economics(4).

It is not solely a question of the "physical" relations of utility but also of "composite exchange", that is to say a "mixture of free and reciprocal transfers of utility and relations of powers which logically expresses the economic relation which is, essentially, one of conflict and cooperation, of struggle and of working together"(5).

The mode of increasing the technological complexity which is most important for the developing countries is the international transfer of technological contents(6). Technological transfer is the typical case of a composite exchange. "To chase after, or to minimise, the power relationships in the economics of technological transfer is to make the latter incomprehensible"(7).

Behind the variables there are agents and strategies

Behind the variables considered there are agents having their aspirations, their powers and their means of action. These agents may be nations, or companies of various types. Their strategies may be compatible or incompatible, complementary or opposed[8].

Now like any definition of strategy that of the development of capital goods comprises: i) fixing the objectives, ii) identifying the constraints, and iii) mobilizing the means of action to solve the problems.

The change of structure implies the elimination of certain constraints.

At a given moment t_o the state of technology is a constraint. The constraints can themselves be divided into "invariants" and "controllable constraints"[9][10]. In a perspective of 20 or 50 years the state of any given technology may be regarded as an invariant (whence the importance of the analysis of the stability of capital goods). The initial level of the production apparatus at the moment t_o is a constraint. If the "variety" of this allows only a production v_o of capital goods which is less than the variety of the objectives V_o the relationship is a constraint. It can, however, be surmounted on condition that the objectives which trigger off the desires of the agents and the variety of the programmes should be at least equal to the objectives. The progress can therefore be set out as follows:

at t_o: state of objectives V_o, v_o : statement of possible production programmes

at t_1: if $v_1 \geqslant V_o \rightarrow V_1$ there is a new state of objectives (aspirations) with $V_1 > V_o$ and so on[11].

In one sense the objective is the negation, the destruction of the constraint[12].

The analysis of technical complexity

The above passage may seem somewhat theoretical to the reader. It does, however, have important practical consequences. It signifies:

has important consequences when drawing up development strategies for the capital goods industry ...

-1. that by the analysis of technological complexity it is possible to determine the state v_o of the production programmes, taking into account the constraint of the existing production apparatus. It makes it possible to determine, for a given combination of factors in the central production unit, of the infrastructure and of the components, those machines and items of equipment which correspond to the technological level being considered. This is what is termed the maximum technological operation space (S^{MTO}).

-2. that it is possible to reason, with realism, concerning the levels of the objectives and of the aspirations (V_o and V_1).

... in regard to the strategic choices to be made ...

Each developing country, as a function of its final demand, has a need for a specific combination of equipment goods[13]. These goods may be produced or imported. The whole constitutes a "space for operation" S^0 which will be modified as a function of the demand. Within the latter a policy of replacing imports of machines will have the significance of determining the most advantageous combination of the factors for the central production unit (A1 and A2), of the infrastructure (B1 and B2), and of the components (C), so that the maximum technological operation space (S^{MTO}) tends to approach as far as possible the space of operation (S^0).

... and the policies to be defined.

-3. that the policies for manufacturing capital goods V_1 cover a wide diversity of situations. They may be simple assembling (within A) of imported parts for the assemblies B and C. They can be combined with the constitution of A and mastery of the components of the infrastructure B1 and B2 according to different types of integration, the components being, essentially, imported.

At another level the industrial policy can propose the production of part of the components.

It is a question, therefore, of identifying, within the assemblies and sub-assemblies, the factors to be developed and those to be introduced.

... of the constitution and the enlargement of the industrial fabric

The combination of these factors, allotted a determined level of technological complexity, constitutes the industrial fabric. There is not one but several industrial fabrics which correspond to various stages of development and various associations of the factors. In one sense, every national industrial fabric is specific.

The question therefore arises of determining to what level it is possible to rise in a pre-determined period of 10, 20 or n years (V_n), taking into account the point of departure (V_o). It also poses, in a more general manner, the question of the level at which the developing countries may consider that they have a significant capital goods industry. Finally it poses the question of evaluating the conditions of reproduction of the production apparatus (or, to simplify, the machines which manufacture the machines), an objective which a number of developing countries may fix at different levels of development.

Another related question is that of the introduction of complex industrial groupings - generally integrated vertically - of the type of the "turnkey" companies. This results in attracting productive forces, so increasing the space of operation S^0. It is not always evident that effects of corresponding technological diffusion follow. Analysis of the technological distances between the island of complexity introduced and the level of complexity of the existing industrial fabric involves returning to the fundamental questions of the effects of encouragement[14], of the poles of development and of the possible couplings, or not, of the variables.

... the effect of encouragement

In fact it is a question of evaluating whether the new variables introduced favour the progress of the existing variables or not.

The approach to the "laws" of change makes it possible to distinguish, in advancing from one level of production to another, firstly the existing variables, and to what extent their progression contributes to raising the index of complexity between levels, and secondly the new variables which have been introduced at the higher level, their weight in the raising of the index of complexity, so studying their potentiality for coupling.

Other important operational implications arise from this analysis.

... of training programmes

Firstly there is the question of existing variables, at one level or another, leading to identifying the content of the progress to be accomplished to develop the existing variables, that is to say to make concrete the apprenticeship function, to identify the possibilities of continuous progress and the discontinuities, and, in particular, to draw the implications in terms of training programmes.

... of policies of technological transfer.

Secondly, and dealing with the new variables to be introduced into the industrial fabric, this leads firstly to identifying the content of the technological transfers to be operated and, as a consequence, to making concrete in operational terms the policies for technical transfer, and secondly to identifying the educational content which is necessary to allow the assimilation of the technological contents.

The same applies in regard to the training and education of artisans, workers in industry, managers and the national industry. In fact it is the mastery of the national industrial fabric which is achieved through increasing the "variety" by apprenticeship and education.

This question is so important that time must be spent on it.

It is necessary to avoid the inversion of control ...

The existence of a barrier in variety often leads the system of piloting (or management) to the impossible situation of coordinating the system (here the sub-assembly A1) operating with the other assemblies (here B1, B2 and C) with which it is coupled. A frequent and spectacular result of this barrier in variety is the inversion of control where finally it is the decision-maker who is controlled by the system[15].

Clearly, therefore, a policy for the production of equipment goods, for example within the framework of a policy of replacing imports, the scope of which would be unrealistic, perhaps increases the space for operation of the country but perpetuates its dependence. A development less dependent on the capital goods industries assumes the simultaneous reduction of the variety of the system and the increase of variety of the decision-maker. The important and related concept of "level of variety"[16] makes it possible to specify the question. It is a question of the variety which a system is capable of exhibiting within a given interval of time.

... by dominating the level of variety of the system

A country can dominate the "level of variety" in a given period whereas it may not be able to dominate the variety of the whole system. Domination of the "level of variety" is made possible by the progressive apprenticeship of complexity and its assimilation, efforts which must necessarily accompany any true process of the accumulation of capital[17]. This leads to the crucial importance:

... which leads to important options.

- of the choice of the entry routes which can be dominated in the industry;
- of the estimation of the levels of complexity and the times for assimilation of these;
- of the knowledge of the apprenticeship carried out in other countries and the means used to assimilate the complexity;

- of the orders and sequences observed in the successive production of capital goods
- of the choice of the forms of integration of the national industrial fabric and that of the timetable of the entries of the new units of production
- of the orientation of the educational system so as to increase the capacities for assimilation in good time.

A.T.C. opens up the prospects of renewal of analyses in these fields.

The analysis of technological complexity could also serve as an instrument in international negotiations

It is, perhaps, the same in international negotiations.

It is felt that A.T.C. should assist in formulating long-term projects for entry and growth of capital goods industries in the developing countries, and as a consequence to contribute towards improving the transparency of markets. The obstacles to entry are not necessarily "physical", and the example of the "cartel" for electrical equipment has often been put forward to emphasize that the barriers erected against entry are not always related to technological complexity(18). The force relationships in the composite exchange are shown in the mechanisms of integration and of financing, the distribution of markets, in technological transfers and the terms for the exchange of prices. They put into effect unequally active agents: companies and governments exercize powers and effects of domination on certain variables.

The configuration of the negotiations varies therefore as a function of the realities of the "physical" and social system.

It is felt that this would be influenced by the levels of complexity corresponding to the stages of development; the technological transfers to be effected, in particular, will be different according to the level, and also on the agents of transfer(19).

A.T.C., associated with other instruments of analysis - such as games theory applied to negotiations[20] - could perhaps open up a way to identify the various types of negotiations, to mark out the terrain for these, and to identify the zones of conflict and cooperation between partners.

It is a question here of potentialities which require to be explored experimentally. In the immediate future we can base ourselves on the following propositions which result from the analysis in Chapter II.

3. PROPOSITIONS FOR THE DEVELOPMENT STRATEGIES FOR THE CAPITAL GOODS INDUSTRIES

The propositions relating to the kinds of "laws" of composition and change in capital goods only constitute a first approach towards a reality, the complexity of which does not need to be demonstrated.

In the same experimental spirit one can now examine how these lead to formulating propositions for the development of the capital goods industries.

Obviously it is not a question, at this level of analysis, to put forward special recommendations for one or other country, but to deduce from the analysis of the capital goods "system" the logical consequences in terms of strategies. This essay therefore extends the analysis, which has its limits.

In the same way in order to emphasize the open character of the necessary discussion it is again presented in the form of "propositions".

- Proposition I: The analysis of technological complexity, whilst it shows the real difficulties of penetration into the capital goods industry by the developing countries, and the conditions for passing from one level to another, does not lead to the conclusion that these difficulties are insurmountable. It tends, on the contrary, to demystify the idea according to which these difficulties are such that it is necessary to renounce such activities, and that it is necessary to remain within the existing international division of labour.

The wrong question is to ask if capital goods constitute a kind of sanctuary of industry reserved to a few elite countries. The answer to this has been given by history. Various countries, in their time under-developed or agricultural, such as the USSR or more recently China, but also countries as diverse as Italy, Spain, Portugal, Finland, Bulgaria, Roumania, the Republic of Korea, Brazil and India, have successively either built a complete structure or made important "breakthroughs" in this sector. Other countries, such as Algeria, have also penetrated into it.

- Proposition 2: The realities - and the constraints - of the technological complexity of capital goods means that there are objective limitations to the progress which is possible in a given time. Understanding these limitations should not be a brake but, on the contrary, an encouragement to use these degrees of freedom fully. This leads to the following subsidiary propositions:

SP 2a: To a given level of available production factors there corresponds a space of maximum technological operation making it possible to produce an assortment of machines. From that time onwards the first problem is *to occupy this space for operation* as completely as possible.

SP 2b: The second problem is one of fixing the objectives and the programmes for increasing the production of machines over a given period, at a level compatible with the progress of the production factors, and linking together the assemblies and sub-assemblies which form them.

The wrong question is that of asking whether the developing countries can enter into the sector, whereas the true problem is of knowing how the present international division of labour can be restructured, taking into account firstly the degrees of complexity within the universe of machines and secondly the specific characteristics of each developing country or group of developing countries, of their existing production capacities and those which they can reinforce during the next twenty years.

Two traps can be seen: <u>the first</u> - and the most important - is that of frequently underestimating the possibilities by misunderstanding the real conditions of manufacture of the different groups of capital goods. <u>The second</u> - for the same reason - is of drawing up unrealistic plans which cannot be applied since the complexity barriers to be overcome have been poorly evaluated. A variant of this attitude is the transfer of manufacturing installations which are out of scale with the management capacity of the country, and which therefore fail irremediably.

The planner must therefore avoid these traps from the beginning. His view of the field is necessarily a long-term one: 10 or 20 years. He must be conscious of the fact that his choices commit the future for a long while. Undoubtedly it would not have been possible, 60 or even 20 years ago, for these countries to have, apart from some general principles of action, such sophisticated methods available to them. It has been necessary for them to demonstrate the movement by moving. However an extensive international experience has today been accumulated, and advantage should be taken of this to allow each country, choosing its own route, to obtain that information which will facilitate the shortest and most effective route for it.

The effective occupation of the space for maximum technical operation S^{MTO} comes up against three kinds of limitations.

- The first may arise from the fact that the machines which the existing variables make it possible to construct necessitate sizes of companies which are incompatible with the situation of the country, and/or excessively long production runs for the size of the market.

In this latter case one solution could be sought within a framework of cooperation agreements at a sub-regional or regional scale.

. The second may arise from the self-limitation imposed by the country itself. Lack of information on the possible multipurpose nature of the existing production apparatus can be one of the causes. Another can arise from the interest importers have in purchasing from abroad rather than manufacturing locally. National monopolies in certain sectors of the economy can have the same discouraging effect.

. The third may arise from the state of international relationships, by the space occupied by foreign subsidiaries within the country restricting the effective possibilities of operations, together with the degree of competitiveness of the product.

These circumstances may limit the occupation of the S^{MTO}, but they are not generally incapable of elimination.

- Proposition 3: Increasing the space for maximum technological operation S^{MTO} necessitates a change in the structure of the combination of assemblies A (central production unit), B (technical infrastructure), C (components) and the sub-assemblies A1 (management), A2 (means of production), B1 (semi-finished products) and B2 (technical services).

Two types of strategies can be conceived:

. The first is to increase the variety of the machines and of the production apparatus, according to the dominant standards of the international supply; this results in an increase in the complexity of the system.

. The second is to attempt to minimize the increase in the complexity of the system by: i) re-designing and simplifying the machines or ii) selecting technological alternatives which minimize complexity.

The first is the easiest. The second necessitates a considerable political desire for realization, an institutional infrastructure, some design capabilities and information on the alternative technology. This new route for development, because of its potential importance, is dealt with later.

SP 3a: Industrial policies must on the one hand face up to the constraints, whilst on the other they have degrees of freedom of action.

On the side of the constraints the production of pre-determined capital goods implies the existence of pre-determined production factors which are ordered according to production routes. It is essential to have in assembly A the means of production ϕ and the men to work and direct, having pre-determined skills. In the same way the assemblies B and C are necessary. If the factors for production do not exist in the country it is necessary to transfer them.

In numerous developing countries there is no other way to start than by acquiring the means of production (A2) and those components (C) which would be too complicated to manufacture.

The heritage of history, the level of the industrial fabric and of the infrastructure of the human forces, constitute other objective data which limit the field of possibles in a given time.

On the side of the freedom of action, the choice of the means of production, the constitution or not of the sub-assemblies B1 and B2 or a part of these, the manufacture of certain components, are the field of explicit decisions.

A wide variety of policies is therefore available, according to the characteristics of each country, its initial constraints, its levels of aspiration and its political desires.

The essential question is therefore one of efficient usage of these freedoms of action and of choice. This leads to the following propositions:

- Proposition 4: Despite the diversity of possible - and effectively operated - policies a certain number of "rules of conduct" appear to emerge when creating and developing the capital goods industry.

1. A minimum B1 and B2 infrastructure is essential

In default of this the manufacture of equipment goods is reduced to assembly activities, that is to say a pseudo-industry for capital goods. Implementation of the infrastructure B is of decisive importance up to and including level 3 of complexity. This is the price to be paid for economic and technological accumulation. In default of this national infrastructure it is impossible to achieve self-sustained progress in the industry.

2. No country, even amongst the most developed, can live in a state of autarky in respect of equipment goods: the international division of activities and the international trading are necessary.

At the lower levels of complexity (1 and 2) the weight of components is low. However most of the time they are too complicated to be manufactured locally, and they must be imported.

In the higher levels of complexity (from 3 upwards) it follows that certain of these components can be produced locally. However since their relative weight increases as one goes up the scales of complexity the constraint of having recourse to imports increases.

3. The introduction of new installations, particularly those integrated vertically and of the turnkey type, must be evaluated with very considerable care.

In the case where, for example, they introduce complexity levels of 4 or 5 into an industrial fabric at levels 1 or 2 it is very unlikely that they will produce any encouraging effect on the existing technological variables. The distance between the latter and the variables which are introduced is too large to allow any coupling. Now it is this coupling which encourages the existing technological variables upwards. In other words the introduction of too great a variety does not favour the function of apprenticeship. In this way isolated islands of complexity are created.

This question is a complicated one: it must be analysed, taking into account the effect of internal diffusion of the technology incorporated in the products manufactured, of industrial migrations to other companies, of the vertical input-output integration relationships of the companies between themselves, of the status of them, etc. However, irrespective of the levels of introduction of the variables, it is important to avoid them cancelling out the progress acquired by previous apprenticeships.

4. It is necessary to adapt the training programmes, particularly those of the management of the companies, and also the structure of the various capital goods industries, to the difference between the compexities required by the objectives selected and those which already exist.

Through this analysis it can be seen that there are profound and structural differences between the companies which produce capital goods. Equipment is manufactured using mass production processes; these are the standard goods. Others are produced to drawings in single units, and using batch production processes. Raising the organic composition of capital in the assembly A, characterized by moving towards increasingly specialized if not automated means of production, displaces the work functions. Direct work is simplified, but the complexity is shifted towards the function of maintenance, product design and organization. On the contrary in the sub-assemblies B1 and B2 - as long as they themselves are not subject to the process of automation - the complexity of direct work increases with the levels.

It follows from this that, according to the choices effected in the spatial and temporal linking of the A, B and C assemblies (see SP 3a) the skills needed from the labour and management will be different. Considered from this point of view training programmes are normally designed according to a mode which is too standardized and not sufficiently linked with the choices of policy and with the structural realities of the industry.

This is particularly true in the case of management training.

Some important research work(21) suggests typological correspondences between the sectoral systems of industrial production and the characteristics of management. The essential functions of production, marketing and research and development are linked differently according to the sectors; the hierarchical organization of the company therefore depends on these links and must differ structurally.

5. The policy of opening the "packet" of technological transfers and the incorporation of national elements necessitates a precise analysis of the technological contents to be transferred at the various levels of technological complexity.

This question is related to the previous one. From the point of view of action it would be useful for the developing countries, using the A.T.C. tool, to identify accurately their existing production factors and their levels of complexity (see the description in the Annex). Using the same measuring instrument it will be possible to identify the variables to be introduced and to consider these in terms of the problems of the transfers to be effected. In this way one can evaluate the possibilities of coupling with the existing variables, and hence the possible function of apprenticeship, the introductions to be effected and the conditions necessary for their assimilation, the rôles of the various agents involved, etc.(22)

- Proposition 5: The aim of the majority of the developing countries, which at the present time have a weak production basis for equipment goods, could be level 3 of complexity of products.

At this level it is possible to produce 40% of the equipment goods. This level makes it possible to produce, in particular, most of the semi-finished products (see the classification of capital goods from a functional and technical point of view), part of the goods common to all branches and, amongst the specific machines for the sectors of final demand, part of agricultural machinery, equipment for the food industries and equipment for the chemical and petrochemicals industries.

At level 4 75% of the products could be manufactured.

One must not pretend that reaching level 3 for developing countries of medium size, which already have a certain base, will not require time: the 20 years between now and the end of the century seems in many cases a minimum. However whether the horizon is slightly more distant or slightly nearer, as a function of the initial bases, resources, policies and international cooperation, this general objective does not seem to be beyond the scope of many developing countries.

It is however necessary to be conscious of the contradictions to be overcome. It can be seen in fact that even level 1 of complexity requires the presence of numerous factors which are nevertheless not very complex. However it is this first primary accumulation which is the most difficult to achieve. The second barrier is the assimilation of the new factors at levels 2 and 3. During this period it is necessary to make progress simultaneously by apprenticeship and the transfer of technologies, and also to list these two forms of progress.

In fact it is level 3 which marks the true "take-off" point for the capital goods industry. This does not mean, however, that progress from there onwards is easy. Progress is achieved at levels 4, 5 and 6 essentially by increasing the complexity of the existing variables. Those countries which have dominated level 3 are then in a position to achieve, by their own endogenous progress, levels 4 and 5. However, and this needs to be confirmed, it does seem that there is a real and qualitative change between levels 5 and 6.[23]

SP 5a: For the least developed countries it seems that agricultural machinery and the production of certain semi-finished and simple products constitutes a preferable route for entry into the equipment goods industry.

The technological routes which are used are capable, at the price of some progress, of allowing the production of machines for building and certain items of equipment for the food industry.

It would seem that this constitutes the best link to use to start forging a longer and more complex manufacturing chain.

Conversely it does not seem that entry into these industries by the manufacture of transport goods and, within agricultural machinery, by the tractor and the combine harvester, always constitute a good choice. Generally the options - often loaded with the symbols of social choice and power - are situated at levels which are too high in complexity to result in true encouraging effects on existing production. However there are undoubtedly exceptions and successful couplings of this kind.

- Proposition 6: The development of the equipment goods industry necessitates operations of periodical restructuring of the structures and of the links between the constituent assemblies and sub-assemblies.

The grouping into "assemblies" and "sub-assemblies" is a representation which expresses a theory of the organization of equipment goods manufacture.(24)

This theory starts from the finding that, in order to produce equipment goods, a final production apparatus, a technical infrastructure and components are necessary.

Historically those countries which are today industrialized have given different answers to the spatial arrangement of these assemblies. Constraints which, initially, could not be eliminated have resulted in a type of vertical integration of activities. In other countries market forces and the existence from the sociological point of view of a class of entrepreneurs have divided up these activities and have led to horizontal forms of integration.

Numerous developing countries find themselves today at the crossroads before the essential choices which have to be made.

The analysis of technological complexity may contribute towards casting light on these.

In fact there do not seem to be other possible choices in numerous developing countries, where the technical infrastructure is almost non-existent, than having recourse to vertical integration. However the rapid increase in complexity of this with increasing levels leads, from level 3 onwards, to difficult management problems. If the central production unit A integrates all or part of the components of B1 and B2 the total complexity exceeds that of the variety of management. The system then runs out of control.

In the case of horizontal integration the production factors B1 and B2 are divided into distinct enterprises. The total complexity is thus divided up and is more easily managed. The difficulty shifts, in this case, towards the mastery of the linkages between the assemblies and sub-assemblies, and hence to the inter-sectoral and inter-company links.

However without blocking the system itself[25] it is necessary that the latter, because of its development, and as a condition of its continuation - should restructure and modify its own links. As soon as circumstances permit a bifurcation towards horizontal integration becomes necessary[26], together with the cleaning up of activities within the vertical enterprises, leading to more effective specialization and distribution of these in relation to other enterprises. In this way the structure has to evolve.

- Proposition 7: The question is posed of the utility and possibility of constructing and utilizing new models of technological development.

It can be seen from this analysis that the creation and growth of the capital goods industries in the developing countries is a possible but difficult enterprise.

It encounters a series of contradictions which must be resolved.

In this way the simple semi-finished products, or those at the bottom of the capital goods range, which are common to all branches of activities, are often products with a lengthy cycle of innovation, which are widely used, and where production is carried out in long production runs and hence at competitive prices.

The capital goods sector is a major employer of labour. This is a favourable circumstance because of the problems of employment in many developing countries. This labour can be comparatively unskilled for the final part of the manufacturing process, but needs to be highly skilled in the previous stages of production. The size of the companies is relatively large, and in all cases the threshold which has to be passed may seem high in many developing countries where the concept of the small and medium sized company does not correspond with the definitions which are used in the industrialized countries.

In brief, therefore, and following the technological "pattern" of the industrial countries - which is reflected in the analysis of the sample of machines - it must not be pretended that the relative advance and, a fortiori, any catching up of the developing countries is not a very long task, the more so as the trend in technological development is towards increasing complexity.

Under these conditions the question must be asked if a bifurcation of the dominant model, towards simpler solutions, is possible. The technological choices of society are at the present time the subject of critical considerations both in the market economy developed countries and also in the developing countries. The first is leading to a flood of publications where ecological criticism is converging with that of the economic and political systems(27). The second current has also given rise to many publications on the subject of intermediate, soft, adapted, appropriate, less expensive, and other kinds of technologies(28). Some initial realizations of this type have already appeared.

In fact, and where capital goods are concerned, one may formulate the basic questions relating to the implementation of a simpler technical model in the following manner.

Is it possible to reverse the historical movements of scale economies, of scaling-up innovation, by designing production installations of a smaller size and moving towards "scaling-down" innovation ?

Is there an unnecessary load of technological complexity in machines, in the excess of components, the degrees of accuracy and excessive tolerances, when compared with the real use of these machines in the developing countries ?

Would it not be of value to hold back the very rapid rate of obsolescence and to move towards the production of machines - perhaps of slightly lower performance - in longer and more stabilized production runs ?

Would it not be of interest to manufacture products which are more durable and to organize, systematically, the recovery of the durable if not imperishable parts of such items of equipment ?

Would it not be of value and possible to re-design machines to a simpler design without them necessarily being copies of old and obsolete models ?

Could not a positive reply to certain of these questions constitute the very conditions for other types of progress of the developing countries, better suited to solving their problems than the imitative transfer of the dominant technological models ? Is international cooperation possible in this field ?

These questions merit detailed examination. In default of this some observations can nevertheless be made.

It does seem that in certain sectors the reversal of the move towards scale economies has begun.

The overload of inessential parts is not so obvious in the case of capital goods as it is in the case of durable or non-durable consumer goods (29). It is nevertheless perceived by some engineers (30). This examination is, without doubt, difficult because of the intrinsic development and the semi-autonomous character of development in technology (31).

The fight against wastage by society leads to considering the design of products in new terms so as to allow, in particular, their dismantling (32).

New replies to these problems could precede the establishment of new technological models - where capital goods would continue to occupy the central position. Perhaps the day will come when, quoting the title of a celebrated book, engineers and public opinion will admit that "simple is beautiful".

C. PROPOSALS FOR AN ACTION PLAN FOR UNIDO

Returning to the initial proposition of this document, which is the management of a complex operation and the growth of equipment goods in the developing countries, it is now even more obvious after this analysis that the contribution which UNIDO could make to this necessitates also a methodology of action - a praxology - in the long term.

The following praxogram is divided up in time into four major operations:

(A) The strategic study of equipment goods carried out by UNIDO/ DIS

(B) The system of information on the technological complexity of capital goods

(C) Assistance in the establishment of national strategies in the developing countries

(D) The strategies for international technical assistance and cooperation.

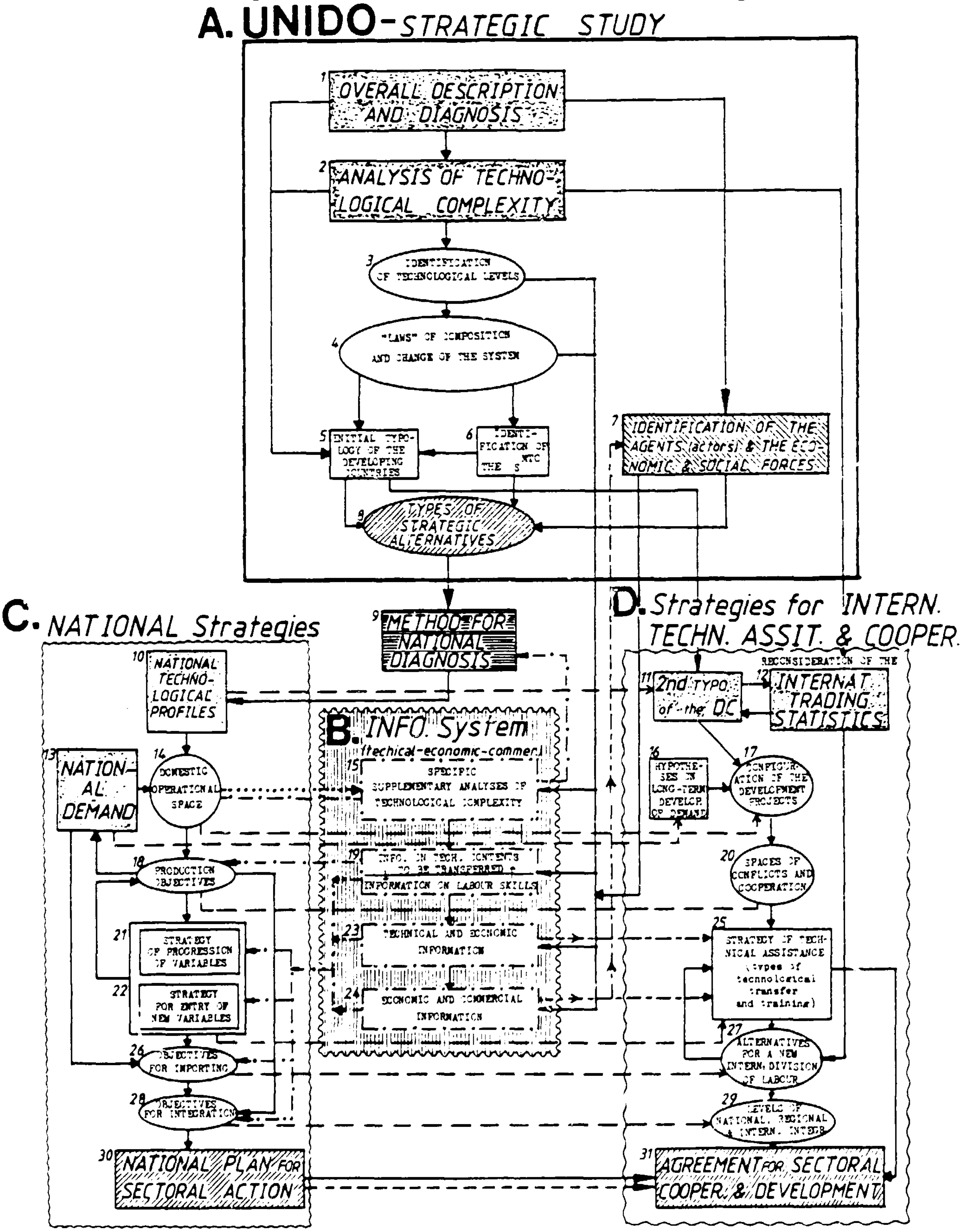
These are briefly discussed below.

1. The strategic study

At the present time this comprises (the numbers correspond with those on the diagram):

- the overall description and diagnosis (1)
- the analysis of technological complexity (2)
- the identification of technological levels (3)
- an approach to the "laws" of composition and change (4)
- an initial typology of the developing countries (5)
- the identification of spaces for maximum technological operation by levels (6)
- an initial analysis of the identification of the actors and the economic and social forces (7)

Capital Goods Praxogram



PFG/RN.

8.8.1980

After the discussion at the Warsaw meeting the proposal is to decide on the types of strategic alternatives (8) and to present these to the First World Consultation on the Sector. The second output of the strategic study, and particularly of A.T.C., would be the establishment of a method for national diagnosis (9) in order to identify the existing situation and the potentialities of the production apparatus. This method would then be tested in some of the interested countries. It would then be adapted and made available to all countries.

2. <u>The system of information on technological complexity</u>

The basis of this system already exists with 318 groups of machines and 35,000 items of data. To be fully operational it is necessary to increase the sample to approximately 1,000 machines and to 100,000 items of data. This is a massive task, but one which it is not impossible to carry out in the light of the acquired experience.

The sample should be particularly enlarged towards the lower end of the scale, and should preferably include the simple instruments and machines which are used, particularly in Africa and Asia.

Amplification of the sample will be carried out by specific supplementary analyses (15) made at the request of the countries (see 13 and 14 in the diagram).

The data would be analysed to constitute information on the technological content to be transferred and the skills of the labour and management, according to the levels and groups of products (19). It would be supplemented by technical, economic and commercial information for the acquisition of machines and equipm nt (22 and 23).

Computer processing of the data - today being carried out for A.T.C. - will be continued, and this would subsequently make it possible to pass the information on to users in the form of magnetic tapes, providing a programme of utilization which they could then adapt to their specific needs and, at the same time, contribute to the analyses and to the augmentation of the data banks.

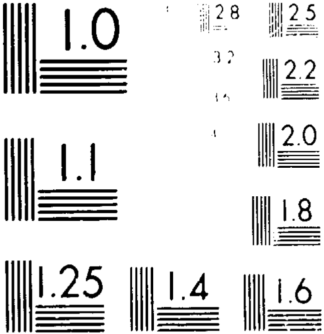
3. Assistance in the establishment of the national strategies

The application of the methods of diagnosis (9) would make it possible to establish national technological profiles (10).

The examination, using well-known methods, of the national demand (13), compared with that of the technological profile, would lead to an evaluation of the domestic operational space (14), that is to say the composition of the groups of machines to be produced or to be imported and corresponding to the national and sectoral development projects. The reasoned choice on a basis of A.T.C. of the production objectives of the machines to be manufactured locally (18) would make it possible to draw up a strategy of progression for the existing variables - the apprenticeship function (21) and the strategy for the entry of new variables - and the transfer of technologies function (22). Then would follow the determination of the objectives for importing (26), those of national integration (28), and the forms of the latter. Finally a national plan for action in the development of capital goods would be drawn up.

4. The strategies for international technical assistance and cooperation

The construction of national technological profiles in the developing countries (10) would make it possible to specify the typology of the latter (11). The application of A.T.C., by breaking down international trading into the elements of A2, B1, B2 and C, would make it possible to reconsider the statistics on capital goods and, undoubtedly, to see international trading


1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

from a new viewpoint (12).

The collection of information on national projects (13, 14 and 18), coupled with the hypothesis of the long-term development of demand (16), would make it possible to define and to compare the configuration of the development projects for the equipment goods industry (17). One could then appreciate the spaces of conflicts and cooperation resulting from the projects of the partners (20).

In this space of cooperation the national strategies for progress in the existing variables (21) and the introduction of new variables (22) would be shown by specific strategies of technical assistance relating to programmes of training and detailed technological transfer (25).

Comparison of the projects and the objectives of production and the importing of the countries (26), compared with that of the spaces of conflicts and cooperation (17), would lead to the formulation of alternatives for a new international division of labour (27).

Comparison of the integration objectives (28) would make it possible to specify these by indicating the levels of national, regional and international integration (29).

Finally consideration of the national plans for action in the sector (30), and the alternatives of the new international division of labour (27) and of integrations (29), would make possible an international agreement for sectoral cooperation and development (31), a very flexible framework which could fulfil the functions of indicative planning, similar to that which is practised in numerous market economy developed countries.

Notes to Chapter III

1. W.R. Ashby: An introduction to cybernetics - Chapman Hall - London, 1956.

2. J.Mélèse: L'analyse modulaire des systèmes de gestion - Une méthode efficace pour appliquer la théorie des systèmes au management - Editions Hommes et Techniques, 1979.

3. It is in these terms that the research work of IIASA is presenting the problem of the control exercised by one system on another.
See Cyril Davies, Ada Demb, Paul Espejo and Roman Ostrowski: Multi-organizational strategies: An analytical framework and case illustrations (The impacts and opportunities of North Sea Oil: and Bratsk-Ilimsk, The organizational implications of the concept of territorial production complex) - International Institute for Applied Systems Analysis, Laxenburg - Austria, February 1977.

4. A. Zvorikine: document cited in Chapter I - Reference 9.

5. F. Perroux: Pouvoir et économie - Bordas, 1973.

6. One must insist on the expression "technological contents". In order to escape from the vague generalities of technological transfer it is these contents which it is necessary to identify. A.T.C. is a means for identifying these contents.

7. Pierre F. Gonod: Clés pour le transfert technologique - Institute for Economic and Social Development - World Bank, August 1974.

8. It follows that the necessary supplement to A.C.T. should be the analysis of the agents and the strategy of the actors.

9. Walter Buckley: Sociology and Modern Systems Theory - Prentice Hall Inc. - Englewood Cliffs - New Jersey, 1967.

10. The reader who is interested in the consequences of this distinction when defining development strategies may refer to the World-wide study on the agricultural machinery industry, UNIDO/ICIS.199 - 29 June 1979 - Chapter IV B: The integration of agricultural and industrial strategies.

11. See Pierre F. Gonod: Nouvelles représentations des transferts technologiques (Déséquilibres structurels et contreparties) - Mondes en Développement No. 20, 1978.

12. Y. Barel: Prospective et analyse des systèmes - D.G.R.S.T. - February 1972.

13. See the example of Mexico: Capital goods programme in Mexico - Conception - Content and achievements - M.F. Fajnzylber - Séminaire sur les stratégies et instruments visant à promouvoir le développement de l'industrie des biens d'équipements dans les pays en développement - Algiers 7-11 December 1979.

14. See F. Perroux: Note sur la notion de "Pôle de croissance" - Economie appliquée No. 8, 1953; L'effet d'entraînement: de l'analyse au repérage quantitif - Economie appliquée, 1973; and Albert O. Hirschman: The strategy of economic development - Yale University Press, 1966.

15. J. Mélèse: document cited, Ref. 2.

16. Van Court Hare J.: L'analyse de système, outil de diagnostic - Paris - Dunod, 1973.

17. See Georges Corms: L'idéologie du développement ou le libre-échange au XXe siècle - Le Monde Diplomatique - November 1979.

18. The dominant position of transnational companies in the international market: Monograph on the electrical industry - R.S. Newfarmer - UNCTAD/ST/MD/13. Consequences for the developing countries of the restrictive commercial practices of transnational companies in the electrical equipment industry: Monograph on Brazil. Study produced by B. Epstein and K.R.V. Mirow - UNCTAD/ST/MD/9.

19. See, in Annex 1, the document "Some aspects of the transfer of technology and engineering in the capital goods industry" - ID/WG.324/4/Add.1, 7 August 1980

20. See in particular the book by Jean Pierre Ponssard: Logique de la négociation et théorie des jeux - Les Editions d'Organisation, 1977 - which sets out the methodological elements for dealing with problems of competition and negotiation.

21. See Joan Woodward: Industrial organizations - Theory and Practice - Oxford University Press, 1965.

22. The appended document, "Some aspects of the transfer of technology and engineering in the capital goods industry", develops this question.

23. Level 6 of complexity of capital goods could correspond to what certain authors term the "post-industrial" society, even if this term is questionable.

24. Fr. Vidossich: Busqueda de una teoria para producir bienes de capital en los paises en via de desarrollo - January 1980 - Report for UNIDO/ICIS.

25. Blockage of the system can take different forms. For example the vertically integrated company which produces its own inputs obviously has weaknesses. It is difficult for it to specialize. The inertias towards the application of technical progress, and to the introduction of electronics in particular, are reinforced.

26. These circumstances are, in particular, the increasing density of the industrial fabric, reinforced technical capabilities and the existence of an embryonic engineering capability.

27. See in particular amongst the many publications: Orio Giarini et Henri Loubergé "La civilisation technicienne à la dérive - Les rendements décroissants de la technologie" - Editions Dunod, Paris 1979.

28. See in particular E.F. Schumacher: Small is beautiful; appropriate technology. Problems and promises - OECD Development Centre 1976; UNIDO: Development and transfer of technology series.

29. See, in particular, J. Baudrillard: Les systèmes des objets - La consommation des signes - Denoël-Gauthier, 1968.

30. The following comment by an electronics engineer of Western Union, now retired, is evidence of this growing consciousness: "Before my retirement I made the observation that American engineers seemed to have lost the ability to do anything in a simple fashion. One cardinal principle which I applied in my work was this: if your device has a defect, don't try to cure it by adding more complexity; rather, go back into the original design and find the cause. Look under the hood of any modern car and you will see the death of that concept". - Frank T. Turner: Modern Science and Technology on Parson's Position - Technology and Society I.E.E.E. - Vol. 7, No. 25 - March, 1979.

31. See the publications of G. Simondon: Du mode d'existence des objets techniques - Aubier-Montaigne, 1969.

32. Research in this direction has been carried out by institutes such as the M.I.T. - see Robert L. Lund and W. Michael Denney: Extending product life: time to remanufacture ? - Center for Policy Alternatives - Massachusetts Institute of Technology, 1978 - AMACOM.

with 09990

Distr.
LIMITED

ID/WG.324/4/Add.2
19 September 1980

ENGLISH
Original: FRENCH

United Nations Industrial Development Organization

Global Preparatory Meeting for the First Consultation on the Capital Goods Industry

Warsaw, Poland, 24 - 28 November 1980

TECHNICAL ANNEX *)

Prepared by the
Sectoral Studies Branch,
Division for Industrial Studies

*) This document is an addendum to the study "Technology in the service of development", related to discussion subject No. 2 on the agenda: Types of technologies in the service of development of the capital goods industries.

This document has been reproduced without formal editing.

80-43770

CONTENTS

SUB-GROUPS OF CAPITAL GOODS

- LIST OF SAMPLES -

1. SAMPLES OF SUB-GROUPS OF CAPITAL GOODS

381

1.01 Hand field tools: axes, chisels, spades, rakes, cutters, etc.

1.02 Simple hand tools for engineering: wrenches, hammers, files, saws, pliers, cutters, etc.

1.03 Hand tools for carpenters, woodcutters, etc. Not motor-driven.

1.04 Tools for bricklayers, plumbers, etc. Simple materials and manufacture.

1.05 Tools for engineering, assembly, etc. comprising various parts, complex, torque limiters, etc.

1.06 Hardware articles, locks, keys, padlocks, marine ironmongery and similar.

1.07 Metal furniture for offices, restaurants, industry, etc.

3.01 Doors, screens, window-frames, fixed staircases, metal sheet for building, profiles, etc.

3.02 Structural components of medium size and weight for bridges, sheds, depots, chimneys, buildings, etc.

3.03 Structural components, heavy and semi-heavy, for bridges, buildings, sheds, depots, etc.

3.04 Metal sections for ships, barges and similar.

9.01 Containers, barrels, drums, kegs, pails, strong-boxes, strong-rooms etc.

9.02 Metal stamping and pressing services, of normal and medium size and precision.

9.03 Small precision and micro stamping services.

9.04 Heavy stamping services (bodywork for trucks, coaches, etc.). without own tools.

9.05 Reynolds and similar chains, for transmission and lifting.

9.06 Springs of all types, including heavy and semi-heavy duty and for micro-mechanical engineering.

9.07 Screws, nuts, washers, rivets, pins, etc. excluding aerospace, military, highly specialized, etc.

9.08 Collapsible and similar metal tubes. Own production of special tools and printing.

9.09 Valve and tube fittings - wrenches, turned goods, for houses, buildings, etc. (Public works).

9.10 Wire netting and similar, of various materials, except the very specialized.

381

9.11 Stoves, ovens and heaters, simple, non-electric.

9.12 Chromium, cadmium, nickel and enamel plating, etc. (Excluding sophisticated installations).

382

1.01 Reciprocating petrol engines (without clutches).

1.02 Diesel engines up to 500 hp, series manufactured (without clutches).

1.03 Diesel engines of more than 500 hp.

1.04 Gas and other engines.

1.05 Steam engines, stationary, simple, traditional.

1.06 Steam turbines.

1.07 Gas turbines, excluding very heavy duty.

1.08 Hydraulic turbines (with only one part of the controls).

1.09 Non-conventional engines, nuclear engines, etc.

1.11 Specific parts, components and mechanical accessories for turbines.
Control units, principally for gas turbines.

2.01 Hand tools.

2.02 Wheelbarrow and single-axle trailer.

2.02 Animal-drawn plough.

2.05 Manual wheelbarrow and portable sprayer - plastic container and compressor.

2.07 Mounted mouldboard plough, 2 furrows.

2.08 Mounted mouldboard plough, 1, 2 or 3 furrows, reversible.

2.09 Mounted 2-3 disc plough.

2.10 Chisel plough.

2.12 Cultivator with rigid tines - single bar with rigid tines.

2.13 Seed drills in general, multi-drill, current types.

2.14 Single-drill units, precision type, current - excluding sophisticated seed-drills.

2.15 Trailed harvester for fruit.

382

2.16 Forage cutter, normal and motor-driven.

2.17 Crushers and grinders for feedingstuffs.

2.19 Grain and cereal dryer, continuous, fixed and mobile.

2.23 Twin-axle trailers, metal, common and tipping

2.25 Front-loader, only the mechanical drive part.

2.27 Spiral auger, tractor-driven.

2.30 Spraying units, tractor-driven and similar, including pumps up to 60 kg/cm^2.

2.31 Trailed and self-propelled sprayers, pneumatic, without motor and without tractor.

2.33 Manure spreader, hanging type, simplified type.

2.37 Harvester alone and harvester-loader, tractor-driven.

2.40 Maize harvester and similar.

2.41 Self-loading truck, non-tipping - current types, tractor-driven.

2.42 Haymaking unit, with rotating head.

2.44 Hay baler - hav lifter, tractor-driven.

2.45 Round baler

2.52 Small air-cooled single-cylinder engine.

2.61 Discs for plough.

2.62 Wheeled tractors up to 25 hp - without engine - including articulated mini-tractors.

2.63 Wheeled tractors above 25 hp, without engine.

2.64 Caterpillar tractor, without engine.

2.65 Articulated (swinging) tractors, without manufacture of the engine.

382

3.01 Machine tools for metals, chip-removal, simple

3.02 Machine tools for metals, chip-removal

3.03 Machine tools for metals, chip-removal, high complexity, special, automated.

3.04 Machine tools for metals, cold-forming, simple.

3.05 Machine tools for metals, cold-forming, complex, automated, etc.

3.06 Machine tools for hot-forming of metals.

3.07 Machine tools for wood.

3.08 Machine tools for wood, production and special, for furniture and sawmills.

3.09 Machinery and equipment for treatment of wood and similar.

3.10 Special mechanical accessories for chip-removal machine tools, comprising many parts (dividers, measuring, feeders, etc.). Excluding accessories produced from sheet metal.

3.11 Blast furnaces.

3.12 Steelmaking furnaces.

3.13 Continuous casting, excluding components (C).

3.14 Rolling mills of more than medium size. Cold and hot, with input and output measurement.

3.15 Handling equipment for the iron and steel industry.

3.16 Equipment for drawing, wire-making, cold prcision rolling and extrusion.

3.17 Specific equipment for ferrous and non-ferrous casting.

3.18 Special casting equipment: low pressure, shell moulding, vacuum, centrifugal, etc., up to semi-automated.

3.19 Equipment for the production and casting of strategic metals: Ni, Cr, Ti, Co, V, W, etc.

3.21 Special accessories for chip-removal machine tools, produced from sheet metal (control boxes, protectors for guides, cables, etc.).

3.22 Machine tools for metals, chip-removal amd forming, heavy and ultra-heavy duty.

382

4.01 Equipment for the food products industry: bread-making, including ovens, but not electric types.

4.02 Equipment for the food industries: biscuits, pasta and similar.

4.03 Equipment for the food products industry: milk and cheese (excluding large installations).

4.04 Equipment for the food products industry: ice-cream, juices, sweets, lozenges and similar.

4.07 Equipment for the drinks industry - not including the production of bottles and containers.

4.08 Equipment for the stock-raising industry (simple).

4.09 Equipment for small-scale slaughterhouses - excluding automatic and refrigerated.

4.10 Equipment for dehydration, freeze-drying, deep-freezing, etc. (without compressors).

4.11 Refrigerated rooms, without compressors (excluding brickwork).

4.12 Refrigeration balconies

4.13 Textile machinery: spinning, preparation for spinning, winding, reeling, twisting, yarn treatment.

4.15 Textile machinery: knitted goods.

4.18 Machinery and equipment for the production of cement.

4.19 Machinery and equipment for the ceramics, clay, asbestos and similar industries - current equipment.

4.20 Civil engineering: cranes and hoists.

4.21 Equipment for mixing and transporting cement. Cement pumps - excluding the chassis of trucks.

4.22 Special equipment for large civil engineering projects - this is only an interpretation to show the necessary basic structures.

4.23 Fixed plants for the preparation of concrete - production of piles, pipes and other prefabricated concrete components - excluding totally automated equipment.

4.24 Plant for road surfacing (cement, asphalt, etc.) without chassis and without engines.

4.25 Simple asphalt plants, only for final preparation (not as raw material).

382

4.27 Machinery and equipment for mining: drilling and excavation (excluding portable).

4.28 Continuous transportation equipment: bucket and belt conveyors and similar, for mining operations.

4.30 Equipment and installations for preparation: screening, crushing, vibrators, etc. for mining applications.

4.31 Equipment and plant for concentration, refining and pelleting for mining operations.

4.33 Equipment and plant for drilling and extraction of offshore oil. Platforms.

4.34 Oil and gas pipelines of welded sheet, without stations and without valves.

4.35 Stations for oil pipelines, valves and similar.

4.36 Chemical and petrochemical equipment: cracking and processing columns (structures only).

4.37 Chemical and petrochemical plant: heat exchangers, coolers, surface condensers and other evaporators, reheaters and similar.

4.38 Chemical and petrochemical plant: pressure vessels and spherical reservoirs.

4.39 Chemical and petrochemical plant: furnaces for refineries, dryers, ovens, de-aerators, autoclaves (not fitted).

4.40 Chemical and petrochemical plant: spheres, storage tanks, metal silos (without ancillary equipment).

4.41 Chemical and petrochemical plant: mixers, filters and other equipment for industrial applications.

4.44 Equipment for the mineral oils industry.

4.45 Equipment for the vegetable oils industry.

4.46 Equipment for cellulose production.

4.48 Machinery for typesetting and printing, binding, duplicating, etc.

4.49 Machinery and equipment for printing and similar.

4.50 Equipment and installations for refuse treatment. Compacting.

4.51 Equipment for the collection and transport of refuse (excluding the chassis).

382

4.52 Machinery for the leather and footwear industry.

4.53 Machinery for the manufacture of tyres, inner tubes and rubber parts.

4.54 Other machinery for the rubber industry: mixers, rolling mills, moulds, etc.

5.02 Personal calculators, electronic, without print-out, simple.

5.03 Personal calculators, electronic, with print-out and some sophistication.

5.04 Calculating machines for industrial use, accounting machines and similar.

5.06 Computers and their peripherals.

5.08 Electronic cash registers.

5.09 Scales, weighing machines, dynamometers, mechanical and similar.

5.10 Electronic scales, integrated or not, and similar.

5.13 Mechanical typewriters.

5.14 Electric typewriters, with or without programming and memory.

9.001 Machines for injecting plastics, bakelite and similar.

9.002 Compressors and complete refrigeration units up to 5 hp, but excluding fractional hp.

9.003 Refrigeration compressors above 5 hp.

9.004 Air conditioning apparatus up to 5 hp, without refrigeration compressor.

9.005 Air conditioning above 5 hp. Large-scale installations for buildings, industry, etc. without compressors.

9.006 Machinery for vacuum production.

9.007 Air compressors up to 5 hp. With reservoir and automatics.

9.008 Air compressors above 5 hp, reciprocating, rotary, turbo, helicoidal, etc.

9.009 Fans, blowers etc. up to 5 hp. Including fractional electric motors.

9.010 Fans, blowers, etc. above 5 hp, without motors and without connections. Excluding special types.

382

9.011 Windmills and similar.

9.012 Dryers and similar.

9.013 Simple fire-fighting equipment, portable or fixed (excluding fire-doors).

9.014 Automatic and/or sophisticated fire-fighting equipment. Short range.

9.015 Motorized pumps, special parts, ladders, etc. Without chassis, excluding long-range equipment.

9.016 Travelling cranes, gantries, pulley blocks, cranes etc., up to 10 tonnes load.

9.017 Travelling cranes, gantries, cranes etc., 11 to 50 tonnes load.

9.018 Travelling cranes, gantries, cranes etc., over 50 tonnes load. Iron and steel and special applications.

9.019 Stackers up to 4 tonnes, electric.

9.020 Stackers up to 4 tonnes, driven by internal combustion engine (without manufacture of engine).

9.021 Stackers of more than 4 tonnes, electric or internal conbustion engine (engines acquired).

9.022 Mobile cranes, all capacities, without engine.

9.023 Lifts - complete equipment, not installed.

9.024 Hoists including hydraulic - complete equipment, not installed.

9.025 Mechanical garages - complete equipment, not installed.

9.026 Escalators - complete equipment, not installed.

9.027 Continuous simple conveyors, fixed and mobile, bucket, belt, etc. (excluding tyres).

9.028 As 3829.027 but for medium and heavy loads, excepting those for mining applications.

9.029 Cable-cars, cable-ferries and similar - all uses, including mining - equipment not installed.

9.031 Burners and similar.

9.032 Boilers for water heating, etc.

382

9.033 Steam boilers with rated capacity up to 20 $kg/m^2.h$

9.034 Steam boilers with rated capacity up to 70 $kg/m^2.h$

9.035 Steam boilers with rated capacity above 70 $kg/m^2.h$

9.037 Steam accumulators and similar.

9.038 Evaporators.

9.039 Steam condensers and similar.

9.040 Heat exchangers.

9.041 Small and medium power industrial furnaces - fixed, continuous, up to 1000°C. Including electrics.

9.042 Small and medium power furnaces, but above 1000°C.

9.043 High power furnaces, stress relieving, etc. excluding iron and steel.

9.044 Equipment for tempering, cementation and general heat treatment installations.

9.045 Ordinary equipment for electroplating.

9.046 Equipment for electroplating and similar, advanced, automatic and special.

9.047 Air purifiers and extractors for dust, smoke, paint etc. equipment and installations.

9.048 Equipment and installations for sand-blasting, shot-blasting, etc.

9.049 Road construction machinery: excavators and loaders, without manufacture of the engine.

9.050 Road construction machinery: motorized graders, without manufacture of the engines.

9.051 Road construction machinery: motorized scrapers.

9.052 Road construction machinery: compressors, compactors, without engine.

9.053 Road construction machinery: crawler tractors, without engine.

9.054 Road construction machinery: ordinary and special-purpose trucks.

9.055 Stationary and transportable small capacity soil plants.

9.056 Stationary and mobile crushing and grinding plants for roads and civil engineering.

9.057 Screening, sieving and separating machinery.

382

9.058 Loading and unloading termianls for ports: minerals and vegetables.

9.061 Sluice-gates up to medium-heavy duty.

9.062 Sluice-gates up to heavy and very heavy duty.

9.066 Machinery for the tobacco industry - cigarette-making machines.

9.067 Equipment for plants producing sugar and alcohol from sugar and similar.

9.069 Equipment and installations for plants producing alcohol from vegetables: babassu, cassava and derivatives.

9.070 Machinery and installations for cotton treatment: including presses.

9.071 Equipment and installations for conventional painting: spray-gun, dipping, etc.

9.072 Equipment and installations for non-conventional painting, automatic, programmable, etc.

9.073 Equipment for service stations (excluding air compressors).

9.074 Equipment for vehicle maintenance workshops: engines.

9.075 Equipment for vehicle maintenance workshops: chassis, tyres, steering, etc.

9.077 Packaging and similar machines, with or without automatic weighing.

9.078 Machines for bottling, bottle-washing and similar.

9.079 Industrial sewing machines.

9.081 Machinery and equipment for laundries.

9.082 Machinery and installations for kitchens (hotels, industrial, restaurants, etc.) excluding highly advanced.

9.083 Machines for cleansing public places and similar - cleaning of floors, marble, etc.

9.085 Telescopic terminals for airports.

9.088 Test beds for reciprocating engines, turbines and similar.

9.089 Motorized equipment for urban cleansing, snow ploughs and other units for towns.

382

9.090 Electric transmission lines: simple ancillary mechanical components such as regulators, arms, supports, clamps, etc.

9.091 Automatic vending machines.

9.092 Motorized portable tools for all uses (air and electric).

9.093 Centrifugal pumps for non-corrosive liquids, for use at ambient temperatures, up to 50 hp.

9.094 Centrifugal pumps for non-corrosive liquids, for use at various temperatures, up to 50 hp.

0.095 Pumps for corrosive liquids, all powers, all types - various temperatures.

9.100 Mechanical components (MC) (C1) of one or several parts: screws, nuts, washers, rivets, pins, etc. mass produced.

9.101 MC : for transmission of movement, mass produced: clutches, brakes, torque limiters, axial force limiters, unions, gaskets, cardan joints, various kinetic parts.

9.102 MC : gear systems, offering a very specialized service, including raw materials.

9.103 MC : ordinary and special bearings up to P.2.

9.104 MC : reducers up to 10 hp - without input and output connections - excluding fractional horsepowers.

9.105 MC : reducers, between 11 and 50 hp.

9.106 MC : reducers for inputs above 50 hp - all types - excluding couplings.

9.107 MC : speed variators up to 10 hp input (mechanical models).

9.108 MC : speed variators of over 10 hp input (mechanical models).

9.109 Components for oleodynamic and hydropneumatic circuits (excluding fluid-drive)

9.110 Components for compressed air circuits - accumulators, excluding manometers and compressors.

9.111 MC of one or a few parts: levers, handwheels, cams, drums, etc.

9.112 Pumps and components for lubrication circuits.

9.113 Components for refrigeration circuits - excluding industrial deep refrigeration.

9.114 Valves for water, liquids and gases, non-corrosive, for use at ambient temperatures, manual operation.

382

9.115 Valves for water, liquids and gases, non-corrosive, automatic, safety, programmed - ambient temperature.

9.116 Valves for corrosive liquids and gases, any type and use - for non-corrosive materials at non-ambient temperatures.

383

1.01 Fractional AC and DC electric motors, insulated up to 120°C - excluding micromotors and very special types.

1.03 AC and DC motors up to 50 kW - insulated up to 120°C, also indicative for dynamos.

1.05 Electric AC and DC motors of more than 50 kW, excluding those using highly advanced technology.

1.20 Low-power transformers up to 10 kVA.

1.21 Transformers up to medium power.

1.22 Semi-heavy and heavy transformers.

1.31 Relays of all types, excluding electronic.

1.32 Medium and high voltage circuit breakers.

1.36 Reciprocating and similar engines for aeronatics, astronautics, etc.

1.38 Starter motors, dynamos and similar for automobiles, motorcycles, road machines, tractors.

1.39 Electromagnetic brakes, clutches.

1.41 Simple electric components, specifically for machinery control: switches, microswitches, footswitches, cut-outs, lampholders, indicator lamps, etc.

1.42 Electric components for power circuits up to 50 kW: switches, fuses, cut-outs, inverters, starters, etc.

2.02 Telex equipment.

2.09 External aerials and shared TV-aerial installations, telescopic aerials. Not including rotating aerials.

383

3.02 Toasters, mixers, grills, for industrial use and similar, excluding equipment for large installations.

3.06 Heaters for water, food, etc. Excluding large and automatic installations.

3.07 Electric and/or electronic instruments for automobiles, tractors and similar (excluding clocks).

9.34 Normal electrical equipment for automobiles, tractors, road machines, etc. Excluding dynamos.

9.40 Electric and electronic (limited) equipment for signalling and control of urban traffic, railways, etc.

9.46 Mass produced electric welding sets, excluding special types.

9.47 Special, automatic, welding sets (Φ VI).

9.50 Continuous and batch electric furnaces, up to 500°C.

9.52 Semi-equipped iron and steel furnaces, charging, discharging, handling and body for manufacture.

384

1.01 Ships, barges, launches, boats, small fishing vessels, tugs and similar (simple design).

1.02 Cargo vessels up to 20,000 T.

1.03 Special cargo and/or cargo/passenger vessels of more than 20,000 T and up to 100,000 T.

1.08 Lake and river craft, passenger and/or cargo (very simple types are incorporated in 3841.01).

1.10 Hovercraft, without turbines.

1.12 Floating dredgers.

1.13 Platforms, floating ports and docks, with simple infrastructure, without bridges, cranes and other complex equipment.

1.14 Reciprocating marine engines

1.15 Reciprocating marine engines, diesel, up to 500 hp, regarded as mass produced.

1.16 Marine engines, diesel, above 500 hp.

384

1.17 Marine engines: steam turbines.

1.18 Marine engines: parts and components.

1.19 Parts and components for vessels: cargo lifting, transporting, unloading and similar.

1.22 Parts and components for vessels: chains, anchors, rudders and cast and forged components of more than P2 - transmission shafts and similar.

1.23 Parts and components for vessels, fixed and variable pitch propellers.

2.03 Diesel locomotives with mechanical transmission.

2.04 Diesel locomotives with hydraulic transmission.

2.05 Rail-cars, underground and similar.

2.06 Conventional and articulated tramcars.

2.07 Passenger coaches.

2.08 Goods wagons of all types, excluding Decauville.

2.09 Hovertrains and similar - advanced high-speed equipment.

2.10 Conventional forged and cast components for rolling stock: bogies, couplings, wheels, welded and turned axles, complete suspensions, etc.

2.11 Various mechanical components for goods and passenger stock: brakes, springs, pneumatic suspensions, supports, etc.

2.12 Mechanical components for rail tracks (without rails): points, mechanical parts for electrified lines, etc.

2.13 Locomotives (steam) Decauville and battery.

3.01 Ordinary and utility automobiles for building taxis, trucks, vans, ambulances, etc.

3.03 Trucks of up to 15 tonnes, including engines.

3.05 Trucks of above 15 tonnes, articulated and special trucks, including highly specialized.

3.07 Bodywork for buses, trolleybuses, truck cabs and similar.

3.08 Trolleybus chassis, fully equipped.

3.09 Bodywork for liquid and solid loads, normal and special, trailers.

384

3.13 Simple mechanical components, of one or a few parts (wheels, rings, studs, nuts, etc.).

3.14 Simple mechanical components, of one or a few parts (pistons, rings, valves, etc.).

3.15 Other mechanical components (carburettors, petrol pumps, filters, lubrication, diesel pumps, etc.).

4.01 Bicycles and tricycles, without engine.

4.02 Motorcycles and scooters with trailer.

4.03 Engines for bicycles.

5.01 Single piston-engined planes, up to 4 persons, civil use, without engine.

5.03 Twin turbo-prop planes up to 25 tonnes unladen weight - four turbo-jet planes up to 25 tonnes weight.

5.04 Single-jet engined planes, non-military, less than Mach 1.

5.07 Twin and four-jet engined planes of more than 25 tonnes unladen weight.

385

1.03 Mechanical apparatus for linear, angular and plane measurement, fixed and adjustable gauges.

1.07 Liquid and gas flow meters, indicators and recorders (excluding sophisticated applications.

1.08 Liquid meters and recorders - incorporated in 3851.07, sheet 002.

1.09 Meters, indicators and recorders for electricity consumption.

1.14 Parking meters, taximeters, tachometers, operating meters and similar (normal equipment).

1.23 Drawing machines and similar, with tables, etc.

1.25 Complete metal design equipment.

1.27 Mechanical apparatus for tracing, sheet cutting, readout, etc.

1.29 Topographic and geodesic apparatus and similar.

385

1.36 Mechanical instruments for surgery, general examinations and similar (few parts, classical equipment).

1.39 Complete odontological equipment, excluding radiography.

1.41 Equipment of medium and normal complexity for hospitals and doctors: inhalation, pressure, blood, etc.

3.05 Recording clocks, control equipment for night watchmen, working hours and similar.

NOTE ON MEASURING THE COMPLEXITY OF MACHINES AND EQUIPMENT

2. NOTE ON MEASURING THE COMPLEXITY OF MACHINES AND EQUIPMENT

Evaluation of the complexity of machines and equipment raises difficult theoretical and pricatical problems.

These difficulties are similar to those experienced by statisticians when measuring production and productivity.

It is known that price is an indifferent means for appreciating the complexity of products. Price is the result of a social process, involving not only production but also distribution.

It is tempting to avoid the disadvantage of price by using a direct expression of the working time needed to produce goods. This more satisfactory procedure comes up against other difficulties. First of all it is necessary to add to the present direct work not only indirect work but also past work, "crystallized" in the means of production which are utilized. One comes up against the problem of reducing the heterogeneous working times of different qualities to standard and "abstract" units.

In calculations of the overall productivity of factors it is frequently necessary to have recourse to weighting by the respective wages of the various categories(1). This method can be criticized in the same way as weighting by prices when establishing a production index. Wages, as historical and social categories - like prices - are only an approximate reflection of the complexity of work. Attempts to account by way of integral working times have been carried out, particularly in the USSR(2) and in France(3). This work does not appear to have resulted in any operational applications. It would, however, seem that such work is of the greatest value when studying the modification of the existing international division of labour, as it is shown in the capital goods sector.

Another direction of research work has been the subject of initial papers. This involves measuring the information content of equipment goods. The number of specifications and the degrees of tolerance are expressed in "bits"(4). In this field, which has hardly been opened up as yet, several problems have arisen, in particular relating to the algebraic form of the measuring formula. A machine operating as a system where all the parts are interdependent - rather than autonomous - would seem to be more the result of multiplication than addition. Here again, and even more than in the previous case, no operational tool is usable at the present time.

All the same it is possible to distinguish the complexity of the product from the complications of its manufacture. The complexity of the product expresses the functions which it has to carry out, its operational requirements, its efficiency, its safety and its relations with the environment. This functional complexity (aims and conditions of use) implies an internal complexity of the product which is reflected in the large number of components or different parts, the inter-dependencies between these parts and the complexity of each part or component. This can be broken down into complexity of design and complication of manufacture. These two latter may go together, but this is not always the case.

One is therefore led to measure on the one hand the complexity of the product and on the other the complexity (or the complication) of its manufacture. Given the two conditions i) that there is a relationship between the two measurements, and ii) that the latter are correctly expressed, we therefore have :

$$CP = f(n\ In)$$

where :

CP = the complexity of the product P

$f(n\ In)$ = the complexity of the combination of the inputs necessary to manufacture P

Both approaches have been tried.

In the case of the complexity of the products - and despite the previous reserves concerning prices, but also because no other information was usable - a measurement α was used which is the value in Dollars per kilogramme of the product, together with a coefficient β which is the speed of innovation of the product. The latter has been measured on the basis of the rate of change of products in years (50 years, 50 to 35, 35 to 25, 25 to 15, 15 to 10, less than 10). The indicator α (price in $/kg) provides, in the absence of any other indicator an initial if rough indication. One feels that some relationship should exist between the complexity of a product and its unit price, but many distortions can affect this relationship: prices and values cannot always coincide. In the case of the older products with a low coefficient β (that is to say technologically stable products) and of wide-spread use their present prices probably no longer have any relationship with their initial complexity. Furthermore economies in the use of raw materials and the corresponding reduction in the weight of the machines, may raise the coefficient α without the complexity being modified. The limits of the significance of α have therefore led to concentrating the analysis on the production function and on the identification of the inputs.

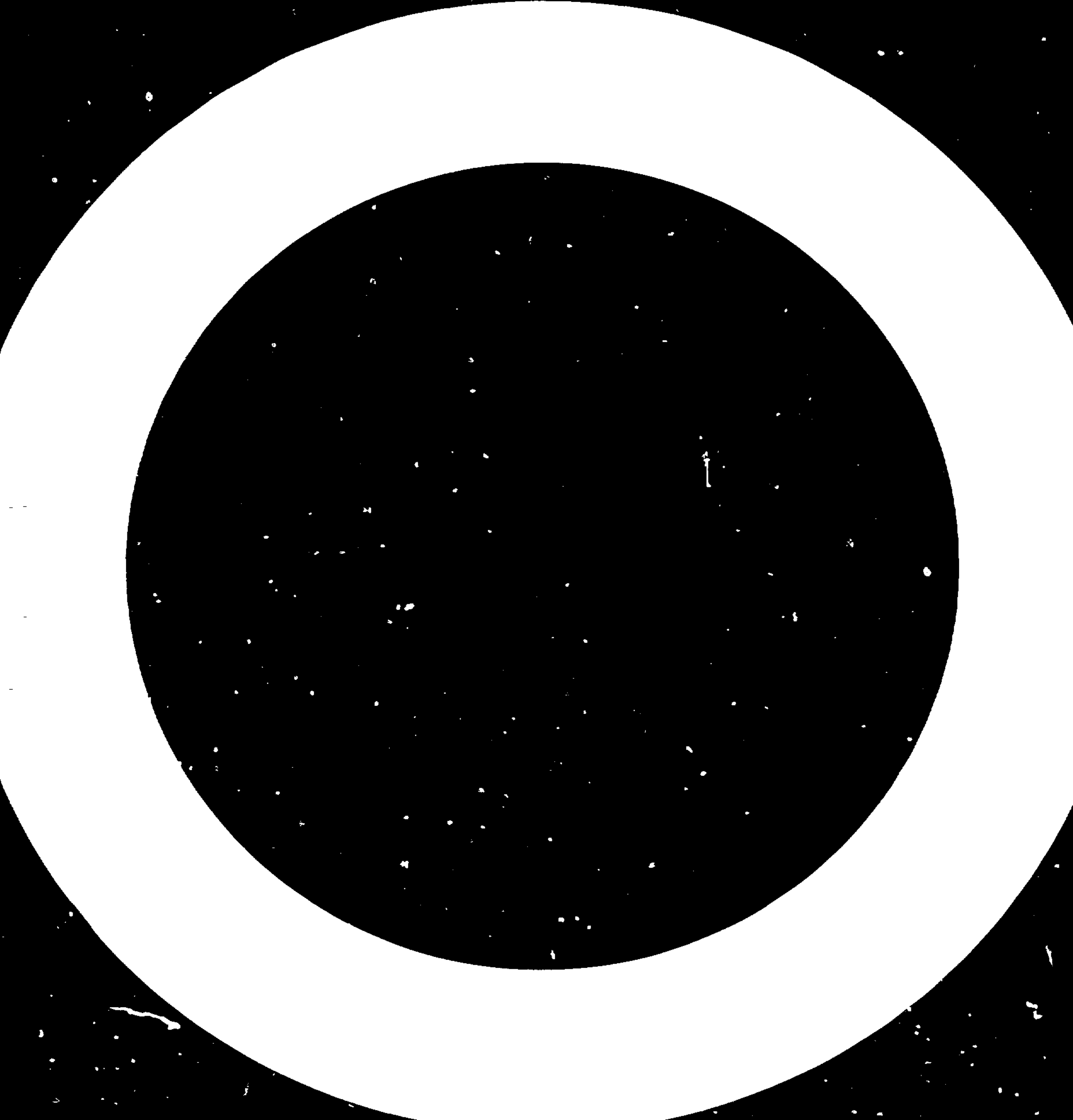
(1) See the classic work of John W. Kendrick : "Productivity trends in the United States" - Princeton University Press, 1961, and the work of Jean Vincent in France : Revure Etudes et Conjunctions, 1958-1964.

(2) See in particular the work of J. Kvacha : Some questions in the measurement of work productivity - Economic Questions No.6, 1956 - and M. Edelman : The first intersectoral balance of work expenditure in the national economy of the USSR - Viestnik Statistiki, 1962 - No. 10 - and, more recently, the work of Prof. V.K. Dmitriev and R. Bezousov in the USSR and M. Minkov in Bulgaria.

(3) See, particularly in France, the work of Denis Cepède and Pierre Gonod : Concept et mesures de la productivité (The concept and measurement of productivity) - SEDEIS No. 923, June 1965.
J. Magaud : Equivalent travail d'une production. Nouvelle méthode de calcul et de prévision (The equivalent work of production. A new method for calculation and forecasting) Population - March-April 1967.
Nicole Dubrulle and Patrick Ranchon : Demande finale et emploi, approche par la méthode de l'équivalent-travail d'une production (Final demand and employment, an approach by the method of work-equivalent of production) - Cahiers du Centre d'Etudes de l'Emploi - P.U.F., 1977.

(4) Jean Thoma : Energy, entropy and information (Chapter - Estimating the information content of capital) - International Institute for Applied Systems Analysis - Laxenburg, Austria, June 1977.

TECHNICAL DEFINITION
OF THE SIX LEVELS OF COMPLEXITY
FOR THE FACTORS OF BLOCKS
A1, A2, B1, B2, C



$3A_1$. TECHNICAL DEFINITION OF THE SIX LEVELS OF COMPLEXITY FOR THE 9 FACTORS OF THE BLOCK "PRODUCTS AND PRODUCTION UNIT"

1. Product weight and manufacture

I - Light to medium industry

II - Medium-sized industry

III - Medium-sized heavy industry

IV - Heavy industry

V - Ultra-heavy industry

VI - Highest precision industry for micromechanics, fine optometry, microelectro-mechanics, etc.

2. Hours of know-how

I - Up to 1 hour of KH/1,000 dollars of CG

II - From 1.1 to 2 hours of KH/1,000 dollars of CG

III - From 2.1 to 4 hours of KH/1,000 dollars of CG

IV - From 4.1 to 7 hours of KH/1,000 dollars of CG

V - From 7.1 to 10 hours of KH/1,000 dollars of CG

VI - Over 10 hours of KH/1,000 dollars of CG

3. Laboratory

I - Metrology, weights, electrics, materials resistance, simple static and dynamic testing (e.g. fatigue testing) of parts, chemical analysis of materials, and the like

II - Dynamic testing of mechanical, fluid-dynamic, thermodynamic, electrical and other forms of performance for machinery, equipment and their components of up to intermediate size and complexity; failure and deformation testing of finished products under static and dynamic load

III - As under II, but for catalogue-listed machinery and equipment of intermediate weight and/or complexity

IV - Hydraulics laboratories: hydrodynamic basins, models of dams, channels, hydraulic machinery, etc.; conventional subsonic aero-dynamic laboratories

V - Electrical laboratories for work with high and very high voltage, and the like; other advanced testing, as under II and III, for heavy machinery and equipment, both catalogue-listed and specially produced

VI - Supersonic wind tunnels; advanced simulators; testing of high-technology aeronautical, marine, space, civil-engineering and military equipment

4. <u>Direct hours per ton</u>

I - Less than 200 direct hours/ton of product

II - Between 200 and 400

III - Between 400 and 800

IV - Between 800 and 1,600

V - Between 1,600 and 3,200

VI - Over 3,200

5. <u>Number of types</u>

I - Up to 3

II - From 4 to 15

III - From 16 to 50

IV - From 51 to 250

V - From 251 to 500

VI - More than 500

6. <u>Variety of models</u>

I - Up to 3

II - From 4 to 7

III - From 8 to 15

IV - From 16 to 31

V - From 32 to 63

VI - More than 64

7. <u>Manufacturing series</u>

I - Continuous very high series

II - From 1,000 to 500

III - From 500 to 100

IV - Up to 1-3 per month

V - Repetitive unit manufacture

VI - Special (non-repetitive) unit manufacture

8. <u>Assembly</u>

I - CG of very limited complexity and weight, delivered to the user or seller ready for use, all that is required being to read the manufacturer's instructions, which usually accompany the product; includes all cases of storable capital goods

II - CG requiring a highly mechanized assembly line fed by auxiliary assembly lines for groups and subsystems; applies to sophisticated products of medium and semi-heavy weight produced in a continuous series, such as trucks, road-building machines, etc.

III - CG delivered partially assembled to the user, with final assembly and geometric, dynamic and performance testing conducted at the customer's plan with the assistance of assembly personnel provided by the CG manufacturer; examples are machinery incorporating large and/or complex basic structures, for whose installation the know-how and guidance are made available by the manufacturer

IV - Cases where an assembly mason is needed to mount the capital goods, the labour being provided by the maker (these being specialists). This complication becomes more difficult when:

V - The capital goods require specialists from the constructing firm as well as other workers for the assembly and construction of the appropriate infrastructure and/or additional personnel. This arises in cases of large-scale operations or installations

VI - The ultimate degree of difficulty is reached in cases of highly complex and very special capital goods for which the maker needs a whole organization capable of transferring a great deal of know-how by means of courses, simulated operations, practical work under instructors, etc. (For instance, for aircraft, ships, etc.).

9. Size of enterprise

I - From 50 to 100 persons employed

II - From 101 to 250

III - From 251 to 500

IV - From 501 to 1,000

V - From 1,000 to 3,000

VI - Over 3,000 persons employed

3A$_2$. TECHNICAL DEFINITION OF THE SIX LEVELS OF COMPLEXITY FOR THE 30 FACTORS OF THE BLOCK "MEANS OF PRODUCTION"

1. For all the factors of block A2, except the quality control, the six levels of complexity are characterized by the following general definitions:

I - Machinery, equipment or installations with universal operating cycles and fully manual or almost fully manual operation; common, conventional technology of limited precision

II - Machinery, equipment or installations of advanced universal design and/or high precision

III - Machinery, equipment or installations with semi-automatic performance cycles

IV - Catalogue-listed machinery, equipment or installations with automatic performance cycles and fixed, rigid working programmes

V - Automatic cycles with flexible programming of every type: numerical control, computerized numerical control and the like; machining centers

VI - Special custom-designed machinery or installations (not listed in the catalogues) for one or more special operations, such as stationary transfer machines and the like

2. For the quality control the definition of the six levels of complexity are the following:

I - Pressure, static load, dynamic equilibrium, welding, etc.

II - Geometric testing according to standards

III - Dynamic operational testing, with or without standards, not involving the use of a special test stand

IV - Use of special test stands for series-produced products

V - Use of test stands for non-series-produced and/or heavy products

VI - Highly specialized testing (usually performed to order) of complex equipment

$3B_1$. TECHNICAL DEFINITION OF THE SIX LEVELS OF COMPLEXITY FOR THE 8 FACTORS OF THE BLOCK "SEMI-FINISHED PRODUCTS"

1. Iron castings, conventional processes

I - Elementary, primary, craft activity, without standards. Mainly manual operations. Cupola furnaces

II - To standards. Ordinary grey and white iron. Limited weights. Mechanical moulding for smaller parts. Value of r always less than 30 kg/mm2. Electric furnaces occasionally used

III - Malleable, nodular cast iron alloyed with Mn, Cr, Ni and other elements. Complex parts. Semi-mechanized casting. Control of earth and sands. Very thin walls, microporosity, etc.

IV - Special alloys. Rather unusual cases. Very large parts. Very strict quality control. Automatic installations

2. Steel casting, conventional processes

I - Elementary, no standards. Manual operations

II - To standards. Carbon steels. Up to parts of medium weight and complexity

III - Special steels with Cr, Ni, Mo, Mn and other alloying additions. Semi-mechanized casting. Complex parts, heavy

IV - Special alloys. Large parts. Automatic installations. High level of quality control

V - Highly complex or large and very large parts for military applications, highly specialized. Special alloys

3. Casting of non-ferrous metals, conventional processes

I - Ordinary aluminium, bronze and brass castings, no standards. Manual operation

II - Small and medium-sized parts. To standards. Bronze, brass and Al, Mg, Zn alloys with low and medium-level mechanical properties. Semi-mechanized operation. Partial quality control

III - Bronze, brass and Al, Mg, Zn and other alloys with high-grade mechanical properties. Up to heavy parts. Systematic quality control

IV - Very heavy parts (for example, large propellers). Special non-strategic alloys. Automatic installations

4. Casting and forging of strategic materials: all processes

V - Small parts for aeronautical engineering, turbines, piston engines for aeronautics, space travel, satellites. Special mechanical properties. Very strict quality control. Military, naval, land and air applications, including rockets

VI - As V with medium-sized pieces as maximum. Very special mechanical properties

5. Pressure and centrifugal casting, etc.

I - Zamak, aluminium and other non-ferrous metals. No standards. Simple and manual equipment

II - For ferrous and non-ferrous metals, to standards. Small and medium-sized parts. Semi-automatic equipment. Normal quality and complexity

III - For ferrous and non-ferrous metals. To standards. Up to large and complex parts. High-level quality control. Good mechanical properties

IV - For ferrous and non-ferrous metals. Special cases with regard to shape, resistance of materials and size. Strict quality control. Highly automated installations

6. Other casting processes: microfusion, shell moulding, chill moulding, vacuum casting, etc.

II - Simple cases for shell moulding and chill moulding. To standards. Simple equipment. Ferrous and non-ferrous metals. Limited level of mechanical properties

III - Almost all processes for ferrous and non-ferrous metals. Medium-sized parts. Strict quality control. Semi-automatic installations or equipment. High degree of complexity. Thin walls

IV - Special cases. Very complex or heavy parts or parts with high mechanical resistance. Maximum quality. Automatic equipment. For ferrous and non-ferrous metals

7. Hammer forging

I - Light parts. Manual operations. Simple shapes. No standards

II - To standards. Up to medium-weight parts. Limited guarantees

III - Semi-heavy and heavy parts. Guarantees and standards

IV - Special cases. Ultra-heavy parts. Strict quality control. High mechanical resistance

V - Incorporated in 4-V

8. Stamping, etc.

I - Light parts of simple form. No standards

II - To standards. Normal complexity of parts. Irregular quality. Simple, conventional equipment

III - Multi-stage forging. Upsetting. Extrusion, etc. Medium-weight parts. Semi-automatic and automatic equipment for smaller parts. Quality. Guarantee. Materials of moderate resistance

IV - Special requirements as to shape, alloys and complexity. Large parts. Strict quality control. Automatic equipment, automated installations. Other hot-farming technologies

V - Incorporated in 4-V

$3B_2$. TECHNICAL DEFINITION OF THE SIX LEVELS OF COMPLEXITY FOR THE 15 FACTORS OF THE BLOCK "TECHNICAL SERVICES PROVIDED BY THIRD PARTIES"

1. Stress relief and annealing

I - With simple installations and limited quality control. Parts of limited size. Partial guarantees

II - To standards. Guarantees. Up to semi-heavy parts, medium thick walls. Controlled atmosphere. Conventional installations

III - Up to semi-heavy and heavy parts. Strict quality control. Thick walls. Automatic installations. Laboratory

IV - Ultra-heavy parts. Special cases. Complex automatic installations. Special processes. Research and development laboratory

2. Heat treatment

I - Elementary installations. Limited weight and quality control. Normal materials. No standards

II - To standards. Hardening, case hardening, tempering and normalizing. Moderate complexity. Conventional installation

III - The foregoing processes for an extended range of steels. Larger parts and heavier weights, up to medium. Nitriding, carbo-nitriding and similar processes. Semi-automatic equipment. Correct quality controls. Guarantees. Laboratory

IV - Special requirements and advanced technology. Strict quality control. Complex automatic installations. Heavy parts. Research and development laboratory

3. Surface metal deposits, etc.

I - Semi-craft-type installations. No quality control

II - To standards. Irregular quality control. Nickel-plating, chromium-plating, cadmium-plating, zinc-plating, phosphating, tin-plating, etc. Small and standard parts. Non-automatic installations

III - Medium-sized parts. Normal quality controls. Laboratory. Surface deposits by powder metallurgy methods. Hard porous chromium. Other processes. Semi-automatic installations

IV - Special requirements. Automatic and programmable installations, etc. Large parts. All advanced technological processes. Strict quality control. Research and development

4. Manufacture and maintenance of tools

I - Maintenance of simple tools. Manufacture of simple tools. Irregular quality. Limited know-how

II - Maintenance of tools of medium complexity. Precision expressed in 1/100 mm. Medium size. Manufacture of cutting and shaping tools and simple dies for extrusion, etc. Irregular quality. Conventional equipment. Limited guarantees. Some standards

III - Maintenance of complex tools including broaches, gear-cutters, milling cutters, etc. for tolerances up to ISO 6 and 7. Manufacture of multiple or compound tools and special tools of medium complexity. Guarantees. Standards. Metrology laboratory. Not including series production of tools

IV - Maintenance of highly complex and/or special tools for metal and woodcutting etc. Large size. In small dimensions for tolerances up to ISO 5 and 6. Simple drills for wells, etc.; maintenance. Manufacture only of special tools of medium complexity (excluding large-scale series production). Standards, guarantees, metrology laboratory. Small-scale R and D

V - All complex special cases for all applications in maintenance and manufacture. Maintenance of tools for well-drilling, including oil wells, and mining. R and D

5. Construction of dies for cold stamping

I - Crafts-type construction with simple equipment. Limited quality. Small parts

II - Moderately equipped workshops. Parts of standard dimensions and medium complexity. Limited durability. Irregular guarantee and quality

III - Workshops with good but incomplete equipment. Up to parts of medium size. High complexity in small parts. Precision. Guarantee. Durability. Simple progressive dies. Includes own know-how

IV - Workshops with complete and high-quality equipment. Precision, guarantee, productivity, durability. High complexity, progressive and multiple dies, etc. Micro-stamping. Large parts. Special cases. Relevant own know-how. Laboratory

6. Construction of moulds, stamping dies, chill moulds, etc., for metals

I - Low quality. Wide tolerances. Small workshops with standard equipment. Simple parts of limited weight. No guarantee

II - Medium-size workshops with varied standard equipment. Irregular guarantees and quality. Up to parts of medium size. Semi-complex shapes (depth, walls, ridges, etc.)

III - Well equipped workshops for parts of up to semi-heavy weight. Considerable degree of own know-how. Normal guarantees, precision and durability. Systematic quality control. Complex shapes

IV - Very well equipped workshops. Up to large and complex parts. Special requirements. Relevant know-how. High level of guarantee, durability and precision. Solutions for large series. Quality control and other laboratories

V - Specific solutions for naval, land and air armaments. Civil aviation, turbines, piston engines. R and D laboratories

7. <u>Construction of jigs, templates, etc.</u>

II - Limited own know-how. Design by third parties. Workshops with standard and incomplete equipment. Moderate complexity. Precision expressed in 1/100 mm. Partial guarantees

III - Highly developed own know-how. Design by third parties. Workshops with good but incomplete equipment. Air conditioning. Precision expressed in 1/1,000 mm. for small parts. Guarantees. Quality. Highly developed metrology. Up to medium-sized parts

IV - Workshops with complete and advanced equipment. Large scale parts. Special and complete solutions for large series. Advanced know-how. Guarantees. Laboratory. Very high precision

8. <u>Light boilermaking services, plate up to 1/2"</u>

I - Semi-crafts-type workshops. Standard equipment. Limited precision. Design work by third parties. Low complexity. Conventional welding

II - Well equipped workshops. Partial guarantees. Standards. Own designs and design work by third parties. Normal precision. Profiles and structures up to complex level. Manual or semi-automatic operation. Various types of welding

III - Workshops with complete and advanced equipment. Guarantee, standards, quality controls. Own designs and design work by third parties. Complex and precision operations. Machines automated and/or with programming. Stainless steel. Special welding for various materials. Complex cases with strict quality control including pressure and similar tests

9. <u>Semi-heavy and medium boiler-making services, plate up to 1"</u>

I - Small workshops with simple, incomplete equipment. Elementary quality control. Limited complexity. Design work by third parties. Conventional welding. No standards

II - Medium-sized workshops with good but incomplete equipment. Conical, spherical and complex structures. Design work by third parties. Standards. Partial guarantees. Some simple mechanization. Adequate quality and precision

III - Workshops with complete equipment. Technological advanced operating stations. High degree of complexity. Strict quality control including welds. Guarantees. Standards. Design work by third parties

10. Heavy boiler-making services, plate up to 1 1/4"

II - Medium-sized workshops with incomplete, conventional equipment. Partial general quality control, including welding. Adequate hoisting gear. Manual welding and semi-automatic welding sets. Medium complexity. Plate up to 2" and related sections. Some standards. Design work by third parties

III - Well equipped workshops with some advanced machines. Standards. Correct quality control, including welding. Guarantees. High degree of complexity. Conical, spherical parts, etc. Design work by third parties and own know-how. Plate up to 4" and related sections. Adequate hoisting and materials handling gear. Machining limited to flanges, drilling and tapping

IV - Very well equipped workshops. High quality. Standards. Guarantees. High degree of complexity. Pressure and other tests. Conical and spherical parts. Various materials. Design work by third parties and own know-how. Machining limited to flanges, some flat work, drilling and tapping

11. Manufacture of gear-wheels or gear-cutting alone

I - Workshops with conventional, universal equipment. Parts up to medium size. Quality class IV. Standard shapes. No guarantees

II - Medium-sized workshops. Quality class III. Parts up to medium size. Cylindrical, conical, straight and helicoidal. Simple corrections

III - Well equipped workshops. Quality classes II and I. Great variety of tooth shapes and corrections. Excluding more complex shapes. Guarantees. Up to medium size. Strict control. For large sizes up to 5 m in diameter. Classes IV and III

IV - Very well equipped workshop. Advanced metrology. All the most complex shapes, corrections and sizes (excluding super-heavy gear wheels). Special surface treatment and materials of highest resistance

12. Special machining, fine and standard

I - Automatic turning of standard complexity, precision and size. Grinding, flaring, milling services etc.

II - Screw cutting. Deep hole drilling. Broaching. Splined shafts. Internal and external super-finishing. Jig boring service. Maximum quality ISO 7 and 6

IV - The same services as in II but with maximum quality ISO 4 and 5. Well equipped workshops, air conditioning, advanced metrology. Machining centre services

13. Medium and semi-heavy special machining

II - Complex automatic turning. Deep hole drilling. Honing, grinding, milling, broaching, jig boring. Large flat surfaces, slotting, etc. Standard quality. Adequate metrology. Incomplete guarantees

III - Jig boring services etc. (as II) at a level of greater precision up to classes ISO 6 and 7. Complex shapes. Materials of good mechanical resistance. Adequate metrology. Guarantees

IV - Special cases, very complex shapes. Materials of high mechanical resistance. Up to precision of class ISO 5. Construction of special tools for the operation of the service. Grinding of threads, racks, spherical parts, etc. Guarantees. High grade metrology. Air conditioning

14. Special heavy machining

III - Vertical and horizontal turning, grinding and super-finishing. Standard and precision flaring machines. Large flat parts. Up to 25 tonnes. Cast iron, steel and boiler-making. Standard quality. Adequate guarantees. Appropriate metrology

IV - Same as III but workshop better equipped in variety and capacity of machines (up to 50 tonnes) and precision. Single parts for sub-assemblies. Simple test benches. Advanced metrology. Good quality. Guarantees. Standards

V - Very well equipped workshop with capacity above 50 tonnes. Special and complex cases, with test bench. Strict quality control. Stainless steel and other special materials. Guarantees. Standards

15. Cold stamping

I - Crafts-type workshops. Primitive quality control. Small and simple parts. Small series. Conventional machinery

II - Medium and small workshops. Standard and medium-sized parts. Limited complexity. For non-ferrous metals and normal steels. Medium precision. Adequate quality control

III - Well equipped workshops. Good quality. Complex progressive stamping. Deep drawing. Conventional or automatic machines. For non-ferrous metals, normal steels, stainless and other. Possibly joining of stamped pieces. Guarantees. Tests

IV - High precision micro-stamping. Very large parts (for example, lorry chassis). Precision line stamping. Deep drawing of large parts. High degree of complexity. Some assembly. Tests, guarantees.

3C. TECHNICAL DEFINITION OF THE SIX LEVELS OF COMPLEXITY FOR THE 18 FACTORS OF THE BLOCK "COMPONENTS"

1. Mechanical: simple machine components consisting of one or very few parts

I - Screws, washers, nuts, pins, rivets, flywhells, pulleys, levers, knobs, springs, etc. Ferrous and non-ferrous. According to geometrical standards but without the corresponding quality

II - Great variety of shapes and sizes, more complete than I. According to geometric and quality standards. Ferrous and non-ferrous. Tempered and ground parts

III - Special cases with regard to shape, materials and resistance. Tempered. High precision. Guarantees. Laboratory. Own know-how in some cases

V - Components for aeronautics, aircraft engines, satellites, rockets, etc. Strict quality control. Maximum guarantee. Research laboratory. Special materials. Creative capacity

2. Mechanical: compound machine components up to medium complexity and weight

I - Couplings, de-couplers, power limiters, gaskets, clutches, universal joints, cams, drums, brakes, levelling devices, supports, etc. With and without standards. Limited size, power, variety, performance and quality

II - Medium and small workshops. According to geometrical and quality standards. List I expanded as to variety, power, size, etc. up to normal performance. Add to the list: small variators, simple reducers of up to 25 metric horsepower, shock absorbers, etc.

III - Medium sized and larger workshops. High performance, standards, guarantees, quality control laboratories, testing stations. Variety of models and power. Complex variators, reducers, multipliers, safety devices, simple ball-bearings up to 17 mm diameter, etc. Reference power about 50 metric horsepower

IV - The same as III, but with a greater variety of types, models, performance, power, capacity and complexity. High quality. Testing stations. Creative capacity. Ball-bearings up to medium size and for appropriate applications. R and D

V - Added to IV: greater variety of series manufactured ball-bearings. Special ball-bearings. Components for aeronautics and the land, naval and air arms industry. Advanced R and D

3. <u>Mechanical: compound machine component up to heavy, complex and special</u>

III - The same list as 2.III in greater size, power, performance, etc. Small series. Add: reducers, gear boxes, angular take-off devices, etc. Medium-sized workshops with conventional and advanced machines. Standard quality. Normal metrology. Partial guarantees. Some standards. Power only for reference of the order of 75-100 metric horsepower

IV - Same list as above, with greater guarantees, power, load, size and quality. Excluding ball-bearings. Power greater than 100 metric horsepower. Testing stations. Advanced metrology. Inspection stations

V - Includes high-power equipment. One-off heavy manufacture. Special. Special ball-bearings. Solutions for land and sea military equipment. Advanced R and D

4. <u>Hydraulics</u>

II - Components for low-pressure circuits up to 70 kg/cm^2. Pumps, motors, distributors, valves, cylinders, filters, tanks, etc. Simple equipment. Little variety of types and models. Normal quality and guarantees

III - Components for moderate pressure and power. Variety of types, models, and power, though limited. Performance tests. Guarantees. High quality

IV - Components for high pressure up to 200 kg/cm^2. Large cylinders. Further mechanisms, fluid drive and variators, testing units, dynamometers, brakes and servo-brakes, shock absorbers, accumulators, motors, etc. Medium and high power. High degree of complexity. Quality. Guarantees. Testing laboratory. R and D

V - Special components. One-off or small series. Normal military applications. Piston aircraft engines. Public works. High degree of complexity, large dimensions. Testing stations. Developed R and D service

VI - Very special applications for civil and military aviation, land and sea armaments, large public works and high-power machinery. Very considerable level of testing stations and R and D

5. <u>Pneumatics</u>

II - Simple components, pistons, valves, distributors. Little variety as to power, flow and characteristics. Limited guarantees

III - Quality, guarantees, operating tests. Add: humidifiers, dosing appliances, automatic valves, brakes, clutches, accumulators, filters, large pistons, engines, etc. Greater power and variety than in II

IV - Servo-mechanisms, automatic mechanisms. Special cases for micro-mechanics. Large-scale or high-power equipment. Laboratories. R and D

V - Very complex and large-scale applications. Components for civil and military aviation and land and sea armaments

6. <u>For vacuum circuits</u>

III - Simple pumps, preparatory. Low power. Accessories for vacuum circuits. Vacuum up to 10^{-3} mm Hg. Quality. Tests. Guarantees

V - Medium and high capacity pumps. High vacuum of less than 10^{-3} mm Hg. Complex accessories. For special industrial applications. High quality. Guarantee. Tests. Laboratory

7. <u>Electrics: control and monitoring</u>

In this speciality, more than in others, the same description covers products with very different degrees of reliability and/or performance. Therefore, to make it possible to subdivide the equipment into I to VI, there is no other option to continue by applying the general criteria already stated. That is to say that we begin at level I with very elementary products like buttons, keys, switches, alarms, etc., without strict or clearly defined standards, passing to material for the aeronautic and space travel industries for environment that demands high reliability of operation (for example, tests against explosions) for the armaments industry, etc., all the latter being divided between V and VI.

8. <u>Electrics: for power circuits</u>

The same general approach is adopted as in point 7. Here also the categories go from I to VI.

9. <u>Electronics</u>

IV - Vacuum and gas tubes, simple series. Semi-conductors (resistances and capacitors). Printed circuits. R and D

V - Vacuum and gas-filled tubes. Semi-conductors (resistances, capacitors, active parts, etc.). Advanced R and D

VI - Special material. Military applications. Micro-miniaturization. Very advanced R and D

10. <u>Linear and angular measurement</u>

III - Mechanical appliances that can be incorporated in machines with precision of 1/10 and 1/20 mm. Circular and linear division services

IV - Appliances and instruments for mechanical measuring, precision 1/50 and 1/100 mm, capable of being incorporated in machines. Solex and similar appliances. Automatic gauges. Pneumatic measuring devices. Laboratory

V - All types with visual read-out. Automatic positioners. NC and CNC. Optical and optical-electric measurement devices. Mar-Poss and similar appliances. R and D

11. Lubrication

I - Static elements for greasing and oiling points. Pressure or gravity types. Simple seals, axial and rotary. Grease guns. Sprayers. Medium quality. Some standards

II - To standards. Quality. Great variety of components, distributors, dosing appliances, manual and mechanized pumps, gauges, safety, etc. Guarantees

III - Automatic lubrication circuits, small and medium power. Hydrostatic and hydrodynamic versions. Constant temperature. Filters. Laboratory and testing station. High quality. Guarantees

V - For high-power automatic circuits. Special cases. Programmed pumps. Applications for aviation, aero-turbines, gas and steam turbines, nuclear energy, etc. High quality. Strict controls, tests, guarantees. R and D

12. Cooling by means of circulating water or liquids

II - Pumps, low-power electric pumps for water; distribution devices, batchers, filters, levels, valves, radiators, cooling and settling tanks; simple, manually-operated, average quality; some standards and partial guarantees

III - For water, cooling liquid in metal-cutting applications, and other liquids for machinery and equipment cooling systems; semi-automatic systems with up to average flow capacity; safety features, testing, guarantees and standards

IV - As under III, but for automatic applications; corrosive liquids; any flow-rate; magnetic cleaning devices; refrigeration plants; quality, standards, guarantees; R and D

V - Special cases with ou without contamination; laboratories; nuclear-energy, military, aeronautical and similar applications; advanced R and D

13. For the refrigeration industry (excluding compressors)

III - Basic components of low power and/or flow-rate; semi-automatic applications; thermostats, valves, distribution devices, radiators, etc.; quality, guarantees, basic standards

IV - Automatic components; high complexity, precision, quality; sophisticated industrial applications; guarantees and laboratory; R and D

V - High power and special cases for civil applications; low and ultra-low temperatures; military applications; advanced R and D

14. For steam and gases, whether or not corrosive; any temperature

II - Simple cases, low temperatures and pressures, non-corrosive media; limited guarantees, no standards

III - Average temperatures, pressures and flow-rates; semi-automatic applications; non-corrosive media; guarantees and standards

IV - Automatic applications; high pressures, temperatures and flow-rates; corrosive media; guarantees, safety features, standards, laboratory

V - Very high pressures and/or temperatures; corrosive media; R and D

VI - Applications in atomic power plants, military applications and the like; advanced R and D

15. Temperature, flow, pressure, humidity, electrical metering, etc.

III - Elementary instruments for liquids, gases and electricity. Little variety. Limited precision of reading. To standards. Guarantees. Tests

IV - Increase in variety and precision - situation intermediate between elementary and advanced. Complex instruments. Standards. Guarantees. Tests. Laboratories

V - High precision of readings. Compound and complex recording instruments. Very large and small power. Special cases for industry. Laboratory. Considerable R and D

VI - Application for aeronautics, space travel, satellites, rocketry. Military industry in general. Advanced R and D

16. Optics

III - Manufacture of simple apparatus. Normal lenses. Combination with normal mechanical appliances

IV - Optics combined with micro-electro-mechanics. Precision reading apparatus. Coated lenses. Optical assemblies. Guarantees. High quality. Laboratories

V - Optical equipment for invisible radiation (Hertzian, infra-red, ultra-violet, etc.). Most usual applications. Advanced R and D. Optics for visible radiation with micro-mechanics. High-precision and complex optics for cine cameras, still cameras, etc. Considerable R and D

VI - Complex and specialized military application. Advanced R and D

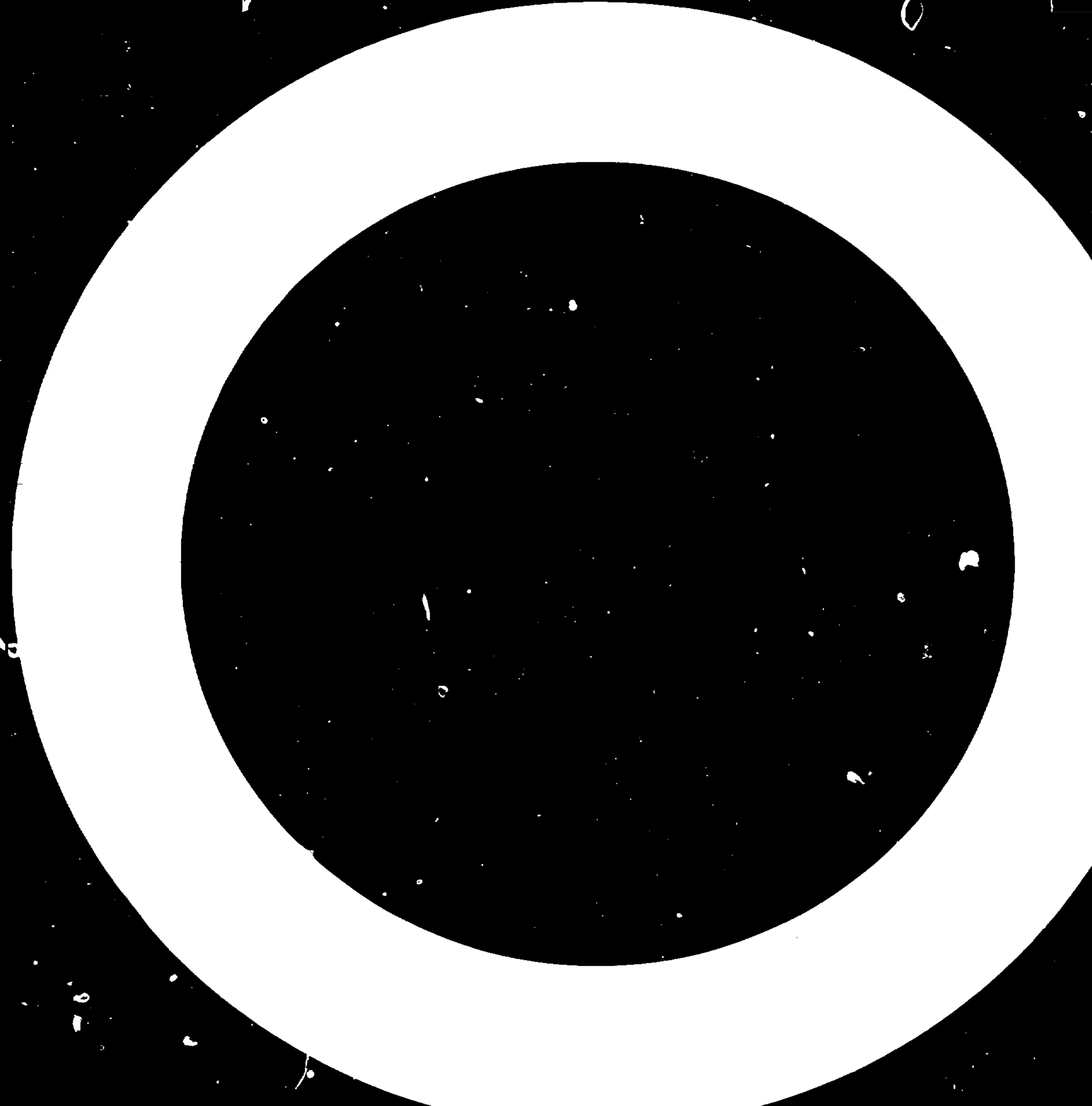
17. Other very specialized branch-specific components

These are found at all levels except level I. The heading includes only those components which, although they may entail the use of disciplines or techniques already mentioned under C (from 1 to 16), are intended exclusively for particular branches or families of products. Examples: A hydraulic copying machine designed by a firm specializing in hydraulic equipment (C.4) will be classified under C.17 because of the specific nature of the component. Combs and other components for textile machinery, ploughshares, etc., are single-element components which are not classified under C.1 but under C.17 because they are used exclusively in a specific capital goods branch.

18. Other, non-metallic, branch-specific components

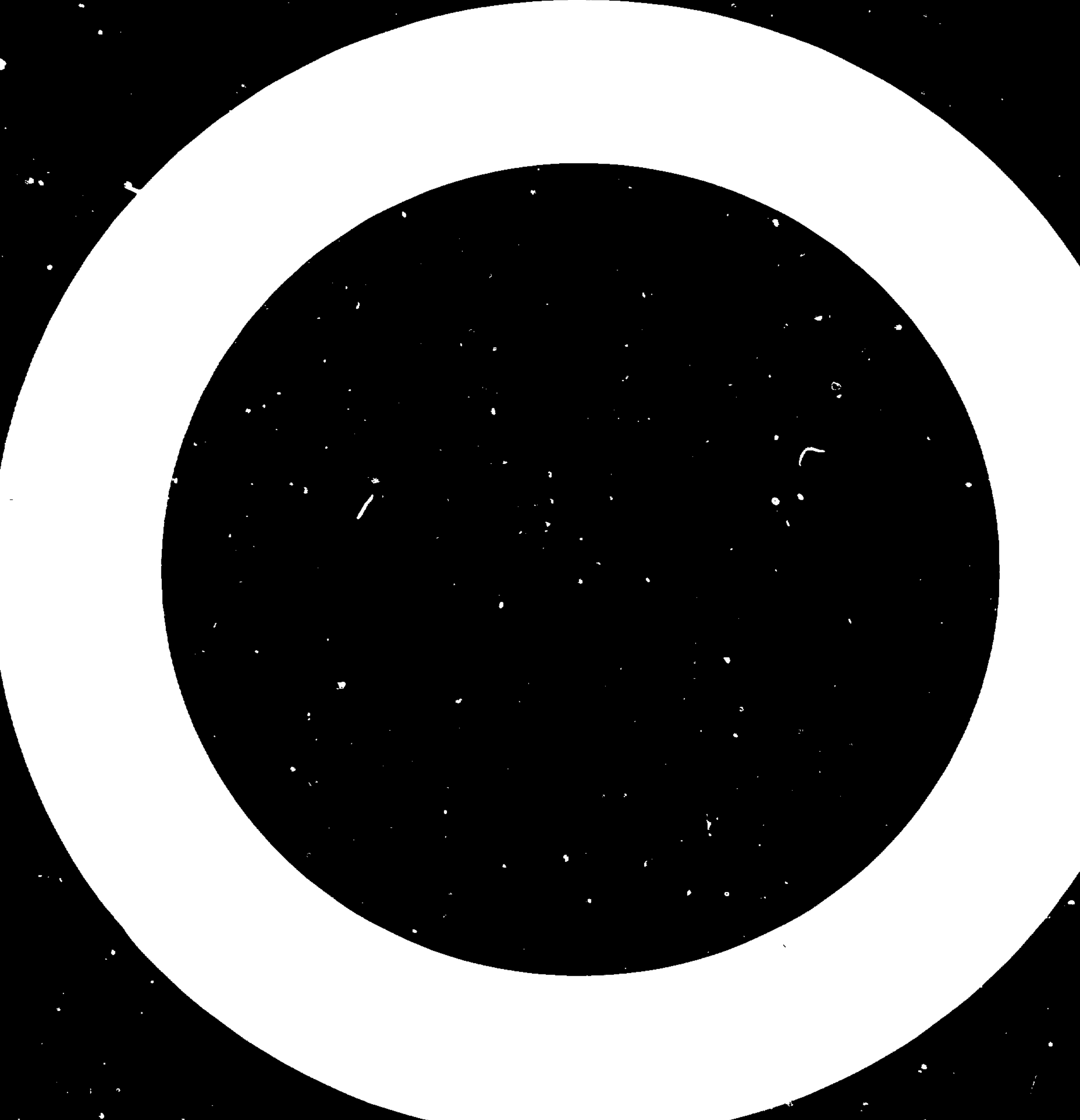
These are found at all levels except level I. The list of materials does not cover the entire spectrum, but only those materials which are of greatest significance for the calculation of I_c; namely:

- Components of natural and synthetic rubber; tires; components of plastic, composite materials, bakelite and the like
- Components of glass, crystal, plexiglass and the like
- Components produced using ceramics, rare earths, graphite, insulating mica and the like.



QUANTIFICATION OF THE SIX LEVELS OF COMPLEXITY FOR THE FACTORS OF BLOCKS A1, A2, B1, B2, C

-- Tables -



4A$_1$. QUANTIFICATION OF THE 6 LEVELS OF COMPLEXITY FOR THE FACTORS OF BLOCK A1

Manufacturing factors: product and production unit

Symbol	Factor	Technological levels					
		I	II	III	IV	V	VI
P	Weight of manufactured product	1.00	1.68	2.83	4.76	8.00	13.45
Hs	Hours of know-how per $US 1000 of finished product	1.00	2.00	4.00	8.00	16.00	32.00
L	Laboratories	1.00	1.68	2.83	4.76	8.00	13.45
Hd	Direct hours/tonne	1.00	2.00	4.00	8.00	16.00	32.00
Vt	Variety of types	1.00	1.41	2.00	2.83	4.00	5.66
Vm	Variety of models	1.00	1.41	2.00	2.83	4.00	5.66
S	Series of Vm, average	1.00	1.41	2.00	2.83	4.00	5.66
M	Assembly	1.00	1.68	2.83	4.76	8.00	13.45
T	Industrial size	1.00	1.68	2.83	4.76	8.00	13.45

4A₂. QUANTIFICATION OF THE 6 LEVELS OF COMPLEXITY FOR THE FACTORS OF BLOCK A2

Manufacturing factors: means of production

Each factor of the Block A_2 is quantified through the geometric progression (except quality control):
Level I = 1, II = 1.19, III = 1.41, IV = 1.68, V = 2.00, VI = 2.38

No.	Equipment designation	Technological levels I	II	III	IV	V	VI
1.	Cutting of all types						
2.	Folding, bending, rolling, etc.						
3.	Cold deformation of wire and strips					x	
4.	Riveting, threading, upsetting (cold)					x	
5.	Stamping and pressing					x	
6.	Other non-cutting machine-tools (catalogue-listed or not)						
7.	Welding of all types						
8.	Turning: horizontal, all types						
9.	Turning: with two or more chucks	x	x				
10.	Turning: vertical and plateau	x					
11.	Turning: spherical, globoid, dressing, spec.	x	x				
12.	Planes: horizontal, vertical, bench-type, cutting						
13.	Broaching	x	x			x	
14.	Milling						
15.	Drills and screw-cutting machines (chip-removal)						
16.	Broaching machines						
17.	Gear-cutting machines						
18.	Grinders						
19.	Superfinishing machines and other operating by abrasion	x	x				
20.	Electro-erosion machines, laser apparatus and other high-technology equipment	x					
21.	User-built machinery	x	x		x		
22.	Assembly machinery	x	x	x	x		
23.	Machine-tools, combined: cutting/non-cutting	x	x	x			
24.	Machine-tools: other chip-removal						
25.	Machines for use in manufacturing electric motors	x	x				x
26.	Machines for use with plastics, rubber and similar materials						
27.	Scouring, cleansing, degreasing equipment and the like					x	
28.	Painting equipment					x	
29.	Furnaces and drying apparatus		x			x	
30.	Quality control	1.0	1.0	1.0	1.0	1.0	1.0

4B$_1$. QUANTIFICATION OF THE 6 LEVELS OF COMPLEXITY FOR THE FACTORS OF BLOCK B1

Semi-finished products

No.	Designation	Technological levels					
		I	II	III	IV	V	VI
1.	Casting or iron, conventional	1.00	1.41	2.00	2.83	x	x
2.	Casting of steel, conventional	1.00	1.68	4.76	8.00	13.45	x
3.	Casting of non-ferrous metals, conventional	1.00	1.41	2.00	2.83	x	x
4.	Casting and forging of strategic materials	x	x	x	x	16.00	32.00
5.	Casting: pressure, centrifugal and the like	1.00	1.41	2.00	2.83	x	x
6.	Casting, others: microfusion, shell and chill moulding, etc.	1.00	1.41	2.00	2.83	x	x
7.	Hammer forging	1.00	1.41	2.00	2.83	4.00	x
8.	Stamping	1.00	1.41	2.00	2.83	x	x

$4B_2$. QUANTIFICATION OF THE 6 LEVELS OF COMPLEXITY FOR THE FACTORS OF BLOCK B2

Technical services from third parties

No.	Designation	Technological levels					
		I	II	III	IV	V	VI
9.	Stress relief, annealing, normalizing, etc.	1.00	1.41	2.00	2.83	x	x
10.	Heat treatment	1.00	1.41	2.00	2.83	x	x
11.	Metallic coatings, scouring, etc.	1.00	1.41	2.00	2.83	x	x
12.	Tool manufacture and maintenance	1.00	1.68	2.83	4.76	8.00	x
13.	Die-making for cold stamping	1.00	1.41	2.00	2.83	x	x
14.	Metal moulds, dies, shell moulds	1.00	1.68	2.83	4.76	8.00	x
15.	Manufacture of jigs, templates, and the like	x	1.41	2.00	2.83	x	x
16.	Light boilermaking services, plating to ½"	1.00	1.41	2.00	x	x	x
17.	Medium boilermaking services, plating to 1"	1.00	1.41	2.00	x	x	x
18.	Heavy boilermaking services, plating to 1¼"	x	1.41	2.00	2.83	x	x
19.	Manufacture of gears or gear-cutting alone	1.00	1.41	2.00	2.83	x	x
20.	Special machining, high-precision and standard	1.00	1.41	x	2.83	x	x
21.	Special machining, medium and semi-heavy	x	1.41	2.00	2.83	x	x
22.	Special machining, heavy	1.00	1.41	2.00	2.83	x	x
23.	Cold stamping	1.00	1.41	2.00	2.83	x	x

4C. QUANTIFICATION OF THE 6 LEVELS OF COMPLEXITY FOR THE FACTORS OF BLOCK C

Components

No.	Designation	Technological levels					
		I	II	III	IV	V	VI
1.	Mechanical: simple, of one or few parts	1.00	1.41	2.00	x	4.00	x
2.	Mechanical: composite, medium complexity and weight	1.00	1.68	2.83	4.76	8.00	x
3.	Mechanical: composite, high complexity and/or weight	x	x	2.83	4.76	8.00	x
4.	Hydraulic	x	2.00	4.00	8.00	16.00	32.00
5.	Pneumatic	x	1.68	2.83	4.76	8.00	x
6.	For vacuum circuits	x	x	2.00	x	4.00	x
7.	Electrical: for control circuits	1.00	2.00	4.00	8.00	16.00	32.00
8.	Electrical: for power circuits	1.00	2.00	4.00	8.00	16.00	32.00
9.	Electronic	x	x	x	8.00	16.00	32.00
10.	Measuring: linear, angular and plane	x	x	2.83	4.76	8.00	x
11.	Lubrication	1.00	1.41	2.00	x	4.00	x
12.	Cooling, with water or liquid circulation	x	1.41	2.00	2.83	4.00	x
13.	Refrigeration industry (excluding compressors)	x	x	2.83	4.76	8.00	x
14.	Steam and gases, corrosive and non-corrosive	x	1.68	2.83	4.76	8.00	13.45
15.	Instruments for the measurement of temperature, flow-rate, pressure, humidity, electrical values, and the like	x	x	4.00	8.00	16.00	32.00
16.	Optical	x	x	4.00	8.00	16.00	32.00
17.	Branch-specific components, metallic	x	2.00	4.00	8.00	16.00	32.00
18.	Branch-specific components, non-metallic	x	1.68	2.83	4.76	8.00	13.45

SAMPLE OF

TECHNICAL SHEET

5. SAMPLE OF TECHNICAL SHEET

STUDY OF CAPITAL GOODS - UNIDO	GROUP: 3829
PRODUCT DENOMINATION: AIR COMPRESSORS UP TO 5 HP WITH TANK, AUTOMATIC	Nº: -
	[illegible]: -

A - CENTRAL UNIT OF FABRICATION

A_1 - PRODUCT and PRODUCTION UNIT

	I	II	III	IV	V	VI	MIN	MAX	MED
P	X						1	1	1
Hs	X						1	1	1
L							–	–	–
Hd	X	X					1	2	1.5
Vt	X	X							
Vm	X	X					1	1.98	1.49
S	X	X					1	1.41	1.2
M	X						1	1	1
T		X	X				1.68	2.83	2.25
Tot							7.68	11.22	9.44

SUMMARY

Sub Group	Minimum	Maximum	Medium
A_1	7.68	11.22	9.44
A_2	21.42	26.98	24.15
B_1	6.00	6.83	6.41
B_2	13.89	14.48	14.18
A	29.10	38.20	33.59
B	19.89	21.31	20.59
C	10.50	13.68	12.08
Ic Total	59.49	73.19	66.26

OBSERVATIONS: ____________________

A_2 - MEANS OF PRODUCTION

	I	II	III	IV	V	VI	MIN	MAX	MED
1		X	X	X			1.19	1.68	1.43
2		X	X				1.19	1.41	1.3
3		X	X				1.19	1.41	1.3
4									
5									
6			X				1.41	1.41	1.41
7		X	X				1.19	1.41	1.3
8		X	X	X			1.19	1.68	1.43
9			X	X			1.41	1.68	1.54
10									
11									
12									
13									
14			X	X			1.41	1.68	1.54
15			X	X		X	1.41	2.38	1.89
16			X	X		X	1.41	2.38	1.89
17									
18			X	X			1.41	1.68	1.54
19			X	X			1.41	1.68	1.54
20									
21									
22									
23									
24			X	X			1.41	1.68	1.54
25									
26									
27									
28		X	X				1.19	1.41	1.3
29		X	X				1	1.41	1.2
30	X			X			2	2	2
Sub TOT							21.42	26.98	24.15
B									
TOT							21.42	26.98	24.15

SHEET: -

B₁ → B_1 - SEMI-FINISHED PRODUCTS

	I	II	III	IV	V	VI	MIN	MAX	MED
1			X	X			2	238	241
2									
3			X				2	2	2
4									
5									
6									
7									
8			X				2	2	2
Sub TOT							6.00	6.83	6.41

B_2 - TECHNICAL SERVICES FROM THIRD PARTIES

	I	II	III	IV	V	VI	MIN	MAX	MED
9			X				2	2	2
10			X				2	2	2
11		X					1.41	1.41	1.41
12			X				283	283	283
13									
14			X				283	283	283
15									
16									
17									
18									
19									
20		X					1.41	1.41	1.41
21									
22									
23		X	X				1.41	2	1.7
Sub TOT							13.89	14.48	14.18

C - COMPONENTS

	I	II	III	IV	V	VI	MIN	MAX	MED
1		X	X				1.41	2	1.7
2									
3									
4									
5									
6									
7									
8									
9									
10									
11		X	X				1.41	2	1.7
12									
13									
14									
15			X				4	4	4
16									
17		X	X				2	4	3
18		X					1.68	1.68	1.68
Sub TOT							10.50	13.68	12.08

CHARACTERISTIC PARAMETERS

	1	2	3	4	5	6	MIN	MAX	MED
α									
β									

COMMENTS:

Elaborated by: UNIDO	Date: April 1980	MODIF.	X	2	3	4	5	6

TABLES OF RESULTS

(Tables 1 to 27)

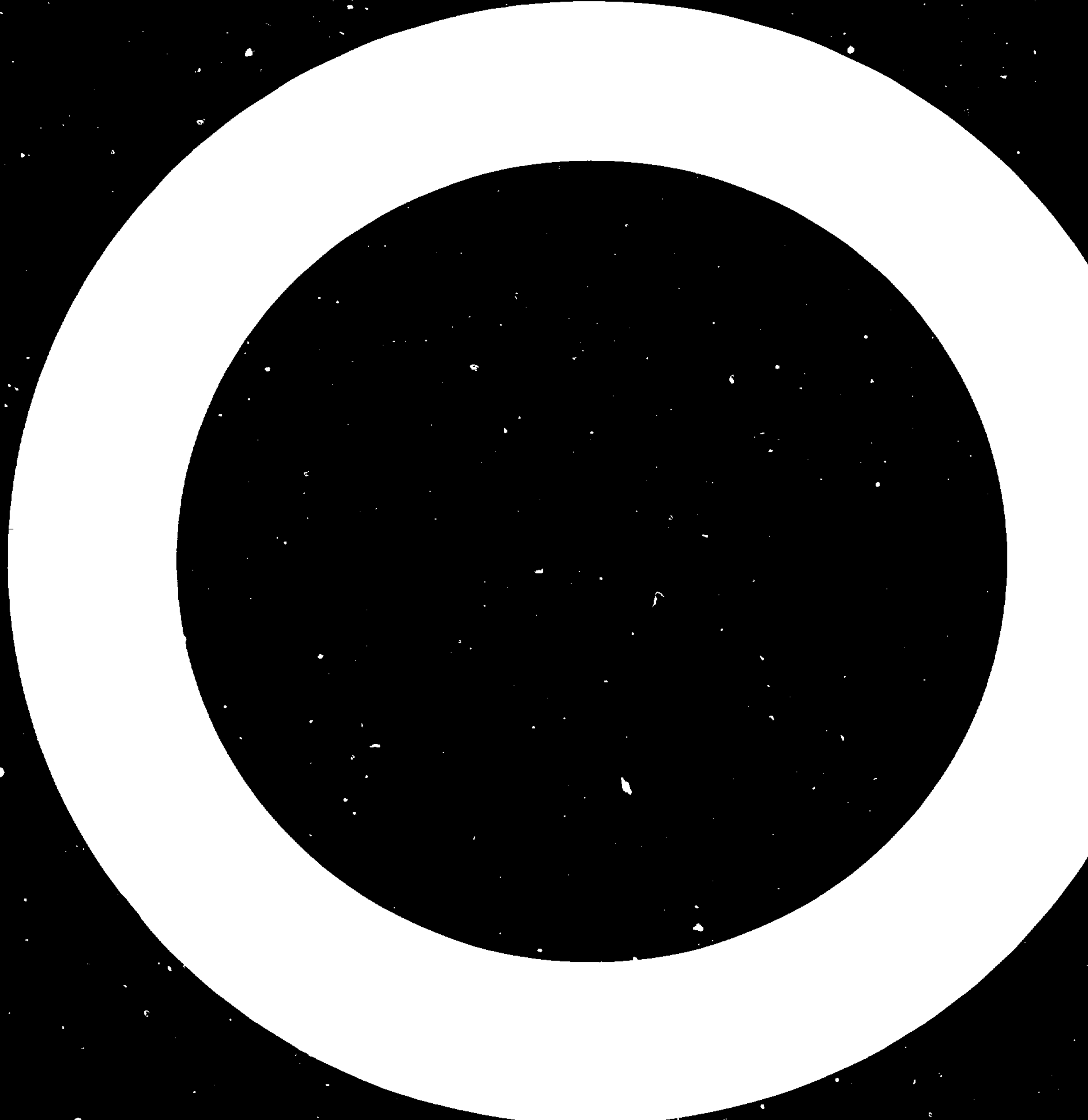


Table No. 1

Results for total complexity

Total complexity groups	Number of products and %		Simple met. products (381)	Non-electr. machines (382)	Electrical machines (383)	Transport equipment (384)	Measuring and control equipment (385)
0 to 15	0	0 %	0	0	0	0	0
15 to 35	20	6,3%	10	9	1	0	0
35 to 65	61	19,2%	13	38	3	7	0
65 to 100	103	32,4%	0	74	13	5	11
100 to 130	60	18,9%	0	46	4	8	2
130 to 180	45	14,1%	0	37	3	5	0
180 to 250	20	6,3%	0	9	0	11	0
250 to 320	5	1,6%	0	3	0	2	0
320 to 620	4	1,2%	0	0	0	4	0
> 620	0	0 %	0	0	0	0	0
TOTAL	318	100 %	23	216	24	42	13

Table No. 2

Results for total complexity, excluding components

Total complexity groups	Number of products and %		Simple metall. products (381)	Non-electric. machines (382)	Electric. machines (383)	Transport equipment (384)	Measuring and control equipment (385)
0 to 15	0	0	0	0	0	0	0
15 to 35	23	7,2 %	10	12	1	0	0
35 to 65	112	35,2 %	13	78	12	8	1
65 to 100	128	40,3 %	0	93	9	14	12
100 to 130	34	10,7 %	0	24	2	8	0
130 to 180	15	4,8 %	0	7	0	8	0
180 to 250	3	0,9 %	0	2	0	1	0
250 to 320	2	0,6 %	0	0	0	2	0
320 to 620	1	0,3 %	0	0	0	1	0
> 620	0	0	0	0	0	0	0
TOTAL	318	100 %	23	216	24	42	13

Table No. 3

Results for complexity according to the categories
of capital goods in Class 38
(dispersion of the mean complexities)

	Mean complexities by groups					
	TOTAL			WITHOUT COMPONENTS		
	MIN	MEAN	MAX	MIN	MEAN	MAX
Simple metallurgical equipm. (381)	31,67	38,89	46,22	29,93	36,82	43,82
Non-electrical machines (382)	81,61	102,59	123,71	59,47	73,10	86,84
Electrical machines (383)	68,78	88,91	109,13	53,16	67,52	81,95
Transport equipm. (384)	142,92	176,14	209,50	95,32	112,09	128,98
Measuring and control equipm. (385)	70,70	88,12	105,65	61,19	74,20	87,31
TOTAL	395,68	494,65	594,21	299,07	363,73	428,90

Table No. 4

Results for complexity according to the functions of capital goods (dispersion of the mean complexities)

Groups of capital goods	Mean complexities by groups					
	TOTAL			WITHOUT COMPONENTS		
	MIN.	MEAN	MAX.	MIN.	MEAN	MAX.
semi-finished groups	32,91	39,20	45,58	31,11	37,40	43,78
components or sub-assemblies	65,01	86,46	108,05	53,71	70,60	87,60
"autonomous" finished products	88,48	109,10	130,10	63,25	75,49	87,85
finished products integrated into a production process	93,81	119,81	145,94	65,99	83,11	100,33
TOTAL	280,21	354,47	429,67	214,06	266,60	319,56

Table No. 5

Mean complexities of capital goods
according to the nature of the demand
(dispersion of the mean complexities)

	Mean complexities of the groups					
	total			without components		
	min.	mean	max.	min.	mean	max.
goods common to all the branches	71,27	90,90	110,65	56,86	71,25	85,77
goods common to several branches	78,24	99,02	119,92	57,25	71,06	84,97
goods specialized by the demand sectors	93,89	115,89	138,02	65,83	78,73	91,73

Table No. 6

Goods common to all the branches
Results for the total complexity

Total complexity groups	Number of products and %		Simple met. products (381)	Non-electr. machines (382)	Electric. machines (383)	Transport equipment (384)	Measuring and control equipment (385)
0 to 15	0	0%	0	0	0	0	0
15 to 35	2	2,9%	1	0	1	0	0
35 to 65	20	29,0%	6	9	2	3	0
65 to 100	27	39,1%	0	16	7	1	3
100 to 130	10	14,5%	0	7	1	1	1
130 to 180	5	7,2%	0	4	1	0	0
180 to 250	4	5,8%	0	1	0	3	0
250 to 32L	1	1,4%	0	1	0	0	0
320 to 620	0	0%	0	0	0	0	0
> 620	0	0%	0	0	0	0	0
TOTAL	69	100%	7	38	12	8	4

Table No. 7

Results for the complexity excluding components
Goods common to all the branches

Total complexity groups	Number of products and %		Simple metall. products (381)	Non-electr. machines (382)	Electric. machines (383)	Transport equipment (384)	Measuring and control equipment (385)
0 to 15	0	0	0	0	0	0	0
15 to 35	4	5,8%	1	2	1	0	0
35 to 65	29	42,0%	6	14	6	3	0
65 to 100	24	34,8%	0	15	3	2	4
100 to 130	9	13,0%	0	5	2	2	0
130 to 180	2	2,9%	0	1	0	1	0
180 to 250	1	1,4%	0	1	0	0	0
250 to 320	0	0	0	0	0	0	0
320 to 620	0	0	0	0	0	0	0
> 620	0	0	0	0	0	0	0
TOTAL	69	100%	7	38	12	8	4

Table No. 8

The complexity of capital goods common to all the branches, broken down into 11 groups of products

	complexity							
	total complexity				complexity without components			
	MIN	MEAN	MAX	disp.%	MIN	MEAN	MAX	disp.%
1. small mechanical components (screws, nuts, etc.)	30,39	39,74	49,21	46,72	28,90	37,64	46,50	45,37
2. steel elements for construction	35,20	42,97	50,87	37,33	31,86	39,18	46,62	38,49
3. small electrical equipment	53,53	73,77	94,11	54,30	43,94	60,00	76,14	53,50
4. miscell. techn. equipment (aero-space, control, measurement)	63,61	79,58	95,67	37,95	49,05	59,94	70,92	33,57
5. pumps, compressors, boilers	66,31	81,92	97,67	36,69	51,07	61,44	71,91	33,03
6. engineer. parts, not for machines	60,51	86,72	113,07	58,68	51,52	73,20	93,22	56,06
7. storage and handling equipment	79,54	93,08	106,73	29,37	58,93	67,02	75,20	25,01
8. machine tools	79,28	106,45	133,80	46,38	48,05	65,06	82,22	49,58
9. engines of all types	84,76	113,69	142,79	52,53	65,22	87,37	109,66	51,53
10. road transport equipment	93,76	121,84	150,08	48,75	71,01	90,86	110,85	46,28
11. office equipment	138,57	168,79	199,06	34,68	114,51	133,06	151,66	27,27

Table No. 9

The complexity of specific capital goods :
examples for 11 essential demand sectors

	total complexity				complexity without components			
	MIN	MEAN	MAX	disp. %	MIN	MEAN	MAX	disp.%
1. Agricultural machinery	56,67	64,88	73,20	25,48	65,75	50,60	55,54	19,35
2. Agro-food industries	80,95	95,80	110,80	30,61	54,19	64,70	75,33	32,77
3. Chemicals and petrochemicals	76,46	100,16	123,98	44,03	65,98	82,97	100,07	41,12
4. Building and building materials industries	84,86	107,35	129,99	40,88	59,63	73,94	88,38	38,84
5. Mechanical engineering	86,13	113,95	141,92	49,06	54,19	70,20	86,32	47,32
6. Extraction of minerals	92,01	130,32	168,79	59,11	61,36	84,44	107,65	54,06
7. Agro-industries (tobacco, alcohol, leather, textiles, ...)	106,29	132,13	158,15	36,49	68,90	85,24	101,71	37,22
8. Heavy metallur. (iron and steel, forging, foundries)	107,64	137,49	167,46	41,74	69,01	86,23	103,55	40,05
9. Transport equipment: road	128,72	162,67	196,78	68,05	87,64	106,68	125,85	34,31
10. Tpt equipment: rail	167,74	197,65	227,70	33,04	108,29	120,17	132,15	21,87
11. Tpt equipment: air	389,59	460,97	532,41	30,18	232,36	259,72	287,15	22,10

Table No.10

Equipment for agriculture, building and the agricultural industries

Demand sectors	means of the complexities of the groups					
	total			without components		
	min	mean	max	min	mean	max
agricultural machinery (35 machinery)	56,67	64,88	73,20	45,75	50,60	55,54
building and building materials industries (24 machines)	61,92	77,38	92,97	45,83	56,59	67,46
agro-industries (28 machines)	93,31	113,94	134,70	60,58	73,97	87,47

Table No. 11

Breakdown of capital goods by size of the central unit

Size of company (no. of employees)	TOTAL (products)		Semi-finished products	Parts and sub-assemblies	Autonomous machines and equipment	Equipment integrated into a "complicated" process	Goods common to all the branches	Goods common to several branches	Specialized goods
	No. of products	%	A	B	C	D	BC TB	BC	BS
			percentages						
up to 100	5	1,6	0	1,9	1,8	0	0	2,2	1,9
100 to 250	33	10,4	66,7	9,6	13,7	0	7,2	8,8	12,7
250 to 500	87	27,3	33,3	19,2	32,0	13,6	29,0	25,3	27,9
500 to 1000	81	25,5	0	40,4	21,0	20,5	30,4	28,8	20,2
1000 to 3000	68	21,4	0	25,0	17,3	43,3	13,1	28,6	21,5
>3000	44	13,8	0	5,8	14,2	22,7	20,3	6,6	15,8
TOTAL	318	100	100	100	100	100	100	100	100

Table No.12

Breakdown of Division 38 (ISIC) by principal groups
and by complexity levels

Complexity level	Capital goods (all)	Simple metal products	Non-electrical machines	Electr. machines and equipment	Transport equipment	Industr.control and measuring equipment	Semi-finished product	Parts and sub-assemblies	Autonomous machines and equipment	Equipm. integrated into a "complicated process	Goods common to all the branches	Goods common to several branches	Specialized goods
		381	382	383	384	385	A	B	C	D	BC TB	BC	BS
I (0 to 30)	3,5% (11)	30.0	1.9	0	0	0	33.3	3.8	3.7	0	0	5.5	3.8
II (30 to 55)	14,1% (45)	56.5	12.0	16.7	4.8	0	66.7	17.3	13.7	6.8	20.3	5.5	15.8
III (55 to 100)	40,6% (129)	13.0	42.1	58.3	23.8	84.6	0	50.0	41.1	29.5	50.7	47.2	32.3
IV (100 to 180)	32,7% (104)	0	38.4	25.0	31.0	15.4	0	28.8	29.7	56.8	21.7	35.2	36.7
V (180 to 320)	7,9% (25)	0	5.6	0	31.0	0	0	0	10.0	6.8	7.2	6.6	8.9
VI more than 320	1,3%	0	0	0	9.5	0	0	0	1.8	0	0	0	2.5
Total	100,0%	100% (23)	100% (216)	100% (24)	100% (42)	100% (13)	100% (3)	100% (52)	100% (219)	100% (44)	100% (69)	100% (91)	100% (158)
Mean for the group													

( ) number of products analysed

Table No. 13

Gains in equipment goods produced as a result of
uniform increases in the complexity levels
of the 80 factors

All the factors at least at level	381	382	383	384	385	Total gains in terms of machines
1	1	1	0	0	0	+2
2	+1	+1	+0	+0	+0	+4
3	+15	+46	+2	+0	+3	+66
4	+1	+41	+10	+18	+1	+71
5	+0	+40	+4	+5	+0	+49
6	+3	+87	+8	+19	+9	+126
Total	23	216	24	42	13	318

Table no. 14

Profile of distribution by levels of complexity of production factors for capital goods common to all branches

Factors :	Levels of complexity					
A1	I	II	III	IV	V	VI
Weight	78	62	28	13	0	19
Know how	57	60	41	15	4	1
Laboratories	34	25	32	22	6	0
Direct hours	56	72	46	16	9	4
Variety of types	10	90	74	32	3	0
Variety of model	53	87	50	32	7	3
Series	85	72	63	26	4	4
Assembly	82	15	9	6	0	4
Number of employees	10	60	75	50	29	15

Table no. 14 cont'd

Blocks	A2	Levels of complexity I	II	III	IV	V	VI
Oxycut-ting	1	7	43	74	65	0	13
metalworing by forming	2	4	29	32	9	0	3
	3	4	25	31	12	0	3
	4	4	13	26	29	0	7
	5	4	18	60	63	0	9
	6	1	18	41	40	1	16
Welding	7	7	34	53	16	0	4
Metalworking by chip removal	8	4	21	62	76	4	0
	9	0	0	16	25	1	1
	10	0	7	15	10	0	4
	11	0	0	10	19	3	3
	12	4	10	7	0	0	0
	13	0	3	34	16	1	4
	14	4	21	66	66	22	25
	15	7	26	68	56	24	38
	16	1	13	41	34	22	25
	17	1	16	22	12	0	0
	18	4	26	62	54	1	13
	19	0	1	29	26	0	12
	20	0	0	3	1	0	6
	21	0	0	12	1	0	19
	22	0	0	0	0	1	10
	23	0	0	1	26	1	12
	24	0	13	37	34	3	25
	25	0	0	12	18	3	0
Miscellaneous painting, etc.)	26	0	1	26	37	0	6
	27	1	32	60	26	0	4
	28	9	40	74	25	0	10
	29	1	10	49	25	0	1
Quality	30	85	21	22	53	6	13

Table no. 14 cont'd

B1	Levels of complexity.					
	I	II	III	IV	V	VI
1	1	6	44	34	0	0
2	1	4	32	22	3	0
3	1	4	34	15	0	0
4	0	0	0	0	1	0
5	1	4	37	31	0	0
6	1	6	38	25	0	0
7	3	6	19	7	0	0
8	3	4	31	18	0	0

Table no. 14 cont'd

B2						
9	1	7	54	32	0	0
10	3	12	63	40	0	0
11	9	34	43	19	0	0
12	6	43	82	42	15	0
13	6	24	62	54	0	0
14	3	10	54	41	0	0
15	0	4	22	19	0	0
16	1	9	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	3	12	1	0	0
20	0	29	0	6	0	0
21	0	1	4	1	0	0
22	0	0	0	0	0	0
23	0	18	19	4	0	0

Table no. 14 end

C	Levels of complexity					
	I	II	III	IV	V	VI
1	19	72	56	0	10	0
2	1	15	26	15	1	0
3	0	0	4	3	0	0
4	0	1	9	12	0	0
5	0	1	9	9	0	0
6	0	0	0	0	0	0
7	0	10	31	19	3	0
8	0	6	16	13	0	0
9	0	0	0	13	4	1
10	0	0	3	0	0	0
11	0	37	32	0	0	0
12	0	4	10	6	0	0
13	C	0	10	1	0	0
14	0	0	6	0	0	0
15	0	0	32	21	1	0
16	0	0	0	0	0	0
17	1	28	63	50	13	1
18	1	34	65	44	7	0

Table no. 15

Profile of distribution by levels of complexity of production factors for capital goods common to all branches

Factors	Levels of complexity					
A1	I	II	III	IV	V	VI
Weight	39	63	64	38	10	7
Know how	30	59	58	30	4	0
Laboratories	35	10	36	11	4	0
Direct hours	53	71	47	18	3	2
Variety of types	23	89	65	18	4	1
Variety of models	53	78	60	38	16	1
Series	37	48	64	63	43	37
Assembly	79	3	38	25	4	9
Number of employees	13	41	68	55	30	4

Table no. 15 cont'd

Blocks	A2	Levels of complexity					
		I	II	III	IV	V	VI
Oxycutting	1	18	70	78	32	0	1
Metalworking by forming	2	13	57	48	3	2	1
	3	12	54	42	9	1	3
	4	9	30	29	7	0	3
	5	11	43	51	24	0	5
	6	5	34	48	17	3	8
Welding	7	9	63	51	8	0	0
Metalworking by chip removal	8	14	55	82	39	7	1
	9	0	0	11	8	3	1
	10	1	28	26	2	3	0
	11	0	0	7	4	1	2
	12	16	35	21	0	1	1
	13	0	3	20	2	0	2
	14	13	58	72	25	33	9
	15	16	59	72	22	41	16
	16	9	46	49	7	36	9
	17	5	23	14	2	0	1
	18	11	52	49	23	8	9
	19	0	0	30	4	1	4
	20	0	1	5	0	2	1
	21	0	0	4	0	0	4
	22	0	0	0	0	0	5
	23	0	0	2	16	2	9
	24	0	30	35	8	4	7
	25	0	1	4	4	0	1
Miscellaneous (painting, etc.)	26	0	2	10	8	0	0
	27	3	27	26	5	0	2
	28	20	70	41	3	0	1
	29	1	13	21	7	0	0
Quality control	30	85	11	34	27	9	21

Table no. 15 cont'd

B1	Levels of complexity					
	I	II	III	IV	V	VI
1	3	10	48	48	0	0
2	1	10	40	38	16	0
3	0	5	33	25	1	0
4	0	0	0	0	11	2
5	1	1	23	13	0	0
6	0	1	15	12	0	0
7	2	12	26	18	1	0
8	2	10	29	22	0	0

Table no. 15 cont'd

B2						
9	3	8	45	27	0	0
10	4	17	63	38	0	0
11	2	24	33	8	0	0
12	3	41	83	46	3	0
13	1	24	60	28	0	0
14	2	13	41	23	1	0
15	0	2	17	8	0	0
16	0	10	1	0	0	0
17	0	0	2	0	0	0
18	0	0	0	0	0	0
19	0	13	26	11	0	0
20	0	24	1	1	0	0
21	0	15	20	5	0	0
22	0	1	5	0	0	0
23	0	23	21	3	0	0

Table no. 15 end

C	Levels of complexity					
	I	II	III	IV	V	VI
1	17	74	72	0	11	0
2	0	25	40	24	1	0
3	0	0	13	10	0	0
4	0	0	15	22	7	0
5	0	2	18	18	3	0
6	0	0	4	2	0	0
7	0	7	42	33	5	0
8	0	17	32	18	1	0
9	0	0	0	26	5	0
10	0	0	5	3	1	0
11	0	38	38	0	11	0
12	0	3	11	4	0	0
13	0	0	4	3	0	0
14	0	1	8	12	3	0
15	0	0	38	36	12	0
16	0	0	8	4	1	0
17	0	28	70	58	14	1
18	0	34	62	42	2	0

Table no. 16

Profile of distribution by levels of complexity of production factors for capital goods specific for one branch

Factors	Levels of complexity					
A1	I	II	III	IV	V	VI
Weight	27	55	63	39	16	8
Know how	34	55	51	34	7	1
Laboratories	35	9	39	15	5	0
Direct hours	45	66	47	16	2	2
Variety of types	27	89	49	15	1	0
Variety of models	74	82	27	10	1	1
Series	23	43	53	58	39	29
Assembly	68	8	27	32	13	20
Number of employees	12	40	52	47	35	15

Table no. 16 cont'd

Blocks	A2	Levels of complexity					
		I	II	III	IV	V	VI
Oxycutting	1	17	73	79	32	2	1
Metalworking by forming	2	11	68	51	1	1	2
	3	9	67	46	2	1	2
	4	3	31	33	6	0	2
	5	8	54	55	22	0	4
	6	4	51	59	11	2	10
Welding	7	8	77	74	11	0	1
Metalworking by chip removal	8	6	59	32	44	5	1
	9	0	0	9	8	2	1
	10	1	32	34	5	3	1
	11	0	0	9	9	1	1
	12	8	41	37	0	4	1
	13	0	6	27	4	1	3
	14	8	59	78	31	37	11
	15	10	65	86	20	39	19
	16	4	52	58	9	53	12
	17	2	41	27	4	0	1
	18	6	66	58	15	6	4
	19	0	3	33	4	0	3
	20	0	3	8	1	2	0
	21	0	0	3	0	0	2
	22	0	0	0	0	0	1
	23	0	0	4	15	1	8
	24	1	38	41	9	4	6
	25	0	0	2	1	0	0
Miscellaneous (painting, etc.)	26	0	1	7	1	0	0
	27	0	27	32	5	0	1
	28	14	72	53	4	0	2
	29	4	16	20	3	0	1
Quality control	30	80	11	46	17	8	20

Table no. 16 cont'd

B1	Levels of complexity					
	I	II	III	IV	V	VI
1	2	13	51	48	0	0
2	1	14	44	41	15	0
3	1	6	37	30	0	0
4	0	0	0	0	9	2
5	0	1	17	22	0	0
6	0	0	14	18	0	0
7	2	13	29	27	3	0
8	1	12	27	21	1	0

Table no. 16 cont'd

B2						
9	1	13	49	35	0	0
10	1	25	68	51	0	0
11	1	16	34	16	0	0
12	4	41	75	46	8	0
13	1	26	50	27	0	0
14	1	11	35	26	1	0
15	0	7	18	15	0	0
16	0	22	14	1	0	0
17	0	2	4	0	0	0
18	0	1	1	0	0	0
19	0	20	34	20	0	0
20	1	20	4	3	0	0
21	0	11	22	3	0	0
22	0	1	9	2	1	0
23	0	22	29	4	0	0

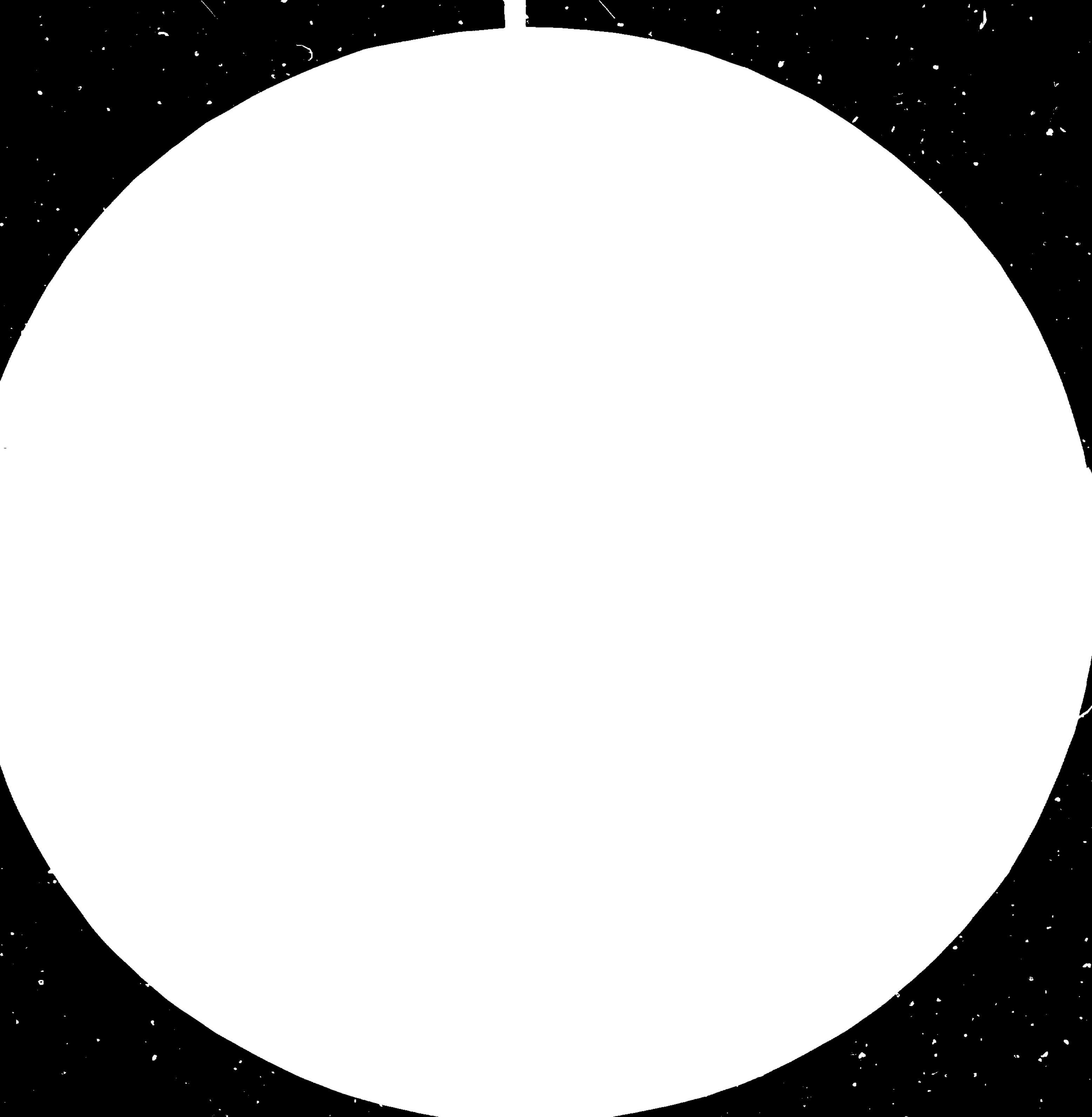
Table no. 16 end

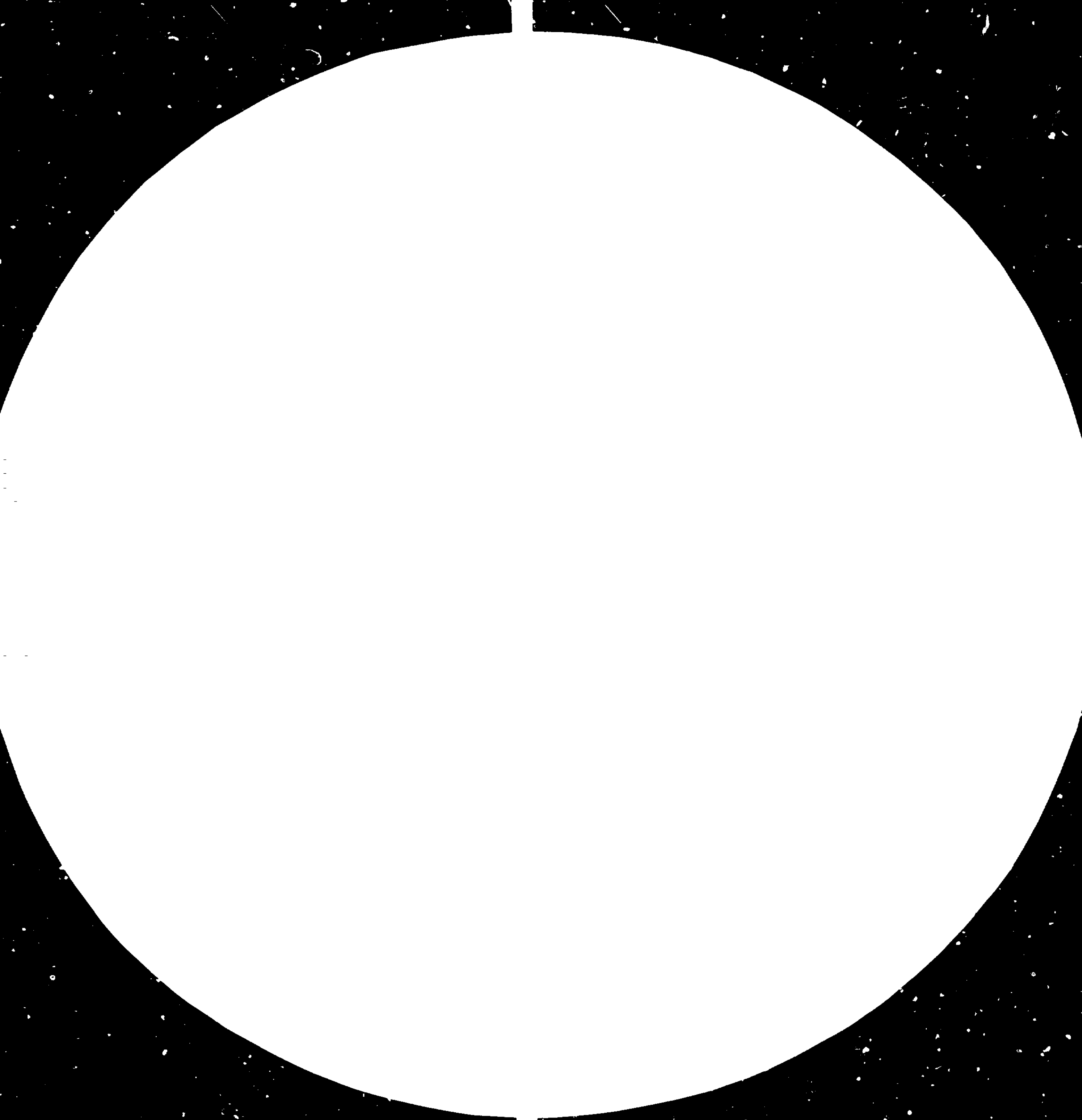
C	Levels of complexity					
	I	II	III	IV	V	VI
1	24	79	64	0	5	0
2	3	38	55	25	8	0
3	0	0	15	15	1	0
4	0	3	21	37	15	2
5	0	4	26	23	9	0
6	0	0	6	0	1	0
7	0	18	42	34	8	2
8	0	16	35	25	7	2
9	0	0	1	29	7	2
10	0	1	6	1	0	0
11	1	32	41	1	9	0
12	0	2	18	9	0	0
13	0	0	9	8	1	0
14	0	1	13	7	2	0
15	0	0	47	28	11	2
16	0	0	4	3	3	0
17	0	25	65	49	18	4
18	1	32	70	38	6	2

Table No. 17

Frequency of utilization of the variables of sub-assembly A1

Factors	Goods common to all the branches	Goods common to several branches	Specialized goods
Weight	100%	100%	100%
Know-how	100%	100%	100%
Laboratories	72%	76%	74%
Direct hours	100%	100%	100%
Varieties of types	100%	100%	100%
Varieties of models	100%	100%	100%
Production runs	100%	100%	100%
Assembling	99%	98%	97%
Number of employees	100%	100%	100%





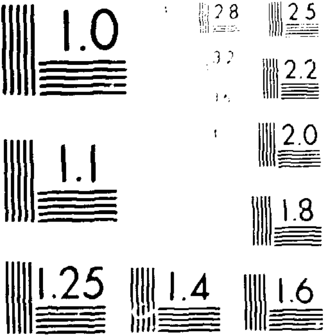

1.0
2.8
2.5
2.2
1.1
2.0
1.8
1.25
1.4
1.6

Table No. 18

Frequency of utilization of the variables of sub-assembly A2 as percentages

Blocks		Goods common to all the branches (69)	Goods common to several branches (91)	Specialized goods (158)
Oxy-acetylene cutting	1	100	96	99
Metal working by deformation	2	46	71	84
	3	43	73	79
	4	53	49	48
	5	81	73	78
	6	66	66	77
Welding	7	62	77	91
Metal working by chip removal	8	91	97	94
	9	26	11	9
	10	24	39	47
	11	21	8	13
	12	13	49	50
	13	43	21	30
	14	87	93	92
	15	91	94	97
	16	59	76	82
	17	32	33	56
	18	84	83	84
	19	43	32	35
	20	9	8	10
	21	28	8	4
	22	12	5	1
	23	29	23	22
	24	63	51	56
	25	18	6.5	2
Miscellan. (painting, etc.)	26	46	14	7
	27	76	41	39
	28	91	91	93
	29	53	28	26
Quality control	30	97	95	94

Table No. 19

Frequency of utilization of the variables of sub-assembly B1

B1	Goods common to all the branches (69)	Goods common to several branches (91)	Specialized goods (158)
1	56	91	75
2	41	68	70
3	37	50	54
4	1	12	9
5	51	30	31
6	47	22	25
7	25	40	47
8	34	40	49

Table No. 20

Frequency of utilization of the variables of sub-assembly B2

B2	Goods common to all the branches	Goods common to several branches	Specialized goods
9	62	55	67
10	75	79	90
11	66	51	47
12	96	95	97
13	85	74	70
14	76	59	56
15	35	24	35
16	9	11	27
17	0	2	4
18	0	0	1
19	15	34	52
20	32	24	25
21	7	25	32
22	0	5	9
23	28	33	40

Table No.21

Frequency of utilization of the variables of sub-assembly C

C	Goods common to all the branches	Goods common to several branches	Specialized goods
1	87	92	94
2	31	47	66
3	4	17	19
4	15	29	49
5	15	25	38
6	0	4	6
7	41	53	62
8	26	42	58
9	15	26	52
10	3	7	6
11	47	58	63
12	12	14	23
13	10	8	13
14	6	14	16
15	34	53	58
16	0	8	7
17	78	79	77
18	79	80	82

Table No. 22

Structure of the total complexity by levels and assemblies

	A1	A2	A	B1	B2	B	C	means A + B + C
N1	8.65	11.44	20.10	0.51	2.96	3.48	1.69	25.27
N2	12.45	17.83	30.29	2.25	5.59	7.85	5.00	43.14
N3	19.92	23.16	43.08	7.78	11.10	18.89	17.38	79.35
N4	29.16	28.39	57.55	14.24	16.98	31.22	41.18	129.95
N5	54.50	33.89	88.40	27.15	29.04	56.19	88.23	232.82
N6	122.54	50.57	173.11	49.92	44.27	94.20	229.92	497.23

Table No.23

Sub-assembly A1

Frequency of utilization of the factors
by complexity level of the capital goods
in percentages

General levels of complexity	N 1	N 2	N 3	N 4	N 5	N 6
Weight	100	100	100	100	100	100
Know-how	100	100	99	100	100	100
Laboratories	0	39	73	90	100	100
Direct hours	100	100	100	100	100	100
Varieties of types	100	100	100	100	100	100
Varieties of models	100	100	100	100	100	100
Production runs	100	100	100	100	100	100
Assembling	91	98	98	100	100	100
Number of employees	100	100	100	100	100	100

Table No.24

Sub-assembly A2

Frequency of utilization of the factors by complexity level of the capital goods in percentages

levels / factors	N 1	N 2	N 3	N 4	N 5	N 6
1	82	98	99	99	100	100
2	54	70	66	76	92	100
3	63	59	64	78	88	25
4	9	45	37	60	84	100
5	82	89	70	76	88	100
6	45	73	67	74	88	100
7	55	75	76	91	92	25
8	64	77	96	100	100	100
9	0	5	9	21	28	0
10	0	7	33	57	68	100
11	0	5	9	20	28	0
12	55	23	32	56	64	25
13	9	11	23	36	72	75
14	64	66	94	98	100	100
15	73	84	96	100	96	100
16	27	30	73	95	100	100
17	0	14	37	66	56	75
18	45	45	87	94	96	100
19	0	5	29	50	76	75
20	9	2	6	10	20	75
21	0	2	15	10	8	0
22	0	2	3	6	12	0
23	9	14	23	30	20	75
24	0	16	50	77	88	75
25	0	5	9	7	0	0
26	0	16	22	12	16	75
27	18	43	51	45	56	100
28	64	89	91	96	100	100
29	27	43	34	24	36	75
30	45	86	97	100	100	100

Table No.25

Sub-assembly B'

Frequency of utilization of the factors
by complexity level of the capital goods
in percentages

factors \ levels	N 1	N 2	N 3	N 4	N 5	N 6
1	18	27	74	87	88	25
2	18	32	60	82	80	50
3	0	23	41	70	72	25
4	0	0	4	8	36	100
5	0	16	33	42	64	50
6	0	14	28	32	52	50
7	18	27	31	49	76	100
8	27	27	40	45	76	100

Table No.26

Sub-assembly B2

Frequency of utilization of the factors
by complexity level of the capital goods
in percentages

factors \ levels	N 1	N 2	N 3	N 4	N 5	N 6
9	27	34	54	80	92	100
10	64	61	83	91	100	100
11	9	45	46	57	88	100
12	64	89	98	99	100	100
13	54	75	71	75	88	100
14	27	41	66	60	84	100
15	0	20	20	42	72	100
16	0	2	7	81	60	25
17	0	0	0	0.9	28	25
18	0	0	0.8	0.	4	0
19	0	11	27	55	84	100
20	0	5	29	34	32	0
21	0	0	16	41	56	25
22	0	0	2	11	16	25
23	0	7	28	51	72	25

Table No.27

Assembly C

Frequency of utilization of the factors by complexity level of the capital goods in percentages

factors \ levels	N 1	N 2	N 3	N 4	N 5	N 6
1	64	82	91	99	96	100
2	0	18	44	74	88	100
3	0	0	7	28	36	25
4	0	2	23	58	72	100
5	0	2	19	44	68	100
6	0	0	0.8	10	4	0
7	0	18	41	80	100	100
8	9	11	37	62	96	100
9	0	0	12	41	84	100
10	0	7	3	7	8	0
11	0	11	50	82	100	100
12	0	0	7	29	64	25
13	0	2	5	17	28	75
14	0	0	5	18	56	75
15	0	5	44	74	92	100
16	0	0	4	6	12	100
17	9	41	79	94	96	100
18	27	45	82	97	92	100

with
09990

Distr.
LIMITED

ID/WG.324/4/Add.1
3 August 1980

Original: ENGLISH

United Nations Industrial Development Organization

Global Preparatory Meeting for the First
Consultation on the Capital Goods Industry

Warsaw, Poland, 24-28 November 1980

SOME ASPECTS OF TRANSFER OF TECHNOLOGY AND ENGINEERING IN THE CAPITAL GOODS INDUSTRY *)

Prepared by the
Sectoral Studies Section,
International Centre for Industrial Studies

*) This paper is an addendum to the study "Technology in the service of development", related to the issue No. 2 of the Agenda - types of technologies in the service of development of the capital goods industry.

This document has been reproduced without formal editing.

80-42444

CONTENTS

INTRODUCTION

In order to define a strategy for the transfer and acquisition of technology in a given industry it is first of all necessary to identify the various components of this technology. It is not, in fact, possible to transfer the technology of the industry in an overall manner in a "package"; it is necessary to differentiate this technology. When it involves the transfer of technology this differentiation of the technology of a given industry must be carried out by taking into account firstly the various types of supports on which the technology is introduced into and used in the industry.

These supports may be material (technology is incorporated in machines, sub-assemblies, components and intermediate goods), they may consist of written documents (design books and specifications), or again the technology may be "supported" or integrated by individuals or groups of individuals. Another characteristic of technology is also involved in the transfer of technology; this is the level of elaboration of the technology. This level of elaboration of the technology, which conditions its capacity for diffusion and transmission, can be looked at in one of two ways: from the level of conceptualization of the technology (technical know-how, technical knowledge, technological knowledge, scientific knowledge), or on the basis of the degree of socialization of the technology (socialized technology, alienated technology).

- "socialized" technology, that is to say technology which is socially available and accessible without restriction. This includes free information and knowledge of technical processes which have fallen into the public domain

- "alienated" technology, that is to say technology which is retained and only ceded by virtue of a right of ownership or by a special agreement

Technical know-how is essentially incorporated by individuals or groups of individuals.
The privileged mode of transmission of know-how is by working and collaborating closely with the persons who hold this type of technology. The transfer of know-how is carried out through technical cooperation agreements, technical assistance and, in certain cases, by the sale of know-how licences.

In the capital goods industry (and more generally in the mechanical and electrical industries) certain written documents, the product of know-how and technical and technological knowledge accumulated by firms, play an important role in the competition between firms. These documents often have the legal status of know-how. They may consist of:

- design drawings of assemblies and sub-assemblies
- detailed execution drawings
- specifications for manufacture and assembly
- standards for design and construction
- standards for management service.

The relative importance of the components and sub-components of the technology for manufacturing capital goods varies as a function of the following principal factors:

- product design (capital goods), whether standard or custom made
- product complexity (number of components)
- the cycle of innovation of the products
- production runs
- production routes
- the mode of evolution of production routes.

These factors are not completely autonomous in relation to the others. There is, for example, a relationship between:

- product design and production runs
- product complexity and production routes
- product design and cycle of innovation.

Implementation of a strategy for the manufacture of capital goods will necessitate special studies for each case in order to determine the components and the sub-components of the technology for manufacturing these capital goods which must be mastered as a matter of priority. The systematic and detailed list of the various components and sub-components, together with their modes of support, is the first task to be carried out in such an approach, so that it is then possible to select and rank the components and sub-components as a function of the choice of strategies for the development of products and routes.

CHAPTER I. CHALLENGES INVOLVED IN THE TRANSFER OF CAPITAL GOODS MANUFACTURING TECHNOLOGY.

When one is led to take an interest in capital goods one naturally gives priority to the material aspect, the machines, the components, the sub-assemblies and the manufacture, that is to say the hardware aspect. In a way which may, at first sight, seem paradoxical the most important aspect in the capital goods industries, and one which is often minimized, is the non-material, the supply of information, the software. This importance of software in the capital goods industries is reinforced by the dynamism of the social division of labour in the industrialized countries between the productive sectors: capital goods, intermediate goods, consumer goods.

1 - The strategic role of the capital goods industries in the mastery of software

1 - 1. The importance of software

Chapter I emphasized the quantitative importance of the service and design activities, that is to say of software, in the capital goods industries. In terms of number of jobs these service and design activities account for 25 to 30% of the total jobs. In the consumer goods and intermediate goods industries the software activities are in general much lower, representing only about 10 to 15% of the jobs.

We have been able to see, that software activities develop as a function of the complexity of the capital goods to be constructed, and that this development of software activities is carried out through a diversification of this type of activity:

- diversification of design and R & D activities;
- diversification of production organization activities: activities involving methods, planning and supplies;
- diversification of technical support activities;
- diversification of quality control activities;
- diversification of marketing and engineering of demand activities.

It is this important diversity of the software activities in the capital goods industries which makes any analysis of these industries difficult and complex. For Professor T. Vietorisz, who spent many years in research on the capital goods industry: "These industries defy analysis and elude effective policy-making based solely on the traditional approach of tracing the flows of material resources through producing and consuming activities .... Key issues compel the broadening of the analytic focus from material flows alone to a parallel concern with information flows, especially as embodied in organizational structure and symbolic communication systems"[1].

In attempting to understand the dynamism of operation of the capital goods industries T. Vietorisz suggested looking more to the construction of an information model which would integrate three principal dimensions: the differentiation of structures (or their diversification), external liaisons (extension and diversity of external communications), and structural integration (interrelations, flexibility).

---

(1) T. Vietorisz: "Structure and change in the engineering industries." Meeting of steel experts on the industrial and technological development of Latin America. Washington D.C. - 21-25 June, 1971. Inter-American Development Bank.

1 - 2. A trend: the transfer of software activities linked with the consumer goods and intermediate goods industries towards the capital goods industries

The quantitative and qualitative importance (appreciated in terms of their diversity) of software activities in the capital goods industries is due in a large part to a movement of transfer of software activities linked with the consumer goods and intermediate goods industries towards the capital goods industries. This movement of transfer is the principal result of technical progress trends in the industrialized countries.

The principal characteristic of technical progress in the industrialized countries for several years has concerned the saving of labour. The widespread and general use of automation, and in particular the recent development in micro-electronics (micro-processors), has accentuated this trend of technical progress and has enlarged its impact. One of the characteristics of automation is to integrate into machines, or rather into complexes of machines, part or all of the activities of preparation and work organization. If mechanization has made it possible to integrate into capital goods part of the individual skills of workers automation makes it possible to integrate into capital goods the collective work of the workers by means of the software of complexes of automated machines. The collective labour of workers in a production unit can be appreciated in an initial analysis through the total information (technical and organizational) which the production workers exchange between themselves and also with the workers in the departments dealing with the preparation and organization of production and, to a lesser extent, with workers in other departments (design, quality control, marketing, etc.).

"Communication and the exchange of information was one of the characteristics of the groups of homogeneous workers who were trained on the new assembly lines or even, with more effort and difficulty, in spatial isolation, amongst the operators on a long production line. This contributed to the profits of the owner and towards improving the quality of the product, but one can consider as being positive for the worker the fact that he developed a true professionalism"(1). Through the software of automated systems for machines automation corresponds to the monopolizing of the collective know-how of the workers(2) by capital. Now, through automated systems of machines, the "collective know-how" confronts the workers: "With the widespread use of electronic systems for process control communication is often replaced, where it exists, by an exchange of information with the computer or with the data processing terminal; the possibility of centralized control in this way is recovered. Better still one eliminates the human intermediary, which can introduce errors into transmission, from the hierarchy of the enterprise; finally this control is effected in real time"(1).

It is also under the impulse of the widespread and generalized use of automation that innovation in the consumer goods and intermediate goods industries is increasingly taken over by the capital goods industries(3). The capacity of the manufacturers of capital goods

(1) Angelo Dina, La situation actuelle en Italie (The present situation in Italy), Bulletin of the Fondation Renard. Dossier post-Taylorisme, No. 88-89, May-June 1978.

(2) Automation has often been presented as the replacement of the mental activity of man by machines. This type of transfer corresponds rather to the process of automation which is situated in the same logic as mechanization at the level of replacement of the physical force of man.

(3) This observation is to be compared with one of the conclusions of the recent OECD report on "La science et la technologie dans le nouveau contexte socio-économiqe" (Science and technology in the new socio-economic context), Paris, Sept. 1979: "The remarkable progress accomplished in the field of electronics has opened up vast possibilities of innovation for electronic products and equipment goods. This advance is contrasted with the trend towards depression manifested in the chemical industries sector and other industries producing intermediate goods" (p. XI).

to master the introduction of automation in their machines, to propose new automation processes and to enlarge the automation of processes already partially automated, is one of the increasingly strategic factors for competition for manufacturers of capital goods.

It is again under the impulse of automation which transforms the processes of batch production into processes of continuous production that final clients have not yet been capable of mastering the design of industrial complexes through their new works departments. The widespread and general use of automation has resulted in the creation of autonomous engineering structures, or those linked with the manufacturers of capital goods. The engineering structures integrated in the capital goods manufacturing companies have a tendency to reinforce themselves (to the detriment of the autonomous engineering companies) in the form of specialized design services, of services of assemblers or of a general contractor. These structures increasingly constitute a normal prolongation of the marketing activities of companies manufacturing complexes of automating machines.

Maintenance activities, in the same way as other software activities, have a tendency, under the impulse of automation, to be transferred from the consumer goods and intermediate goods industries towards the capital goods industries (and in certain cases towards specialized companies). It should be emphasized that maintenance activities involve software activities rather than hardware activities[1].

---

(1) In his book: "La Parole et l'Outil" (The Word and the Tool) (PUF 1975), J. Attali classes maintenance and repair activities amongst dominant information activities under the same heading as the activities of consultancy companies, architects, etc. "Maintenance is an information, since it makes it possible to maintain order in the parts of a machine and to avoid its degradation" (op. cit., p. 68).

2 - Capital goods and the international division of labour

It was emphasized in the previous paragraph that, under the impulse of technical progress and in particular under the impulse of the widespread use of automation, a differentiation took place in the industrialized countries between the following productive sections:

- firstly the consumer goods and intermediate goods industries, with the widespread use of continuous production processes and of unskilled labour;

- secondly the capital goods industries, with the polarization of skilled labour in these industries and in the specialized design companies (engineering, management and maintenance) which are increasingly linked to them.

It is on the bases of this social division which operates in the industrialized countries that an attempt has been made to impose the new international division of labour: the industrialized countries specializing in capital goods industries, specialized service companies and research centres, whilst the consumer goods and intermediate goods industries, can more easily be transferred to the developing countries.

Implementation of this international division of labour has been encountering with new trends in the world economy:

- certain newly-industrialized countries, such as India, Korea, Brazil and Argentina, are beginning to export capital goods towards the developing countries.

- the relocation of industry is, in certain cases, operating only on certain segments of the production route.
- the industrialized countries are attempting to protect their national industries and are opposed to any competition from the developing countries in certain consumer goods industries (textiles, for example), operating innovations which economize on labour and hence on labour costs.

Despite these trends it is around the capital goods that the principal challenge of the new international division of labour is located, and it is around these capital goods that competition is becoming more intense in the industrialized countries for "exports to the Third World, since the growth of these exports is the inevitable counterpart of the increasing imports of manufactured products, raw materials or energy"(1).

2 - 1. Specialized and complex capital goods

The social division between productive sections in the industrialized countries which depend on the introduction of innovations at the level of capital goods has, as its consequence, the increasing specialization of the manufacture of capital goods and the increasing diversity and complexity of capital goods: "Since the industrial revolution the need for technical innovations in capital goods has not ceased to make itself felt. The search for new models and efforts to improve the reliability in operation of machines have resulted in the increasing specialization of production and the increasing diversity and complexity of products"(2).

---

(1) Interfuturs - OECD Paris 1979

(2) OECD "La science et la technologie dans le nouveau contexte socio-économique" (Science and technology in the new socio-economic context) Paris, September 1978, p. 74.

This evolution of capital goods in the industrialized countries makes the transfer of technology for the production of capital goods to the developing countries more difficult.
It also makes the capital goods supplied by the industrialized countries less and less suited to the economic and social conditions specific to the developing countries.

3 - Difficulties in transferring software dominant technology

A large part of the software activities in the capital goods industry involves the technology of organization. The efficiency of a design office, of an engineering department, is based on the methods of organizing work. The technology of organization is concerned essentially with a production and/or design work collective. The software of the capital goods industries therefore has an essentially collective aspect. This collective software is shown through the methods of organization but also through the attitudes and reflexes of the workers which reflect the acceptance and the adaptation or, in certain cases, the rejection of these methods of organization. These attitudes and reflexes of the workers in relation to the methods of organization constitute the collective know-how of the workers. It is through this collective know-how of the workers and the methods of organization that the collective labour[1] of the workers is exercised, that is to say the exchange of technical and organizational information necessary for the production of goods and for the carrying out of design work and engineering.

3 - 1. An aspect of transfer of technology which is still inadequately studied

The transfer of technology of a software character is generally carried out through training programmes in specialized training sessions and in sessions in the production units. This type of transfer is generally concerned with the acquisition of the knowledge and know-how which each worker must master individually if he is to accomplish a particular task. The acquisition of collective know-how is rarely taken into account in the operations of transfer.

---

(1) As opposed to individual know-how and the individual knowledge of the workers

It can be observed that many operations of the transfer of technology come up against the particular transfer of organization technologies:

- "It is not basic technical training in regard to manufacture which is lacking in the Indian companies which manufacture measuring instruments but rather the modern management techniques applied in the more industrialized countries"(1).

- According to the Director General of the Algerian National Iron and Steel company: "We have found in Algeria that the transfer of technology through individuals can be carried out effectively; Algerian engineers, foremen and operators have nothing to fear from their homologues in any other country. By contrast, however, we find that the transfer of collective technology is only mediocre. It is in this field that it is necessary to direct our research. How is it that we are capable of assimilating technologies at an individual level, but not at a collective level ?"(2)

The transfer of codifiable knowledge does not, a priori, present any difficulties: the transfer of organizational knowledge should be easier than the transfer of more abstract scientific and technical knowledge. By contrast the transfer of collective know-how relative to the technologies of organization is surely the most difficult to carry out. Difficulties in the acquisition of collective know-how undoubtedly necessitate rethinking training programmes and adapting machines and production systems as a function of the cultural and social characteristics specific to a country.

---

(1) UNIDO - Le développement des services d'études techniques dans les pays en voie de développement (The development of technical design services in the developing countries) - UNIDO ID/67 (I/WB 56/28).

(2) P. Judet, Ph. Kahn, A. Kiss, J. Tousciz - Transfert de Technologie et Développement (Transfer of technology and development) - Paris 1977, p. 532. International study days on the transfer of technology and development - Dijon - 30 September, 1 and 2 October 1976.

3 - 2. A preliminary phase: Memorization of industrial experience

Much of the research work which has been carried out on the problems of transfer and mastery of technology from the industrialized countries to the developing countries has placed the emphasis on obstacles to the circulation of technical information, on different strategies for widespread diffusion, of controlled diffusion or of retention of this information by the companies in the industrialized countries which hold this technical knowledge. By contrast very little work has been done on revealing the central role which the functions of memorization play. Without memorization, without the implementation of structures capable of storing knowledge and know-how which are specific to the geographically socio-economic conditions of the developing countries, the policies of transfer of technology implemented by the developing countries can only result, in the best of cases, in new forms of economic dependence.

The developing countries cannot arrive at technical and hence economic and political independence unless they have this capacity for memorization of the industrial and technical experiences which they have acquired through the operations of transfer of technology[1] organized by companies in the industrialized countries.

---

(1) In Mexico the Register of Transfers of Technology, created in 1973 to evaluate the cost and content of imports of technology, is beginning to take over this function of memorization of technical experiences. "A second aspect of the Registry's evolving role is increasing the domestic capacity to evaluate technical aspects of know-how and R & D. As a start the Registry is making contact with local information sources such as the State-owned Laboratorios Nationales de Fomento Industrial - an R & D facility with a reasonably sophisticated information bank - and the Centro de Información a la Industria - also a technical information bank - based in Mexico City. Closer coordination with such agencies could broaden the Registry's own knowledge of technology and enable it to tap sources to help research and evaluate the technology offered" (Business Latin America, June 7, 1978).

Implementation of these capabilities for memorization, and the objectives to be assigned to these memorization capabilities, can differ according to the level of mastery of the techniques concerned and according to the industrial branches concerned. In the case of the capital goods industries, characterized by a software dominant technology, necessitating considerable collective know-how, the objectives of the implementation of memorization capabilities by the developing countries could be related:

- to the collecting of observations on the difficulties encountered by different workers' collectives in relation to the transfer of technology of organization, and in respect of certain types of division of labour;
- to attempt at interpretation of these difficulties;
- to attempt at the adaptation of certain forms of the division of labour and of the technologies of organization.

This memorization of industrial experience relative to the implementation of capital goods industries can only be carried out within the permanent structures linked to these industries:

- structures of specialized engineering for the mechanical and electrical industries (engineering of the supply).
- centres for technical study and research, specializing in mechanical and electrical engineering.
- centres for research, study and training on methods of organization in mechanical engineering.
- reinforcement of the studies and organization structures in companies manufacturing capital goods.
- structures of the engineering of the demand.

CHAPTER II - ROUTES AND CHANNELS FOR TRANSFER OF TECHNOLOGY TO DEVELOPING COUNTRIES.

1 - Entry routes

One may assume that the developing countries will begin their entry into the manufacture of capital goods by producing those products which call on the least complex production routes, that is to say boilerwork and heat welding. It is this which the sectoral studies have, in general, verified:

- The study on capital goods for the iron and steel industry notes that entry of the developing countries into manufacturing capital goods:

"commences with the production of metal structures and boilerwork and progresses to the production of medium and finally heavy metal structures.

This is followed by the production of heat welded products such as gantries and elements of sub-assemblies for the treatment of minerals, with the integration of mechanical components such as speed reducers.

This results, progressively, in the construction of the principal upstream and downstream equipment, from agglomeration to finishing"(1).

- The study on capital goods for petrochemicals and fertilizers shows that entry of the developing countries into manufacturing capital goods takes place through:

  - the construction of metal structures,
  - the assembly of pipework,
  - the construction of boilerwork.

Even in the case of complex capital goods such as process compressors, the sub-assemblies, calling mainly on boilerwork or heat welding (stator, oil unit), can be constructed in certain developing countries.

---

(1) Study : IREP : Biens de capital pour la sidérurgie (Capital goods for the iron and steel industry)

- The study of capital goods for the production of electrical energy emphasizes that, in the manufacture of hydraulic turbines, the developing countries can begin by producing elements and sub-assemblies (evacuation, man-holes, tanks, reservoirs, footways, pressure vessels, etc.).

"These parts do not demand major industrial resources. They involve sheet metal of less than 60 mm thickness. The resources which are needed are capacities for bending and welding (manual welding, without major quality control). No methods department is necessary. Manufacture can be carried out on the basis of working drawings supplied by the firm owning the technology. Mastery of the manufacture of this type of plant by the developing countries may take 3 to 5 years and represent 25% of the overall price of a hydraulic turbine".

1 - 1. Some examples of entry into the manufacture of capital goods

Before independence Algeria had only one small and old unit for the production of concrete reinforcing rod[1]. The S.N.S., the National Iron and Steel Company, undertook the construction after independence of a first iron and steel unit with a production of 500,000 t/year in the initial phase (beginning of the sixties). Many foreign manufacturers participated in the enterprise from the first phase onwards: Russian, German (Hoesch, then Demag), Italian (Innocenti), British (Davy & Atkins), French (Sofresid and Vallourec) and Japanese (Nippon Steel). From the beginning the S.N.S. clearly showed its desire to participate in the equipment and the erection by systematically promoting its national potential for manufacturing equipment goods.

(1) cf. Study: "Capital goods for the iron and steel industry", p. 30.

To this end the potential available in existing units was carefully listed in the metal constructional work, boilerwork and mechanical engineering sectors.

The following were effectively integrated:

- light, medium and heavy metal structures,
- gantries,
- speed reducers,

whilst new capacities for erection were developed.

On this occasion the following advances were achieved:

- from the construction of light and medium metal structures to the construction of heavier structures
- from the construction of light gantries to the construction of heavier gantries
- from the production of parts to the production of complete speed reducers, etc.

Tunisia[1]. A small iron and steel unit of about 450 t/year was constructed in Tunisia[2], from 1964 to 1966, for the production of concrete reinforcing rod and small merchant goods. The unit was designed by Atkins and built by Davy Ashmore (cast iron division), Creusot-Loire, (steel division) and Morgardshammer-Asea (rolling mills and finishing). The Tunisian Iron and Steel Company required its foreign partners and suppliers to accept not only local participation in painting and civil engineering but also in metal structural work; the Tunisian SGI company supplied and partly erected the metal framework of the rolling mill and the steelworks, and this intervention allowed this Tunisian company to produce relatively heavy structural work for the first time.

(1) cf. Study: "Capital goods for the iron and steel industry", p. 31.
(2) at Menzel Bourguiba a wire drawing plant and then a plant for the production of metal structures were subsequently built.

In the absence of a sufficiently experienced design office SGI could only produce this structural steelwork using the assistance provided by the consultant engineer and by the design offices of the suppliers: this is the basic condition for the effective implementation of a potential production capacity.

Tunisia[1] has for several years been establishing its phosphate fertilizers industry. Production units in this type of industry, which very frequently operate with corrosive materials, require major maintenance work. A maintenance shop was therefore created at Gabés for the phosphoric acid plant, and a cooperation and technical assistance agreement was signed with a French boilermaking company.

In Morocco[1], which also has a phosphate fertilizer industry, the subsidiary of a French company built the drying ovens (diameter 4 m, length 20 m). The mechanical parts (crown wheels, bearings, etc.) were imported.

In conclusion it can be said that the manufacture of capital goods (or sub-assemblies) such as boilerwork and metal structural work (framework) are privileged routes for developing countries to commence the manufacture of capital goods and then to expand the production towards a more complex products.

(1) Study on capital goods for the petrochemicals industry. (IREP).

2 - The "hard cores"

As a function of the presentation of the complexity of products and production routes, as described in Chapter I, the capital goods in respect of which the transfer of manufacturing technology will be most difficult to realize will be the capital goods which are complex from the point of view of the products (measured by the number of elements, for example the tractor) and those which call on complex routes (forging, casting, heat treatment and machining).

- The study on capital goods for the iron and steel industry observes that in this case the "hard core" (that is to say that group of capital goods which presents the greatest problems for integration in the developing countries) consists of:

  - high-performance mechanical equipment,
  - measuring, control and regulation equipment,
  - goods closely linked to processes, such as catalysts,
  - and, very generally, all equipment which makes it possible to link, modulate and control a system.

- In the study on capital goods for the building industry the capital goods where the transfer of technology is difficult to realize are those which call on the advanced technologies: equipment for drilling, dumpers, and sub-assemblies for hydraulic systems.

- In the field of capital goods for the production of electrical energy, and more precisely for the mastery of the construction of hydraulic turbines, the hard core consists of:

  - the active part of the rotating movement (a part of high technicity, requiring very skilled labour, very accurate machines and know-how in respect of control, adjustment and coating with anti-friction metal),

- the turbine regulation system, composed of electronic and hydraulic sub-assemblies.

- In the case of the study on capital goods for petrochemicals and fertilizers the hard core consists of:

  - some rotating machines, or sub-assemblies of these very high-performance or very specific machines: process compressors (or rotors for these compressors), gas turbines, process pumps,

  - most of the control and regulation equipment.

In conclusion the hard core for complete mastery of the manufacture of capital goods by the developing countries consists of:

- certain sub-assemblies of rotating machines of high technicity,

- systems for electronic and hydraulic regulation.

2 - 1. Example of capabilities for manufacturing capital goods for petrochemicals in some advanced developing countries

in Brazil:

- Brazilian boilerwork companies can provide 90% of this type of plant used in the construction of chemical investments. The principal firms, which have foreign names (Nordon, Mitsubishi, Creusot-Loire), are now 100% nationalized companies; they have signed licencing and cooperation agreements with their former parent company. Reactors of thicknesses up to 50-80 mm are built locally.

- In the field of pipework and valvework all the equipment (pipes, connectors, flanges, valves) are produced locally except for some alloy steel tubes and some spherical valves (necessitating very accurate machining) which are imported.

- Mechanical equipment is provided by Brazilian companies which have retained their original names such as Worthington, Breguet-KSB, Gould and Sulzer.

Most of the pumps, meeting API chemical standards, are produced locally (up to a power corresponding to a flow rate of 10,000 m^3/h at 6-7 bars).

Steam turbines (up to a pressure of 40 bars) are also built locally.

Turbo-alternators are built within the framework of cooperation agreements with foreign firms such as Siemens.

- Electrical equipment (motors, transformers, rectifiers, cables) are supplied by Brazilian companies, which also install them. Some variable speed motors are imported.

- Most of the instrumentation equipment is imported. Some foreign companies (Mazoneillan, Fischer Central) are beginning to produce small control valves locally. The purchase of instrumentation equipment and work is usually the subject of an overall contract with a foreign company.

- In the field of equipment goods for the production and distribution of electrical energy about 30 companies produce a wide range of electrical equipment; the majority of these are subsidiaries of multinationals, the two largest of which are General Electric of Brazil and Siemens S.A.

in India:

- Indian boilerwork companies are capable of providing all boilerwork equipment, except when there is a shortage or lack of supply of special steels. Some companies have design capabilities which are still weak, and so have to ask foreign engineering companies to produce the working drawings of items such as heat exchangers.

- In the field of electrical equipment goods the importance of a public company, Bharat Heavy Electrical Ltd (BHEL), must be emphasized, as this has certainly contributed towards favouring the development of the electrical equipment goods sector:

"Founded in 1955 this company signed, during its first years, technical collaboration agreements with the United Kingdom, the Soviet Union and Czechoslovakia to train personnel and to obtain technical designs and machinery. At the present time BHEL, with an annual capacity of 4,000 to 5,000 MW is one of the top ten manufacturers of electrical equipment in the world. This company is currently devoting 3 to 3.5% of its turnover to research and development, and has signed a collaboration agreement with the West German K.W.U. company to make large size steam turbines and generators up to 1,000 MW, and is presently engaged in the manufacture of its first 500 MW set. In all smaller ranges the company is self-sufficient. The increase of the capacity installed in India by 1,720 MW in 1974-75 is 80% due to BHEL, and of the additions which are forecast in the fifth Five-Year Plan 85% will consist of BHEL equipment"(1). At the present time India has arrived at a stage which allows it to be present on the international market; 15% of BHEL's production goes to foreign users(2), whilst its technical capabilities and its low labour costs(3), both in design and manufacture, mean that this company is able to find large outlets in the developing countries.

(1) "Energy supplies for developing countries: Issues in transfer and development of technology". UNCTAD Secretariat. TD/B/C.6/31 - 17 October 1978.

(2) During the 1976-77 financial year the company received an order from Libya for the turnkey production of a 2 x 120 MW power station, an order from New Zealand for hydraulic generators with a total power of 544 MW, and an order from Saudi Arabia for the Wadi-Jizou electrification project.

(3) Production costs are, on average, 10 to 15% lower than those of Japanese companies.

- 90% of valvework and valves is provided by Indian firms.
- Pumps are manufactured by the KSB company (subsidiary of the German company), but production is still insufficient to meet the demand.

- In the field of compressors, air compressors are produced locally. Gas compressors are also produced locally as a result of a collaboration agreement with a foreign firm.

- A collaboration agreement for gas turbines has been signed with the American Worthington company.

At the "ACHEMA" world exhibition of equipment for the chemical industries, held at Frankfurt in 1978, Indian firms manufacturing capital goods participated for the first time in this type of exhibition, attended by the main world manufacturers and exporters of chemical equipment.

The principal Indian firms manufacturing capital goods are either public companies or subsidiaries of foreign companies, the most important of which is A.P.V. (subsidiary of the British company). The firms in the public sector were created with the support of technical assistance from the USSR and Czechoslovakia. The production capacities of these public firms are frequently under - utilized.

<u>In the Republic of Korea:</u>

Capacities for manufacturing capital goods have developed very rapidly in Korea. Boilerwork companies are at the present time capable of building this type of equipment up to 100 mm thickness, whilst electrical engineering companies can provide practically all the electrical equipment for chemical investments.

It is in the field of mechanical engineering that the most rapid changes have taken place with the construction of the Changwon complex. "This industrial complex, a pet project of the Government, is supposed to "Korealize" machinery supplies, a basic need for national security"(1). This complex, in which about a hundred Korean companies are sharing, including the principal machinery manufacturers (Samsung Heavy Industries(2), Doewoo Machinery and Huydai) and the Japanese Toyo company (25% of the capital), is being built by the Korean Halla Construction company. In 1968 41 companies were already producing machines or components in this complex.

- for the production of energy (hydraulic, thermal, nuclear): turbines, generators, boilers, nuclear reactors.
- for the iron and steel industry: blast furnaces, convertors, rolling mills.
- for the chemical and petrochemicals industries: tanks, heat exchanger towers, compressors, filters.
- for desalination installations.
- for building and public works.

Licence agreements have been signed on a world scale with the principal machine manufacturers: General Electric (USA), Combustion Engineering (USA), Neyrpic Creusot-Loire (France), Alsthom-Atlantique (France), Krupp (FRG) and Demag (FRG).

When this complex is completed in 1981 it is forecast that Korea will cover 70% of its domestic requirements for machinery. The complex, built on the coast with its own port facilities, is also directed towards exporting (in 1978 $1,055 million were exported out of a total production of $2,878 million).

---

(1) The Japan Times - June 7, 1978

(2) It should be noted that the Sam Sung group, the principal shareholder (50%) in the complex, is also the parent company of the Korea Engineering company.

3 - The channels for transfers of technology for manufacturing capital goods

The various sectoral studies on capital goods summarize the different channels used for the transfer of technology for manufacturing capital goods:

- creation of join-ventures and subsidiaries
- licences to use patents
- know-how licences
- contracts for the engineering and construction of factories
- contracts for the study of product design
- management contracts
- training contracts
- contracts for cooperation and technical assistance.

The study on agricultural machinery justly emphasizes the fact that purchases of patents and know-how licences are the two most widely used systems for transfer, but points out that other channels of transfer could be used.[1]

- "joint ventures" (cooperation agreements). The value of this type of agreement is that it makes it possible for the experts of the holding company to work with the personnel of the recipient company.
- employment of consultants, experts and specialized technical departments to acquire the various components and sub-components in the technology for manufacturing capital goods.
- purchase and detailed analysis of capital goods in order to acquire the principal aspects of design, production and utilization.

---

(1) "Because of the preoccupation with "contractual transfers" there has been too little analysis of other ways of acquiring technology which might in some cases be useful alternatives. Consequently the range of options in technology markets is only partly explored and still less understood". UNCTAD - Manual on the acquisition of technology by developing countries - New York 1978, p. 5.

- The systematic utilization of published technical information. This type of channel for the transfer of technology should be systematically used. The quantity of information and knowledge assembled in this way is often very considerable. This metnod makes it possible to reduce the cost of transfers of technology, agreements for transfer being limited only to those segments of the technology which are still alienated by firms.
- Training of the personnel of the developing countries in industrial complexes located in the industrialized countries or in other developing countries.
- Employment of national workers who have emigrated for some years to the industrialized countries, and who have acquired industrial experience.

This preoccupation of the study on agricultural machinery not to limit transfers of technology simply to agreements for licensing patents and know-how, but to diversify the channels of transfer of technology, links up with one of the conclusions of Chapter I: the technology for manufacturing capital goods calls on technical knowledge and know-how which is very diverse, and which can be acquired in many different manners. In order to ensure the maximum transfer of know-how, technical and technological knowledge, to place the maximum number of partners holding this technology in a situation of competition, and to reduce the cost of the operations of transfers of technology, it is of value to the developing countries to diversify the channels for acquisition of technology and to select those channels which are best suited to the transfer of each component and sub-component of the technology to be transferred.

Adapt the media used in the transfers

The study on agricultural machinery draws attention to the fact that transfers of technology between industrialized countries and developing countries operate between partners who do not have the same mastery of technical language and technical symbols (layouts, diagrams, formulae, drawings, standards, etc.), and who do not have the same culture. "This gap cannot be offset by a bridge of paper documents sent by mail. This gap can, however, be bridged in different ways.

- Printed information: drawings, manuals, descriptions, standard procedures can be rethought and rewritten so as to be simpler and more accessible and clearly explaining "how to do it".

- Symbolism: local traditions and habits should be incorporated in the media, avoiding references to unfamiliar environments.

- Visual support: preference should be given to visual supports and images rather than written instructions. Information integrating all three dimensions and photograpns are easier to understand than technical concepts.

- Inter-personal relations: the accent should be placed on transfers by means of inter-personal relationships through training on the job, assistance from experts and practical demonstrations of production systems.

- Written language: the written language should be, as far as possible, simple and standardized with a limited use of idiomatic expressions.

4. The challenges, difficulties and channels for transfer of some components of the technology for manufacturing capital goods

4 - 1. Technology of design of the production process

This component can be broken down into two principal sub-components:

- Analysis of the supply and demand - selection of capital goods to be built (Preliminary studies relating to the capital goods industries)
- Design of production units - Selection of production routes, specification of machines (Study of process engineering).

4 - 1.1. Preliminary studies

This type of study is very often carried out by the specialized design offices of the final clients (New work departments) or by specialized engineering companies. In the developing countries the owner does not have any new works department and must therefore call on specialized design companies or foreign engineering companies. However it is essential that owners in the developing countries should specify at the stage of the preliminary studies the fundamental orientations (alternative technology, products to be produced, routes, etc.) which the design or engineering companies must integrate. If the owner is to be able to fulfil his role of orientation and control of the work of the design and engineering companies he must have his own design office structure. This structure, consisting of engineers and economists, must be capable of carrying out, or at least following, studies in regard to the demand, supply, complexity and technological routes. UNIDO has undoubtedly a special role to play in assisting the developing countries in creating design offices for the final client in the capital goods industry. The organization of training courses in this field would be very desirable.

4 - 1.2 Process engineering in capital goods units

In the process industries (petroleum, petrochemicals, chemicals, iron and steel, food and agriculture and cement) one of the most difficult design tasks to master is the process engineering which, in the industrialized countries, is often delegated to a specialist engineering company. The role of process engineering is to establish the flow sheet which dictates the lay-out of the production unit and the principal characteristics of the equipment. The flow sheet of a given production unit is an optimization of the process as a function of the expected characteristics of the final product, the specific characteristics of the inputs, and the other factors involved in production.

For the developing countries the strategy of entry into, and development of, the capital goods industries assumes a concept of production units for capital goods rather different from that in the industrialized countries. In these countries the division of tasks between the production units, the specialization of units on certain well-defined productions and the organization of labour are the product of their economic and social history. In the developing countries it is a question of designing capital goods production units which optimize, as far as possible at a given moment, the demand, the capacity of the supply, the degrees of complexity and the multipurpose production routes. The basic concept, the design of flow sheets for production units in the capital goods industries in the developing countries, is more complex in its realization than in the industrialized countries. It is under these conditions that one can speak, in the capital goods industries to be developed in the developing countries, of the necessity for specialized processed engineering structures in the capital goods industries.

Engineering companies capable of supplying process engineering for the capital goods industry are not very numerous. Such companies must have a very high mastery of the know-how of specific production in the capital industries and, more generally, in the engineering industries. They must be capable of moving outside the classical solutions which they know and of proposing new formulae for the organization and management of production. They must be capable of developing the standardization of equipment and of developing new formulae for modular construction.

The Techniberia study on capital goods for the building industry has defined, in detail, the services which process engineering should provide (engineering for manufacturing and assembly processes) for the production units manufacturing capital goods for the building industry:

- Selecting phases of the production process, and those phases which should be sub-contracted
- Determining sequences of operations and work cycles
- Determining times for operations
- Defining standards and specifications for components and sub-assemblies
- Arranging machines and work stations in the production units
- Determining movements of materials and parts
- Defining quality control tests
- Selecting and choosing machines and other equipment
- Determining systems for receiving components and sub-assemblies and systems for partial and final assembly
- Designing test and quality control tests

For each of the principal operations (boilermaking, forging, casting, machining, heat treatment and assembly) the study gives, in detail, the various tasks which process engineering needs to carry out.

4 - 2. Technology of product design

4 - 2.1. A strategic technological component for companies in the industrialized countries

- In the case of complex capital goods (public works equipment, tractors, pumps, compressors, gas turbines, hydraulic turbines, etc.)(1) the technology of product design integrates the results of R & D and constitutes the principal factor in competition between firms. As a consequence the transfer of the technology of product design for complex capital goods is sometimes difficult to realize because of the obstacles and limitations to transfers raised by the firms which possess this type of technology. The Techniberia study on capital goods for the building industry and the study on agricultural machinery emphasize this aspect of the obstacles to the transfer of technology.

---

(1) "In turbines there is very considerable competition between manufacturers on the world market, with increasingly rapid obsolescence in the design of turbines and methods of manufacture. This obsolescence does not relate to the whole of the turbine, but only to certain sub-assemblies. What manufacturers seek is the reduction in the cost of manufacture of these sub-assemblies as a result of research carried out in the metallurgy of metals and in the design of manufacturing methods. R & D effort and design study is essential if the company is to maintain its position in international competition".

- In the study on capital goods common to all branches[1] ICME notes two principal obstacles to the transfer of technology concerning the construction of capital goods:

  - cartellisation and international agreements between firms in the industrialized countries,
  - the fear of firms holding know-how of creating their own competition by signing agreements for the transfer of technology to countries with low labour costs.

Techniberia proposes overcoming these obstacles by reinforcing the capacity for negotiations of the developing countries by concerted action of these countries at regional market level (Andean Pact, Arab countries, EFTA). The size of a regional market makes it possible for the developing countries to negotiate the transfer of technology under better conditions. The strategy for transfer could be as follows[2]:

- Determine the components and sub-components of the technology of manufacturing the capital goods to be mastered,
- Organize a strategy for assimilation of technology and innovation
- Transfer modular techniques which are not so far mastered
- Train personnel (innovation, design, process engineering, organization of maintenance, etc.).

---

(1) Study: ICME - "Capital goods common to all branches of industry."

(2) Study (TECNIBERIA): "Capital goods for the building and public works industry", p. 195.

4 - 2.2. A priority: adaptation

All the sectoral studies on capital goods emphasize the importance of adapting the design of capital goods to production capacities, to available materials and to the conditions of utilization of the capital goods, which are specific to each of the developing countries.

- The study on capital goods for the building industry and the study on agricultural machinery both draw attention to the adaptation of equipment to the geological characteristics of the soils being worked and to the particular conditions of use of these items of equipment. This adaptation of the design of capital goods is not easy to carry out, even for fairly simple capital goods. In fact the design of hand-tools or animal-draught equipment adapted to local conditions at a technical and agronomic level necessitates similar knowledge to that used in the design of sophisticated machines, even if the level of production and of technical resources change.

- The adaptation of capital goods does not relate solely to their particular use in the developing countries but also concerns the specific conditions of production and of local supplies of materials, components and sub-assemblies.

The study on capital goods for the petrochemicals industry recalls the experience of Brazil which only began to participate in the supply of capital goods for refineries constructed in Brazil from the time that a group of Brazilian industrialists created, in 1975, the "Association Brasiliena para el desenvolvimiento de las industrias base" with, as its objective, the study of the specifications of American engineering companies and their adaptation to local construction capacities. In India, at a symposium organized by the Indian Engineering Association, it was emphasized that: "If the detailed specifications for an item of equipment are determined outside India, and if this equipment must finally be purchased in India, it can happen that such equipment with foreign specifications is not available in India. However, detailed examination of the specifications may show that the specifications relative to the materials used and to the manufacturing details can be modified and adapted to local availabilities of material and the capacities of Indian manufacturers of equipment goods."

4 - 2.3. Centres for the study of specialized research and design technologies

The study on agricultural machinery emphasizes the role which has to be fulfilled, in the implementation and development of this sector, not only by research and special testing centres for agricultural machinery (Agricultural Machinery and Testing Centre - AMRTC) but also by research and testing centres common to the various mechanical engineering industries (Metal Industry Research and Development Centre - MIRDC). In the case where the level of development of agricultural machinery does not yet justify the creation of a centre specific to this sector it is nevertheless suggested that provision be made for a research and testing centre for the engineering industries.

The role of these research and test centres would be to:

- Define technologies and production processes adapted to local materials and components
- Contribute to personnel training
- Collaborate with sectors using capital goods in order to adapt, test and improve the machines
- Standardize and control local or imported materials
- Carry out economic and technical evaluation studies on the manufacture of certain capital goods.

Part of the activities of research and design of capital goods can therefore be grouped in the centres of technical studies which specialize in one sector or are common to the mechanical engineering industries. This is one of the preoccupations of the UNIDO document on "The development of Engineering Design Capabilities in Developing Countries"(1) which gives priority to the need to establish sectoral design centres.

It is nevertheless firmly pointed out that "Design and production should never be in self-contained departments but should rather form part of the same continuum. While it is not always possible to have design and manufacture in the same geographical location it is essential to ensure that there are very good communication links between these two activities to foster cooperation, for no design can be economical unless it takes cognizance of the manufacturing capabilities of the producing concern"(2).

---

(1) UNIDO - 1972 - ID/67 (IDI/WG.56/28).

(2) op. cit., p. 26.

Within the framework of considerations and research on the adaptation of technologies for the developing countries the United Nations (UNIDO, UNCTAD, Economic and Social Commission) have insisted in recent years on "Product Design" and "Plant Design". It can be confirmed, on the basis of what has been said above, that the adaptation of technologies also undoubtedly necessitates the mastery of "Capital Goods Design" as a priority. The mastery of "Capital Goods Design" passes through the organization of the technical design, a division of labour which can be different from that implemented in the industrialized countries.

4 - 3. Engineering of the demand

Once they have been constructed the capital goods must be utilized to constitute a new production unit. This function of supplying capital goods to form a new productive unit is carried out by specialized engineering companies. In certain cases the companies producing capital goods integrate this engineering activity as a complement to their sales activities.

Secondly in order to construct public works (roads, airports, ports, bridges, etc.) or buildings (including the industrial buildings which house the capital goods), companies involved in building use capital goods. The methods of use, the definition of the tasks to be carried out, the organization of the intervention concerning these capital goods, are defined for the realization of each project by an engineering structure which is either independent or integrated by the public works and buildings enterprises.

- The study on capital goods for the building industry has emphasized the role of engineering (a specialized company, or a structure integrated in the public works and building companies) in relation to capital goods for the building industry.

In the developing countries the role of the engineering of demand is particularly important to favour the adaptation of constructional equipment to geological, economic and social conditions, and in particular labour conditions, specific to the developing countries.

The iron and steel engineering companies in the developing countries are not numerous. One can cite the case of Dastur, the Central Engineering Design Bureau (CEDB), and Metallurgical and Engineering Consultants (MECON) in India. The CEDB was created by way of a cooperation agreement signed with the Soviet engineering organization Gipromez. This form of transfer of technology for the mastery of engineering is also found in Mexico and Algeria.

In Latin America the public petrochemicals companies Petroquisa (Brazil) and Pemex (Mexico) have developed their own engineering capabilities in the field of preliminary studies and project management. The detailed engineering is largely mastered in Mexico as a result of the creation of engineering companies such as Bufete Industrial. Despite the implementation of research structures, in particular in Mexico by Pemex (creation of IMP), process engineering is generally carried out by foreign firms.

In India the public companies producing fertilizers and chemical products have established their own engineering structures:

- The Fertilizer Corporation of India has created its own Planning and Development Division (P.D.)
- The Fertilizer and Chemical Company of Travancore (FACT) has created the FACT Engineering and Design Organization (FEDO)
- The Indian Government has created the public engineering company Engineering India Ltd.

These engineering structures carry out preliminary studies, project management and part of the detailed studies, but they have not generally arrived at a state of mastering process engineering.

The private Indian Tata Group has centralized its design and new works capabilities within Tata Consulting Engineers.

In the Republic of Korea the first engineering structures were created in the early seventies with State support. In the field of petrochemicals the most important engineering company is Korea Engineering Co.[1]. This firm, after having mastered the engineering of preliminary studies, buying and detailed project studies, has now launched into a strategy of programmed mastery of process engineering. This firm has built a polyester resin unit in Saudi Arabia. It should be recalled that in 1978 the Korean Keang Nam Enterprise Ltd., purchased the American Pritchard Engineering Company, and that the Korean Simotech Engineering Company has created a joint engineering venture with the American Bechtel company.

4 - 3.1. Experiences in the transfer of engineering technology

Within the framework of the realization of the iron and steel complex at El Hadjar in Algeria the state Iron and Steel Company, SNS, established as its objective the formation of its own engineering structure. At the beginning of the project all the studies concerning the production of cast iron and the general engineering of the complex were carried out in Paris by a French engineering company. For the rest there was only a site department, assuming control of the work.

(1) This company is a subsidiary of a Korean capital goods manufacturing company Sam Sun Co. and of the Japanese Engineering company Toyo Engineering Co.

Subsequently the SNS has created a new works department at El Hadjar. This department has an operational design office which sub-contracts for the foreign engineering company. Since the SNS wishes to use this design office as a starting point for an engineering department it is looking at different formulae for association with foreign engineering companies with a view to training its personnel in engineering work.

Formula for sub-contracting with Company A

This formula, which lasted for two years, was used for the design of the rolling mill and the general services. However it had two major disadvantages: the first was linked with the fact that the time needed for the design work was considerably increased by the many to-and-fros which the drawings had to make between the two countries. The second was linked with the attitude of the specialist engineers and the engineering companies. These are fully prepared to supply the basic data and to check the calculations, but found difficulties in supplying their own working methods.

Formula for integration with Company B

For the project for the cold rolling mill the SNS provided, in the contract signed with company B, that the latter would integrate SNS personnel during the design work with a view to training them. However this procedure was rapidly found to be ineffective. Using as a pretext its responsibilities in relation to the satisfactory realization of the design work as in regard to the time for this company B did not provide for a sufficient number of hours for training the SNS personnel and had not, in fact, integrated these personnel.

Formula for the direct responsibility with Company C

In the light of these two previous experiences the SNS decided to train its engineering department by giving it total responsibility for some less complex sub-assemblies: the plant for coating tubes, general services, fluids, power stations, and administrative buildings. To train the personnel for this engineering department the SNS would recruit some specialist engineers directly and ask company C to second some draughtsmen for a determined period.

In India it seems that they have followed a similar route in starting up and developing their engineering activity.

On the basis of these various formulae for association, as tried out by the SNS, it is already possible to sketch out some corclusions:

- it appears that there is some incompatibility between the responsibility of an engineering company in regard to the satisfactory execution of the design studies and maintaining delivery dates, and its training activity.

It is for this latter reason that only the formula of direct responsibility for the project by means of a national engineering structure can reconcile the responsibility of an engineering company and its training task. Within this framework the transfer of know-how can be realized by the integration of a foreign team provided by the engineering companies in the developed countries. Integration according to such a formula seems to be possible. According to the level of development of the national engineering structure this integration can be effected with a single company over several years or, step by step, as a function of the projects to be handled.

Conclusion

The capital goods industries are at the present time at the centre of challenges of the new international division of labour. The developing countries, which have fixed as their objective the acquisition of the mastery of their process of industrialization, and of orientating the industrialization as a function of their own economic and social needs, must acquire as a matter of priority the mastery of development of their capital goods industry.

The new international division of labour is the prolongation, at an international level, of the trends towards social division in the industrialized countries, shown through the polarization of the activities of software and of skilled labour in the capital goods industries. These trends in the social division of labour in the industrialized countries makes the mastery of the technology of manufacturing capital goods by the developing countries more difficult. They draw attention to the difficulties of transfer of software dominant technology which brings into play the acquisition and adaptation of collective know-how. Furthermore these trends in the social division of labour in the industrialized countries, which have important repercussions on the characteristics of capital goods (highly developed automation, specialization of the machines), pose the problem of adaptation of capital goods by the developing countries.

Mastery of the technology of manufacturing capital goods by the developing countries passes through mastery of various software activities (R & D, design, production management, technical supports, engineering of the offer, engineering of the demand) and mastery of the interrelationships between software activities and capital goods manufacturing activities. It is the mastery of the dynamism of these interrelations, and in particular of the interrelations between R & D, design and production studies, which constitute the real "hard core" in the transfer of technology for manufacturing capital goods.

with

09990

Distr.
LIMITED

ID/WG.324/4/SUMMARY
23 September 1980

ENGLISH
Original: FRENCH

United Nations Industrial Development Organization

Global Preparatory Meeting for the First Consultation on the Capital Goods Industry

Warsaw, Poland, 24 - 28 November 1980

TECHNOLOGY
IN THE SERVICE OF DEVELOPMENT*

Prepared by the
Sectoral Studies Branch,
Division for Industrial Studies

* This document relates to discussion subject No. 2 on the agenda and has been reproduced without formal editing

80-43844

Issue No. 2 "Types of Technologies in the Service of Development of Capital Goods Industries" to be submitted at the global preparatory meeting for the first consultation on the capital goods industry, is based on the reference study "Technology in the Service of Development" (ID/WG.324/4), the present document being an abstract of it.

In order to facilitate the examination of this document, it is suggested to divide the discussion of theme No. 2 into 3 parts:

1. An approach to the "laws" governing the composition and changes in capital goods
2. The technological strategies
3. An integrated plan of action for UNIDO.

Growth in respect of equipment goods in the developing countries necessitates the management of a complex operation. This complexity arises not only from the diversity of the sector, which covers millions of products, but also from the diversity of the situations and objectives of the various developing countries. In order to assist these countries in defining and implementing strategies an attempt has been made, as an initial approach, to formulate what may be termed the "laws" of the composition and change of the equipment goods sector.

These "laws" of technological development in capital goods are located at the interface of the laws of nature and of economics. In order to identify them it was necessary to construct a new tool: the analysis of technological complexity (A.T.C.). This method uses different concepts of systems analysis. It has been centered on the function of production and on the identification of inputs.

Measurement of the complexity of machines was therefore carried out by measuring the complexity of their manufacture.

This involves four operations: firstly the identification of the variables, that is to say the inputs which are needed to manufacture each group of machines; secondly the technical definition of each complexity level variable; thirdly the choice of a grading scale for complexity and the calculation of an index; fourthly the classification of these variables into sub-assemblies or "blocks" which describe the structure of the production of capital goods.

The variables which have been retained amount to 80. Defining the levels of complexity for each variable is a combination of technical analysis with a historical reference. The technologies belong to different generations which can be historically dated. 6 levels have been considered for each variable which have been concretely defined. The absence of criteria and of an available methodology to quantify the weight of the considered variables has led to having recourse to a conventional grading system justified by an empirical appreciation based on the knowledge of the sector.

The variables were classified into "sub-assemblies" in the structure of the production of capital goods. The 80 variables are divided up into three blocks:

A. The central production unit

B. The production infrastructure

C. The components incorporated in the capital goods.

The central production unit is the block which supplies the completely assembled product to the final user. It necessarily includes both men and means of production. It can therefore be divided into two sub-assemblies. The first, A1, is centred on the management of the enterprise. The sub-assembly A2 consists of the means of production, that is to say the machinery which is essential for the functions of the central production unit.

The infrastructure consists of the semi-products and technical services sub-assemblies.

The sub-assembly B1 "semi-finished products" covers the principal activities of the "first converting of metals" activity, that is to say foundry work, forging and stamping.

The sub-assembly B2 "technical services" covers all the normal sub-contracting work in the engineering industries (annealing, heat treatment, metallization), the supply of manufacturing equipment (tools, dies and moulds, gears, etc.), and also the manufacturing processes which are characteristic of metal fabrication and engineering construction (boilerwork, machining and stamping).

The components are an assembly which belongs to the simple or complex engineering industry (ball bearings, for example) or the electrical or electronic industries, or specialities such as hydraulics, pneumatics, measuring instruments, etc.

The analysis of technological complexity has been effected by means of a sample of machines and other items of equipment. An attempt has been made to constitute this sample in such a way that it would be significant of the whole. The selection involved 318 groups of machines, all belonging to the group of "fabricated metal products, machinery and equipment" (group 38 of the international ISIC nomenclature).

The products selected represent "groups of goods" with homogeneous characteristics and representative more of a type of industrial manufacture of capital goods than the manufacture of a single product.

In its proportions the sample is a reduced image of the capital goods sector as it can be observed in the developing and developed countries.

On the basis of this sample, a system of information on technological complexity has been constructed, the combinatory possibilities of which are very high. With 318 groups of products, 80 variables and six levels of complexity, the system has a recording capacity of 152.640 data. As compared with this theoretical capacity the analysis of the 318 groups of machines has effectively mobilized about 35.000 data. The magnitude of this figure has justified the processing of the information by computer.

This analysis has led to distinguish some kind of "laws" of complexity and change in the sector, while exercising the caution that was prompted by the newness of this undertaking. A discussion of the results obtained is essential to reach an intelligence of the situation in this key sector. The analysis of the technological complexity of the capital goods therefore completes the global description and the general diagnosis 1/. These two analyses constitute the essential elements of the strategic study of the sector contributed by UNIDO.

1. An approach to the "laws" governing the composition and change in capital goods

The analysis suggests that there exists within the tremendous variety and complexity characteristic of the capital goods a set of order relationships and a non-arbitrary ordering of the universe of machines.

These relationships have been described in an essay as "propositions", thus emphasizing the non-dogmatic and open-to-discussion aspect of these conclusions.

As a whole, 8 main propositions and 19 subsidiary propositions have been formulated regarding the laws of composition, while 7 main and 10 subsidiary propositions concern the laws of change.

These propositions are summarized as follows:

A. "Laws" of composition

- Proposition 1 (*): Capital goods are characterized by the considerable heterogeneity of their technological contents and, consequently, by their complexity.

1/ See "Capital Goods in the developing countries" - ID/WG.324/3 - related to the Issue No. 1

(*) The principal "propositions" are accompanied by subsidiary propositions: these are related to the principal propositions by having the same number, followed by a distinguished letter.

SP 1a = Complexity due to components increases with total complexity.

SP 1b = The dispersion of production complexity for capital goods without components is smaller, although it still remains large.

- <u>Proposition 2</u>

• Considered as products (international classification), the machines show great inequality of complexity. The mean complexities are arranged in the following order: simple metal products $<$ electrical machines $<$ measurement and monitoring instruments $<$ non-electrical machines $<$ transport equipment.

This mean order of complexity with components does not vary when calculated without components; however the dispersions vary.

• Considered from a functional and technical point of view, the machines have the following order of mean complexity: semi-finished products $<$ parts $<$ autonomous finished products $<$ integrated finished products and sub-systems.

• Considered as goods intended for other branches of activity, the machines have the following order of mean complexity: goods common to all branches $\leqslant$ goods common to several branches $<$ specialized equipment.

SP 2a = The total mean complexity of capital goods increases with the specific character of the demand for these goods.

SP 2b = The mean complexity, without components, of capital goods considered according to the nature of the demand, does not seem to vary significantly between goods common to all branches, those common to several branches and the specialized equipments.

SP 2c = Within each group of capital goods there exist technical alternatives which make it possible to modify the levels of complexity downwards or upwards.

- Proposition 3: The mean complexity of goods common to all branches, which represent 40% of the value of capital goods, is less than that of the mean of all capital goods. The weight of the components is less, but the dispersion of complexity is considerable. There is a technological gap between the products of low complexity and the others.

SP 3a = The mean complexity of manufacture, without components, of capital goods common to all branches is at the same level as that of the other major groups of capital goods. In general, it is therefore not easier a priori to produce them.

SP 3b = The order of total complexity of the groups of products which constitute the class of capital goods common to all branches is as follows: small mechanical components $<$ elements for construction in steel $<$ small electrical equipment $<$ miscellaneous hydraulic control and monitoring technical equipment $<$ pumps, compressors, boilers $<$ mechanical sub-assemblies and parts for machines $<$ storage and handling equipment $<$ machine tools of the universal type $<$ engines of all types, petrol, diesel or electric $<$ road transport equipment $<$ office equipment, typewriters, calculators, computers.

SP 3c = The order of complexity without components in those groups of components which constitute the class of capital goods common to all branches is as follows:

small mechanical components < elements in steel for construction < miscellaneous technical equipment < small electrical equipment < pumps, compressors, boilers < universal machine tools < storage and handling equipment < mechanical parts for machines < engines of all types < road transport equipment < office equipment.

- Proposition 4: According to the final demand from the sectors for which they are intended, the order of complexity of specific capital goods is as follows: agricultural machinery < agro-food industries < chemicals and petrochemicals < building and building materials industry < engineering construction < extraction of minerals < agro-industries, tobacco, leather, textiles < heavy metallurgy, iron and steel, forging, foundry < road transport equipment < rail transport equipment < air transport equipment.

Without components, the order of complexity becomes: agricultural machinery < food industries < mechanical engineering < building and building materials industry < chemicals and petrochemicals < extraction of minerals < agro-industries < heavy metallurgy < road, rail and air transport equipment.

SP 4a = The mean complexity of agricultural machinery is lower than that of the capital goods intended for the building industry and the building materials industry. The mean complexity of equipment goods intended for the agro-industries is higher than the previous ones. These three categories of capital goods have a complexity which is lower than the mean of capital goods specific to final demand sectors.

SP 4b = Although on average of low complexity, the group of agricultural machines and implements is characterized by a high level of dispersion, the weight of components being very low for simple machines and implements but becoming important for sophisticated or multi-purpose trailed machines.

SP 4c = The group of equipment goods for the agricultural and food industries has a wider complexity than that of agricultural machinery, and a wider dispersion. The weight of the components is relatively high for the more complicated products. The simplest consist of equipment goods with a mechanical predominance for the traditional agricultural and food industries. The most complex consist of equipment goods linked to the operations of packaging and processing with a predominantly bio-chemical character.

SP 4d = The group of capital goods for the building and building materials industries has a complexity and a dispersion which is higher than that of agricultural machines and goods for the agricultural and food industries. The weight of the components is also higher. However the simplest part of these capital goods has a complexity similar to that of the lowest part of the sample of agricultural machines and implements.

- Proposition 5: The size of the firms in the whole A is an important stratification in the distribution of production of the various groups of capital goods.

- Proposition 6: The rate of innovation of capital goods varies considerably according to the products.

- Proposition 7: The great majority of capital goods are concentrated at levels 3 and 4 of total complexity.

SP 7a = The groups of capital goods are concentrated at specific levels of complexity.

- Proposition 8: The production apparatus for manufacturing capital goods is integrated by cumulative complexity levels which represent various technological generations. Broadening the range of products requires resorting to production factors of higher degrees of complexity.

SP 8a = In order to produce capital goods, it is not only the presence of production factors which is necessary but also that the latter bear a specific index of complexity and, as a consequence, that different generations are mobilized within the technological stock.

SP 8b = Within sub-group A1 of the central production unit, no significant differences are observed in the rate of utilization of variables which define it as a function of capital goods common to all branches, to several branches, or specific goods.

SP 8c = Within sub-group A2, the frequency of utilization of the means of production evolves parallel to, or diverges in relation to the specialization of the machines which they allow to manufacture.

SP 8d = The more the specialization of machines increases the more frequent is the higher utilization of semi-finished products of sub-group B1.

SP 8e = Within sub-group B2, the frequency of utilization of technical services evolves parallel to, or diverges from the specialization of the machines which they allow to manufacture.

SP 8f = For each of the components, the higher the specialization of the machines, the greater the resort to components.

B. The "laws" of change

The previous analysis concerns the kinds of rules which appear to exist in the static arrangement of the capital goods system. It is necessary to supplement this with the dynamism of the evolution which is suggested by the existence of different levels of complexity. These levels are observed today, but they have a history, and time was necessary for them to be established.

It is possible to analyse the conditions of passage from one level to another. This does not mean that it is essential for a given country, which today is at a certain level, to follow exactly the same path. There is no one best way. This does not mean, either, that the same time is needed to advance from one level to another as that taken by other countries in the past. This time could be shorter or longer. Then it is necessary to seek the most favourable "entries", to seek the shortest possible paths, and those factors the domination of which is essential to open up the way to the future most effectively. International co-operation is one of the essential factors for reducing the time needed to advance from one level to another.

Analysis of the "laws" of change is not, therefore, an invitation to fatalism and a requirement for an immutable order. It is an encouragement to active realism, active in the sense that the understanding of the order of things is also the means of acting on them and of accelerating change, realism in the sense that all policies must start from an objective basis.

- Proposition 1: The rise in the total complexity is accompanied by changes in the industrial fabric constituted by assemblies A (central production unit), B (technical infrastructure), and C (components). At levels 1, 2 and 3 A dominates, at level 4, B and C becomes equally important, whilst at levels 5 and 6 the influence of components (C) in the total complexity becomes preponderent.

SP 1a = At level 1 the influence of means of production (sub-assembly A2 of the central unit) on the total complexity is dominant. Then comes the influence of the sub-assembly A1, which is centred on the management of this central production unit. The technical infrastructure and components have a smaller influence.

SP 1b = At level 2 the influence of means of production in the total complexity remains high, as does also that of management. The influence of the technical infrastructure and of components increases.

SP 1c = At level 3 the influence of the sub-assemblies is equalized, the means of production and management are balanced and their influence remains slightly higher than that of the infrastructure and the components.

SP 1d = At level 4 the components take over the majority influence, infrastructure is balanced with management in the total complexity, whilst the influence of the production apparatus is relatively reduced.

SP 1e = At level 5 the trends shown at level 4 are amplified: components, and to a lesser extent the infrastructure, increase in importance, that of management is stabilized, whilst that of the means of production falls.

SP 1f = At level 6 components increase markedly in importance, whilst the relative influence of the tecnnical infrastructure on complexity is reduced. That of management increases appreciably, whilst that of the means of production falls considerably.

- Proposition 2: The influence of components, which is negligible at level 1 of complexity and small at level 2, becomes appreciable at level 3. This influence is reinforced at levels 4 and 5 and at level 6 it becomes dominant.

- Proposition 3: The means of production of the central production unit have a dominant influence on complexity at levels 1 and 2. This influence remains considerable at level 3 but then relatively declines at levels 4, 5 and 6.

- Proposition 4: The technical infrastructure B has an influence on total complexity which increases from levels 1 to 3, is relatively stabilized at levels 4 and 5, and is then reduced at level 6.

  SP 4a = Sub-group B1 (semi-finished products) increases its influence up to level 3, and this is maintained up to level 6.

  SP 4b = Sub-group B2 (technical services) has a relatively constant influence from level 1 to level 5, but falls at level 6.

- Proposition 5: The sub-group A1 represents to some extent the management, in the central production unit, of men and machines. Its influence on the total complexity is considerable at the first three levels. It has a tendency to fall, relatively, at levels 4 and 5 and to increase at level 6. However the rates of increase tend to rise at the higher levels.

- Proposition 6: Amongst the production factors more than 50% are necessary at level 1 of the total technological complexity of machines. In order to advance to level 2, the presence of 80% of these factors is necessary; at level 3 practically 100% are necessary. (These propositions are independent of the level of complexity of the factors).

- Proposition 7: The basis of the industrial fabric is constructed at levels 1 and 2. It is the first accumulation at these levels which allows a considerable "gain" in the number of machines produced, and in complexity at level 3. From this level onwards, the increasing complexity of the variables brings an increase in the number of more complicated machines, according to a non-linear process.

SP 7a = It follows that the difficulties of primary accumulation at levels 1 and 2 make international co-operation essential, and that the modes of it favour self-sustaining progress to levels 3 and above.

SP 7b = In terms of time, the developing process in the capital goods industry, from level 1 to mastering of level 6 requires a very long time. It is also one of the essential functions of international co-operation to assist in shortening this period at all levels.

2. The technological strategies

The method to analyse the technological complexity (A.T.C.) has been created to assist the national policy-makers in developing countries to control the essential strategic options.

In fact to master these strategic options, it is necessary to reduce the "variety" of the system, defined in cybernetics as the number of "states" that a system can take.

Systems analysis allows there also an interesting approach. It is known, from the work of Ashby, that one system cannot control another unless its "variety" is at least higher (law of required variety). The "variety" of the supply system for capital goods is enormous. If the "demand" system is to dominate that of the supply, therefore it is necessary that national policy-making also be of a higher variety.

This result can be achieved by two means:

1° increase the "variety" of the decision-makers, by means of information;

2° reduce the "variety" of the supply system. This reduction can itself be carried out by two routes:

- reduce the "variety" of the system by significant information; this implies simplifying the complexity of the system while arriving at a significant representation of the real groups of capital goods;

- reduce the complexity which is itself contained in the machines.

Using these concepts has important practical consequences. For example, it makes it possible to determine, for a given combination of factors in the central production unit, of the infrastructure and of the components, those machines and items of equipment which could be fabricated and correspond to the technological level being considered. This is what has been termed the maximum technological operation space (S^{MTO}).

It allows for a realistic reasoning of the objectives, their level and aspirations, as well as of a fabrication policy which can combine a dosage of the necessary sub-groups.

It also makes it possible to ask again such fundamental questions as that of the effects of training, of the poles of development, of industrializing industries, depending on the possible or unfeasible coupling of variables.

The approach to the "laws" of change makes it possible to distinguish, in advancing from one level of production to another, firstly the subsisting variables, and to what extent their progression contributes to raising the index of complexity between levels, and secondly the new variables which have been introduced at a higher level, their weight in the increase of complexity, thus studying their potentiality for coupling.

In the case of the variables which subsist from one level to another, this approach leads to identify the type of progress to be accomplished to develop the existing variables, that is to say, to give a concrete picture of the apprenticeship function, to identify the possibilities of continuous progress, the discontinuities, and, in particular, to draw the implications in terms of training programmes.

Dealing with the new variables to be introduced into the industrial fabric, this leads firstly to identifying the content of the technological transfers to be operated and, consequently, to making concrete in operational terms policies of technical transfer, and secondly to identifying the educational content which is necessary to allow the technological contents to be assimilated.

This analysis is of exceptional importance for the technological policies of developing countries. This is why it was given a particular emphasis 2/ in the study. The different components and supports of technology have been described along the various phases of the industrial projects, from the moment they were conceived to their implementation and start into operation. This analysis shows the importance of the software and the difficulties to transfer it, particularly in the case of the collective software incorporated in the organizational technology. Moreover it shows that the

---

2/ See Annex 1: Some aspects of transfer of technology and engineering in the capital goods industry - ID/WG.324/4/Add.1

ways and means of technological transfers depend, on the one hand, on the structure of the using sectors, on the other, on the technological complexity.

From that, many consequences follow: i) "the" technological transfer is an abstract term; in fact there are transfers with different contents; ii) as the agents involved in these transfers vary, so should the outline of the negotiations to be conducted also vary; iii) without a real control over the transfers, new forms of dependencies may ensue for the developing countries.

It is therefore necessary to memorize the industrial experience 3/ and to establish a national structure for the study and development of the projects.

Mastering the technological transfers and thus controlling the whole of the industrialization movement implies the crucial importance:

- of choosing the appropriate entry routes which can be dominated in the industry
- of estimating the levels of complexity and the period of time required for the assimilation of these levels
- of knowing the apprenticeships which were carried out in other countries and the means used to assimilate their complexity
- of the orders and sequences observed in the successive production of capital goods
- of choosing appropriate forms of integration of the national industrial fabric and of a schedule of the entry into production of new units
- of orienting the educational system in good times so as to increase the capacities for assimilation.

3/ Whence the importance of national case studies on the development of the sector, provided these identify clearly both the specific historical circumstances in which fabrication was started and the ways and chronological order of the entries of fabrication into the sector.

From the analysis of the "system" of capital goods, an attempt was made to draw logical consequences in terms of strategies.

There again, this essay submits also propositions 4/ in order to emphasize the open-to-discussion aspect of its presentation. 4/

- Proposition 1: The analysis of technological complexity, whilst showing the real difficulties of penetration by the developing countries into the capital goods industry, and the conditions for passing from one level to another, does not lead to the conclusion that these difficulties are insurmountable. On the contrary, it tends to demystify the idea that because of such difficulties, it might be better to renounce these activities, and remain within the existing international division of labour.

- Proposition 2: The realities - and the constraints - of the technological complexity of capital goods mean that objective limitations exist to the progress which is possible in a given time. Understanding these limitations should not be looked upon as a brake but rather as an encouragement to make use of these degrees of freedom fully. This leads to the following subsidiary propositions:

  SP 2a = At a given level of available production factors, there corresponds a space of maximum technological operation making it possible to produce an assortment of machines. From that time onwards the first problem is to fill in this space of operation as completely as possible.

4/ which are a complement to the strategies presented in the document "Capital Goods in the developing countries" - ID/WG.324/3

SP 2b = The second problem is one of fixing the objectives and the programmes for increasing the production of machines over a given period, at a level compatible with the progress of the production factors, and linking together the assemblies and sub-assemblies which form them.

- Proposition 3: Increasing the space for maximum technological operation S^{MTO} requires a change in the structure of the combination of assemblies A (central production unit), B (technical infrastructure), C (components), and the sub-assemblies A1 (management), A2 (means of production), B1 (semi-finished products) and B2 (technical services).

SP 3a = Industrial policies must on the one hand face up to the constraints, whilst on the other they have degrees of freedom of action, wherefrom a wide variety of possible policies can be drawn.

- Proposition 4: Despite the diversity of possible - and effectively operated - policies a certain number of "rules of conduct" appear to emerge for creating and developing a capital goods industry.

1° A minimum B1 and B2 infrastructure is essential.

2° No country, even amongst the most developed, can live in a state of autarky with respect to equipment goods; an international division of activities and an international trading program are necessary.

3° The introduction of new installations, particularly those vertically integrated of the "turn-key" type, must be evaluated with considerable care.

4° It is necessary to adapt the training programmes, particularly those of industrial management, to the structure of the various capital goods industries but also to the difference existing between the complexities implied in the objectives selected and the existing capacities.

5° The policy of opening the "package" of technological transfers and the incorporation of national elements requires a careful analysis of the technological contents to be transferred at the various levels of technological complexity.

- Proposition 5: The majority of the developing countries which at the present time have a weak production basis for equipment goods could aim at level 3 of complexity of products. At this level, it is possible to produce 40% of the equipment goods.

  SP 5a - For the less developed countries, it seems that the production of agricultural machinery and certain simple semi-finished products constitutes a preferable way of entry into the equipment goods industry.

- Proposition 6: The evolution in time of the equipment goods industry requires periodical restructuration and the reorganization of the horizontal and vertical links of its constituting assemblies and sub-assemblies.

- The question is put forward as to the possibility and the usefulness of elaborating and implementing new and more simple models of technological development.

These are the main propositions in terms of technological strategies which are being submitted here to the participants of the global preparatory meeting for the first consultation on the capital goods industry.

3. An integrated plan of action for UNIDO

The third part of the study concerns the propositions regarding a plan of action for UNIDO. This plan sets forth 4 main operations:

A. A strategic study of equipment goods carried out by UNIDO/DIS

B. A system of information on the technological complexity of capital goods

C. Assistance to the developing countries for the establishment of national strategies

D. Strategies of international co-operation and technical assistance.

These articulations aim at developing a synergy which isolated operations would not allow. They should also bring a wider "variety" in UNIDO programmes, thus rendering possible a more significant contribution to the management of a complex operation: to increase capital goods in developing countries.