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SMALL-SCALE MACHINE TOOL PRODUCTION 1/

by

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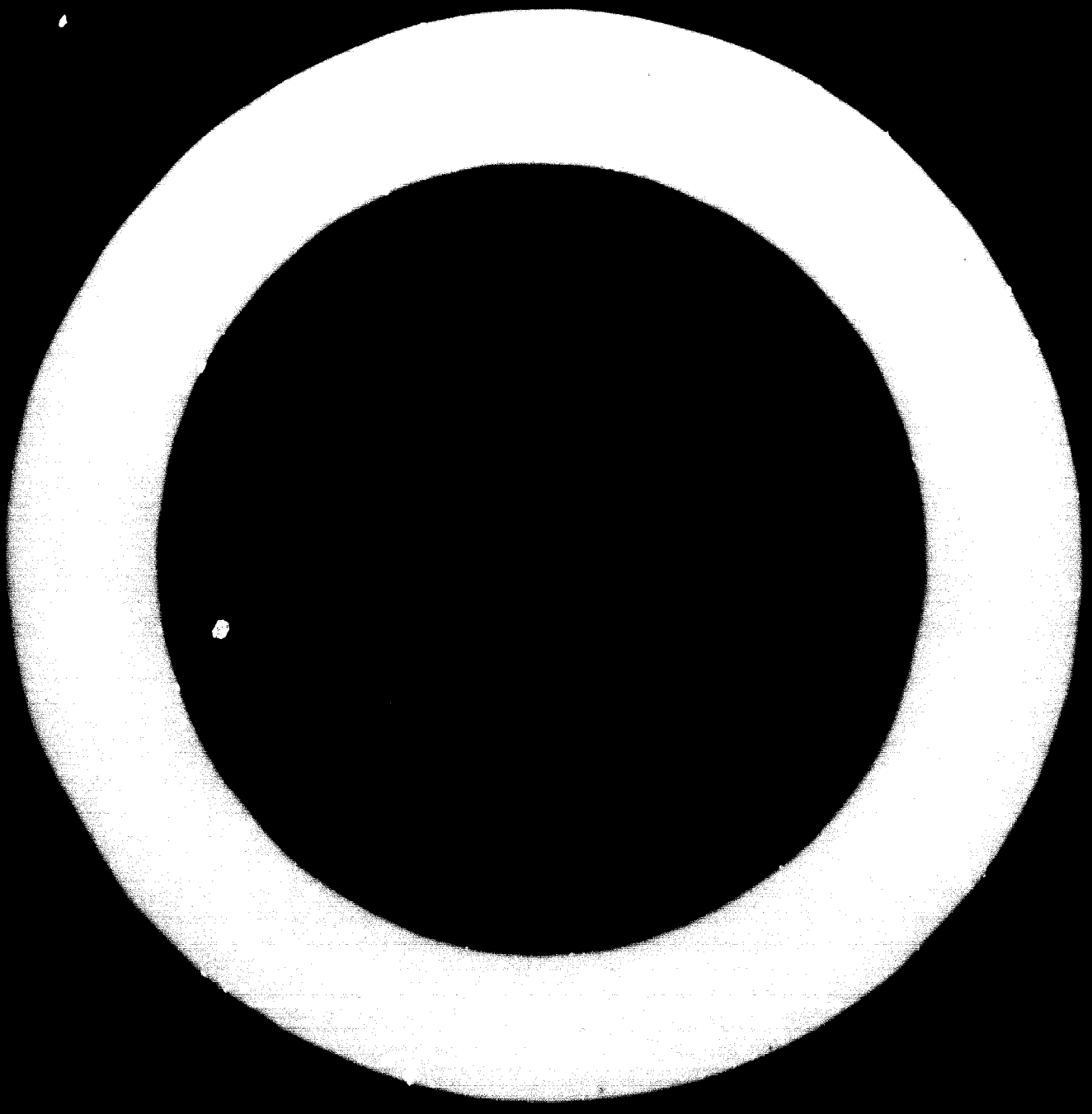

1- TECHNICAL AND ECONOMIC CHARACTERISTICS OF MACHINE-TOOLS

1.1. Machine-tools are characterized basically by their production capacity and working accuracy. These characteristics, in turn, are governed by a number of others of which we will point out the most important ones (this being in no way a complete list):

- cutting and deformation characteristics;
- structure stiffness and control characteristics;
- accuracy of the guide ways and of controlled displacements.

1.2. These characteristics are becoming more and more important in the machine-tool industry's trend. Indeed as stiffness and power of machines increase, it is possible to accelerate cutting or deformation speeds, according to the machine type, to reduce manufacturing tolerances, in short, to increase productivity and manufacturing quality, thereby reducing considerably production costs.

The rate of progress is shown by the fact that in the eighteenth century, when Watt decided to build his steam machine, the maximum accuracy he could attain in the diameter of the cylinder was of about one centimeter, whilst one century later tolerances of about one micron are possible.

1.3. Today's advanced machine-tools stem not only from improved design also to a large extent from the development of other industries, such as:

a) Materials - progress in metallurgy and materials led to smaller components (gears, for example), to the use of tools with high cutting or forming capacity and to improved cutting conditions or improved contact between parts thanks to better lubricating oil, greases and cutting oils.

b) Electronics - the breathtaking advance of this sector has completely changed control systems through automation or programing and, more recently yet, by continuous detection and correction of errors as they occur (adaptative control).

c) Fluidics - the growth of this new engineering branch has quite modified the control possibilities, by itself or in conjunctions with electronics.

Machine-tools have been developing the improvements of advanced industries in such a way that nowadays the machine-tool industry is itself an advanced industry, and not only on that account but also thanks to new specific trends of its own derived from laboratory research and development in manufacturing plants.

If this were not so, it would not be possible to manufacture pieces of such complex shape to such narrow tolerances, nor to have such large production series at such low cost.

The above does not aim at giving a complete characterization of machine-tools, but merely a brief picture of the related problems.

2- CHARACTERISTICS OF PRODUCTION IN SMALL SERIES

Although they are well known, these characteristics are brought up here for the sake of completeness.

Production as one off's and in small series (say 10 to 20 identical units per series) entails specific means of production of great simplicity as far as repeatability is concerned. Conventional machine-tools are generally used since there is no justification for:

- High speed or highly automated machines (such as automatic lathes, numerically controlled lathes, or programmed presses)
- Machining centers performing several operations simultaneously or successively
- Machines with transfer

The conventional types currently used (parallel lathes, milling and grinding machines, etc.) call for a high degree of worker craftsmanship, both in manufacturing the parts and in assembling groups of parts or the machine itself: fitting, scratching, etc. are very important operations. Manufactured parts are inspected individually by the worker himself or by an expert inspector.

Production, however, implies a number of tasks which are performed both upstream and downstream of manufacture progress and which combine with the latter to make up the complete production cycle: work study and preparation, and final inspection.

The above picture is that of a not too developed company. However it should be pointed out that nowadays copying machines, even numerically controlled machines, may find their place in the production of small series.

May we quote in passing M. Kronenberg (*) who cites a case in which a saving of 60% in the time needed to manufacture 6 parts could be obtained by using a numerically controlled lathe instead of a copying lathe. The validity of that particular study is not in question, but it remains to be seen whether it would be equally valid for another company with different technical and administrative structure. That

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(*) Max Kronenberg, "Trends in the design of metalworking machinery and in production methods", United Nations, New York 1969, p.264.

is why we have stated that every machine must suit the overall company with its actual organization has to be taken into account.

A manufacturer of small series cannot simply replace 2 or 3 of his machines by one single unit of higher production capacity. He will have to consider what will become of the men who operate those machines, whether they have the skills needed by the new unit, whether working moves will have to change (1, 2 or 3 shifts), how to provide for higher quality upstream (work preparation). The ultimate decision as to the advantage or disadvantage of the move will be based on an economic study.

Alternatives are pointed out merely to stress the fact that production in small series can no longer be given a simple characterization. Prototypes can nowadays be built with relatively advanced machinery, although still rather different from that used in the production of large series.

Thus, production in small series has its own specific demands as far as the manufacturing company's organization and structure are concerned. It calls for a high degree of capability and flexibility in the study of each particular case as it comes up, and for easy adaptability of the production cycle.

3- CHARACTERISTICS OF SMALL AND MEDIUM SIZE COMPANIES

3.1. It is difficult to define small and medium size companies (S.M.C.), not only because several criteria may be used, such as number of employees, capital or sales turnover, but also because this scale classification can vary from country to country.

For our purposes, we will consider that SMC are characterized by having a small staff (less than 100) and limited human, financial and production resources which usually prevents them from attempty to study and solve themselves their management and marketing problems and from undertaking research applied to their products.

In small and medium size companies there are very few managers, often only one, holding power on the whole company and its several functions - technical, administrative, commercial.

This state of affairs obviously has inherent advantages and disadvantages. The manager has to deal with several fields but as a rule is not an expert in all of them, so he devotes most of his activity to the one he knows best and neglects the others, which brings a serious threat of imbalance to the company.

On the other hand, as the company develops the concentration of power into the hands of one man or of a limited number of people can restrain progress by the lack of appropriate structures.

The other side of the picture is that with only one or two managers, management is very close to the day-to-day work , in particularly very close to production; this is a stimulating environment, which encourages the personnel to cooperate not only as far as production is concerned but also by contributing their own ideas - if the boss allows of course - towards development.

3.2. Nowadays the connection between the concept of medium and small size companies and that of an industrial unit of low profitability is avoided.

Each sector has its optimum size, and every new project in that sector should tend to that optimum size. This size, however, varies widely with the geographic location and in particular

with the development level of the country, and a correction as required in those countries where regional development shows marked differences.

The differences in unit sizes of a given industrial sector, located in areas of different economic and social structures, are usually compensated by the so-called advantages of the level of development of those areas.

Nevertheless, well designed, balanced projects do usually tend towards that optimum size as the country's growth follows its course.

The use of labour against machinery, taken together, is often a very important consideration, mainly due to substandard cultural levels and consequently to the lack of adaptation to new skills which the population of underdevelopped areas show.

Cheap labour is generally unadvisable for high technology jobs. Its low productivity often offsets the low wages.

Coming back to small and medium size companies we must admit that they offer the best economically viable tool for the development of certain activities which can be adapted to the current level of easily available labour.

Developing countries lack technical experts. Demand can not be satisfied, salaries are often incompatible with the average wage of the country. So, in terms of simple profitability for the private sector, and apart from national growth requirements, investments in small and medium size companies, whose activities can take into account the general cultural level of the available labour, are by far more atractive.

4. ECONOMIC PROBLEMS OF THE PRODUCTION OF MACHINE-TOOLS IN SMALL SERIES

4.1. The manufacture of a given kind of machine at a given moment and in a given country may be non-competitive without this in any way implying that the same will be true in general. The overall aspects of such manufacture must therefore be analyzed before discarding it or modifying a policy.

4.2. The would-be manufacturer should know beforehand that it is out of question to turn out any kind of machine; what is needed is a machine that meets the requirements of the customer, both in technical characteristics and in price.

4.3. It follows that in the design both of his machine and of his company a manufacturer must take into account

a) Marketing problems - strategy to be implemented, analysis of customer's needs

b) Sales problems - ability of the selling force, aggressivity in the market, capabilities to study the usage of machines according to customer's requirements

c) Technological capacity - and here several degrees come into consideration:
- at the highest level, capacity for own research and for knowledge of the results of international research
- at a medium level, capacity for development through test work and laboratory studies
- at a lower level, capacity for preparing projects on the basis of his own experience and for estimating the needs of one or several markets (this is the degree more frequently called for in production in small series)

d) Manufacturing capacity as governed by
- available plant and machinery
- organisation (management, general layout of the factory, purchasing of raw materials and accessories, quality control)
- labour (level of skill)

An exhaustive analysis of these problems is beyond the scope of this paper. We shall refer to one or the other in more detail but the main point we want to emphasize is that the economics

of machine-tool production [illegible] of men- or machine-hours but something much more complex, which starts at marketing and selling [illegible] manufacturing and technological capacity.

4.4. On the other hand, it is not enough to study the aspects mentioned so far and which are [illegible] to production. Other factors, extrinsic thereto, are equally relevant and may alter considerably the economics of the problem.

Each firm has a significance beyond its own because it is one of the components which make up the structure of an economy, of a country or of a region: it is thus subject to the interaction of the other components - the extrinsic factors we have mentioned.- When going over each one of those factors in more detail we shall revert to that influence.

4.5. The size of the market and the evolution of its needs may have a favourable role, or an unfavourable one, in relation to the industry. A very small and not too demanding market does not stimulate the manufacturer; if its needs happen to be varied, although small, foreign competition may discourage, or even neutralize, the unsupported of one or other individual manufacturer. On the other hand, if the needs of the market change too quickly a small manufacturer may find that he is unable to keep pace because he lacks appropriate structures.

Relevant to these considerations and to others that will follow is the problem of inter-industry cooperation and State support, to which we shall return later in this paper.

4.6. The trade organization within a region or a country can be and is a powerful tool of progress or of stagnation. If sellers draw a curtain between manufacturers and buyers, the former is shielded from the latter's direct reaction and remains in the hands of the trade, which in most cases lacks an adequate technical structure. This "curtain" effect stems from the fact that the financial resources of the trade are often considerably stronger than industry's, and also from the manufacturer's

lack of aggressivity in the market. The trader who ignores his genuine function, because he does not possess the required marketing expertise [illegible] to give adequate after-sale assistance, merely tries to sell as many machines as possible regardless of whether or not they are the best answer to the buyer's requirements. The manufacturer, in turn, lacks the trade structure needed to discuss with the customer the latter's own problem; the smaller or larger number of machine-tools of his making which are sold is all the indication he has regarding the success of his product and it is only by chance that he may be able to correct those shortcomings which usage alone brings to light and which therefore only become apparent in the customer's shop.

On the other hand, being not a party to the sales contract, the manufacturer runs the double risk of over or underproduction: by stocking machines without knowing the market's needs, or by waiting for firm orders which may result in longer delays and higher prices than the market is prepared to accept. A manufacturer's place in the market can be lost in a much shorter time than it took to build.

4.7. Technological capacity can be at the origin of a successful new model, together with marketing capacity. Experience shows that a company may be a newcomer, lacking the solid credentials of tradition, and still be able to get a firm foothold in a new market thanks to its technological capabilities, which are part of the company's internal resources but are also a tool with which to fight the dominance of established manufacturers of highly industrialized countries.

4.8. The factors which relate to production capabilities are also intrinsic ones. However, here again, extrinsic influences make themselves very much felt.

4.8.1. Thus, if raw materials, accessories or components can be easily acquired in a given country or region, the development of a machine-tool industry will be much easier. On the contrary, importing small quantities of certain products is not always possible or easy, and manufacturers, in the circumstances, are often forced to make themselves almost every component at nearly prohibitive [illegible], or to use components not up to standard.

This is a very important consideration. The cost of materials and of accessories incorporated into a machine-tool may render its manufacture economically non-feasible; they make up a high proportion of final production cost, the raw materials incorporated into a machine without any processing sum up to 25-40% of its total cost.

Foundries operating to good quality standards and structural/ /plate works providing well welded structures are basic requirements for the production of machine-tools and a machine-tool industry cannot be located in a region from which they are absent. A company may contemplate setting up its own foundry, but a given minimum volume of production will be needed to make this solution economically viable. Diagnosis studies in many companies have shown that it is often advisable for a company to do away with an existing foundry. Foundries must be studied separately from other operations, because an overall analysis does not yield data of satisfactory accuracy. Structural/plate work does not lend itself to such clear cut conclusions, but a careful analysis of its operation is also recommended.

The remaining accessories and component parts can be divided into two categories:

a) Components which can be made by the manufacturer himself (such as a cowl for a given device)
b) Accessories which must be purchased outside the company (such as an electric motor)

In the first case, the manufacturer should undertake the production only if it does not call for too much investment and provided that the techniques are similar to his own. Thus, a cowl of the type mentioned under a) is made of thin sheet-metal and does not require a degree of accuracy similar to that needed by the main components of a machine-tool. It is usually not advisable for one shop to work to several degrees of accuracy; workers skilled in given tolerances do tend to observe them in general, which may make for costly components. The problem, obviously, is entirely different when large series are produced.

In [illegible] case, [illegible] to purchase discerningly, i.e. to what is current practice on the market, avoiding the use of accessories of [illegible] characteristics. Again, in the case of [illegible] series the use of special accessories may be justified.

4.8.2. As to machinery, this may depend very much, as to types and characteristics, on whether production series are to be small or large. We have already briefly alluded to this, first in section 2 when dealing with the characteristics of production in small series, then under paragraph 4.8.1. when discussing the manufacture of accessories by the machine-tool maker himself.

We shall now go into more detail regarding the manufacture of special machine-tools, where problems of full use of capacity and of profitability make their weight felt, leaving current types aside. The manufacture of lathes in series of 5 to 10 units hardly justifies the purchase of heat treating equipment or of a slideways grinding machine; however, in the absence of that heat treatment and of that grinding, a lathe can hardly qualify as meeting the minimum requirements demanded by the market. Later in this paper, we shall see how to solve such problems.

Inspection equipment must be considered. This equipment is expensive, but frequently used by the Control Department of a machine-tool maker. A manufacturer must therefore have the most common equipment , and outside of the company he must be able to find facilities for the more expensive one.

4.8.3. Organisation is a basic component of the operating results of any firm, and the problem is to choose the adequate system and to define its scope. A given system may be too much of a burden for a given company, and selecting the wrong system for a company afflicted with low profitability may still lower its profits, unless production is increased; the company may be unable to do so, for instance, because it lacks the required trade structure, and in such circumstances its economic and financial situation will deteriorate further.

For each level of production volume, even in small series, the adequate level of organisation and technical control must be determined.

4.8.4. As stated in sections 2 and 3, labour becomes a predominant factor in small series. The need for middle level technical staff, to ensure the required productivity, must be stressed in this connexion; this need increases in inverse proportion to the level of development of the country or region.

4.9. Without going into any great depth, we must touch here another aspect: large size machine-tools. Large presses, lathes, press brakes, are usually not carried in stock as are smaller machines for common uses. Those large units are thus manufactured in very small series and are often genuine prototypes. We have here an instance where smaller manufacturers may find themselves on an equal footing with larger, better equipped companies, and may compete with them. Actually, of course, this is an oversimplification as large units are not mere extrapolations of smaller ones, and have their own problems. This is nevertheless a field to be recommended to machine-tool manufacturers with a solid experience and good technological capability.

4.10. The economic analysis of the small series production of machine-tools calls not only for a qualitative analysis of several problems, as we have done so far, but also for the quantitative study of the influence of several factors. Such an analysis is done in relation to a definite project and therefore does not find its place in a report of this kind. Factors to be taken into consideration vary, as we mentioned, from country to country, according to the level of development, and from company to company, according to the structure, the dimensions and other features.

We shall therefore confine ourselves to an example (see Appendix) taken from a Portuguese company of medium dimensions and unsatisfactory structure, which only manufactures small series of lathes and shaping machines. We have here conclusive evi-

uence of the influence of the size of the series on production costs, and a clear picture of the structure of a SME without sales services and with correspondingly incredibly low overhead, which, coupled with cheap labour, results in competitive prices and, in most cases, in profitable operations.

[illegible]

[illegible] machine-tools, [illegible] end of production in small series and the solution of problems of machine-tool manufacture, we must now analyse their compatibility, that is to say, whether small and medium size companies with given characteristics lend themselves to the production of machine-tools in small series.

Concerning management, experience shows that, as is corroborated by what we have written above, an able manager supported by a relatively skilled middle level technical staff can cope efficiently with, and control the manufacture of small series of machine-tools. It is true - and such instances are known to be - that some managers are more attracted, even fascinated, by the challenge of solving technical problems than by the possibility of making money from a well organized production plan.

As a result, some alterations will probably be introduced into each series which will perhaps mean a steady, permanent development of the product and may be a challenge to the usual sequence in the life of a product, from beginning to growth to stagnation to decline to disappearance, meaning that it will not be possible to profit from previous experience and that an almost experimental stage will prevail all the time, each small series being made up of a given number of prototypes.

This highly undesirable feature, as against the permanent development of the product, must be considered from yet another point of view in our particular case. A machine-tool manufacturer starts by using himself the machines he manufactured and the further knowledge derived therefrom will probably be incorporated into the next model.
On other words, a small machine-tool factory is virtually a "test laboratory", although somewhat "sui generis". In a big company, a comparable [illegible] laboratory really exists.

The conclusion is, therefore, that only this is the kind of management which is characteristic of it, lends itself very well to the production

of machine-tools in small series, provided that it has a dynamic, up-to-date technical management.

Obviously, as a result of low level of technical staff, of financial resources to test new alternatives of access to the latest technology, etc., a SMC will probably not be able to undertake the manufacture of highly developed machines which might be a spearhead towards expansion. On other words, from a given moment on a SMC cannot develop without external support in the form of financial or technical assistance.

It should be pointed out that these conclusions are drawn from the actual experience of machine-tool companies all over the world; their size usually is such that almost all of them, in relation to companies in general, are considered small or medium size companies. To illustrate this point, these are the average number of employees per company in the machine-tool industry of several countries:

Great Britain	232
Germany	200
Swiss	132
Japan	71
Portugal	71
Italy	47

This figures may be open to discussion due to varying definitions of industry, but they do allow for the conclusion that large size is not a prerequisite for success in this sector.

6- [illegible]

6.1. In the earlier sections, namely in section 4, a number of problems was left open on the solution of which actually depends the profitability of the production of machine-tools in small series.

6.2. First of all it must be stressed that the project should:

- not only cover marketing needs,
- but also allow for the manufacture in small series at competitive prices.

Not every technical manager commands the knowledge required to prepare such projects.

6.3. This is a capital-intensive industry, and the profits of small and medium size companies may not suffice to self-finance expansion. On other words, smaller companies will have limited possibilities of expanding together with larger, more powerful competitors and will thus remain at an ever increasing distance from the latter.

S.M.C.'s will thus have difficulties in getting services of the same quality as larger companies can obtain, because nowadays they lack effective support in administrative, economic and financial management, as well as in marketing and sales, design and production, quality control, purchase of material and equipment, stock management, etc..

6.4. The cooperative type solutions, which provide services and assistance to all at a minimum cost to every participant are the best answer in the case of small and medium size companies.

Our own experience as well as that of other countries, in particular in the machine-tool sector, has been convincing; although in Portugal CIMAP is not yet fullfilling all the functions which it should accomplish results so far indeed satisfactory.

6.5. To our knowledge Technical Centers for Industrial Cooperation (TC) have effectively promoted industrial development by providing the needed infrastructures in sectors where they were lacking, and which were mainly those in which SMC prevail.

Their functions are illustrated by the following examples:
- design, manufacture and test of prototypes (applied research and development)
- market research
- systematic control of quality of machines produced
- encouraging companies to get together in order to systematize and standardize production and sales
- technical and economic studies
- standardization studies
- etc.

TC's possessing more or less well equipped laboratories can supply technological resources, which SMC's lack. Their versatile technical staff provide the companies with technical assistance in the fields where it is needed.

They have access to the results of both fundamental and basic research from all over the world and are thus able to circulate among their members the most uptodate knowledge of interest to their sector. And their cooperative action can be extended as far as we want: purchase of materials in commer, personnal training, etc.

6.6. The importance of the machine-tool industry (*) and the extent of governments interest in its progress, even in those countries which it has a small dimension need not be repeated here. Developing countries (**), in particular, look at this industry as one of the more powerful means to attain the needed level of social and economic development; machine-tools are needed

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(*) Colloquiums about the problems of the machine-tool industry: A. Caranger "L'importance de l'industrie de la machine-outil dans le monde moderne" (Porto - October 1968)

(**) CF. Colloquiums: A. Caranger "Le role de l'industrie de la machine-outil dans les pays en voie de developpement".

to build durable goods, and to be completely dependent on imported machine-tools to maintain his status and, not to come out to underdevelopment.

In large but underdeveloped countries, with a comparatively important market, it has been possible to establish a machine-tool industry which manufactures in large series. For the reasons already mentioned, small countries need a similar industry, and here SMC's will find their places in the production of small series which, as we have shown, is a profitable field.

Such companies are essential components of the industrial and commercial structure of each country. Their absence would result in a broken structure of diminished strength in which every component would be unfavourably affected. However the quality of the machine-tools locally produced should always answer the needs of the country's industrial development.

TC's have an action in this field which is important but can not suffice;further action by governments is therefore needed to supplement the activity of TC's, either reinforcing and helping them directly or indirectly, encouraging basic research in the Universities, establishing commercial structures, etc.

We thus have a number of private and governmental measures which should be coordinated and through which solutions can be brought to the several problems that were left open in this paper. These problems must be solved to ensure the profitability of the manufacture in small series and, above all, in order that these machine-tools may accompany modern technical trends.

APPENDIX

ANALYSIS OF SMALL SCALE PRODUCTION COSTS IN A MEDIUM SIZE COMPANY, IN PORTUGAL

I - SHAPING MACHINE TYPE 2-05

Year	Number of units in series	per unit, in escudos					
		Materials	Labour	Overhead	Total cost	Selling price	Profit
1964	10 units	11600	21500	1700	35100	45000	9900
1965	12 "	13400	20200	1700	35300	45000	9700
1965	2 "	12700	27100	2000	41100	45000	3900
1966	1 "	10600	37800	2400	50800	45000	-5800
1966	10 "	11400	19000	1500	31900	45000	13100
1967	6 "	8500	19900	1400	29800	45000	15200
1969	12 "	12200	20200	1600	34000	50000	16000

N.B. 1 - Variability in material costs results from fluctuations in current prices and from the smaller or larger number of accessories purchased from outside sources.

2 - Variability in labour costs results from the dimension of the series and from new, more advanced manufacturing methods (started in 1966) which even reversed the effect of wages trend.

II - Parallel lathe, type 2

Year	Number of units in series	per unit, in escudos					
		Materials	Labour	Overhead	Total cost	Selling price	Profit
1965	20 units	15200	21000	1500	38000	45000	7000
1966	5 "	13900	25100	1950	40950	50000	9050
1966	4 "	12500	28400	2050	42950	50000	7050
1967	1 "	13600	31200	2250	47250	50000	2750
1968	1 "	14700	29000	2200	45900	50000	4100
1969	10 "	18600	18300	1850	38750	55000	16250

N.B. 1 - The same remarks apply as for shaping machines. Particular mention should be made of the year 1969, in which labour could be substantially reduced which cost of materials increased slightly. This is another example of the decisive influence of manufacturing methods and of the incorporation of components purchased from other manufacturing.

16. 7. 74