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

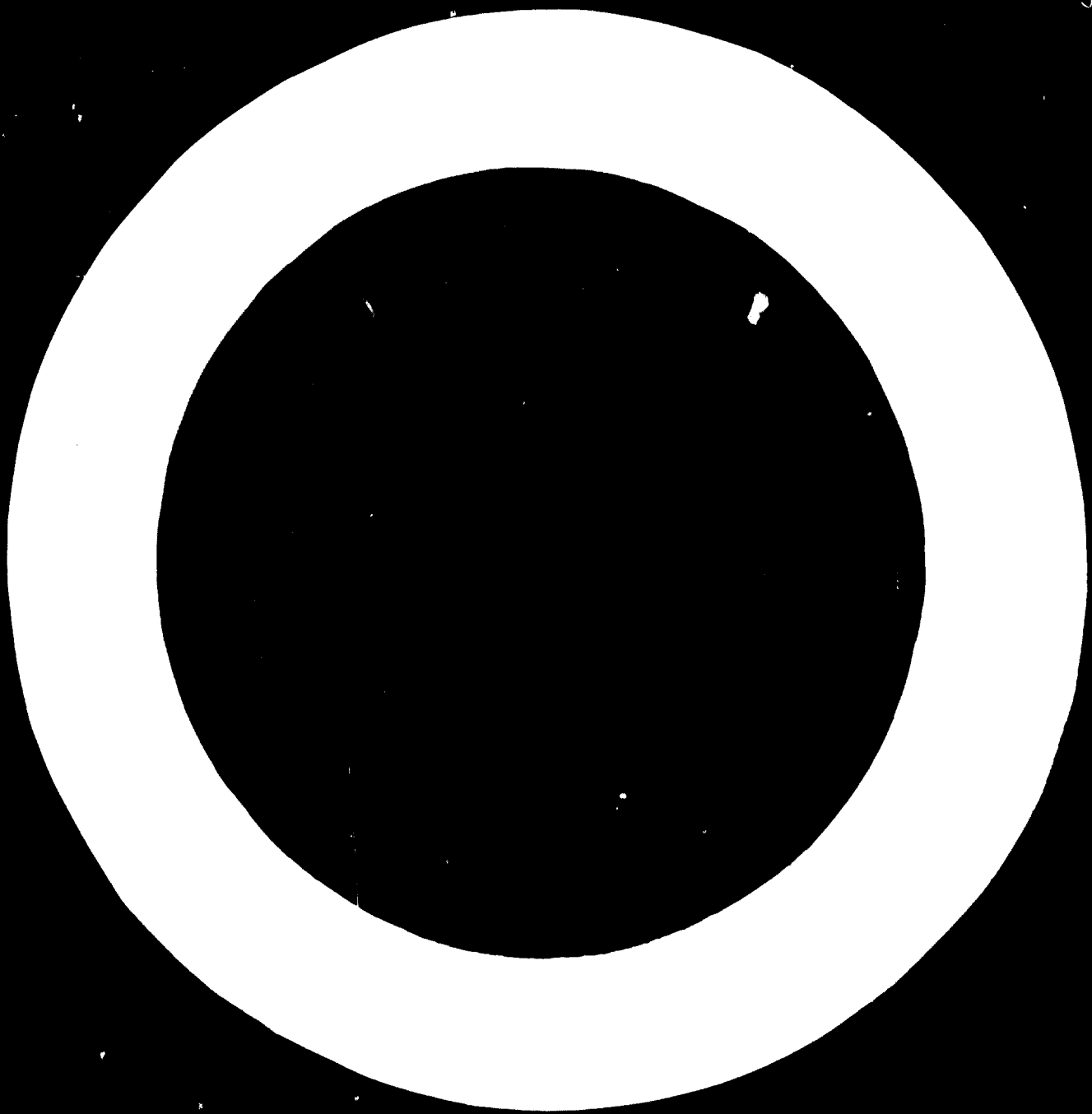
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

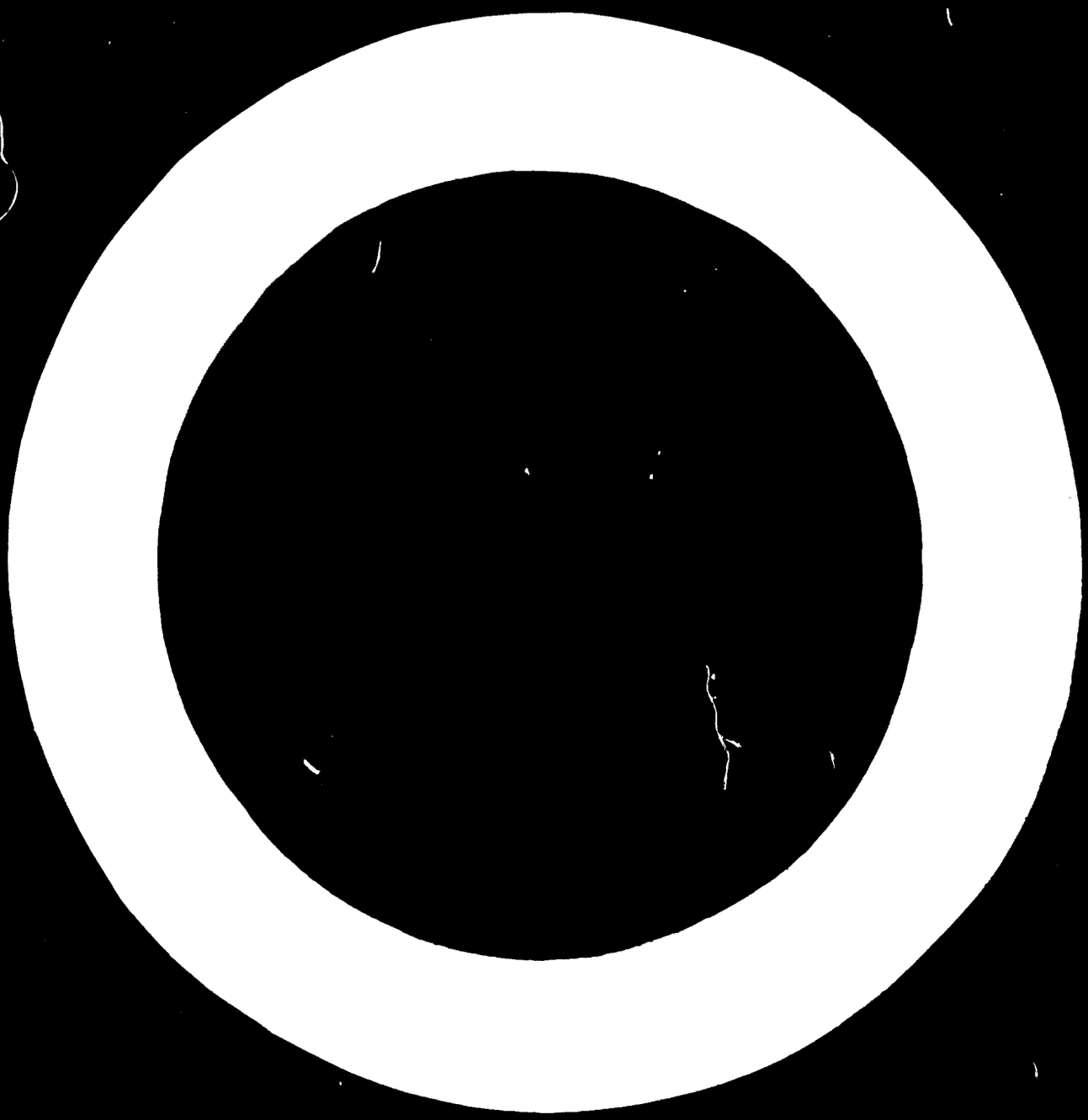
Development of Metalworking Industries in Developing Countries

Reports presented at the United Nations Interregional Symposium, Moscow 7 September—6 October 1966

Sales No.: E.68.II.B.2
ID/6

UNITED NATIONS
New York, 1969





D01383

METHODOLOGICAL AND OPERATIONAL ASPECTS OF MACHINE-TOOL STUDIES IN DEVELOPING COUNTRIES

Secretariat of the United Nations Economic Commission for Latin America

Background data

One of the worst difficulties usually encountered in the preparation of industrial development programmes in developing countries is the lack of reliable basic data on demand and costs in manufacturing activities. The seriousness of the problem depends, of course, upon the industrial sector and whether the work is to be done on the basis of a macro-economic estimate or on the level of branches of industry or specific products.

In relation to certain types of industry, either because of the characteristics of the production process or because of the nature and homogeneity of the goods manufactured or the use to which they are put, the basic data in question are more readily accessible or are relatively easy to determine; it is even possible, in many cases, for coefficients or ratios established in the more highly industrialized countries to be adopted without much adjustment. This would apply, for instance, to activities characterized by a continuous production flow resulting in homogeneous final products, such as the cement, chemical, and petroleum refining industries.

On the other hand, in those sectors of industry which display great flexibility in respect to the machinery they use and the products manufactured, satisfactory basic data and production coefficients are in very short supply and difficult to establish. Outstanding cases in point are the metal-transforming industries. With a few exceptions, the machines used in this branch of activity, i.e., machine tools, are not designed for the specific purpose of manufacturing a given product, but are intended to perform a particular operation (turning, milling, drilling, etc.) which, moreover, can be carried out by different machines. Thus, the capacity of a plant and the technical coefficient for the manufacture of any one product are highly relative concepts that are very difficult to quantify.

The factors conditioning production capacity, for example, will include, *inter alia*, the product manufactured and the machinery used, and the latter, in turn, is not determined by the product to be obtained because of the possibilities of interchanging machines for a large number of operations. One thing which may cause marked variations in technical production ratios in such industries is the standard of quality for the final product. Furthermore, the "universality" of the machines enables enterprises to run several widely differing lines of production simultaneously, which enormously complicates the establishment of technical coefficients and may make them useless in practice unless their precise significance and the possible limits to their applicability are clearly specified.

In developing countries where the degree of specialization is very low, and it frequently happens that the great majority of enterprises manufacture a very wide and varied range of products, this severely restricts the use of coefficients established for more highly industrialized regions, irrespective of the limitations deriving from the differences in capital-labour ratios, in standards of quality, in external economies and so forth. This last factor also has a noteworthy influence on technical production coefficients since, in the countries under discussion, the situation usually existing in the more developed regions is reversed and interindustrial relationships are slight owing to the lack of manufacturing activities specializing in services for third parties, with the result that enterprises show a marked degree of vertical integration, undertaking the manufacture of parts and accessories that in the developed countries are normally purchased from the subsidiary industry.

Little of the literature available on this subject bears on the metal-transforming industries, and the various studies that have been carried out were not exactly planned with a view to establishing production ratios or coefficients for application in other countries or under conditions different from those in relation to which they were determined. The methodologies have varied widely and so have the ways in which data have been presented but, generally, the feature common to all these studies is the rigidity of their findings, in the sense that they cannot be adjusted or amended so as to adapt them to different conditions in respect to volumes of production, technical processes, lengths of series, degrees of integration, standards of quality, composition and characteristics of lines of manufacture.

In carrying out its studies on the metal-transforming industries, ECLA was hampered by the lack of information of this type and consequently each survey had to be preceded by intensive field work to fill some of the gap. Data thus collected, in relation to the specific situation under analysis, might also be open to a good many criticisms of the same sort as those levelled above, with respect to their validity under other conditions. But since they were established in developing countries and correspond to the average conditions, they perhaps need less adjustment and can be more freely adopted for direct application in other countries at similar stages of development, as experience has shown in several instances.

The purpose of this report is to expound the methodology followed in the studies carried out by ECLA in the Latin American countries, as well as some aspects of its application, and a few of the conclusions to be drawn from a preliminary review of the various data assembled. The sole aim is that of offering other developing regions a share in the experience acquired in Latin America, and thus helping to facilitate the execution of any studies that may be undertaken with respect to the metal-transforming industries.

The information presented here relates particularly to the determination of demand for machine tools.

Remarks on the determination of demand for machine tools

It will be as well to state clearly what is understood in the present study by the terms of metal-transforming industries and machine tools. Both are frequently used in the literature of the subject, and what they are meant to cover apparently differs in different places.

In ECLA studies, metal-transforming or metalworking industries include all those activities which in the United Nations International Standard Industrial Classification of All Economic Activities (ISIC) are comprised in the following major groups: 35 Manufacture of Metal Products, except Machinery and Transport Equipment; 36 Manufacture of Machinery, except Electrical Machinery; 37 Manufacture of Electrical Machinery, Apparatus, Appliances and Supplies; and 38 Manufacture of Transport Equipment. The term machine tools is applied only to machinery used for metalworking purposes (whether cutting or forming) and therefore excludes machines for working wood or other materials.

In the case of machine tools, as in that of other capital goods, demand is conditioned by so many factors of such different kinds that to analyse them is a distinctly complex task. To the usual considerations bearing on demand for capital goods, such as, *inter alia*, their durability and its relation to depreciation, degrees of mechanization and the effects of production processes for which greater or lesser volumes of manpower are required, the existence of idle installed capacity or the possibility of making more intensive use of capacity through a system of two or three shifts, which enables production to be expanded without affecting demand for machinery, and the rate of replacement of capital goods whose useful life has come to an end, on account of either wear and tear or economic obsolescence, three others must be added which stem from machine-tool characteristics that cannot be overlooked in a study of demand.

The first is the interchangeability of many machine tools for the fulfilment of one and the same function, although this does not necessarily imply any change in the extent to which operations are mechanized; the second is the dependence of demand on specifications as to the quality and precision of the products to be manufactured, which means that machine performance must be evaluated; and the third consists of the extreme frequency with which technical innovations are introduced in machine tools and the emergence of new machining and metal-forming processes based on such as electroerosion, supersonics, electron beams, explosives and magnetic impulses. Strictly, therefore, demand should be studied in the light of a separate analysis for each of the many activities in which it has its origin. Obvious requisites for such research are, on the one hand, highly complete and detailed statistical information and, on the other, a series of basic data on operational conditions at the level of each activity, which are not easy to obtain or to reconstitute in developing countries.

Another point to be stressed is that inasmuch as the significance and incidence of the various determinants of demand for machine tools are not the same in developing countries as in those at more advanced stages of industrialization, the methodology applied must be adjusted to the needs of these two cases. For example, replacement on account of wear and tear or obsolescence will carry less weight in developing than in developed countries because, as a rule, inventories in the former are relatively new and rapidly expanding. Conversely, the characteristic of interchangeability will be of more importance in small national inventories where machine tools carry out very similar operations and the products manufactured are of a primary nature.

Another factor whose incidence is relatively heavier in developing countries is the qualitative aspect of demand. It often happens that in such countries the metal-transforming industries show high growth rates attributable not only to the manufacture of larger quantities of their products but also, and perhaps in greater measure, to the establishment of new lines of manufacture that are becoming imperatively necessary in view of import substitution requirements.

Consequently, changes are almost constantly introduced in the structure of production and in manufacturing techniques and this affects the characteristics of the machines in demand. This consideration is important also in connexion with the evaluation of installed capacity and the more intensive utilization of existing machine tools. It may well happen that the machine-hours which for some reason may be available in inventories in developing countries cannot really be turned to account for the purposes of expanding production, if the increases in the volume of output are largely to derive from the manufacture of new products calling for more advanced techniques.

From these brief remarks it can be seen that the developing countries need to adopt a methodology slightly different from that habitually applied in the more highly industrialized areas in the study of demand for machine tools. The modifications introduced will be conceptual rather than procedural, and in this sense certain stages of the process of analysis will have to be approached or covered by means of an *ad hoc* interpretation of the facts. Comparison with present or past situations in the industrialized countries may be useful in many cases, provided that the phenomenon under analysis can be adequately interpreted.

But this is not always possible, because the available data are so unsatisfactory both in quantity, homogeneity and explicitness. It would seem that in the field of machine

tools no laws or criteria operate that can be universally applied or extended from one region to another without prior analysis of the situation or phenomena involved, and in practice this means dealing with factors that vary widely in character and are often difficult to quantify.

Despite these complications, such studies are in one sense easier to carry out in the developing than in the highly industrialized countries, as the field of operations is more limited in its extent and less complex as regards range of products and technological alternatives. What is more, their very aims are less ambitious with respect to the degree of detail of their findings; their purpose is rather to arrive at an over-all and approximate assessment of the volume of demand to be expected in the future, and thus provide the general groundwork for evaluating the possibilities of starting domestic manufacture of certain machine tools, usually the simplest, and those that make the least technical demands, or for demarcating the areas of production in which the country's machine-tool industry should develop.

These were the objectives of the relevant studies carried out by ECLA in the Latin American countries and in order to attain them research was conducted at the level of three major groups which strikingly differ from one another in both the nature of the factors determining demand and the characteristics of the machinery required, and which comprise machine tools for production, for maintenance operations and for replacement purposes.

By definition, machine tools for production are all those installed in the metal-transforming industry, even though some of them may be used for making tools and for maintenance and repair work. Thus, demand for such machines is closely linked to the evolution of the metal-transforming industry during the period under study.

All machine tools used in activities other than those comprised in the metal-transforming sector are classified in the maintenance group, although in some instances they may be fulfilling functions that can be described as definitely productive. Demand for these machines is somewhat difficult to analyse, inasmuch as it is contingent not only upon the possible expansion of the sectors using them but also on other and perhaps more important factors which can hardly be expressed in quantitative terms.

Maintenance, in the sense ascribed to it here, if undertaken by workshops proper, is an auxiliary and not indispensable service in manufacturing, mining and other activities, so that the decision for or against its inclusion is influenced by a number of considerations peculiar to each individual enterprise, such as, *inter alia*, the size of the plant, its location with respect to metal-transforming centres where this service could be provided, and the degree of urgency with which maintenance requirements must be met (as determined by the nature of the production process), whose evaluation must be based on careful research. The incidence of this group of machines on aggregate demand may be considerable in countries where the metal-transforming industries are of little significance.

The term replacement is used with reference to cases where a machine tool is finally eliminated from the inventory on the grounds of its unfitness to carry out any operation, and requirements thus represent the net amount of machinery that should be replaced. Consequently, this group does not include machines that ought to be replaced in a specific sector or activity on account of technical obsolescence, loss of precision or other similar causes, if they are still usable for other and perhaps less demanding operations and continue to form part of the plant installed.

This definition, linked as it is to the end of the useful life of the machine, implies that the decision to replace a machine tool is dictated by widely varying criteria, and can only be adopted at the level of each individual unit in relation to the work it is doing. Thus, machine tool requirements under this head can be estimated solely on the basis of specific and highly detailed research. Since in developing countries [illegible] machine-tool inventories have been only recently set up and manufacturing requirements are not very exigent, the incidence of the replacement group on aggregate demand is of minor importance. Accordingly, for the studies undertaken it was thought best to make a very rough over-all assessment of replacement needs, based on a general survey of the situation and on interpretation of the evidence collected elsewhere.

Clearly, then, data on the size and composition of the inventory of machine tools currently in use in the industrial sector, and on the characteristics of the units comprising it, are essential for an analysis of demand, inasmuch as they represent background material for the determination of the machines needed not only to keep pace with the expansion of production in the metal-transforming industries, but for the purposes of maintenance operations in other industrial sectors and replacement of machine tools that have reached the end of their useful life.

Information of this type is not as a rule directly available in developing countries, and has to be procured by means of intensive field work. In such countries, the selection of simpler and more direct alternative procedures which might yield equally useful information or might at least provide guidelines for demand studies is generally ruled out by statistical deficiencies. For example, the national inventory might be approximately quantified on the basis of the records of the machinery imported over a reasonable number of years, from which some knowledge of the age distribution of the machines might also be obtained. But this is virtually impossible in a developing country for want of statistical data on imports, even at the highest level of aggregation, and on domestic production, if any. Separate records of imports of machine tools are seldom kept and, where they are, they include spare parts, accessories and tool kits, besides which, the definition of machine tools applied is not always the same as that adopted in the studies under discussion.

As regards future demand trends, an analysis of the evolution of machine-tool consumption in the past, supposing this can be reconstituted, is not of much value for projection purposes in developing countries for the reasons indicated above. But it should be carried out

because it is useful from other standpoints, as will be seen later.

Hence it appears that the most feasible method of determining future machine-tool requirements is to ascertain the number of units installed in the main consumer sectors and to estimate the expansion of production that is likely to take place in each of these sectors during the period under study.

Determination of the machine-tool inventory and projection of demand

Determination of the inventory

It has already been pointed out that data on the number and characteristics of machine tools installed in a given country are not as a rule directly available in developing regions and therefore have to be obtained by means of a survey of the consumer sectors. For this purpose, sampling procedures are adopted, according to the size of the sector concerned, in order to save time and resources. Here the first problem arises: deciding on the right size of sample.

Although this is a matter of mathematical statistics, some observations may usefully be proffered on the requisites with which the sample should comply, and on its representativeness. In the first place, the extent to which the sample is representative of the universe cannot be measured in terms of its percentage share in the number of workers employed or in the value of output, since the direct proportional relation of machine tools to these magnitudes cannot be established until certain considerations relating to the average size of the plants covered by the survey and of those constituting the universe have been taken into account. The studies carried out have shown that the ratios represented by the number of machine tools per employed person and per unit of value of production vary with the size of the plants (measured in terms of the manpower employed), but that in this respect the behaviour pattern of the former is more clearly defined; the ratio is high for small plants and low in those of larger size. Accordingly, it is easier to use the coefficient of machine tools per employed person than the ratio between machine tools and the value of production, and the resulting estimate is more likely to be reliable. Clearly, therefore, a sample that is strongly influenced by the bigger plants, which may account for a percentage of the manpower employed in the universe, precludes the possibility of ascertaining the total number of machine tools installed by extrapolation based directly on the proportion of the personnel employed in the universe which the sample represents because, in the case of workers not covered by the survey, most of whom would probably be employed in smaller plants, the number of machine tools per worker would exceed the ratio indicated by the sample. Extrapolation by this method would result in under-estimation of the inventory. Conversely, a sample including too many small plants would lead to over-estimation of the existing number of machine tools.

If plant size is an important factor in establishing the total number of machine tools in the inventory, it is of no less significance in relation to the latter's composition. In the bigger plants, the types and characteristics of the machine tools installed are much more varied than in those of more modest size, where the predominant items in the inventory are usually lathes, shapers, drilling and sawing machines, and a few machine tools for the simpler sorts of forming operations.

Consequently, a sample with a high proportion of large establishments will be conducive to under-estimation of the machine-tool inventory as a whole and over-estimation in respect to certain types of machine tools that are used only in the bigger plants; the position will be reversed if the incidence of small enterprises on the sample is heavy. In this sense, the large plants may be said to exert a marked influence as regards the variety, and the small ones in relation to the number of the machine tools inventoried.

Hence, the extent to which a sample is representative of the universe cannot be measured in over-all terms, but must be evaluated in relation to the composition of the universe by plant sizes, and if the composition of the sample differs greatly from that of the universe, extrapolation must be based on size categories. A direct proportional relationship between the machine tools installed and the manpower employed in the sample and in the universe is possible only when the average plant size is the same in the former as in the latter.

The distinction drawn between machine tools for production and machine tools for maintenance operations indicates that two inventories must be made: one in the metal-transforming industry and another in the other pertinent activities, including the extractive industries, construction, manufacturing (excluding metal transforming), provision of public utilities, government dependencies, and so forth. The foregoing comments on the quality of the same apply particularly to the first inventory, production machinery, which is really the more important.

Owing to the nature and characteristics of maintenance services, the conditions that the sample should fulfil in this case and the way in which it should be dealt with in order to obtain information on the universe have not been established in such concrete terms. The ECLA studies carried out in the field in question, which is far more extensive than that of the metal-transforming industries, and in which machine tools do not represent productive resources, have been mainly exploratory, and designed to seek out some data on the stock of machine tools in sectors other than the metal-transforming industry.

In the relevant studies undertaken in Latin America, the size of the sample could not be mathematically established for want of appropriate statistical information on the universe concerned, and other methods had to be adopted as circumstances decreed. The number of plants to be visited was tentatively established, according to the size of the industry under survey, with a view to covering all the activities involved and the range of plant sizes in each.

At this selective stage, every effort was made to work at the lowest possible levels of aggregation with respect

to activities, to ensure homogeneity of products, production systems, etc. In other words, the survey was not conducted at the level of the ISIC breakdown, which is carried only as far as the three-digit group, but at that of a four-digit subdivision established *ad hoc* or by adapting extant national classifications to this system.

In the course of the survey, the initial list was gradually amended and supplemented until in every size category in each activity a measure of constancy was observable in the number of machine tools per worker and in the composition of the machine-tool inventory. It proved possible to fulfil this condition with a sample comprising no more than 10 per cent of the establishments constituting the universe. An important decision that must be taken before a survey relates to whether it is to be nationwide or confined to major centres. Generally speaking, in developing countries a high proportion of the metal-transforming activities is concentrated in two or three such centres.

The next stage in the preparation of the inventory is the extension of the sample findings to the universe in order to estimate the total number of machine tools installed. Although the sampling procedure itself can be carried out in considerable detail, the same does not apply to the extension of the sample, since data on the labour force employed are not usually available at such a low level of aggregation. Industrial censuses do not as a rule go into so much detail, and the extension can be effected only at the level of the ISIC major groups 35, 36, 37 and 38. For this purpose it was decided to group activities by size categories and make the appropriate extrapolation for each of these in respect to both the number of machine tools and the composition of the inventory.

In developing countries, however, an important preliminary step is to find out what proportion of total employment is represented by personnel in establishments that do not need to use machine tools, such as workshops undertaking different types of simple machine repairs, or the installation of electrical fittings and the maintenance of electrical and electronic appliances and accessories, or electroplating and nickelplating, and so on. Evidence of the existence of this situation and of the significance attaching to it, especially in the smaller size categories, was gathered in the course of the surveys.

With regard to the age of the machines, the criteria governing the validity of the sample in relation to the number of machine tools installed and the composition of the inventory are no longer adequate and other factors must be taken into account. But, as previously remarked, in developing countries the inventories have been more or less recently built up, and replacement is not a major component of demand, so there is no need for such accuracy. The information on age requested in the survey is wanted mainly as a general guide and, in addition, for the purpose of checking certain aspects of the calculation, particularly with respect to the size of the inventory. From this point of view, it is decidedly useful to compare the age distribution of the sample with the composition by age groups that can be worked out from the estimated total for the machine-tool inventory and data on imports or apparent consumption of machine tools in previous years. From such a comparison, valuable conclusions can be drawn as to the estimate formulated and the quality of the data used.

The procedure followed for determining the inventory of machine tools used in maintenance operations resembles, in broad outline, the method described above, although the coverage of the sample is extensive rather than intensive, and its extrapolation to the universe is effected at higher levels of aggregation, by more direct and consequently less exact methods. In the case of this inventory, the field of action can be circumscribed and the survey confined to plants whose size exceeds a specific minimum, which can be fixed in the light of a preliminary review of the situation.

In the Argentina study, for example, it was established that maintenance services, as defined here, were found mainly in enterprises employing more than thirty persons, which meant that the field of operation could be restricted to approximately 4 per cent of the existing plants. As regards extrapolation of the results of the studies carried out, it was thought advisable, in view of the wide dispersion of the sample, to deal with the sample data in the aggregate, omitting the stage of inventorying the machine tools in each of the activities covered by the survey; moreover, this procedure may well be adequate for the aims and scope of such studies. It was ascertained that when the inventory in the metal-transforming industries exceeds 20,000 machine tools, the size of the maintenance group ranges from 15 to 25 per cent of this total.

With respect to the composition of the maintenance inventory and the age of the machines, the same observations hold true as were formulated in relation to the metal-transforming industries. Very little diversification is usually found, lathes, drilling machines, shapers, shears, folding machines and others with simple characteristics being by far the commonest items, while the average age in this group is much higher than in the inventory of machine tools for production.

The purpose of the foregoing description is to indicate the most salient aspects of the task of inventorying machine tools. In practice, according to the circumstances and to the availability of basic statistics, operational problems may arise which entail some modification of the procedure, thus making the research either easier or more complicated.

Projection of demand

The problems raised by the projection of demand are also many and varied, and derive from the many factors that affect demand for machine tools. Although in theory many of these factors are relatively easy to identify, their incidence and implications are difficult to assess in quantitative terms and, in practice, therefore, their accurate evaluation is attended by serious difficulties. For the problems thus created, tentative solutions must be sought whereby over-all effects can be analysed in the light of personal experience, information on the situation under study and interpretation of what has happened in other countries.

In these circumstances, obviously, various devices, methods or criteria may be applicable for the purposes of projecting demand. The object of this paper is not to examine all the methods of determining future machine-tool requirements, but to give an account of the method followed in the ECLA studies, thus providing a rough estimate of the prospective volume of demand and a general idea of the direction of its probable trends.

In line with the classification established above, demand was analysed separately for each of the three groups of machine tools: those for production, those for maintenance, and those for replacement.

For production machinery, the procedure comprised three stages. The first consisted of determining the value of production and the volume of employment in the metal-transforming industries at the end of the period covered by the projection; in the second, the aggregate number of machine tools likely to be in use was estimated; and in the third, the composition of this inventory by types of machine was established. Thus, the difference between the inventories computed for the base and for the final year of the projection gave the number of machine tools that would be needed.

The influence of the determinants of demand enumerated in earlier paragraphs will be reflected mainly in the total number of machine tools and the composition of the inventory. In the first connexion, their effect can be interpreted and evaluated through the behaviour pattern of certain indicators such as productivity (measured in terms of value added per worker), value added per machine and the number of machines per person. For the purposes of the studies under consideration, it was thought sufficient to subject these magnitudes to a series of adjustments in order to make them, by means of successive approximations, more or less consistent with one another in respect to both the total projection and the additions to the base-year inventory. A further consideration that was also taken into account for checking purposes was the maintenance of the total amount of investment entailed in the expansion of the inventory at a level which would represent a reasonable proportion of the increased product that should be generated in the projection period.

Assumptions as to the percentage composition of this new machine-tool inventory were deduced from the following points of reference: the structure of the inventory in the base year; changes in the composition of apparent consumption of machine tools; specific manufacturing projects and development programmes, particularly in certain branches of the metal-transforming industry; and breakdowns of inventories in other countries at different stages of economic development.

In view of the difficulties of estimating demand in qualitative terms, and specifying the models, types and characteristics of the machine tools that would be required, so as to define this other important aspect of future demand, it was decided that in the ECLA studies an over-all evaluation from the qualitative standpoint should be based on the average weight of the machines and their average price per kilogramme.

Thus, machine-tool requirements in the production group were established in terms of numbers of units and types of machine, with the indication of quality provided by weight and average price.

As regards machine tools for maintenance, neither local statistical data nor reference material bearing on the situation in other countries were available on a scale that would permit the establishment of the most suitable criterion for determining requirements. In a few instances, however, it was possible to ascertain that the maintenance inventory is equivalent to a relatively small proportion of the production inventory when the latter exceeds 20,000 units. Moreover, the composition of the former is more stable, and the factors primarily influencing the demand generated in the maintenance sector differ from those discussed in the context of production activities, and are usually less dynamic.

Accordingly, it was decided to assume as a first approximation that during the period covered by the projection the inventory of machine tools for maintenance would continue to bear the same proportional relation to that of machine tools for production as in the base year and that its composition would remain constant. Obviously, the validity of this assumption will have to be more carefully tested in the future in the light of such data as may be collected on the subject.

Mention has already been made of the low incidence of replacement on total demand in developing countries, attributable to the fairly recent formation of the inventories. In this connexion, however, some distinctions must be drawn in relation to the ways in which the inventories have been built up. The shortage of capital which is all too well-known a feature of such economies often means that, in decisions to purchase machinery, price carries more weight than quality, with the result that units are imported whose useful life will necessarily be very short.

This noteworthy fact, evidence of which has been found on various occasions, acquires still greater significance in countries possessing a domestic machine-tool industry which, while not very highly developed as regards the variety and quality of its products, is sizable in quantitative terms. Upon the extent to which such a process has taken place will depend the potential incidence of replacement at any given moment; it may attain appreciable proportions even in the case of relatively new inventories.

Thus, given the definition of replacement adopted here, not even a rough over-all estimate of machine-tool requirements for this purpose can be formulated unless data on age distribution are supplemented by an evaluation of the quality of the inventory and of the way in which it has been formed. Numbers are not enough in themselves; qualitative data must also be collected, to which end extremely useful information can be obtained from first-hand inspection of inventories from machine-tool distributors and from other sources.

Machine-tool inventories in Latin America, especially in Argentina and Brazil, showed no signs, at the date when the surveys were carried out, that replacement requirements were likely to be of much significance in the ten-year period selected for the study of demand. They contained, however, a large proportion of domestically

manufactured machines whose standard of quality was not very high, especially in the under ten-years age group, which suggests that in these countries the incidence of replacement on demand may be heavier in the future. The estimates formulated in the case studies were highly tentative over-all computations in respect to both the total number of machine tools and the composition of the inventory by types.

It was assumed that neither machines added to the base-year stock nor those that were less than ten years old in the base year would be replaced during the projection period or, in other words, that the machines over ten years old in the base year would constitute the group in which replacement requirements would be mainly concentrated. A further postulate was that 20 per cent of such machine tools would be replaced in the ten-year period under consideration which would be tantamount to assuming that the average age of the machines in this section of the inventory was about 25 years. In the case studies, replacement represented between 8 and 9 per cent of the total number of machine tools installed in the base year.

Data required and methods of obtainment

In the preparation of machine-tool studies on the lines described above, the supply of data available plays an important role. The degree of detail in which the conclusions deriving from the analysis can be presented, the evaluation of specific situations and the alternative methods of dealing with them that can be adopted, the accuracy of the findings, in short, the methodological process itself, are largely contingent upon the quantity, quality and level of aggregation of the data to hand. Furthermore, the time and resources expendable also exert a marked influence on the findings of the research and the method pursued, particularly if it is the first time that such studies have been undertaken in the country concerned. This was precisely the position in respect to the studies carried out by ECLA in Latin America.

Much of the information in question, as has already been pointed out, is not directly available in the developing countries, and a considerable amount of time and resources has to be spent on assembling it. The field is extensive, and action has to be taken in various directions, so that special attention must be devoted to this stage of the work.

It is particularly important, in this connexion, to establish beforehand what level of aggregation will be adequate for the purposes of the study, or will be feasible in view of local conditions, and to plan the collection of data on that basis; the more detailed the breakdown by activities and types of machines required for the final results, the lower the level of aggregation of the requisite data will have to be. It should be borne in mind that generally little headway can be made in this direction in developing countries, since in the first place the subdivision of activities is limited by the low degree of specialization, and the classification of enterprises at very low levels of aggregation is virtually impossible, while, in the second place, not many subdivisions by types and models of machinery can be established owing to the lack of diversification of the inventories, especially as regards highly specialized machine tools or those whose characteristics are suited to long manufacturing series.

Before embarking on this stage of the collection of data, it is useful to prepare a list of what will be required and adapt the investigation to the aims and objectives of the research. A mistake frequently made is to ask for excessively detailed information, on the supposition that the study will thereby be facilitated or that its findings will be more accurate. While this may be true of specific aspects of the analysis, it is not generally so for the work as a whole since, as has been shown, in many phases a number of assumptions and hypotheses have to be postulated which entail a higher level of aggregation.

To facilitate the listing of the information needed, the main items will be summed up briefly with some indication, where appropriate, of their importance and their repercussions in the various stages of the work. The data in question can be grouped in three major categories, according to whether they are required for the inventorying of the machine tools installed, for the determination of apparent consumption or for the projection of demand.

For inventorying the machine tools installed

Two surveys have to be made to determine the inventories of machine tools for production in the metal-transforming industries, and of machine tools used for maintenance operations in other activities. The information required is much the same in both cases and to save time and space the account given here will be related primarily to the former.

In order to prepare the sample and select the enterprises to be covered by the survey, the size of the universe must first be ascertained in terms of the number of establishments and the personnel employed in each activity and of the geographical distribution of the plants. This information generally can be obtained from industrial censuses or similar sources. However, it may not be sufficiently detailed as regards the subdivision of activities and the breakdown of establishments by plant size which, as has been shown, is an important factor.

In such circumstances, recourse must be taken to the actual source of the data and the original census or sample survey figures must be sought out so that the universe can be reconstructed at the desired level of aggregation. In addition, this procedure will provide a list of enterprises, with the location of each, from which the sample can be selected.

Two points are worth noting here, one bearing on the size of the plants covered by the survey and the other on the datedness of the figures, which may give rise, where expedient, to adjustments of two kinds. In some instances, statistical data may relate only to establishments above a given size (defined in terms of employment levels). This may, according to the size chosen, involve extra work for the purpose of incorporating the smaller plants in the sample, or making an adjustment at the time of extension to the universe, or may entail nothing other than the adaptation of the whole research to the limitations

imposed by the basic statistics. Similarly, if the statistical data do not apply to the year of the survey, information on the universe will have to be brought up to date or the enterprises will have to be asked to supply the relevant figures in respect to the nearest year for which statistics are available, with due regard, of course, to the length of time that has elapsed and the significance of whatever changes may have taken place.

It must once again be stressed that the extension of the sample can only be effected at the level of aggregation for which data on the universe are to hand. If no census data are available for the year of the survey or for one close to it, it will not be possible to carry the breakdown beyond the three-digit ISIC group.

To ensure that the survey can be successfully and speedily completed, it is important to cut the inquiries to a minimum and to prepare the simplest possible questionnaire which will be easy to answer in the environment under study. In the ECLA case studies it was thought sufficient to confine the general question to the following items: (*a*) name and location of the enterprise; (*b*) number of actual working days in the year and average number of hours worked per day; (*c*) number of persons employed (operatives and employees); (*d*) annual sales; (*e*) main activity of the enterprise, and its incidence on sales; (*f*) secondary activities; (*g*) estimated percentage of production capacity utilized. Good results have been obtained with the breakdown of machine tools by types indicated in table 1. In the case of each of these types of machine, the number installed and their ages are ascertained. But for the sake of simplicity, since information on the age of the inventories is mainly for guidance, all that is requested in this connexion is an estimate of average age for each of the two major categories of machine tools (cutting machines and forming machines), with a breakdown by the following age groups: under 10 years old, 10 to 20 years old and over 20 years old. If such figures were requested for each individual machine tool it would make the questionnaires lengthy and the replies and their subsequent tabulation unduly complicated, while little would be gained towards the purpose for which the information was intended.

Table 1

BREAKDOWN OF MACHINE TOOLS BY TYPE

Group A: Metal-cutting machines

- **Lathes**
  - **Bench**
  - **Engine**
  - **Copying**
  - **Plateau**
  - **Vertical**
  - **Turret** (manual and semi-automatic)
  - **Other** semi-automatic (i.e., multi-tool lathes)
  - **Automatic** (single multi-spindle)
  - **Other** (spinning, oval-chuck and other specials)
- **Milling** machines
  - **Universal**
  - **Vertical**
  - **Others**
- **Pantographs**
- **Drilling** machines
  - **Bench**
  - **Pillar**
  - **Radial**
  - **Multi-spindle**
- **Boring** machines
  - **Universal by co-ordinates**
  - **Jig**
  - **Production**
- **Planers, shapers and slotting machines**
  - **Shapers**
  - **Planers**
  - **Milling and planing**
  - **Others** (slotters, etc.)
- **Broaching machines**
- **Threading machines**
  - **Chip-production type**
  - **Forming type**
- **Gear-cutting machines**
  - **Gear cutters**
  - **Grinders, shavers, etc.**
  - **Chamfering**
- **Sawing machines**
  - **Hack-saws**
  - **Bandsaws**
  - **Circular**
- **Grinding machines**
  - **Universal cylindrical**
  - **Surface grinding**
  - **Centreless**
  - **Others** (internal, contour grinders, thread grinders, etc.)
- **Tool-grinding machines**
  - **Universal**
  - **Special**
- **Honing and lapping machines**
  - **Honing**
  - **Lapping**
- **Special multi-station machines**
  - **Machining units, transfer machines, etc.**

Group B: Metal-forming machines

- **Presses**
  - **Hydraulic**
  - **Eccentric**
  - **Friction**
  - **Others**
- **Forging presses**
  - **Upsetters** (hot and cold)
  - **Others**
- **Forging hammers**
  - **Mechanical**
  - **Steam** or air
    - **free forging**
    - **die forging**
- **Machines for sheet**
  - **Shears, hand drive**
  - **Shears, power drive**
  - **Folding, hand drive**
  - **Folding, power drive** (including press brakes)
  - **Bending rolls, hand drive**
  - **Bending rolls, power drive**
  - **Others**

For the survey itself can be conducted either by mail or by direct interviewing: the relevant decision will have to be taken in individual cases in the light of such considerations as the volume of the sample, the resources available and so forth. It need only be pointed out here that in developing countries direct interviewing has obvious advantages over sending the questionnaires by post, although the latter procedure is less burdensome. The following are the main arguments in favour of the former method: the certainty of obtaining replies is greater, especially where small- and medium-sized establishments are concerned; there is a better chance that information will be given correctly; the homogeneity of the replies is safeguarded as errors deriving from wrong classification of the machines, or from terminological or conceptual causes will be minimized; and, lastly, the inventories can be inspected and evaluated at first hand.

For the determination of apparent consumption

As already explained, apparent consumption data are not of fundamental importance for demand projections and serve mainly as a supplementary guide to the elucidation of certain aspects of the research relating particularly to the qualitative evaluation of the machine tools installed, to replacement requirements and to the possible structure and characteristics of future demand. Information on imports, domestic production and exports during a given number of years is therefore needed. Statistics of this kind are seldom directly available and field work must be done.

For import and export figures, it is often necessary to have direct recourse to customs records, and even to carry investigation to the extreme of going through the bills of lading in order to obtain the data at the requisite level of aggregation, severely handicapping the prepara-

tion of a long apparent consumption series. If this information is to be of use for the purposes mentioned, the data should be collected as far as possible in terms of units, weight and value; accessories and tool kits should be excluded; and the machine tools should be classified in accordance with the breakdown adopted for the inventory.

With regard to domestic production, the survey that has to be carried out is usually on a scale small enough for all the existing establishments to be covered. Moreover, this is desirable when the research is extended to future development prospects. The same data should be asked as in the case of imports and in that of the actual breakdown of the machine inventory.

Clearly, the analysis of apparent consumption must relate to the total number of machine tools consumed, whether they are for production or for maintenance, as it is very difficult to ascertain the final use to which either domestic production or imports are to be put. The inferences to be drawn will concern chiefly the average weight and the price per kilogramme of the machine tools that have fed the inventory, the respective percentage contributions of domestic production and imports, and trends in the composition of consumption by types of machine. The possibility of deducing more or less final conclusions from these relationships will depend upon how long a time series can be constructed and on how evenly consumption is distributed throughout the period. In any event, the effort is worth making for the sake of the guidance such information can provide.

For the projection of demand

A country's machine-tool requirements are closely linked to its economic development process in general and, in particular, to the evolution of its metal-transforming industries. In this connexion, all available information must be procured on the growth prospects of the gross domestic product, the manufacturing sector and the metal-transforming industries in the period under study. It is also important to collect data on the establishment of new metal-transforming activities which may affect the composition and characteristics of demand for machine tools as, for instance, the motor vehicle industry, shipbuilding, manufacture of machinery, etc. Information of this type can often be obtained directly from national development programmes and from planning agencies, which obviates the need to spend much time on research. Otherwise, this task too will have to be tackled, but a detailed account of it would be out of place here.

Of great importance for this stage of the study is the information derived from the preceding phases, i.e., from the determination of the inventory and of apparent consumption. Equally useful are any data that may be available on what has happened in other countries, provided they can be satisfactorily interpreted.

Various studies carried out in other regions and touching upon the problem of estimating future machine-tool requirements have noted other methods of criteria applied for this purpose, two of which are worth special mention. One is based on the ratio between the value of the machines purchased and that of the products manufactured by the metal-transforming sector, and the other on the relation between the machine-tool inventory and steel consumption. For various reasons, it was impossible to apply these criteria in the Latin American case studies for the projection of demand itself, but they were considered of interest as a means of cross-checking, although not in very conclusive terms, the order of magnitude of the final figures.

Research Undertaken in Connexion with Machine-tool Studies

A preliminary review of the data collected in Latin American countries where specific studies on machine tools or on the metal-transforming industries in general have already been carried out revealed a measure of uniformity in the evolution of certain coefficients. This suggested the possibility of establishing a set of these proportional relations such that, while making no claim to take the place of an inventory, it might provide a basis for appraising a given situation rapidly and with some degree of accuracy, and even afford background material for machine-tool studies.

To this end, a start was made on systematic analysis of the data with a view to defining, in an initial phase, the general behaviour pattern of the coefficients in question, the factors that may modify them and the effect of these on their magnitude, so as to be able to demarcate the margin of variation to which they were likely to be subject and determine the conditions in which they could be reasonably safely applied. To begin with, research was concentrated on two factors, one relating to the coefficient of machine tools per worker and the other to the composition of the inventories by types of machine.

As regards the former, it is a common practice in studies carried out in the industrialized countries to adopt a fixed ratio between the number of machines installed and the number of workers employed, i.e., around 50 machines per 100 workers. Since not enough data are available for the possibility of applying this figure indiscriminately in the developing countries to be evaluated, it was considered worth while to undertake preliminary research on the subject. The second factor, so far as is known, has not been the object of special analysis.

The metal-transforming industry as defined in the present study, covering four of the ISIC major groups, is an immense body of activities whose production characteristics are heterogeneous in the extreme. Moreover, its structure differs from one country to another and is liable to change as the development process makes headway, particularly in the developing countries. Thus it seems hardly likely that coefficients or ratios could be established for the metal-transforming industries as a whole which at the same time would be applicable throughout the region. Accordingly, the analysis was begun at the lowest level of aggregation consistent with the available data, i.e., that of the four major groups, with the idea that this would permit of greater flexibility

in the application of the coefficients, since the over-all position would be calculated by weighting the sum of the results for each group.

The first steps in the analysis were directed towards determining the behaviour of the coefficients of machine tools per worker and of the composition of the inventories in relation to plant size. It was demonstrated that the magnitude of the former was very closely linked to the latter variable and that, at the same time, the behaviour pattern was different in each of the major groups. By comparison of the findings of the country studies, the extent to which this divergence was attributable to factors other than plant size was also assessed.

If anything like final conclusions are to be reached in an analysis of this kind, it is necessary to handle and have access to much data. Those so far assembled are not sufficient to provide a basis for specific findings, but they do give a fairly clear idea of the behaviour pattern of the coefficients in question.

For illustrative purposes, figure 1 shows how the coefficient of machine tools per person varies in relation to plant size. The curves thus plotted for the four groups are all hyperbolic, only the magnitudes altering, and the variations are as indicated in the figure.

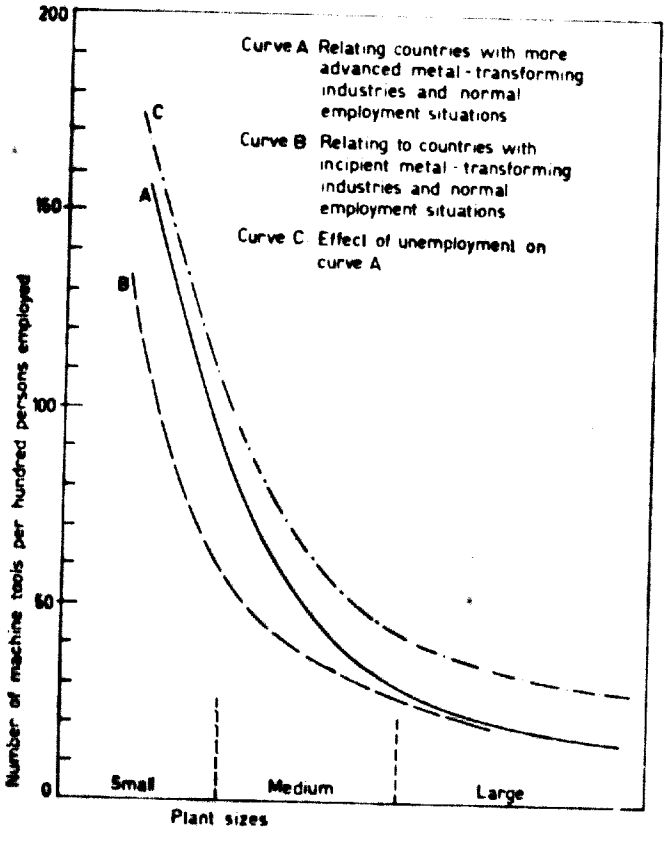


Figure 1

Relation between number of machine tools per hundred persons employed and plant size

In the first place, an important determinant of the changes in the magnitude of this coefficient, irrespective of all other considerations, is the level of employment in the industry. Where unemployment is rife, the number of machines per hundred workers is of course larger, but the shifted curve, instead of remaining parallel to that plotted for a normal employment situation, indicates relatively higher figures for the bigger establishments than for plants of small or medium size. This discrepancy can be noted between curves A and C in the figure; the explanation probably lies in the fact that as a general rule the effect of unemployment is proportionally more significant in large than in small establishments. Thus, in dealing with the coefficient under discussion, it is important to bear the influence of this factor in mind and, in the case of comparative studies, relate it to normal employment conditions.

Furthermore, the coefficient of machines per hundred workers alters from one country to another in accordance with the stages of development reached by the metal-transforming industries concerned; it is lower where they are in the initial phases of development and higher where they are more advanced. Curves A and B in figure 1 represent the variations in this coefficient as between countries at different levels of development or, in other words, whose metal-transforming industries differ in size. Curve A relates to countries with a total machine-tool inventory of more than 100,000 units, and curve B to those whose inventory is less than 30,000 machines. It is worth noting that in both cases similar curves result, from which a curve representing the average position can be safely derived. This suggests that it might be possible to plot a set of curves representing different levels of development and thereby enormously reduce the field of variation of the coefficient, especially in respect of small- and medium-sized enterprises, where the greatest discrepancies occur.

From a comparison of curves A and B it can be seen that the effect of different stages of development on the size of the coefficient is marked in the case of medium- and small-scale enterprises, but not in very large or very small plants where the coefficients draw close to one another. For all practical purposes, the problem reduces itself to defining the position in respect to plants employing from 10 to 300 workers, which is precisely the range within which most metal-transforming establishments in developing countries fall.

The explanations that can be adduced to account for the greater influence exerted by the stage of development in small- and medium-sized enterprises are many and varied. Two, however, deserve special mention. In countries where the metal-transforming industry is of limited dimensions and in the early stages of development, a high proportion of the small- and medium-scale enterprises concentrate their attention on maintenance services or assembly work, or the manufacture of a few simple products, all of which activities are characterized by low ratios between the machines and the number of workers, so that the plants in question naturally show very low coefficients of machine tools per hundred workers. In somewhat more advanced countries, on the other hand, where the industry is on a larger scale, such enterprises also play an important productive role, either as direct suppliers of the market or by providing inter-

mediate products for the larger firms, and this is of course reflected in a higher coefficient of machines per hundred persons.

Secondly, it is important to note that in the latter group of countries the domestic machine-tool industry is beginning to play a more outstanding part in the satisfaction of internal consumer demand, especially with respect to simple and not very high-quality machines. This more plentiful supply of precisely those machines which are in most demand in small and medium establishments naturally helps to explain why such enterprises are better equipped in the larger countries than in those with narrower markets, where domestic production is negligible or non-existent.

The asymptotic nature of the curves as manifested in the very slight variations in the coefficients of machines per hundred workers in the case of large enterprises may account for the fact that in the industrialized countries it is possible to adopt a fixed coefficient, as was pointed out above, without incurring the risk of any significant error, since in the countries in question the proportion of big establishments is higher than in developing countries. The *a priori* inference is that the coefficient commonly used in the industrialized countries is unlikely to be applicable in countries in process of development. Nevertheless, the behaviour of these curves in the industrialized countries would need to be investigated a little further in this connexion. Such research would shed useful light not only on this aspect of the problem, but also on the behaviour pattern of this coefficient and its magnitude at stages of development that the Latin American countries have not yet reached, but towards which they will be heading in the future.

The composition of the inventories by types of machine tools, which is the other proportional relationship studied, is likewise largely conditional upon plant size, while here too the effect of the stages of development reached by the different countries is discernible. Figures 2 and 3 give an outline indication of the trends that it has been possible to trace so far. As in the case of the coefficient of machines per hundred workers, a more specific pronouncement will be possible only when more data have been analysed. Here, the variations depending on plant size tend to follow a straight curve, and the incidence of the stage of development is revealed by the slope of the curve. Moreover, considerable differences are observable from one group to another.

The effect of plant size on the relative importance of the various types of machines in the composition of the inventories can clearly be seen in these figures. For the

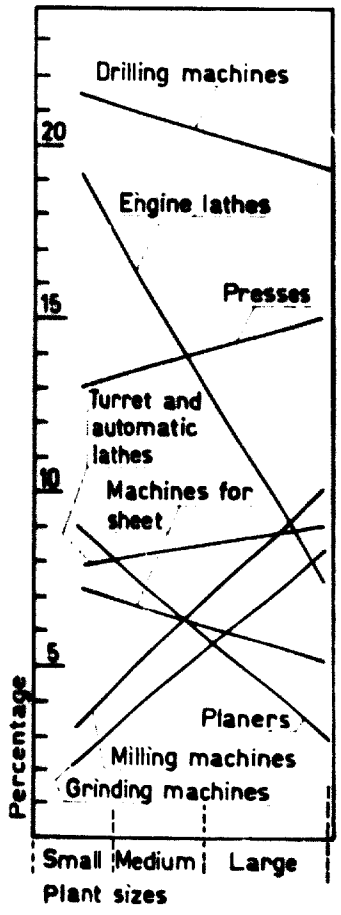


Figure 2

VARIATIONS IN COMPOSITION OF INVENTORIES BY TYPES OF MACHINES IN RELATION TO PLANT SIZES

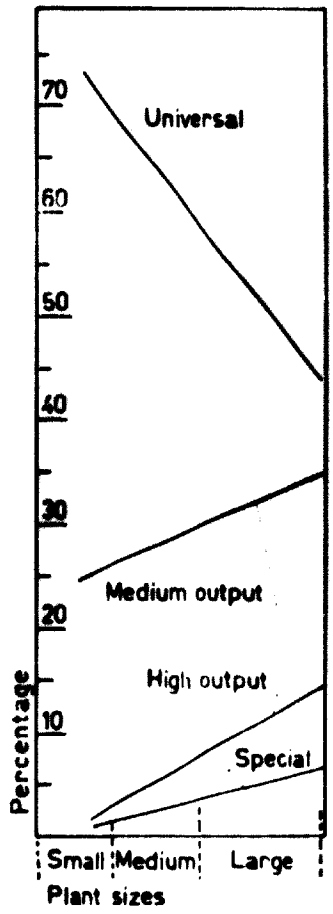


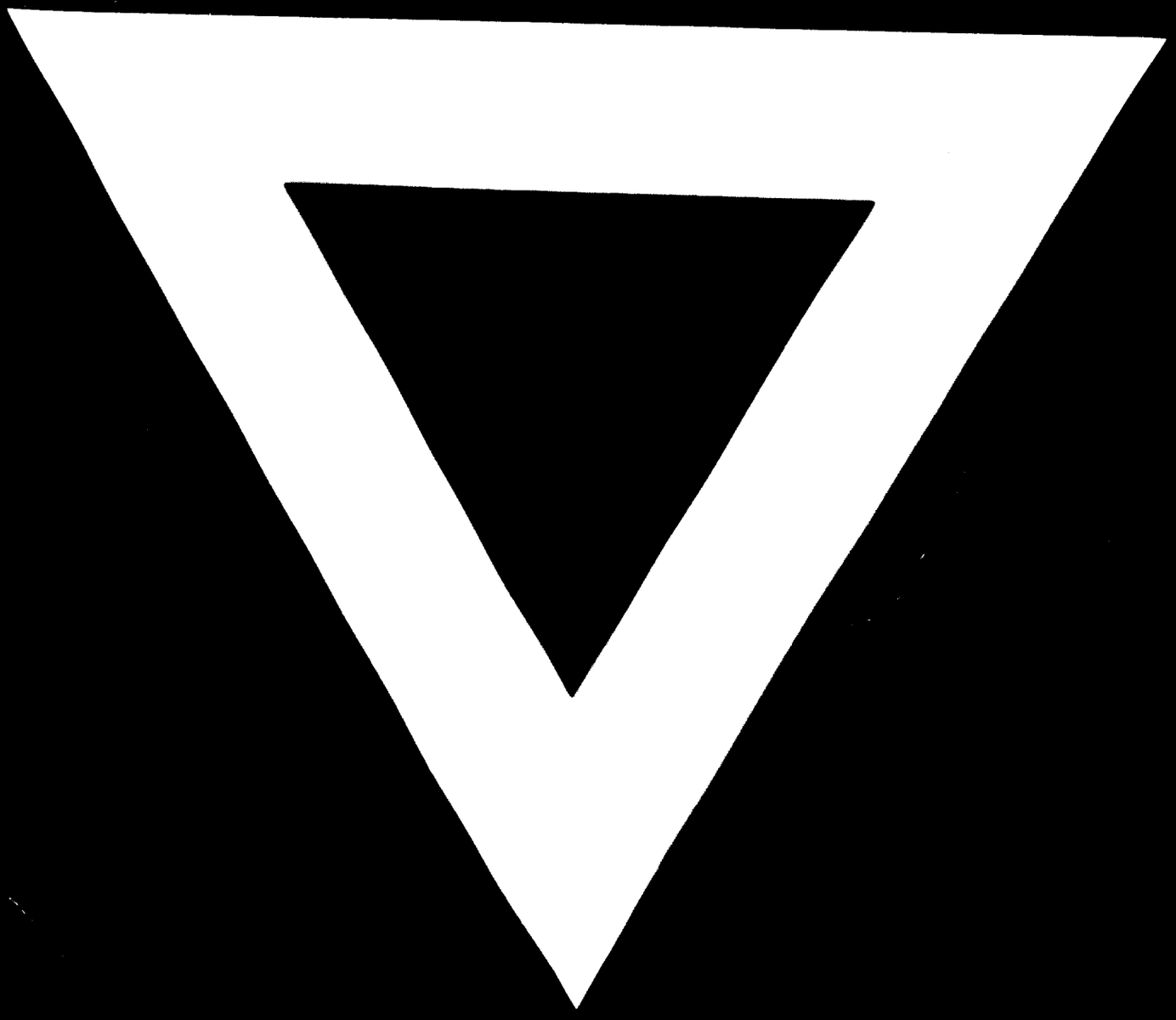
Figure 3

PROPORTIONS OF INVENTORIES REPRESENTED BY UNIVERSAL, MEDIUM AND HIGH OUTPUT AND SPECIAL MACHINES IN RELATION TO PLANT SIZES

sake of simplicity, only those machines that represent major proportions of the inventories are shown in figure 2. Particularly sensitive to plant size, and inversely proportional to it, are the shares corresponding to engine lathes, planers, drills and machines for sheet (shears, folding machines, bending rolls, etc.).

The relative importance of all the other machine tools in the composition of the inventories increases with the size of the plants. This is a logical and unremarkable phenomenon in itself, but some interest attaches to the regularity of the variations. The same may be noted in figure 3, where the machine tools are classified by their characteristics (universal, medium- and high-output, and special).

Although the findings of the research on these proportional relationships are not yet concrete enough for their practical applicability to be guaranteed, it was thought worth while to give some idea, in this brief paper, of the work that is being done in this field and the conclusions reached, so that they may at least afford some general guidance for any studies that may be carried out in other regions.



10.7.74