Development of Metalworking Industries in Developing Countries

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ORGANIZATION OF A MACHINERY CENSUS AND USE OF CENSUS DATA WITH SPECIAL REFERENCE TO INDUSTRIALLY DEVELOPING COUNTRIES

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INTRODUCTION

An inventory, or census, of machine tools and other production equipment used by the metalworking industries is taken in a number of countries. In some countries this has been done only once, in others the studies have been repeated at fairly regular intervals.

All of the studies have certain features in common. This is fortunate because it permits a nation starting such a study for the first time to find reports with which useful comparisons can be made. It also suggests that any country about to plan such a census would do well to follow the general pattern.

The first known national count of production equipment was in the United States in 1925 by American Machinist, a magazine published by McGraw Hill Inc. of New York. The editor at that time was Kenneth H. Condit and the general manager was Mason Britton. They developed the concept. The study was directed by William F. Irish, associate editor.

The reason for that first inventory was plainly stated: "For fifty years the American Machinist has served the makers and users of metalworking equipment of all kinds. From its first issue it has urged the use of the most modern equipment and the scrapping of obsolete tools. Now, to advice and exhortation, it takes pride in adding actual figures on the extent to which modern equipment is in use. It is hoped that users of equipment of this type will study the figures to make sure that their own equipment is in better shape than the average, and that builders will find in the figures tools for sales arguments to present to ultra-conservative buyers."

The original purpose then was to provide a measure of the degree of modernization in industry. It was obvious that some yardstick was needed for measuring obsolescence and the yardstick chosen was age, with the dividing line being an age of ten years.

The originators recognized that it would be more logical to apply different age standards to different types of equipment or to evaluate the productivity of each individual machine, but they also recognized that neither course was practical. They said that a "survey like this one would fall of its own weight if it attempted to be too precise and in so doing introduced into the questionnaire a mass of complication so forbidding that no one in his senses would attempt to answer it." Furthermore, the task of analysing data based on different standards of machine life would be quite beyond the bounds of practicability."

Although the ten-year yardstick has to be used with understanding, it proved so satisfactory that it has been adopted by the organizers of every other census in which any effort is made to measure modernization.

But even that first inventory had important uses besides the stimulus to modernization. The facts about the distribution of different kinds of equipment in different industries proved different from what most people concerned with industry had thought. It turned out that not nearly so much concentration of specialized machines in certain industries existed as had been generally thought. Thus, the screw-machine product industry had scarcely 6 per cent (in 1925) of the screw machines, the bulk of the machines actually being used to make parts in other industries.

The first inventory also pointed up the problem of a lack of a well-defined distinction between different classifications of equipment. This led to a study of how to classify machine tools. A Subcommittee on American Machinist's Questionnaire, in the Durable Goods Industries Committee of the United States Government, was formed. The problems of nomenclature for machine tools will always be with us, but today we have general agreement on most of the older types of machines.

The results of that 1925 inventory were published on 12 May 1927. It may be of interest that they showed that 44 per cent of the equipment was at least ten years old. The total number of machine tools reported in metalworking plants in the United States was 920,000, and the estimated total in the country in all industries was 1.2 million machine tools.

Interest in the inventory was so great that it became a regular part of American Machinist operations. That first inventory included sixteen different industrial classifications but did not include any geographic breakdown. The 1930 inventory was made on the same industrial basis but added a geographic split into eight areas.

Basic changes were made in 1935. Division into twenty industrial categories was made and the geographic division was enlarged. This arrangement was continued in 1940 and 1945.

Extensive changes also were made in the fifth inventory in 1949. The industrial and geographic breakdowns were revised, and there was added an age category to show equipment more than twenty years old. The geographic pattern was revised again in 1963 but has remained unchanged since then. The industrial division has been refined almost at each new inventory. The most recent inventory, the ninth, taken in 1963 reports on equipment in forty-four industry categories, twenty-four geographic areas, and three age classifications.
The types of equipment studied, and the method of classifying them, have also been changed. In the first inventory 117 types of equipment were charted. A number of peripheral types have since been dropped and other types have been subdivided. Currently, the inventory covers 166.

Many of these changes have been made reluctantly because of the problems they create in comparability of one study with the next. They were made because experience in using the studies or changes in the structure of the machine-tool park made them desirable. Some changes can be made without creating a problem. To subdivide a type of equipment, an industry, a geographic area, or an age period does no harm. It provides more detail, without damaging comparability. Thus, a classification of automatic bar machines can be subdivided into no loss of ability to single- and multiple-spindle with no loss of the ability to make comparisons with previous years, but with a clear gain in information. However, if two geographic areas are divided into three along different lines, there is a clear loss in comparability.

Currently, basic changes in the approach will have to be made to accommodate the basic changes in equipment created by the rapid spread of numerical control.

The next country to undertake a comparable study on a regular basis was Japan. The first Japanese census of machine tools was made in 1952. A second was made in 1958 and a third in 1963. I believe it is the current intention to repeat the study at five-year intervals. The Japanese study is made by the Machine Tool Equipment Group, Machinery Statistics and Survey Department, Survey and Statistics Bureau, Ministry of International Trade and Industry (MITI).

The Japanese study gives results for seventeen types of metal-cutting and metal-forming machine tools and for welding equipment. Classifications are by size of plant (six), by type of industry (eight), by area, and by age (under five years, five ten, ten fifteen, fifteen twenty, more than twenty years).

France was the next country to undertake the study on a regular basis. The first French study was in 1955 and subsequent studies were made in 1960 and 1965. At the time of this writing, the 1965 report had not yet been issued, so the 1960 report is here treated as the latest. The studies are by the Department of Electrical and Mechanical Industries of the Ministry of Industry.

The 1960 study reports on twenty-four types of metal-cutting and metal-forming machine tools. It covers nine industries and provides a detailed age breakdown. The original study broke ages into five, ten, twenty, and thirty years. The second study made it five, ten, fifteen, twenty-five, and thirty years. The third study will cover five, ten, fifteen, twenty-five, thirty, and forty years. The reason for this approach is that the study is tied to fixed calendar years of acquisition (before 1925, 1926 to 1935, etc.). No geographic breakdown is considered necessary by the French.

There was discussion for some time of a census in Canada, and various groups approached American Machinist about enlarging its inventory to include Canada. American Machinist felt that such a study should be made by a local organization and offered to assist such an organization in establishing procedures.

The first Canadian census was made in 1958 by Canadian Machinery and Metalworking, a magazine published by MacLean-Hunter in Toronto. The procedure was essentially the same as in the United States, except that no area division was made. The study is scheduled for five-year intervals and was repeated in 1963. At that time it covered sixteen industries and 159 types of equipment.

In Italy, a census was made to cover the status of machine tools at the end of 1958. ISTAT (Istituto Centrale di Statistiche), the official Government statistical agency, made the study at the request of UCMIT (L'Unione Costruttrici Italiane Macchine Usciture), the Italian machine-tool builders' association. It was originally planned to make the study every five years.

The Italian study was extremely detailed. It covered sixty-five types of equipment, fifty-one industries and ninety-one geographic areas. Equipment was classified into age categories with divisions at five, ten and twenty years. Equipment in all classifications is reported as of domestic or foreign origin.

There was an earlier study made in Italy, in 1938 by ISTAT, but it was not made public.

A similar study was also made in Germany in 1938, but not published. In 1953, a study was made in West Germany by VDMA (Veren Deutscher Maschinenbau-Anstalten), the machinery association with headquarters in Frankfurt-Main. This study has not been repeated.

In 1960, a report on the steps needed to increase productivity in Great Britain was made by a Royal Commission. Known as the Mitchell Report, it recommended that a regular count be made of machine tools in Britain similar to American Machinist's.

A McGraw Hill company in Britain was selected for the work by the Machine Tool Trades Association. The survey was made in 1961 by Metalworking Production, published near London.

A second British census was taken early in 1966 and published during the summer of 1966, but was not available when this paper was prepared. That census covers sixteen industries and 174 kinds of equipment. In addition to reporting on age groups divided at ten and twenty years, it reports on whether the machines are of domestic or foreign origin.

The Economic Commission for Latin America (eCI A), an agency of the United Nations, has been instrumental in three censuses. The first, in 1960, was in Brazil and reported on fourty-four types of equipment in four industries. No age data was included. This study was made in co-operation with the National Development Council.

A more detailed study was made in Chile in 1962. This included thirty-six types of equipment, fifteen industries, four plant size categories, three areas, and age groups dividing at ten and twenty years. This study was made by the Instituto Chileno del Acero (Chilean Steel Institute).

In 1963, a census was made in Argentina by ECLA in co-operation with CONADE (Argentine National Deve-
It was based only on estimates provided by machine-tool builders. The 1963 study included some 2,000 plants using machine tools.

In addition to the censuses that have been described, most of which are published and made available to plant managers, engineers, and others, there are a number of countries in which the governments, often through machine-tool research institutes, conduct periodic censuses of machine tools used by central planning organizations but not made generally available. Such studies are generally similar in nature to the public censuses described here. However, because they cannot be used on a broad basis by plant personnel for evaluating performance or for determining market requirements, their usefulness is limited. They are, therefore, outside the scope of this paper.

To summarize this historical introduction, there are now nine nations which have relatively current censuses of machinery installed in production plants. It may be interesting to note that in three (Canada, Great Britain and the United States) a census is made on a regular basis by a private publishing company. Three others (France, Italy, and Japan) have censuses taken on a regular basis by a Government agency. The other three nations (Argentina, Brazil and Chile) have censuses taken cooperatively by an agency of the United Nations and the Governments.

**Organization of the Censuses**

Now a closer look at the method of operation of these censuses: Because *American Machinist* Inventory of Metalworking Equipment is the original census, having been taken nine times since 1925, and has set a general pattern for all the others, and also because it is the one with which I am most familiar, I will describe the procedure in some detail and then comment briefly on the variations in the other countries.

The current procedure for a census begins with a careful review of the types of equipment to be included. Suggestions are invited from many quarters—government agencies, marketing consultants, and users and manufacturers of machine tools. All the suggestions are arranged in the order of types of the last previous inventory. Then, a group of experienced senior editors reviews each proposal in turn. Consideration must be given to developments in types of equipment since the last inventory, but changes must be held to a minimum to preserve continuity.

The *American Machinist* inventory is confined to plant equipment in the metalworking industries. Note that it includes equipment used for maintenance purposes in these industries and equipment used in toolrooms as well as production equipment. But it does not include machine tools used for maintenance or toolroom work in other industries such as chemical, tobacco or wood, or in transportation or service operations. It has never been felt that the need for accurate information in these areas was great enough to justify the time and expense of collecting the data.

The United States Government has developed a classification system for machine tools, called the "Production equipment code." Similar coding systems have been developed in a number of countries. This system is followed, in selecting the classification of types of equipment, as closely as seems practical. At the time of any given inventory, there always seems to be some significant types for which code numbers have not been developed, and in these cases we depart from the code.

The major problem with the next inventory is how to integrate data on numerically controlled machines. Several methods have been proposed, but none meets all the requirements.

During the same planning stage, final determination is made on the other classifications. No change has been made in the age classification since 1949. Originally, the inventory provided two categories: less than ten years old and older. No date could possibly be selected on which all machines would suddenly become obsolete, but a uniform standard of some kind is essential.

Because many types of machine tools have considerable useful life after their tenth year, there were plans to broaden the yardstick. This was done in 1949 when the twenty-year division was added.

It has been suggested from time to time that a five-year measure should also be added, but this is not considered necessary, with data divided into three groups at the ten- and twenty-year marks and with detailed data on the yearly shipments of machine tools available, it is possible to make interpolations of equipment holdings that are accurate enough for most purposes.

Industrial classification is a more difficult problem. Every manufacturer would like to see a classification that included only his plant and his direct and close competitors. This he would be able to make studies of his own capability. The tendency over the years has been to provide ever more detailed industrial breakdowns. In the 1963 inventory, the data was broken into nine major industries and these were in turn divided into subgroups to make a total of forty-four separate industry groups on which data was tabulated. These groups follow the Standard Industrial Classification (SIC) format. Geographic classification has not been changed since 1953. A division into twenty-four areas that follow natural trading habits within the country has been developed. This proves satisfactory to most people, though there are always some who would like to see a finer geographic breakdown.

No classification of the data has ever been made on size of plant other than to run small demonstration studies to give an indication of the relationship. Data on size of plant is available, of course, so that such a study could be made.

The method of tabulation that is going to be used should be fully developed during the planning stage and the questionnaire should then be designed to suit it. In the case of the *American Machinist* inventories, the early ones were tabulated with adding machines. Later, ten or a dozen plant reports at a time were summarized by high-speed electric equipment after the data was punched on
cards. It has not yet been determined whether the data will be handled by card or by tape for the next inventory. With each change, the form and spacing of the questionnaire has been adjusted to suit the changed methods of tabulation.

The questionnaire is complex, and in the case of a large plant requires much time to fill out. Filling out the forms for the American Machinist inventory is, of course, not compulsory. Therefore, the inventory represents an expansion of a sample.

To obtain the sample, questionnaires are sent to each plant, in the metalworking industries, that has twenty or more employees. McGraw Hill maintains a census of manufacturing plants that is used as the mailing list. For the 1963 inventory, this census contained 34,266 plants in the metalworking industries. Repeat mailings were made to all the plants that did not reply. Three mailings were made in all. A total of 7,370 plants returned questionnaires that could be used in the tabulations. These plants represented 21 per cent of the plants in metalworking and employed 27 per cent of the 7,448,000 production workers.

Each questionnaire was classified according to industry (forty-four) and area (twenty-four). Thus, questionnaires were sorted into 1,056 cells. Each of these cells was expanded individually by data processing equipment. Incidentally, in placing the data on cards it was necessary to use one punched card for each type of equipment in each plant. While the cards used for the 1963 inventory were never counted, there were an estimated million.

Expansion is based upon employment ratios. In each cell, containing plants in one industry and one geographic area, it is assumed that there will be a consistent ratio between workers and each type of machine. In addition to the expansion based on size of sample, a small correction is put into each industry, varying for each, to correct for the omission of plants with less than twenty employees.

In addition to a single summary table that reports the total amount of each type of equipment, by age group, tables are prepared and published showing the totals for each industry and for each area. Because this is the form in which most planners in plants would use the data, these tables are given wide distribution through publication in the magazine and through distribution of reprints. For some purposes, it is more convenient to have the data arranged by type of equipment rather than by industry and area; thus, the same data is also assembled into equipment tables. A single table, for example, shows the number of each type of boring machine in each industry and, in each area, by age group. Because these tables present the same data, they are not published in the magazine but are available to those who find this arrangement more convenient.

The 1963 inventory was to represent conditions in January 1963. The first mailing of data forms was in December 1962, with the second and third mailings in January and February. Data collection was complete in March. The results were published in June 1963.

The latest Japanese study covered equipment in the following basic classifications: lathes, drilling machines, boring machines, milling machines, planers, grinders, transfer machines, and other cutting types: bending machines, hydraulic and mechanical presses, shearing machines, forging machines, wire forming, die casting, and arc and resistance welding.

Plants are classified into eight industries in the Japanese study: iron and steel, non-ferrous, metal products, machinery, electrical machinery, transportation equipment, precision instruments, and ordnance.

McGraw Hill prepares the survey forms and distributes them to local government offices. The offices hire people to call at the plants with the forms. McGraw Hill reports that it surveys all plants with thirty or more workers and samples every sixth plant with four to twenty-nine workers.

The French study is done on a sample basis, expanded by the use of data on the number of workers. The original French study, done in 1955, had considerably more detail in both type of equipment and industry than did the 1960 study. The reason for the reduction seems to have been that "particular difficulties were encountered, coming not only from the inherent imprecision of studies by sample when individual cases offer great disparity, but also from errors concerning the age of the machines, errors made rather frequently, it seems, in answering the poll, and resulting in certain contradictions in the results", according to Henri Ournac, chief engineer, of the Ministry of Industry, in his introduction to the 1960 study.

Because of this problem, the French have undertaken an interesting study to see if it is possible to develop mortality tables (la loi de riblomage) predicting the number of machines that will be kept in service at any given time. The French do not propose to replace the five-year census with the mortality study; they intend to continue and to try to improve the census. However, they feel that with the new law serving as a bridge between the censuses and the annual reports on new machines placed in service, more continuous data on industry would be available. There is also the possibility of using the mortality law, if it can be developed, to forecast future trends.

By far the most complete and detailed census of machine tool users I have ever seen is the one made in Italy in 1958. ISTAT reports that it gets data from more than 90 per cent of the machine tool users and reports in great geographic detail. The detail on types of equipment is not as great as in the United States, but the detail on industry and age is greater. Perhaps the work involved in such detail is the reason that the census has not been repeated on the planned five-year schedule.

The Canadian and British censuses are very much like the one in the United States, both in terms of the detail they include and the manner in which they are handled.

The censuses in Latin America are probably more similar to the first census that would be made by any developing nation than are any of the ones we have discussed so far. In each case ECLA, familiar with the American Machinist inventory, has provided technical assistance and encouragement.

In Brazil, ECLA actually did the entire job in co-
operation with local government agencies. The first requirement for any such census is details on the number, type, size and location of the manufacturing plants. In Brazil in 1960, this information existed only in the State of São Paulo. As a result, the Brazilian census is really a simple study of the State of São Paulo which has afterwards been extrapolated to cover the entire country. Although ICIA has not indicated any intention of continuing the study in Brazil, the Brazilian Association for the Development of Basic Industry (ABDIB) is reported to be planning the continuation of the census on a regular basis.

In Chile, data was first collected by mail, followed by a personal canvas by students at the universities. Altogether, it was estimated that 75 per cent of the industry of the country was covered. All the tabulations were handled by punched card (the people handling the census were following in detail the procedures followed by American Machinist). However, details by industry and area were given as reported and only the grand total was expanded to represent the probable total for the entire country.

**Utilizing Inventory Data**

As with any basic set of statistics, many uses can be made of the information in a machine-tool inventory. There are four basic groups that can use this data to advantage.

Simple, direct comparisons can be made by the managers of individual plants. This is easiest to do when the plant has retained a copy of the report it has filed on the machines in the plant. This report can be compared with various classifications of the finished inventory.

One of the most effective tools of modern management is to gauge performance of a plant in comparison with other plants of similar nature, using various factors and ratios that can be precisely measured. With the machinetool inventory, the manager can measure the ratios of new to old equipment, of distribution among various types of equipment and of proportion between workers and machines. In the United States, a number of large companies with multiple plants prepare studies comparing the various plants with each other and with other plants doing similar work.

There have been cases in which such comparisons have revealed that a plant was falling behind in equipment modernization. This may be revealed either by a declining percentage of new machines, by a significant shift by the rest of the industry to new types of machines, or by a sharp difference in the ratio of machines to workers in the plant.

In a period when international trade competition is growing, the plant manager may also find it worth his while to see how his plant stands in comparison with competitors in other countries.

The second group that can make effective use of a machine-tool inventory is made up of firms that manufacture machine tools. Such a study will give a more detailed picture of the nature and location of the markets for machine tools than can be obtained in any other way.

The third group that can use the inventory is made up of the firms that manufacture products used in conjunction with machine tools. These may be cutting tools, holding devices, electric motors, bearings, other parts or accessories, or they may be materials processed by the machines. For all these firms, data on machine tools provides much the same type of information on the nature and location of markets in an indirect fashion that are provided directly for machine-tool builders.

For example, a plant that manufactures dies for thread-rolling machines will find that data on the number and location of thread-rolling machines will be of great help both in planning the distribution method and in evaluating the performance of the people responsible for distribution.

Both of these groups will need data that is detailed as to type of machine and industry classification and (if the country is larger) which divides the country into logical areas.

Finally, the data contained in such inventories is valuable for national planning by government agencies and by associations or groups of firms. The data helps measure the direction and extent of changes that are taking place in the production capability of the nation. Such data gains in value as it becomes available at repeated intervals.

On the national level, such data can be of particular value in discovering whether particular industries need additional incentives for development. In the United States, for example, the American Machinist inventories have provided evidence that was influential in the revision of tax policy as it related to capital equipment.

**Inventory Requirements**

Any country that plans to conduct a census or inventory of metalworking equipment must start with a list of the plants using such equipment. If a good list does not exist, the first step is to compile one.

In many countries, such a census of manufacturing plants is taken and maintained by the government. In some countries, such a census is also maintained on a continuing basis by a publishing company. It makes no difference what source is used for the list if it is a good one.

The next step is to select the types of equipment that will be covered. A comparison of the lists of equipment used in other censuses, as well as some knowledge of the type of manufacturing done in the country, will be helpful in developing this list.

In selecting the list of equipment it must be remembered that the shorter and more general the list the easier it will be to collect the data. On the other hand, the longer and more detailed the list the more useful and informative will be the resulting statistics. The list must be selected to balance these conflicting requirements.

The method by which the data will be collected should be selected and the method of tabulation should also be determined before the questionnaire is prepared.

In general, the data can be collected by sending a form through the mail, or by individual visits to plants. Usually, a developed country will find the mail satisfac-
If there are particular problems in getting questionnaires delivered to plants or in getting them filled out, the slower and more expensive use of interviewers may be necessary.

Decisions must also be made at an early stage as to which industries will be covered and in what detail they will be reported. All of the existing studies concentrate on those industries that use machine tools as a major factor in making a product—the metalworking industries. They usually include equipment in toolrooms and that used for maintenance purposes in these industries, but they do not generally include the equipment used for maintenance in other industries (such as chemical, food processing and textile) or in service shops.

The reason is two-fold; first, the usefulness of the studies of equipment used for production is much greater than the usefulness of a study of equipment used for maintenance; second, if the study is expanded from a sample, there is a reliable base for expansion of production equipment but not of maintenance equipment.

All of the census studies that are expanded from a sample are extended on the basis of employment on an industry basis. They assume that there is a reasonably consistent relationship between employment and equipment among the plants in an industry. This method seems to work satisfactorily if the sample is large enough. There is no such consistency in the matter of maintenance equipment in non-metalworking plants, however, so there is no reliable basis for a detailed extension of data in non-metalworking plants.

If an area breakdown of the data is to be included, it should be determined before the data collection begins. A good area breakdown, like a good industry breakdown, will not necessarily divide the total into units of about equal size, but will make divisions where there are logical differences in method or approach.

A choice may exist as to how data is to be collected. If it is done by a government agency, it is possible to have nearly complete returns because the agency can compel plants to fill out the forms. If it is done by a private organization and there is no compulsion, it will be necessary to achieve the final results by expansion of a large sample.

Based on the existing examples, the studies made by government agencies obtain larger samples but the ones done privately are done much faster and less expensive. There is no way to gauge the relative accuracy of the two approaches. Experience in these matters would suggest that neither method is entirely accurate but that each is adequate for the purposes.

As more and more nations begin to prepare such reports and publish them for use at home and abroad, our knowledge and understanding of the manufacturing facilities of the metalworking industries in the world will increase and the yardsticks for measuring the performance of individual plants, industries or nations will be enhanced.