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TÍTULO: Un estudio estadístico de las capacidades de producción: aspectos metodológicos.

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RESUMEN: Este artículo presenta las características de un estudio estadístico de las reservas de capacidad de producción como uno de los factores para el crecimiento de la eficiencia de producción. Se muestra el papel de la productividad laboral social en los criterios para evaluar la efectividad de la economía nacional. Para este propósito, se ha llevado a cabo un modelo económico-matemático de indicadores de reservas de capacidad de producción a nivel micro y se presentan los resultados de una muestra de observación del uso del equipo realizado en una de las empresas de la industria eléctrica y el cálculo del número requerido de máquinas basadas en él. Se ha identificado una reserva significativa de capacidad de producción debido a una carga incompleta.

PALABRAS CLAVES: capacidad de producción, productividad laboral, método de observaciones de momento, modelización económica y matemática.

TITLE: A statistical study of production capacities: methodological aspects.

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ABSTRACT: This article presents the characteristics of a statistical study of the reserves of production capacity as one of the factors for the growth of production efficiency. The role of social labor productivity in the criteria to evaluate the effectiveness of the national economy is shown. For this purpose, an economic-mathematical model of reserve indicators of production capacity at the micro level has been carried out and the results of an observation sample of the use of the equipment made in one of the companies in the electricity industry are presented. The calculation of the required number of machines is based on it. A significant reserve of production capacity due to incomplete loading has been identified.

KEY WORDS: production capacity, labor productivity, method of moment observations, economic and mathematical modeling.

INTRODUCTION.

The importance of strengthening the role of labor productivity as the basis for increasing economic and social development belongs to the identification of reserves of production capacity.

Reserves of use of production capacity can be formed due to insufficient operation of available resources, improper organization of production and ignoring of scientific methods in the preparation of production plans [N. Nayanzin, S. Ruzevich, 2007, S.A. Bukhanov, M.V. Ovsyannikov, 2012, E.A. Smirnova, N.V. Khokhlova, 2014].

To identify the reserves of production capacity, systematic statistical studies and statistical and mathematical analysis are required [M.A. Ragozina, 2009].

DEVELOPMENT.

The existing statistical reporting on the availability and use of production capacity does not fully meet the task of identifying capacity reserves at existing enterprises. To do this, it is advisable to conduct special sample surveys [M.V. Batyukov, O.V. Titova, 2015].

When developing a survey program, industrial and process features should be taken into account [T.A. Zhurkina, T.N. Likhacheva, 2015]. For single-product enterprises, capacity should be determined in natural or semi-natural units of measurement of production. For multi-product enterprises, it is determined in terms of value, as well as in the machine hours of the installed equipment. In this case, it is advisable to proceed from progressive, technically sound standards, around-the-clock and continuous operation of equipment during the year of operation of the enterprise. The remaining circumstances should be considered as factors of under-utilized production capacity [L.D. Revutskiy, 2002].

The study of reserves of production capacity can be conducted at the micro and macro levels. Let us consider some methodological issues of statistical study of reserves of production capacity at the micro level.

Methods.

The most difficult is the identification of reserves of production capacity of multi-product enterprises. When organizing statistical monitoring at such enterprises, one should proceed from the premise that the capacity of enterprises is determined on the basis of the calendar (annual) reserve of time for all types of process equipment in the machine hours.

The annual calendar reserve of equipment time is subject to adjustment for the period of scheduled repairs and other unavoidable process breaks in equipment operation. Capacity utilization is determined by calculating all types of production in standard hours of machine hours using advanced technically sound industry standards. This will reveal the reserves of machine hours.

Knowing the cost of a piece of equipment, it is easy to determine the power of all process equipment in ruble-hours. The following indicators should be included in the program of statistical surveys of capacity utilization:

- Calendar and available reserve of time for each type of equipment.
- The volume of production of all types of products manufactured at the enterprise.
- Technically sound time standards for the manufacture of each product.
- Intra-shift loss of equipment time.
- Utilization factors of the calendar and available reserves of equipment time [D.M. Selkin, 2012].

The availability of such information will allow solving problems on the optimum loading of all types of equipment for a given nomenclature by adjusting the production volumes of its individual types.

During the study of the reserves of production capacity at the micro level, it is important to determine the best option for the distribution of the production program into groups of equipment that will provide the best technical and economic indicators of the enterprise. Therefore, direct research is preceded by a preparatory period. It has the same meaning as the concept of a "pre-planning period" in the implementation of economic and mathematical modeling of certain indicators. At the stage of the preparatory period, the analysis is carried out in the following directions:

- Study of the composition of the enterprise.
- Analysis of the source data included in the calculation of production capacity.
- Analysis of the utilization of production capacity in the previous periods.
- Analysis of the economic efficiency of measures aimed at increase in the production capacity [Yu.I. Ubogovich, O.A. Sablina, 2014, F.Sh. Gadzhiev, 2012].

Particular attention is focused on the structure of the active part of the production equipment.

Analysis is advisable to conduct in comparison with the data for the years preceding the calculation of power. The indicator such as the specific area per unit of equipment is important.

Analysis of the source data included in the calculation of production capacity, involves the study of the technical condition of production equipment, analysis of shop and factory reserve capacity, the study of the use of reserves of time of installed equipment, analysis of the quality of applicable standards, etc.

Analysis of the use of production capacity in previous periods should be carried subject to the time-based equipment utilization ratio. At this stage, it is necessary to identify the causes of under-utilized capacity [I.M. Petrovich, R.P. Atamanchuk, 1990].

The study of the economic efficiency of measures to increase production capacity is associated with the assessment of the effectiveness of the introduction of new technology.

The study of reserves of production capacity is based, therefore, on the use of statistical methods for collecting information, using data from the technical department, current planning data in combination with building models of optimal production capacity utilization.

Models of optimal capacity utilization can be attributed to linear-program models. On the basis of these models, the optimal variant of the distribution of the production program into groups of equipment can be justified [G.V. Danilov, I.G. Ryzhova, E.S. Voynova, 2010, M.V. Ershova, V.D. Zharikov, R.V. Zharikov, V.V. Zharikov, 2015].

Results and Discussion.

A scientific analysis of existing approaches to statistical study of labor productivity has allowed us to find out that there is no single methodology among economists for studying this category, since labor productivity is a complex, multidimensional concept of economics. In order to uncover the economic essence of the analysis of labor productivity, it is necessary to identify the main aspects of the study, since labor productivity is an integral part of any economic problem, either it is

industrialization or research work.

Let us consider a model of this type in relation to the enterprises of the electrical industry.

There are several types (set) of manufactured products (or parts), which can be denoted by j, $j = 1,2,...,n,$ where n is the total number of manufactured products and $i = 1,2,...m$, where m is the total number of equipment groups.

The coefficients of time (A_{ij}) spent on processing the details of the j-th type on the equipment of the i-th group are determined on the basis of the technological norm of processing time for a product of this type on the corresponding group of machines, taking into account the planned rate of implementation of progressive standards using the following formula:

$$A_{ij} = \beta_{ij}\gamma_i f, \quad (1)$$

where β_{ij} is the technological standard of the processing time of the product of j type on the equipment of the i-th group (in machine-hours);

γ_i – the planned rate of compliance with the standards of the group of equipment;

f – progressivization factor.

The time rate is taken directly from the operational and process maps of the processing of parts. It is considered as the sum of the machining time on this group of machines [A.S. Kazaryan, S.K. Gasanbekov, 2015, K.S. Krivyakin, 2010].

In this model of equipment load, such parameters as the batch size of parts (products), the order of their processing on different machines, equipment load schedules, etc., are not optimized, but are taken as specified for each production method [B.A. Romanov, 2007].

Let T_i be a useful reserve of time (in machine-hours) for the i-th group of equipment. Constraints on the useful reserve of operation time of each group of equipment are set based on the available

time in machine-hours. Note that the concept of “available reserve of time" is identical to the concept of "effective time fund". The useful reserve of time shall be understand to mean the time worked. The available reserve of time for this process group is determined by: the number of pieces of equipment per group q_i; annual useful reserve of time for each piece of equipment T_i^l.

The following applies:

$$T_i = \sum_{l=1}^{q_i} T_i^l \quad , \qquad (2)$$

where l – the index of the piece of equipment in this group.

Subject to the above, the following system of constraints for the model of optimal capacity utilization.

The need for a reserve of time for the operation of equipment should not exceed the actual reserve of fund:

$$\sum_{j}^{n} a_{ij} x_j + y_i = T_i \quad , \; i = 1, 2, ..., m, \qquad (3)$$

where y_i is the amount of reserve of time for the i-th equipment group. This reserve of time is formed if there is an underload of the group equipment i.

Constraints of non-negativity of variables:

$x_j \geq 0$, $j = 1, 2, ..., n$.

In order to bring the planned nomenclature of output into a certain conformity with the established plan in the models of equipment load, bilateral constraints on the production program can be used:

$$B_j^{\min} \leq x_j \leq B_j^{\max} \quad , \; j \in E_2, \qquad (4)$$

where E_2 - a set of types of products such constraints are significant for.

The balance between the necessary and available fund of time for each group of equipment:

$$\sum_{j=1}^{n} \lambda_{ij} x_{ij} \le T_i, \quad i = 1,2,...,m.$$

Constraints of non-negativity:

$$x_{ij} \ge 0, \quad j = 1,2,...,n, \quad i = 1,2,...,m.$$

Constraints on the production of all kinds of products:

$$\sum_{i-1}^{m} x_{ij} = B_j, \quad j = 1,2,...,n.$$

The goal function is the minimum production cost of all products:

$$\min Z = \sum_{j=1}^{n} \sum_{i=1}^{m} Z_{ij} x_{ij}, \qquad (4а)$$

where Z_{ij} is the unit cost of a product of a type j in the i th group of equipment.

When identifying reserves of production capacity, the tasks of minimizing the costs of machine hours are important. Constraints and criteria for optimality in this type of problems will be constructed in a similar way. The goal function takes the form:

$$\min T = \sum_{j=1}^{n} \sum_{i=1}^{m} \lambda_{ij} x_{ij}. \qquad (4б)$$

The model of optimal load of interchangeable groups of equipment may apply an assortment optimality criterion. All considered models are of interest and have been repeatedly described in the literature. However, their practical application is complicated by the lack of necessary data in statistical reporting. Therefore, they can be applied only at the micro level [A.N. Herzen, 2006, A.A. Samerkhanova, E.I. Kadochnikova, 2015].

The models of production capacity based on the rated (regime) reserve of time and the actual annual time fund of equipment are more applicable in practice. To identify capacity reserves, calculations should be made related to the adjustment of the reserve of equipment time used to determine the production capacity [P.P. Lutovinov, N.S. Demin, S.A. Melenkina, 2015].

In summary, for each type of production equipment we find:

1. Rated (regime) reserve of fund:

$$T_{н} = \left[D_k - (П + В)TS - tS\right], \quad (5)$$

where D_k is the number of calendar days in a year;

$(П + В)$ - the number of holidays and weekends;

T - the duration of the shift in hours;

S - number of shifts;

t - number of hours resulting from reduced shifts on holidays (six hours).

2. Действительный годовой фонд времени станка:

$$T_D = T_{н} К, \quad (5а)$$

where $К$ - equipment capacity utilization.

In practical calculations $К = 1 - \frac{a}{100}$, where a is the planned percentage of loss of time for scheduled maintenance. This indicator varies at enterprises from 3 to 6%.

Consequently, the production capacity is planned on the basis of the equipment utilization time ratio is 94-97%. At our enterprise, this ratio is 95%. However, the actual ratio of the equipment is much lower. Consequently, when planning the production capacity of equipment time losses is neglected. They can be considered as reserves for improving the use of production capacity by groups of equipment and by the enterprise in general [E.A. Polovkina, L.D. Badrieva, 2014; L. Seropov,

2010; E.I. Kadochnikova, E.A. Polovkina, E.A. Grigoreva, 2017].

3. The estimated number of machines for each type of equipment and for each product:

$$N' = \frac{NT_{шт.}}{T_D K_н}, \qquad (5б)$$

where N is the annual product release program;

$T_{шт.}$ - piece machine time;

$K_н$ - efficiency ratio.

The task is to determine the required number of machines for the production of each product, taking into account the ratios of useful and actual (95%) utilization of equipment.

First of all, it is necessary to establish the actual equipment utilization ratio over time, therefore it is advisable to conduct a series of independent statistical observations. These may be photographs of equipment operation time, organized in compliance with the rules of sampling observation, instantaneous observations.

The operation and standby time of the equipment can be recorded either manually or using technical means, but it should be emphasized that the sampling method is preferred here. Of course, the sampling results of the use of equipment should be properly assessed and only then used to adjust production capacity calculations.

At one of the enterprises of the electrical industry, instantaneous observations were conducted over the use of equipment during the most complete shifts of each month and quarter. According to the results of the instantaneous observations, the average equipment utilization ratio was determined. This ratio, taking into account the error of instantaneous observation +5% with a probability of 0.95, was in the range of 70-75%. Thus, the overestimated value of equipment utilization is taken into account in the calculation of production capacity.

The required number of machines for the production of six products was calculated, constituting more than 25% of the value of all marketable products. Note that the processing of these six products is carried out on 12 types of equipment.

The release of six products with an equipment effective time ratio of 95% requires 35 machines. In fact, the equipment utilization ratio was only 75%, as a result, 48 machines were used in the production of these products. The difference is 13 machines, which indicates that the equipment is underloaded due to intrashift loss of time. If we take into account the range of products manufactured at the plant, which amounts to several hundred items, the reserves of production capacity will be very significant.

CONCLUSIONS.

The problem of insufficient capacity utilization, and their inefficient use in a market economy is of particular importance, and its solution can act as a competitive advantage of an enterprise. Highly significant in this context is the use of statistical methods to obtain reliable information about the actual capacity utilization [E.A. Polovkina, E.A. Grigoreva, 2017].

The results of this study of reserves of production capacity should be taken into account when developing measures aimed at improving production efficiency.

A systematic study of reserves of production capacity implies further improvement of statistical information, which will provide a comprehensive study of the problem and contribute to the reduction of capital investments in capacity growth.

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