Economic and Statistical Analysis of the Management Efficiency by the Supply Chain Strategy and Grouping Method

Ekaterina Anatolevna Grigoreva[1*], Elvira Anasovna Polovkina[2], Liliya Faridovna Zulfakarova[2]

[1,2]*Kazan Federal University*

[1]ekaterina_kazan@mail.ru

***Abstract*— The paper considers the possibility of using statistical methods to identify the impact of organizational factors on improving production efficiency. It investigates the existing problems in the application of the grouping method in the analysis of management effectiveness. The authors used a systematic approach to the statistical study of production and management efficiency. Methodological approaches to the integrated assessment of enterprise activities were developed by combining three characteristics in one grouping – the level of technical equipment, labor efficiency and capital productivity. Further research is aimed at developing and examining a generalized assessment of the organizational and technical level of enterprises on the basis of the grouping method.**

***Keywords*—** *management efficiency, labor productivity, economic and statistical analysis, supply chain strategy, labor organization, grouping method.*

1. Introduction

Management is a part of the entire production process. It is called upon to ensure "the fullest use and development of the potential of the productive forces in order to satisfy the entire mix of social needs and achieve social goals with the least labor costs". From this perspective, the category of management efficiency should reflect the contribution of management to the overall results of business and operations.

At the same time, management is a relatively independent sphere of application of productive labor that is characterized by the size of management resources and the cost value of aggregate labor. In this regard, the results of management activities can be considered in two aspects: from the position of the management system itself as a subject of management and from the standpoint of the entire management system as the organic unity of the management subject and object. Accordingly, one can distinguish two approaches to assessing the management efficiency - an assessment of management efficiency in qualified and broad senses of this term [1-10].

The management efficiency in a qualified sense characterizes management as an independent sphere of labor application and is oriented towards studying the costs of living and materialized labor in management and the results achieved in this sphere. The management efficiency in a broad sense implies studying the contribution of management proper to the final results of the business and operations of the relevant units. The study of management efficiency in a qualified sense is of independent interest [7].

The currently proposed various options for assessing management efficiency in the broad interpretation of the term are aimed at applying one or another modification of the procedural foundations to determine the economic effectiveness of new technologies and investments. In other words, the available proposals are based on the calculation of improving the management of the annual economic effect and the payback period of the additional costs for implementing measures to improve management as the main indicators of economic efficiency. Without denying the legitimacy of this approach when analyzing certain areas of improving management efficiency, we consider it necessary to emphasize that this approach does not take into account whether the achieved results of business and operations are the greatest possible under the existing conditions, or there are still unused reserves in management [9], [11- 13].

When solving the problems posed in this particular area, application of economic and statistical analysis methods play an important role to determine the extent to which the results achieved correspond to the potential possibilities of production and at what expense they are received. This type of economic and statistical analysis is based on the performance comparison of different types of enterprises. These comparisons reveal differences in methods, technology and production organization, in the use of certain types of resources, as well as in the results of business and operations which are characterized by the volume of output, labor productivity, capital productivity, profitability, cost, and etc [3].

2. Materials and Methods

The formation of populations which serve the basis for grouping of enterprises relies on the sectoral classification of enterprises. However, the industry is a set of enterprises which are in different conditions for many characteristics: the range of products, the scale of production, its technical level, natural and climatic conditions, etc. In connection with the above circumstances, a comparative analysis of the enterprises activities in a certain industry requires to develop a system of successive groupings of enterprises. First of all, we should focus on groupings of enterprises in order to ensure comparability of the objective conditions of the compared enterprises' activities. The formation of homogeneous groups of enterprises should be based on a sufficiently developed system of indicators that describe the size, composition, condition, organization and standardization of means of labor and labor resources. The need for a system of statistical indicators to specify resources is determined by the versatility and variety of the real connections between economic phenomena, the multiplicity of characteristics that determine them. This system of statistical indicators should comprehensively describe the composition of inputs of enterprises and associations [4], [14-17].

A systemic approach to the problem of statistical study of production and management efficiency presupposes an interrelated consideration of resources, the level of their use, and the eventual outcomes obtained. Each direction is characterized by a system of indicators that comprehensively reflect the size and composition of the inputs of enterprises and associations, their efficiency, performance of business and operations [11], [18,19, 20].

Thus, the characteristics of only the composition, condition and movement of a resource - fixed assets - can be given on the basis of approximately 20 indicators, among which may be the ratio of the active part of fixed production assets, the ratio of automatic machines and equipment, the ratio of equipment aged over 10 years, the proportion of the installed equipment in the core production shops, the ratio of the metal-cutting equipment as a part of the manufacturing equipment, wear factors of the fixed production assets, facilities and equipment, coefficient of renewal and retirement rate, etc. Such a large number of indicators cause certain difficulties in developing the groupings of enterprises both in terms of their potential capacity and performance of business and operations. In this regard, it is important to work out methods for multidimensional classification based on a large set of characteristics [2], [19].

3. Results

The main idea of multidimensional classification methods is that it is carried out simultaneously along the entire set of characteristics that describe the units of the studied population rather than sequentially by individual characteristics like in cross classification. This complex or set of characteristics forms the so-called attribute space. If the unit of the population (for example, an industrial enterprise) is characterized by m attributes, then each unit is regarded as a point in the m-dimensional space. The task of multidimensional classification is to isolate the condensations of points in this space which form homogeneous groups in a certain respect. In accordance with the terminology of cluster analysis, on the basis of which multidimensional classification problems are solved, such homogeneous groups of units of the studied population are called clusters [5], [14]-[16] [21-23]. Units of population belonging to the same cluster should be similar to each other, and the degree of similarity between units within the cluster should be greater than between units that are included in different clusters. If under the similarity of units to understand the geometric proximity of the corresponding points in the multidimensional attribute space, then as a measure of similarity it is natural to use the concept of distance between points, and the function definition will determine the rule for calculating the distance between any two units of the studied population. The most common measure of similarity based on the concept of distance is the Euclidean distance which is calculated by the formula:

$$d_{ij}^2 = \sum_{k=1}^{m} \left(X_i^k - X_j^k \right)^2,$$

where X_i^k – value of k attribute in i unit.

The application of multidimensional classification methods should be based on a preliminary analysis of the variation degree in the level of attributes in the individual units of the population under study. Attributes that have a small variation within the studied population should not be included in the grouping base. Thus, for a specific population a set of indicators that characterize a particular direction in the assessment of various types of resources will be modified.

It should also be taken into account that the peculiarity of a number of algorithms for cluster analysis is the absence of a formal criterion for choosing one or another variant of partitioning the population into homogeneous groups. The groups are selected visually taking into account the possibility of a meaningful interpretation of the clusters obtained. In this regard, one way to verify the quality of multidimensional grouping is to

compare the results of groupings obtained by different methods.

The coincidence degree of grouping results by different algorithms can act as a criterion to assess the quality of classification. Another additional method of testing the homogeneity of the selected groups and evaluating the significance of the differences between them can be a technique based on the criterion of G.S. Kildishev and Yu.I. Abolentsev.

There is also another possible approach to the construction of groupings based on a combination of characteristics at the same time - using a multidimensional mean as a generalized basis of a grouping. The multidimensional mean is determined from the relative values of p_{ij} which represent the ratio of the i attribute values in the j unit of the population to the average value of the i attribute for the whole population. Thus:

$$\overline{p_j} = \frac{\sum_{i}^{m} p_{ij}}{m},$$

where m is the number of attributes used as the basis of the grouping and characterizing each unit of the population.

On the basis of the obtained means for each unit of population, the grouping can be performed using the same techniques as for the one-dimensional case.

The next step in the comparative economic statistical analysis is the joint consideration and analysis of groupings according to the level of potential opportunities and effectiveness indicators of using different types of inputs, which makes it possible to identify groups of enterprises which have achieved the greatest effect in using resources and obtaining eventual outcomes of business and operations.

We will show the scope of economic and statistical analysis of labor productivity and capital productivity levels based on the system of interrelated groupings. The first step was to group enterprises of one of the machine-building industries in terms of their technical equipment. After the preliminary analysis, the specific weight of machinery and equipment in the value of fixed production assets, the degree of work mechanization, the electric power per worker, and the ratio of machines and equipment up to 10 years old were selected as indicators that characterize the technical equipment. Based on the multidimensional grouping by the set of these indicators using cluster analysis methods, were obtained the results for population of 118 enterprises given in Table 1.

Table 1. Grouping of enterprises according to the level of technical equipment

Technical equipment	The number of enterprises	Average values in the group			
		specific weight of the active part of fixed assets, %	specific weight of equipment up to10 years old, %	mechanization of labor, thousand rubles / person	electric power of labor, kWh / work hour
Below average	38	43,3	47,9	1,72	8,4
Average	22	43,5	51,1	1,88	9,8
Above average	58	51,3	70,0	2,50	11,7
Total	118	47,3	59,5	2,14	10,3

Table 1 indicates that out of 118 enterprises in the industry, 49.1% of enterprises have a high level of technical equipment, 18.7% - an average level and 32.2% - the level below the average. It should be assumed that enterprises with the same level of technical equipment should have approximately the same indicators of resource efficiency, such as labor productivity and capital productivity.

Table 2. Grouping of enterprises by the level of labor productivity and capital productivity

Labor productivity and capital productivity	Grouping of enterprises			
	by the level of labor productivity		by the level of capital productivity	
	units	% of total	units	% of total
Below average	61	51,7	58	49,1
Average	23	19,5	29	24,6
Above average	34	28,8	31	26,3
Total	118	100,0	118	100,0

At the same time, the grouping of enterprises according to the level of labor productivity (Table 2) shows that 28.8% of enterprises have higher than average level of labor productivity, 19.5% of enterprises have an average level of labor productivity and in 51.7% of enterprises labor productivity is below the average level.

The grouping of enterprises by the level of capital productivity shows that 26.3% of enterprises achieved a high level, 24.6% of enterprises have an average level, and 49.1% of enterprises have a low level of capital productivity.

To form the groups of enterprises that are homogeneous in terms of labor and capital productivity level, a principle based on the methodology for estimating the value of the general mean from the results of sample observations can be used. Indicators describing the results of enterprises and the level of resource use are formed under the influence of many external and internal factors.

In accordance with the sampling method theory, it can be argued with a certain probability that the value of the general mean will be in the interval:

$$\overline{X} - t\mu_{\overline{X}} \le \widetilde{X} \le \overline{X} + t\mu_{\overline{X}},$$

where X and $\widetilde{X}$ are respectively the value of the sample and the general mean;

$\mu_{\overline{X}}$ - standard error of the sample mean;

t - confidence coefficient corresponding to the accepted level of confidence figure.

Enterprises that have a level of labor productivity (capital productivity) in the specified confidence interval are referred to the group with the average level for the population studied.

If the value of labor productivity (capital productivity) is less than the lower limit of the confidence interval, i.e. $X_i \langle \overline{X} - t\mu_{\overline{X}}$, then by efficient use of living or materialized labor, enterprises will be classified in groups below the average level for the whole population.

Finally, a group with a level above the average will include enterprises that have a level of labor productivity (capital productivity) greater than the upper limit of the confidence interval, i.e. with values $X_i \rangle \overline{X} + t\mu_{\overline{X}}$.

The combination of groupings of enterprises by the level of technical equipment and labor productivity (Table 3) enables to identify the groups of enterprises that have achieved the highest results in their operations, and a group of enterprises that have reserves of productivity growth due to better use of technical capacity.

Table 3. Grouping of enterprises according to the level of technical equipment and labor productivity (the number of enterprises)

Technical equipment	Capital productivity			
	below the industry average	average	above average	total
Below the industry average	23	5	10	38
Average	10	7	5	22
Above average	28	11	19	58
Total	61	23	34	118

4. Results

Thus, out of 61 enterprises that are included in the group with a level of labor productivity below the industry average, 28 or 45.9% of enterprises have a level of technical equipment above the industry average; 10 enterprises or 16.4% of this group have an average level of technical equipment. In the remaining 23 enterprises, the level of technical equipment is lower than the industry average, i.e. only 37.7% of enterprises have a level of technical equipment that corresponds to the level of the efficient use of living labor.

However, the conclusions drawn are based only on the analysis of the effectiveness of living labor.

The combination of groupings of enterprises in terms of the technical equipment level and use of fixed production assets leads to a somewhat different estimates of the operation results of control objects. Thus, 36 enterprises (30.4% of the total number) enter the group of enterprises that have achieved the greatest effect when using fixed production assets. Growth reserves of capital productivity due to better use of technical potential are available at 60 enterprises of the industry, which is more than half of all enterprises - 51.0% (Table 4). In addition, when comparing the numbers of enterprises that fall into groups with low, medium and high levels of labor productivity and capital productivity, it is revealed that it is not uncommon for an enterprise to have a low capital productivity, but an average and even high level of labor productivity and vice versa.

Table 4. Grouping of enterprises according to the level of technical equipment and capital productivity (the number of enterprises)

Technical equipment	Capital productivity			
	below the industry average	average	above average	total
Below the industry average	6	12	20	38
Average	9	9	4	22
Above average	43	8	7	58
Total	58	29	31	118

Thus, a comprehensive assessment of the performance of enterprises by the use effectiveness of living labor and means of labor is possible when all three characteristics are combined in one grouping - the level of technical equipment, labor productivity and capital productivity.

5. Discussion

Considering the grouping of enterprises by a combination of these characteristics leads to the following conclusions.

Of the 118 enterprises studied, 17 or 14.4% enterprises achieved the level of use of fixed production assets and living labor that corresponds to the level of their technical equipment.

Among the enterprises considered, 18 or 15.3% have high efficiency indicators for the use of fixed production assets and living labor with a low and average level of technical equipment. This group is adjoined by 18 enterprises (15.3%) which achieved higher efficiency indicators for the use of fixed production assets, while the level of labor productivity corresponds to the level of technical equipment, and by 2 enterprises that have high labor productivity along with an average level of technical equipment and a high capital productivity.

The remaining 63 enterprises (53.4%) have reserves for increasing labor productivity and capital productivity, since with a high and average level of technical equipment, respectively, there are average and low use efficiency levels of the of fixed production assets and living labor correspondingly.

A particularly thorough analysis of the use of labor and material resources should be carried out at 28 enterprises, representing 23.7% of all enterprises in the sector which have a high level of technical equipment, but a low level of labor productivity and capital productivity, and also at 7 enterprises (6.0%) with an average level of technical equipment, but here labor productivity and capital productivity are lower than the industry average.

At these enterprises, whose share is 29.7% in number, it is necessary to improve management in order to use resources more efficiently. For other enterprises, the issue of efficiency growth reserves should be considered differentially in terms of types of resources. Thus, 6 enterprises with a high level of technical equipment have achieved high levels of labor productivity, but the level of capital productivity is lower than the industry average. At 9 enterprises with high technical equipment, there are still reserves for increasing labor productivity and, even more, growth in capital productivity (at these enterprises, its level is lower than the industry average, and labor productivity corresponds to the average level).

Having received these groupings, the management should carry out a detailed analysis of the use of labor and material resources. At the same time, the analysis should be differentiated, allocating losses from downtime of resources and losses from unproductive consumption of resources and irrational consumption of resources. So, the losses from idle workforce at the enterprise are characterized by losses of working time due to absenteeism, entire shift and intra-shift downtime. Determining the amount of reserves to improve the use of working time requires the use of reports data on the implementation of the manpower plans and data from specially organized observations (timing, the method of moment observations). A necessary supplement to the analysis of the losses of working hours is to analyze the reasons for the workers' turnover, study of the suitability of the employee's qualifications for the nature and complexity of the work performed by them, analyze the level of labor organization at enterprises, reasons for overtime work and work on weekends, etc [10], [23].

The analysis of the use of fixed production assets and labor should be interrelated, since the lack of a balance between the number of jobs and the size of labor force is one of the essential factors in reducing the use efficiency of fixed production assets [6].

The above version of the groupings was based on an assessment of one of the directions characterizing the potential capacity of enterprises to achieve the eventual outcomes of production, namely, on assessing the level of technical equipment. A comprehensive assessment of the objective conditions for the activities of individual enterprises includes a description of both the technical and organizational aspects of the production at the enterprise. The evaluation of the organizational level in turn should be carried out in three directions: the level of organization of production, labor and management [1], [22].

The system of indicators characterizing the level of organization of production is designed to assess the

level of specialization and co-production, the size of an industrial enterprise, the composition of technical equipment, the use of production equipment for shifts, the turnover of current assets, and so on.

The indicators of the level of the labor organization characterize the level of the labor standardization and the organization of workplaces, the composition of workers by qualifications, prevalence of team form of labour organization, the labor turnover, their even distribution by shifts, the level of labor discipline, etc [12].

With the help of indicators of the level of management organization, it is necessary to determine the technical equipment of managerial work, the rationality of the composition of structural divisions, the conformity of the employees' qualifications to the position they occupy, the ratio of the number of workers and engineers and employees, the stability degree of engineering and technical staff, etc [8], [21].

When forming indicators of the organizational and technical level, one should focus on those of them that reflect the size, composition, status and rationing of labor and material resources. In this regard, in future studies it seems possible to develop methodological approaches to obtaining a generalized assessment of the organizational and technical level of enterprises, which can serve as the basis for grouping to isolate aggregates of enterprises that are homogeneous by objective conditions of functioning.

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