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# Statistical analysis of costs and prospects of digitalization of Russian mechanical engineering

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**Abstract.** The article studies the problem of formation of costs at machine-building enterprises as one of the key factors of intensive growth under uncertainty conditions and transition to an innovation-based development. Such changes require monitoring of the structure and economic content of the cost of engineering products for development of proposals to reduce production costs. The purpose of the study is a statistical analysis of the structure and economic content of the cost of production. The main methods of research are structural analysis; methods of comparison and graphical representation of the results allowing to trace the dynamics of changes are analyzed in this article. The factors influencing the change of expenses structure are depicted. The key cost elements causing growth of machine-building production costs are revealed. Statistical cost analysis is aimed at finding of internal reserves to reduce it and to create further prerequisites stimulating implementation of innovative projects in the development of mechanical engineering.

## 1. Introduction

Mechanical engineering is one of the most important industries in Russia. During the last four years, an average of 15 per cent of GDP is created due to its functioning. Nowadays, 34.5% of total number of working population is employed in industry in general works at the enterprises of the machine-building complex [1]. Mechanical engineering is an accelerator of new knowledge, inventions, high technologies, as well as of the material and technical basis for implementation of innovative potential.

Trends in the modern development of industrial production are formed within the framework of digital transformation. Following the main trends of the “Industry 4.0” concept [2] makes it necessary for enterprises to redistribute and optimize production costs. In such situation, the main attention is paid to a significant increase in financing of innovative projects in the field of digital technologies and their adaptation to the existing conditions of production.

On the other hand, the existing cost structure of an enterprise cannot be changed simultaneously. A significant part of them is due to functioning of the already formed production system and the presence of existing obligations, including consumers, suppliers, personnel and other stakeholders.

In order to understand possibilities, trends and potential mechanism of digital transformation of machine-building enterprises, it is necessary to study and analyze in detail the current system of production costs formation, which main factor is the cost of industrial production.



The cost of machine engineering production is one of the main factors in formation of the industry profits. In particular, the publication [3] is devoted to the study of problems associated with formation of costs at industrial enterprises and cost analysis. Cost optimization is a key mechanism to improve production efficiency and enterprise management. There is an inverse functional relationship between the profit and cost values.

Over recent years, digitalization of industrial production has become the most relevant research topic. Tendencies and prospects of development of digital economy [2], adaptation of digital models to conditions of the particular enterprise or a field of activity [4], [5] are studied in different countries all over the world.

The purpose of this study is to assess the prospects of digitalization of machine-building enterprises as a result of redistribution of production costs based on their statistical analysis. The main objective of changing the cost structure is to reduce the most significant cost items in favor of the costs for digital technologies creating and maintaining. In particular, the identification and use of internal reserves of the enterprise will allow, as a result of reducing resource intensity or labor intensity, to use the resulting savings to enhance digitalization.

One of the main conditions for obtaining reliable information about the cost of production is a clear definition of production costs composition, which allows forming the main source for profit growth [6].

The main objectives of the cost analysis are [7] objective assessment and determination of dynamics of the most important structural elements of the cost; determination of factors influencing the dynamics of costs; identification of the value and causes of deviations; identification and formation of reserves for cost redistribution.

The nature of these tasks shows the great practical importance of cost analysis in the activities of machine-building enterprises.

## **2. Research method**

In the course of the research, the following general scientific methods were used to ensure the complexity of the problem study: structural analysis, comparison method, grouping, concretization, method of graphical representation of the results.

The following main sources of information were used (in order to identify internal reserves for cost reduction):

- Rosstat official statistics (Russian industry, Russia in figures, Russian Finance), required for structural analysis [8, 9];
- various regulations governing the planning, accounting and calculation of the cost of production at machine-building enterprises.

In statistical analysis practice in order to identify the cause and effect relationship of changes in ratings is formed by several objects of research (2–3 enterprises). This is done to track the cumulative dynamics, conduct a generalized analysis, identify common factors and causes, and then to form specific conclusions on the object of study based on comparison with other objects.

This study is based on the principle: ‘from general to particular’; it means that the set of Russian enterprises producing machinery and equipment is analyzed on the bases of official statistics, and then an analytical comparison is formed on the example of a particular enterprise.

This method of analysis has been chosen for two reasons:

1. Cost data is a trade secret of many enterprises. Problems arise due to the difficulty of obtaining the required information, as well as the possible unreliability of the results due to the information closure of enterprises concerning their costs. Official statistics are attractive because they are freely accessible.

2. As the object of the study, the entire machine-building complex is presented in order to form conclusions and proposals for general recommendations, which may be used at any industrial enterprise.

### 3. Results

Let us consider the main performance data of enterprises producing machinery and equipment within the period of 2005 to 2015 (table 1).

An overview of the main indices permits to make the conclusion that the number of such enterprises is increasing. During 10 years, the growth of such enterprises amounted to more than 5000, which demonstrates the desire to develop this type of activity throughout the country.

As is known, the increase in the number of enterprises (potential taxpayers) affects macroeconomic indicators such as GDP, employment and unemployment levels, budget revenues. The volume of own production also increases almost 3 times in total during the period under review [10].

Profitability of machine-building products decreased during the whole period, for a combined total of more than 34%, which may indicate a significant increase in costs and simultaneous cooling-off in consumer demand. Despite the increase in the number of enterprises, the number of employees has decreased by more than 300 thousand people. This tendency is due to significant impact of modern technologies, in particular, due to development of automated production with minimum human participation. On the other hand, the decline in the attractiveness of the machine-building complex as a promising area of employment stimulates the outflow of the capable to work population to other fields of activity.

**Table 1.** Key performance indicators of enterprises in ‘Production of machinery and equipment’ category within the period of 2005 to 2015 (Rosstat).

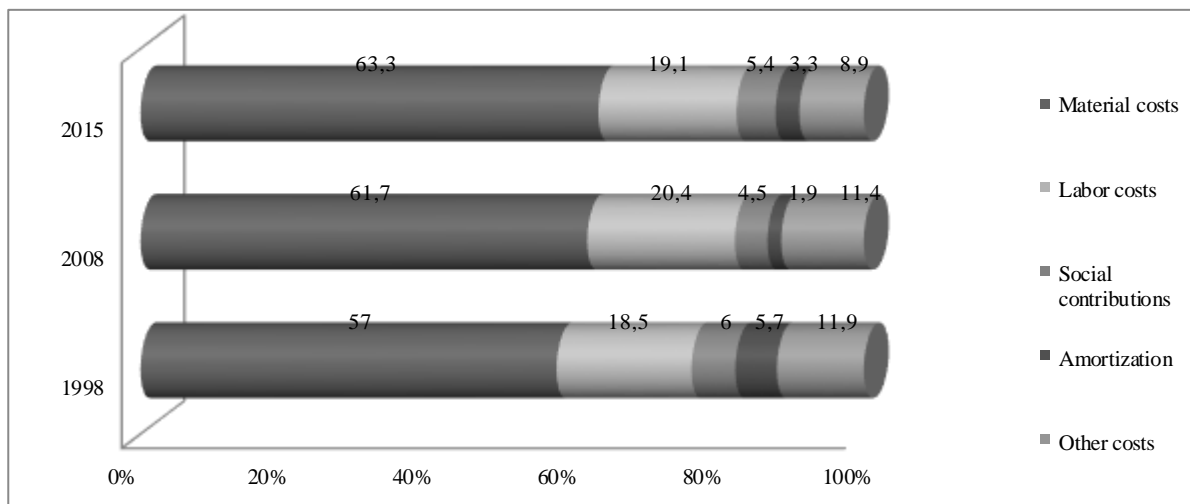
Name of indicators	Values by years						Absolute change in indicators over the entire period
	2005	2008	2011	2013	2014	2015	
Number of operating organizations (by the end of the year)	22842	23039	24312	25928	27812	28068	5226
Volume of shipped goods of own production, billion roubles	403	859	781	982	1079	1143	740
Average annual number of organization employees, thousand persons	905	835	666	658	636	603	−302
Costs of production, billion roubles	382	829	766	964	1107	1103	721
Balanced financial result (profit minus loss), billion roubles	20.81	30.54	15.04	17.95	−27.55	39.78	18.97
Profitability of sold products (work, services), %	5.4	3.7	2	1.9	−2.5	3.6	−1.8
Labour capacity, thousand roubles /person	444.9	1029.3	1172.7	1492	1697	1896.3	1451.4
Costs per 1 rouble of production (work, services), kop.	94.8	96.4	98.1	98.2	102.5	96.5	1.7

Production costs have increased, which adversely affects the development of enterprises as a factor of influence on the price of products and profits. Such dynamics demonstrates the lack of desire of enterprises management to reduce costs or inefficient development strategy.

It should be noted that the most common main structural elements of costs formation for many industries, including machine engineering, are the following [11]: material resources; energy; wages; insurance premiums; depreciation and other expenses.

The cost structure by cost elements in difficult periods of development of domestic economy is shown in the diagram (figure 1).

According to the results of structural analysis of cost elements in the cost, it has been found out that machine engineering is a material-intensive and labor-intensive industry. In 1998 material costs amounted to 57% of the cost of production, in 2008 — 61.7%, and in 2015 — 63.3%. The share of material costs in production of machine engineering products is more than half of its cost, and at some enterprises it reaches 80% of total costs.



**Figure 1.** Cost structure in machine engineering production within economical instability periods in Russia.

According to statistics, the average share of material costs is 60% of the cost of production. Labour costs include management personnel salaries, the share of which is the largest. Based on these features, the presented components (material costs and labour costs) are the key areas and sources of reserves for cost reduction and profit growth [12].

Thus, high material and labour intensity of production may be the main limiting factors of digital technologies development in the mechanical engineering. In the first case, it is due to the necessity to change technological solutions and transition to new types of automated equipment. In the second case it is due to the necessity to reduce a significant number of staff.

Optimization of the cost structure and transfer of a part of funds from saving the material and labour resources to creation and adaptation of digital technologies will contribute to intensive innovative development.

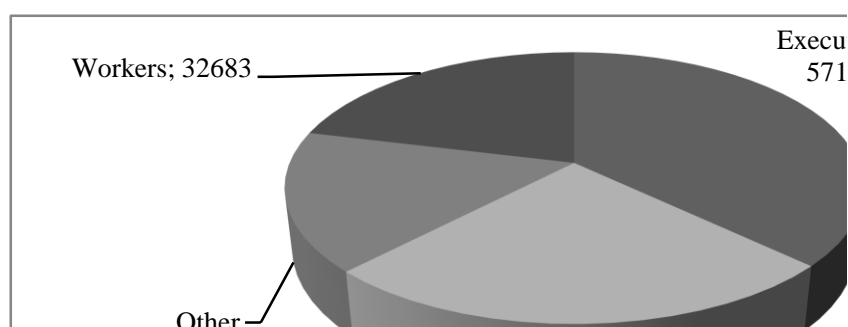
The main role in providing an enterprise with material resources is played by the quality and regularity of supplies, accounting and analysis of material costs, as well as the range of products. The change in the value of material costs in the production process is influenced by many factors, one of which is the organization of production, taking into account technological characteristics. Active management of these factors is possible in the case, if information on trends in factor changes and the strength of their impact on the cost of finished products will be received by material costs responsibility centres in due time [13, 14].

The main factor in the growth of costs is the price of input resources, which impact is always significant. For example, the dynamics of energy prices is given in the table 2 [15].

**Table 2.** Prices for main types of fuel and energy resources (Rosstat).

Type of Resource	Resource prices by years						
	2005	2010	2011	2012	2013	2014	2015
Natural gas per 1000 m <sup>3</sup>							
Production price, rbls	330	626	686	1224	1301	1639	1785
Purchase price, rbls.	1436	3081	3562	4062	4638	4666	5205
Ratio	4.4	4.9	5.2	3.3	3.6	2.8	2.9
Motor petrol per 1 ton							
Production price, rbls.	9159	16699	18576	19094	20108	20946	21995
Purchase price, rbls.	16984	24814	28775	34523	35539	38496	40470
Ratio	1.9	1.5	1.5	1.8	1.8	1.8	1.8
Diesel fuel per 1 ton							
Production price, rbls	12000	16340	20766	23512	22847	23587	21995
Purchase price, rbls.	16830	24157	30488	34075	36275	36622	40470
Ratio	1.4	1.5	1.5	1.4	1.6	1.6	1.8
Electric energy per 1000 kWh							
Production price, rbls	451	665	782	859	910	1009	989
Purchase price, rbls.	914	1539	1914	1933	2149	2103	2189
Ratio	2.0	2.3	2.4	2.2	2.4	2.1	2.2

According to statistical information, the production price (resource cost) and consumption price may differ several times. This situation directly affects a significant increase in the share of energy costs in the enterprise total costs. Similar situation has developed with the share of imported raw materials in the overall structure of material costs, the cost of which depends on changes in foreign and national currencies.

**Figure 2.** Average monthly accrued wages of enterprise employees by personnel categories in 2015 (rbls.)

In the figure 2, the average monthly wages of employees in 2015 are given by personnel categories. Managers get the highest salary, which exceeds the average wage of workers by 1.7 times. Optimization of labour costs of administrative and managerial personnel, the share of which can reach up to 70% of the total number of employees of enterprises, is also one of the sources of internal reserves to reduce production costs.

Indirect costs are those costs, which do not directly affect the cost of production. They are of general nature and are necessary to serve the enterprise production and economic activities. In the cost of production they are represented by the following components: depreciation, repair costs and other expenses [16].

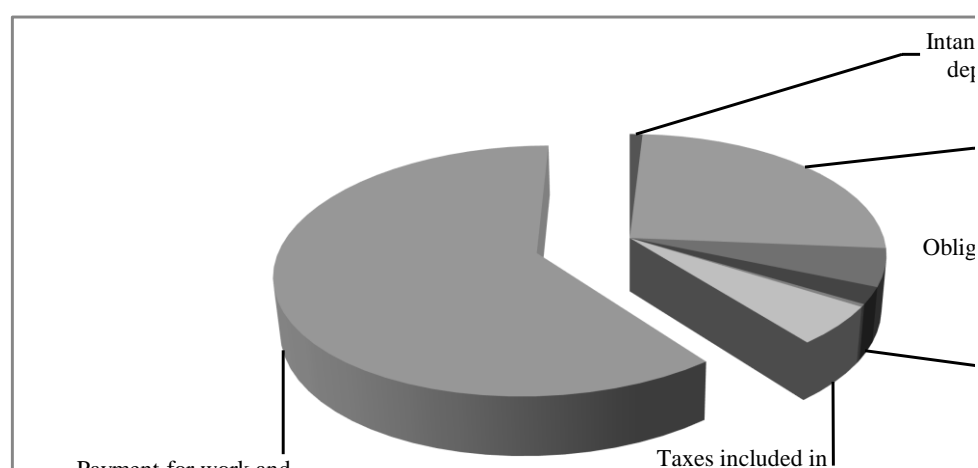
Identification of reserves for reduction of expenses on production service costs is carried out by means of analysis of their dynamics, causes of deviation from cost estimates, as well as the explicability of their allocation between commercial products and incomplete production. [17, 18].

The most important type of costs for machine-building enterprises, which actively develop innovation activity and attempt to provide competitive advantages are research and development costs. [19] (table 3).

**Table 3.** Research and development costs (million roubles) (Rosstat).

Expenditure heading	Cost values per year					
	2005	2008	2010	2011	2013	2015
Cumulative costs	12633.4	23918.6	32838.8	41251.7	59346.9	74693.9
Internal operating costs	11998.1	23283.2	31948.7	40012.1	56667.9	70882.8
• Labour costs	4421.8	8908.2	11200.2	13241.2	17319.2	21357.5
• Social insurance contributions to PFR, Social Insurance Fund (SIF), Federal Compulsory Medical Insurance Fund (FCMIF)	1135.8	2173.1	2722.5	3908.0	4788.2	5961.5
• Equipment purchase costs	636.1	936.3	1235.4	1070.7	1847.4	2251.7
• Other material expenses	2911.9	6257.1	9884.2	14327.8	18298.0	20194.2
• Other operating costs	2892.5	5008.4	6906.4	7464.4	14415.1	20118.0
Capital costs	635.3	635.4	890.1	1239.6	2679.0	3811.1
• Land plots and buildings	48.0	26.0	24.2	34.9	126.5	366.1
• Equipment	448.0	530.2	766.3	1075.9	1694.3	2491.5
• Other capital costs	139.3	79.2	99.6	128.8	858.2	953.4

According to the results of statistical analysis, research and development costs are steadily increasing throughout the analyzed period, almost 6 times in total. The largest share in the internal current research and development costs belongs to the labour costs. In capital expenditures, 60% of all costs are spent on purchasing of equipment. The increase in costs has reflected in the annual volume of research and development works carried out by own employees of enterprises, which has amounted to more than 200 billion roubles in recent years.



**Figure 3.** Structure of other costs in per cent.

Enterprise other costs structure includes payment for works and services of non-productive nature provided by the third parties (which share among all other costs is 61%), rent (26%), taxes included in the production cost of obligatory insurance payments (10%) (figure 3). Increase in rent indicates

reduction in own capital assets (buildings, structures, machinery and equipment), which is also confirmed by reduction in depreciation by 3% in the structure of production costs [20].

In the cost structure, the costs of purchasing imported materials and components, which affect the amount of material costs and the cost price as a whole, are of particular importance. This cost component directly depends on foreign economic relations of the countries, which can suspend enterprise activities in case of deterioration of political and economic relations. The significance of this factor is confirmed by information about general structure of export and import of machinery, equipment and transport vehicles (figure 4).



**Figure 4.** Dynamics of export and import of machinery, equipment and transport vehicles of the Russian Federation (in per cent of total export and import) [21]

Import of machinery, equipment and transport vehicles is continuously increasing. The decline periods of 1998 to 2000 and 2008 to 2010 are due to import substitution policy, activated as a result of crisis in the economy. Such dynamics is generally positive for foreign trade, but negative for development of industry in general.

The share of exports of similar goods for the analyzed period is reducing. Small increases observed within the periods of 2000 to 2001 and 2008 to 2009 are related to the industrial policy of the state. For solving the problem of the fastest possible transition to development and manufacturing of new high-tech equipment, in most cases the machine-building enterprises are forced to use imported components and materials. It will result in material costs increase in the structure of the cost of their own products, and subsequently in their prices [22].

Such situation may be avoided by implementing effective innovation projects, increasing funding for research and new developments at the expense of funds obtained as a result of savings due to reducing the enterprise costs.

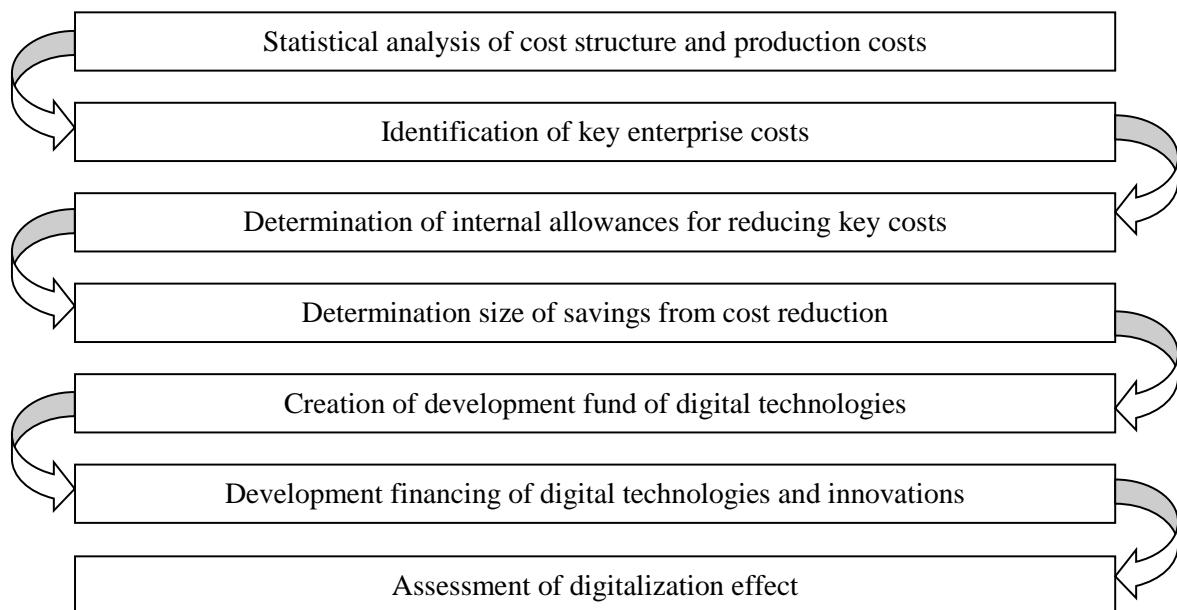
According to the results of statistical analysis of production costs in mechanical engineering, it has been found that the cost structural components in mechanical engineering do not change for a long period.

In course of research, the key features of financing the development of digital technologies at machine-building enterprises have been formed (figure 5).

The authors' process of identifying internal sources of investment based on changes in the cost structure will ensure development of digital technologies in mechanical engineering. The presented process shows a step-by-step sequence of actions from cost analysis to implementation of digital technologies at enterprises. Its key feature is creation of a special development fund, which is formed by identifying the value of potential savings due to cost reduction.

Resources of the created development trust fund will be assigned to implementation of projects in the field of digitalization. Under such conditions, the enterprise total costs and hence the profit will remain unchanged. Therefore, stable efficiency of activities will be assured.





**Figure 5.** The sequence of development of digital technologies at machine-building enterprises.

#### 4. Conclusion

In the system of indicators characterizing the efficiency of production and sales, the cost of production is one of the main factors.

According to the results of the carried out statistical analysis of machine engineering products' cost, it has been revealed that in the cost structure the largest share belongs to material costs (60%), labour costs (20%) and other costs (15%). Formation of reserves for enterprise costs reduction due to these components is the main prerequisite to development of its innovative activity due to redirection of savings to financing of researches and implementation of advanced development in the field of digitization.

#### 5. Directions for future research

The presented research results form the basis for further development of strategic and tactical measures to optimize costs. On their basis, it is planned to develop an integrated managerial solution and approach aimed at enhancing of innovation activities and intensive development of machine-building enterprises in the direction of digital technologies.

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