Improvement of Methodology for the Analysis of Construction Indicators

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Abstract. The development of market relations in the construction complex of Russia requires the solution of problematic issues not only of a regional nature, but also of a federal level. This is due to the improvement of the methodology for the analysis of economic indicators in construction. Based on the study of modern theoretical and conceptual approaches and methodological developments in construction practice for the analysis of production, business and financial activities of construction corporations, an author's concept of a prognostic analysis of the development of the region's building complex with detailed indicators and analytical procedures for their step-by-step solution is proposed. The achievement of the research goal has led to the use of methods of induction, deduction, and general scientific knowledge. The article also uses correlation and regression analysis, analysis of variance and coefficient analysis as the basis of the author's, system-process approach within the framework of the research problem under consideration. The real advantage of modern information and communication technologies used in the forecast analysis, which provides an opportunity for a more objective formalized assessment of the modern development directions of the construction complex of a separate region and Russia as a whole, has been proved.

1. Introduction

Modern economic challenges, due to the action of a number of factors of an objective, and sometimes completely unpredictable nature, are very painful - crisis both for the world economy and for the economy of any state. Crisis situations require innovative approaches to solve a whole range of economic problems, often quite costly for any national economy. The Russian economy is no exception. In this regard, the economic, including resource, financial, etc. crises occur in an avalanche-like manner, in accordance with the technological, industrial, economic, organizational, and financial chains of creating added value of final products of any kind, which have a destructive, destabilizing effect on development and the functioning of industrial corporations, including construction organizations.

In such organizational and economic conditions, the importance of obtaining an objective assessment of the expected results from the implementation of managerial influences on the stabilization of the economic situation multiplies. Formalization and mathematical description of the economic situation allow us to promptly affect the productivity of labor in a timely manner, providing the required and sufficient profitability of the economic activities of national corporations. The construction industry is largely decisive, since in parallel with it, a whole complex of production sectors operates: metallurgy, building materials industry, engineering, transport, etc.

In order to level out the effects of crisis situations in the future, their predictability through the expected calculated values of economic indicators, problems related to the analysis of achieved results, operational efficiency and obtaining objective predictive information to develop effective managerial decisions go to a new level. Moreover, to take into account the time factor, which is largely decisive in such economic conditions, modern information and communication technologies are used in the digital transformation of various aspects of the production and economic and financial activities of construction corporations.

Significant advantages of information and communication integration of modern technologies as the main mechanism of the digital economy are highlighted in the World Bank Review for 2016 - the development of innovations, a sharp increase in efficiency, the integration of labor and capital. The most important results of the development of the digital economy can be:
- improving the efficiency of capital use;
- development of competition;
- reducing the cost of industrial products through a comprehensive cost reduction;
- an increase in the number of corporations and the associated increase in new jobs;
- an increase in the middle class as a solution to the problems of reducing poverty and overcoming social inequality of the population [1].

In order to ensure high-quality interaction of analytical systems and technological platforms, taking into account the fact that the main element in this is the organizational, technical and technological partnership of corporations, it is necessary to consider the digital economy (digitalization) as an organic ecosystem. In this regard, one of the defining tasks of our time is the development of scientific approaches to forecasting.

The creation and use of various analytical systems - by type of economic activity, by territorial characteristics, in the context of the most important macro and microeconomic indicators - is an important part of the forecasting process of social, economic and organizational development. At the same time, a distinctive feature of strategic predictive analysis is the dynamics of changes in the economic situation from causes and factors to consequences and results.

Experience shows that the main tasks of economic analysis at the stage of forecasting research are traditionally:

- substantiation of an economic strategy, setting goals and objectives, developing managerial decisions based on a quantitative assessment of selected groups of development indicators and expected (prospective) calculated indicators;
- analysis of the actual resource and financial security of the potential and real possibility of the production program;
- definition, generalization and classification of factors affecting the production and economic and financial activities of the corporation for their subsequent accounting, or vice versa - leveling;
- development and proposal of organizational and economic measures with elements of forecasting economic results from their implementation to prevent possible negative consequences, on the one hand, or to increase the economic efficiency of activities, on the other.

Thus, strategic forecasting analysis is aimed at identifying objectively acting trends and patterns that take place in economic processes, including identifying promising areas of development and developing an effective economic policy for the appropriate level of economic activity: federal, regional, and sectoral. It should be emphasized that the most important feature of the forecast analysis is its conduct from causes and factors to economic consequences and results. The purpose of the forecast analysis is, first of all, the substantiation of the economic strategy, goals and objectives of the development of construction in the near future.

The main component of the methodology of strategic predictive analysis is a systematic approach that provides for multifactorial research and a common goal setting that allows you to combine individual areas of analysis, general and private, quantitative and qualitative indicators and production factors into a single system for a comprehensive integrated assessment. At the same time, strategic predictive analysis takes into account the synergistic component of the economic activity of construction corporations. This approach is due to the fact that the construction complex largely determines the final economic efficiency of the economic activity of industrial corporations at the regional and federal levels. In this regard, the use of multivariate regression models in economic analysis is quite motivated based on the assumption that the level of the resulting indicator depends on the integrated influence of a number of different factors on it.

In economic theory and practice, considerable experience has been accumulated in the formation of a methodology for economic analysis at all stages of its development, as applied to various economic structures, including in the management system of construction corporations. Modern methodological and methodological aspects of economic analysis are considered in the works of Schaltegger S., Wagner M. [2], MelnikM.V. [3], Barilenco V.I. [4], Kogdenko V.G. [5], Davenport T. [6]. The specified scientists and researchers have developed both the basic principles of economic analysis and specific analytical techniques adapted to organizations of various types of economic activity. The issues of determining the methodological tools relevant to the analysis of the sustainable development of the construction complex are devoted to the work of Geraskina I.N. [7], Selyutina L.G. [8], Guskova M.F. [9]. The development of the forecasting methodology for various socio-economic systems is reflected in the scientific works of I. Zenkina [10], Tikhomirova B.I. [11], Frenkel A.A. [11, 12], Bezrukova T.L. [13], Hank J.E., Wichern D.U., Wrights A.J. [14], Lyubushina N.P. [15], Kaplan R.S., Norton D.P. [16] and other authors.
A retrospective analysis of domestic and foreign studies on the methodology of economic analysis and forecasting revealed a number of problems in this scientific field. In particular, a number of methodological and methodological issues have not been resolved related to the improvement of the forecast economic analysis of construction as a complex system formed at various hierarchical levels of management. In addition, the results of a study of the heritage of modern representatives of economic science prove a certain flaw and insufficient scientific validity of the existing conceptual approaches in the theory of forecast management analysis of the production, economic and financial activities of construction corporations. In this regard, the modern development of market relations in the construction complex of the Russian Federation requires the solution of problematic issues of a regional nature. This is primarily due to the improvement of the methodology for the analysis of economic indicators in construction corporations in Russia. Based on the study of modern theoretical and conceptual approaches and existing construction practices at the regional level, as well as methodological developments for the analysis of the production, economic and financial activities of contracting construction corporations, the author proposes his own concept of predictive analysis of the development of the region’s building complex. A methodological approach to the quantitative detailing of volumetric and qualitative indicators and an analytical toolkit for step-by-step solution of tasks were developed. The study identifies and generalizes the groups of dominant factors, offers scenario options for using various economic methods on the basis of which simulation economic and mathematical models are built to analyze and substantiate the forecast for the development of the region’s building complex. Also identified are the basic requirements that must be met by methods of economic analysis, taking into account the challenges facing them. In particular, the following requirements apply to them:

- the possibility of an active impact on the dynamics of the analyzed economic processes and phenomena;
- compliance with the specifics of the object of analysis;
- the availability of appropriate information support;
- the ability to balance methods;
- the use of modern information and communication technologies in the calculations.

2. Materials and Methods

2.1. Development of conceptual approaches and methodology for the analysis of economic indicators of regional construction corporations

From the point of view of a systematic approach, the economy of the region is a complex open system with the inherent synergy effect. In this regard, in the prognostic analysis of construction as an integral part of the region’s economy, a number of problems arise:

- firstly, the definition and study of the structure of the system - an analysis of the dynamics of structural changes (by organizational and legal forms, ownership, territorial aspect, etc.);
- secondly, a quantitative analysis of construction as a specific type of economic activity using modern research methods and information and communication technologies;
- thirdly, the receipt, processing, storage and use of data on the dynamics of development of construction in the context of the identified structures.

Summarizing performance indicators of the regional construction complex can be considered the amount of net profit, profitability of construction production, as well as the cost of construction and installation works, labor productivity and capital productivity. The reduction in the cost of construction and installation works is directly related to the increase in profit and reflects the efficiency of the use of material and labor resources. In the final cost of construction products, ultimately, the results of all measures to increase production efficiency and factors affecting the final results of operations are reflected.

The proposed analytical grouping of indicators of construction development in the region is based on a system of interrelated indicators of production, investment and financial activities of construction organizations. At the same time, the peculiarities of the development of the regional construction complex, the directions of improving the economic mechanism of the industry related to highlighting the efficiency indicators of the use of production resources (labor resources, fixed assets and capital investments) were taken into account.

The analysis of the system of interrelated indicators is hierarchical - from the main indicators to auxiliary, less significant. At the same time, the use of a combination of different methods and modern information and
communication technologies in the analysis of individual indicators when processing large amounts of information allows us to comprehensively assess the impact of a significant number of factors on this indicator. In the course of the economic grouping of factors that influence the selected system of indicators for the development of construction, the following stages should be distinguished:

1) the formation of a common system of factors;
2) the selection of the main factors determining the dynamics of indicators of development of construction;
3) determination of the form of relations and analysis of changes in factors.

All factors are divided into endogenous - depending on the activities of construction corporations, and exogenous - not depending on the results of activities. In turn, endogenous factors are classified depending on the role of individual elements of production (means of labor, labor, and subject of labor).

So, for example, factors affecting labor productivity (as well as capital productivity) are in constant interaction so that a change in one of them leads to a change in the influence of other factors. Therefore, from a methodological point of view, labor productivity and capital productivity should be considered as complex dynamic systems with an internal relationship. A characteristic feature of systems of this type is that the general effect of the influence of individual factors is not equal to the arithmetic sum of the effects of the influence of each factor, as is assumed in the study of simple dynamical systems. This feature is based on a specific feature of complex dynamic systems - emergence. In this regard, in a predictive analysis, it is important not to replace real relationships with formal schemes, but to adapt well-known models and methods to the study of objectively existing dependencies. From this point of view, it is advisable to identify the growth reserves of the analyzed indicators, on the one hand, on the basis of models with mixed forms of relationships, and on the other hand, use a system of interrelated economic and statistical methods for this.

In general, the analyzed indicators can be represented in the form of a model (1):

\[ Y_t = Y_0 \cdot \left[ f(x_1, x_2, \ldots, x_n) \right], \tag{1} \]

where

- \( Y_t \) is the value of the indicator at the end of the analyzed period;
- \( Y_0 \) is the value of the indicator at the beginning of the analyzed period;
- \( I_{int} \) an integrated index that takes into account the change in the analyzed indicators due to factors whose influence can be determined on the basis of the practical activities of a construction corporation or by a direct account;
- \( x_1, x_2, \ldots, x_n \) are factors taken into account in the regression model.

\[ I_{int} = I_1 \cdot I_2 \cdot \ldots \cdot I_n, \tag{2} \]

Where \( I_1, I_2, \ldots, I_n \) are partial indices of the influence of individual factors.

The quantitative influence of factors by the index method is determined provided that there is a functional relationship between the analyzed indicators and the factors that influence them.

The use of such a complex method in the analysis of the level and growth rates of labor productivity and capital productivity is due to the presence of a synergistic connection of the elements of complex dynamic systems.

The process of building an economic model can be divided into three stages. At the first stage, an analysis of the matrix of pair correlations for the dynamic series of indices of change of indicators \( (I_t) \) is carried out in order to carry out a preliminary selection of factors \( (x_1, x_2, \ldots, x_n) \) included in the regression equation. At the second stage, the model is refined in order to obtain an economically significant result by identifying non-essential factors and their exclusion from the model based on the \( t \)-criterion calculated for each indicator. The third stage is possible if among the factors included in the model at the previous stage, multi-collinear factors are identified. In this case, the integral index, taking into account the change in the generalizing indicator due to the identified factors, the influence of which can be determined by direct counting, is calculated as the product of the indices of individual factors.

And so, the first stage of modeling includes the selection of the most significant factors that directly affect the resulting economic indicators. To determine the degree of impact on the actual value of these indicators of factors taken into account in a multivariate regression model, we should exclude the influence of factors calculated by direct counting using indices (3):

\[ Y_t = Y_0 \cdot \left[ f(x_1, x_2, \ldots, x_n) \right] \tag{3} \]
Where \( Y_t \) is the calculated level of the analyzed indicator that does not take into account the influence of direct counting factors;
\( Y_t \) is the value of the indicator at the end of the analyzed period;
\( I_{\text{int}} \) is an integral index that takes into account the change in the analyzed indicators due to factors whose influence can be determined by a direct score;
\( Y_0 \) is the value of the indicator at the beginning of the analyzed period.

For example, an integral index that takes into account changes in labor productivity in construction due to factors whose influence can be determined by a direct account is calculated as the product of the indices of the selected factors. Such factors include: a) endogenous: change in the shift factor of machines and mechanisms (\( I_1 \)); quality condition of the active part of fixed assets for construction purposes (\( I_2 \)); construction losses associated with the correction of the marriage (\( I_3 \)); a change in the specialization level of construction industry (\( I_4 \)); a change in the concentration level of construction production (\( I_5 \)); rhythm of work; change in loss of working time (\( I_6 \)); the level of material consumption of works (\( I_9 \)); change in losses of working time due to staff turnover (\( I_{10} \)); loss of working time due to illness (\( I_{11} \)); the economic effect of rationalization (\( I_{12} \)); b) exogenous: changes in the structure of work by type of construction (\( I_{13} \)); a change in the reproductive structure of works (\( I_{14} \)); provision of construction organizations with materials, structures, products (\( I_{15} \)). The influence of a factor on the dynamics of labor productivity is determined by the corresponding calculation formula, taking into account the specifics of the selected factor.

The construction of index models is based on the assumption that the analyzed indicator should be presented in the form of a product of the factors determining it, and this product should reflect its size and the order of location of the index factors.

The influence of factors that cannot be determined by direct counting using indices is calculated using a multivariate regression model (4). In this case, an assumption is made about a linear relationship between the factor and the analyzed indicator.

\[
I_t = a_0 + a_1x_1 + a_2x_2 + \ldots + a_nx_n, \quad (4)
\]

where \( I_t = \frac{Y_t}{Y_0} \) is the index of change in the adjusted indicators compared with the baseline for the analyzed period.

\( x_1, x_2, \ldots, x_n \) are the “regression” factors that affect the value of the adjusted indicators.

The use of multivariate regression models in predictive economic analysis is based on the assumption that the level of the resulting indicator depends on a number of factors influencing it. A necessary condition for the successful use of regression models is the abstraction in the research process from non-essential factors, averaged values of secondary and subjective factors [17].

For further analysis, from the entire set of factors \( x_1, x_2, \ldots, x_n \) only factors with a high correlation coefficient with the \( I_t \) function and a low coefficient of pair correlation with other factors are selected. However, this selection criterion is not strict. It allows only revealing the tightness of statistical relationships between individual factors, which is the initial information for the subsequent qualitative analysis of interdependent factors. In this regard, it is necessary to have a scientifically based methodology as a starting point for building a model and interpreting the results. One of the methods of such a scientific approach is a fairly complete sampling and classification of quantitatively measured factors affecting the analyzed indicators.

For example, if the results of the analysis showed that some two factors are statistically dependent, but not physically dependent, then both of them can be included in the model. If the value of one factor can be found by the value of another (factors are not independent), only one of them is included in the model. However, it should be noted the lack of regression analysis as a method for assessing the quantitative effect of individual factors on the resulting indicator. When analyzing the dynamic series of selected factors by the methods of correlation and regression, the model does not include factors whose influence on the resulting indicator seems insignificant [18]. At the same time, when considering the results of modeling from both theoretical and practical points of view, it may turn out that the conclusions about the insignificance of the influence of one or another factor are clearly distorted.

2.2. Prediction of labor productivity based on the construction of a linear multifactor correlation model of the regional building complex

In the study of the dynamics of the labor productivity indicator when using a sample of construction organizations of two levels (federal district - administrative formation and subject - territorial unit), they are formally generalized and the following factors are included in the regression model:

\[
I_t = a_0 + a_1x_1 + a_2x_2 + \ldots + a_nx_n, \quad (4)
\]
For the analysis of labor productivity at the level of administrative formation (district), the model has the form (5):

\[ \bar{Y} = 5.5735 + 0.0679x_1 + 0.0035x_2 + 0.0201x_3 - 1.7106x_4 + 0.0080x_5 \]  

Accordingly, for the analysis of labor productivity in the construction organizations of a territorial unit (subject), the dependence is obtained (6):

\[ \bar{Y} = -0.1827 + 0.0481x_1 + 0.0024x_2 + 0.0096x_3 + 0.1572x_4 + 0.0031x_5 \]  

The statistical characteristics of the regression equations are shown in table 1.

**Table 1. Statistical characteristics of the regression equations (1 option).**

| Level of question | Multiple correlation coefficient \((R)\) | Multiple determination coefficient \((R^2)\) | Actual value \(F\)-test | Argument Factors \((x)\) | Values \(t\)-test for regression coefficients |
|-------------------|------------------------------------------|------------------------------------------|--------------------------|--------------------------|-------------------------------------------|
| Administrative formation | 0.9910 | 0.9821 | 551.6598 | \(x_1\) | 4.8444 |
|                     |                                   |                                          |                          | \(x_2\) | 2.2229 |
|                     |                                   |                                          |                          | \(x_3\) | 9.2704 |
|                     |                                   |                                          |                          | \(x_4\) | -3.7797 |
|                     |                                   |                                          |                          | \(x_5\) | 3.9938 |
|                     |                                   |                                          |                          | \(x_6\) | 3.8587 |
|                     |                                   |                                          |                          | \(x_7\) | 3.0826 |
|                     |                                   |                                          |                          | \(x_8\) | 5.1431 |
|                     |                                   |                                          |                          | \(x_9\) | 0.3786 |
|                     |                                   |                                          |                          | \(x_{10}\) | 1.4714 |
| Territorial unit    | 0.9874 | 0.9749 | 392.1038 |                          |                               |

*Source: Authoring*

Statistical analysis of the obtained regression equations showed their significance: the actual value of the \(F\)-criterion is greater than the recommended value for a 5 percent significance level; the multiple correlation coefficient reflects the presence of a fairly high tightness of the relationship between the function and the argument factors. However, a further analysis of the obtained equations revealed the presence of feedback between the function and factor \(x_4\) (for the conditions of administrative formation), however, a qualitative economic analysis assumes a direct relationship between the indicator of labor productivity (output) and the average wage category of the worker. In addition, the obtained regression coefficients for materiality were analyzed. A comparison of the obtained values of the \(t\)-test with the recommended values showed that the factor \(x_4\) (for the conditions of the territorial unit) is not statistically significant for the obtained relationship. For these reasons, factor \(x_4\) is excluded from further analysis. In this regard, there is a need for re-modeling.

During the second stage of modeling, the following equations were obtained: for the analysis of labor productivity of construction organizations of an administrative formation (5) and for analysis at the level of a territorial unit (6):

\[ \bar{Y} = 0.0241 + 0.0368x_1 + 0.0041x_2 + 0.0154x_3 + 0.0037x_5 \]  

\[ \bar{Y} = 0.3271 + 0.0507x_1 + 0.0024x_2 + 0.0100x_3 + 0.0035x_5 \]  

The statistical characteristics obtained at the second stage of modeling the regression equations are given in table 2.
Table 2. Statistical characteristics of the regression equations (option 2).

| Level in question           | Multiple correlation coefficient \( (R) \) | Multiple determination coefficient \( (R^2) \) | Actual value | ArgumentFactors \((x)\) | Values \(t\)-test for regression coefficients |
|-----------------------------|---------------------------------------------|-----------------------------------------------|---------------|--------------------------|-----------------------------------------------|
| Administrative formation    | 0.9859                                      | 0.9719                                       | 454.0087      | \( x_1 \)               | 2.6375                                        |
|                             |                                             |                                               |               | \( x_2 \)               | 2.1111                                        |
|                             |                                             |                                               |               | \( x_3 \)               | 7.0448                                        |
|                             |                                             |                                               |               | \( x_4 \)               | 1.8362                                        |
|                             |                                             |                                               |               | \( x_5 \)               | 5.0029                                        |
| Territorial unit            | 0.9873                                      | 0.9747                                       | 506.7918      | \( x_1 \)               | 3.1541                                        |
|                             |                                             |                                               |               | \( x_2 \)               | 6.4951                                        |
|                             |                                             |                                               |               | \( x_3 \)               | 1.9451                                        |

*Source: Authoring*

2. 3. Comparison and verification of the obtained quantitative characteristics of labor productivity models for the construction complex of different regional levels

Statistical verification of the obtained regression equations showed their significance. The analysis of the introduced indicators in the obtained equations also confirmed the statistical significance of the regression coefficients. The value of the multiple correlation coefficients has changed insignificantly and reflects the presence of a sufficiently high coupling tightness. The coefficient of multiple determination of \( R^2 \) was 0.9719 for the level of administrative formation and indicates that 97.19% of the total variation of the adjusted production indicator is determined by the change in the indicator factors included in the model. For construction organizations of a territorial unit, the value of this indicator is slightly higher - 97.47%.

In the linear model, the free term of equation \((a_0)\) does not have an independent economic interpretation, denoting the initial ordinate of the regression hyperplane in five-dimensional space. The regression coefficients for each factor-argument always have a certain meaning and indicate how on average the independent variable will change when the corresponding factor changes by one with the average level of other factors included in the model. The signs at the regression coefficients are consistent with economic considerations about the direction of the influence of factors on the level of labor productivity. Judging by the given models, the greatest impact on the adjusted output indicator is exerted by the growth in the capital-labor ratio and the share of workers with progressive wage systems, since the regression coefficients for these factors are greatest. However, regression coefficients having different physical meanings and units of measurement do not provide an accurate quantitative assessment of the influence of each factor. In this regard, based on the regression coefficients of the obtained equations, the quantitative share of the influence of each of the considered factors in relation to the level of the base year is calculated. The analysis of labor productivity showed that in all the periods under review exogenous factors had a negative impact on the level of labor productivity.

3. Results

Studies prove that it is necessary to have a scientifically based methodology as a starting point for building a model and interpreting the results. One of the methods of such a scientific approach is a fairly complete sample with an apodictic classification of quantitatively measured factors affecting the analyzed parameters.

Thus, the results of the study, coupled with forecasting and mathematical description (modeling) of development scenarios for the regional building complex based on the proposed methodology, made it possible to quantify the dynamic characteristics of the retrospective, i.e. formed in the past time period, cause-effect relationships for different levels of organizational, economic, and management systems. The obtained trends allow us to give a quantitative and qualitative assessment of the factors determining labor productivity, to provide a mathematical description of the dependencies, as well as to calculate the real reserves of labor productivity growth in the construction corporations of the region and outline the main directions for their implementation in the future.

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