# A Systematic-Functional Approach in Managing Innovative Development of Construction Enterprises in Ukraine

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***Abstract*** **– The existing theoretical provisions and methodological recommendations on applying a systematic-functional approach in managing innovative development of construction enterprises are improved in the paper.**

**Based on the performed research results, the classification of innovative development types was developed and the essence of the "innovative development" concept was clarified; the method for evaluating innovative development of construction enterprises was developed; the model for regulating the effectiveness of applying a systematic-functional approach in managing innovative development of construction enterprises was developed; the mechanism for monitoring the economic efficiency of applying a systematic-functional approach in managing innovative development of construction enterprises was improved; the method for predicting the economic efficiency of applying a systematic-functional approach in managing innovative development of construction enterprises was improved.**

**The practical value of the research results is in the development of methodological tools for applying a systematic-functional approach in managing innovative development of construction enterprises.**

***Keywords*** **– management, innovative development, enterprise, systematic-functional approach**

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## 1. Introduction

In the context of globalizing the information and communication systems, there is no doubt that innovation is the most important factor in competitiveness. It is the very innovation that ensures the growth of demand for products, completed works, and services of construction companies. Innovation is the reason for the emergence of better and cheaper materials, bolder designs, technologies that are more economical, etc. Despite this, it should be recognized that to obtain the expected economic effects from the introduction of innovations, a rational system of managing the processes of putting forward creative ideas and introducing innovative products and technologies is necessary [6]. The problem is in the lack of systematic, scientifically based theoretical and methodological-applied provisions on applying a systematic-functional approach in managing innovative development of construction enterprises.

A review and analysis of literature sources suggests that the "innovative development" concept is widely used at the macro, meso and micro levels, as well as at the world economy level. This concept is often considered at the level of certain types of economic activity as well [8]. Among the research subjects it is necessary to distinguish the following: tools (methods), mechanisms and models of ensuring innovative development [5], [10], programs, plans, models, vectors, priorities, scenarios, and strategies of innovative development [3], [8], factor conditions for ensuring innovative development, monitoring and evaluating the current state of innovative development [12], its forecasting and building trends [9], [19].

Among many modern scientific works that relate to innovative development, those that are close to the problems of this research will be analyzed. Thus, while studying innovative strategies in underground construction, authors carefully justified the conditions and principles that should be implemented and professed adhering to the provisions of the Sustainable Development concept [21]. The author's ideas are fully based on systematic-functional approaches for the development of management construction. However, it should be recognized that strategic innovation management, especially in the context of sustainable development, should be closely linked to tactical and operational management [8]. Unfortunately, this aspect of system-functional connections in construction development management is very poorly covered [4]. The same regards the studies [5], [17]. The authors rather one-sidedly highlighted the management problem, completely ignoring the conditions for monitoring the innovative development strategy implementation, predicting its effectiveness, and adjusting.

To a certain extent, the answers to the questions were found in the work [22]. The authors mainly focused on technological innovations for large and medium-sized construction enterprises [15] and management approaches used by construction enterprises [11]. These researchers were able to prove that the management approach and the nature of technological innovations are among the most significant factors in innovative development of construction enterprises [16], [20].

Along with these indisputable conclusions, the questions about the sufficiency of these conditions to ensure the competitiveness and rationality of managing innovative development of construction enterprises have arisen. This question has arisen because innovations are associated with significant risks, the sources of which can be both inside and outside the enterprise, that is, they can be unmanageable.

This opinion is confirmed in [1], where there are carefully studied the environmental factors that influence innovative development of construction enterprises. The authors argued that in the context of globalization, construction enterprises have unprecedented opportunities for innovative development, but at the same time they are experiencing global challenges that increase the requirements for quality, safety, rational management, and financial stability. Despite this, the authors did not provide the applied mechanisms for adapting to the globalization conditions and countering threats.

The ideas based on the provisions of modern systemology, made a successful attempt to model innovative development of enterprises [18], where the practice of Innovation Management in German enterprises is critically analyzed, and the applied recommendations for management optimization are formed [14]. From the standpoint of both systemic and functional approaches, the authors demonstrated the options for managing innovative development of the enterprise's project activities. Despite this, the issue of monitoring and regulating innovative development at various stages of business project implementation remains open.

Scientific circles often pay attention to innovative development based on the principles of scientific and industrial cooperation, and the use of the potential of artificial intelligence to solve economic, managerial, and engineering-technological problems. In the work [12], based on the empirical data, it is convincingly proved that the risk of investing in innovations and the need to profess the provisions of the sustainable development concept is optimal based on scientific and industrial cooperation. As a result, applying a systematic-functional approach in innovation management is an objective necessity. In general, sharing the position of the authors, there are reasons to state that: the recommendations of an organizational nature proposed in [12] is a necessary but insufficient condition to ensure the rationality of applying a systematic-functional approach in managing innovative development of construction enterprises.

We fully support and agree with positions covered in the work [7], which focused on the social and financial-economic responsibility of innovation entities for the implemented projects, the role of artificial intelligence in innovation management and the relevance of standardizing innovation development management processes [13]. Despite this, we note that innovative development is characterized by permanent changes [6]. The issue of standardization in innovative development management should be considered very carefully. First, it is advisable to identify the signs of constant and variable processes in innovative development management clearly. In addition, with using the capabilities of artificial intelligence, it is necessary to predict the vectors and nature of innovative development for a sufficiently long period with a sufficient level of reliability.

Therefore, despite many scientific works and significant achievements in the theory and practice of managing innovative development of construction enterprises, there are a number of issues that remain studied in fragments.

In particular, the following issues for construction enterprises are: classification of innovative development types, the essence of "innovative development" concept; methods for assessing innovative development; models for regulating the effectiveness of applying a systematic-functional approach in managing innovative development; mechanisms for monitoring the economic efficiency of applying a systematic-functional approach in managing innovative development; methods for predicting the economic efficiency of applying a systematic-functional approach in managing innovative development [2].

All those have led to the choice of the topic of scientific research.

## 2. Objectivities

The aim of the research is to develop new and improve the existing theoretical provisions and practical recommendations for applying a systematic-functional approach in managing innovative development of construction enterprises.

Achieving this objectivity has led to solving the following scientific problems: to clarify the essence of the "innovative development" concept and form a classification of innovative development types; to analyze the actual state of the construction services market in Ukraine; to identify methodological problems of assessing innovative development of construction enterprises and reveal the essence of the ways to solve them; to develop a model for regulating the effectiveness of applying a systematic-functional approach in managing innovative development of construction enterprises; to improve the mechanism for monitoring the economic efficiency of applying a systematic-functional approach in managing innovative development of construction enterprises; to improve the method of forecasting the economic efficiency of applying the systematic-functional approach in managing innovative development.

## 3. Research Methods

The following basic methods of scientific knowledge are applied in the paper:

- concretization, generalization, formalization, systematization, methods of induction and deduction - when clarifying the essence of "innovative development" concept and forming a classification of innovative development types;
- a method of expert assessments, in particular questionnaires, index method, tools of set theory - when analyzing the actual state of the construction services market in Ukraine, as well as identifying methodological problems of assessing innovative development of construction enterprises and revealing the essence of the ways to solve them;
- methods of economic and mathematical modeling, a method of morphological analysis and tools of discrete mathematics-during the development of a model for regulating the effectiveness of applying the systematic-functional approach in managing innovative development of construction enterprises; to improve the mechanism for monitoring the economic efficiency of applying the systematic-functional approach in managing innovative development of construction enterprises; to form recommendations for improving the method of forecasting the economic efficiency of applying the systematic-functional approach in managing.

## 4. Results and Discussion

### *4.1. The Essence and Types of Innovative Development*

The "innovative development" concept is widely used. It is used to study the problems of the macro-, meso - and micro-levels, as well as the problems of the world economy. This concept is often considered at the level of certain types of economic activity as well. The research subjects include: 1) problems of innovative development; 2) tools (methods), mechanisms and models for ensuring innovative development; 3) programs, plans, models, vectors, priorities, scenarios, and strategies of innovative development; 4) factor conditions for ensuring innovative development; 5) monitoring and assessing the current state of innovative development, its forecasting and constructing trends.

Given the variety of contexts in which the "innovative development" concept can be applied, it is important to identify its essential features.

The conducted research suggests that the general, fundamental features that are characteristic of innovative development at any level include those presented below (Table 1.).

*Table 1. Classification of innovative development types of construction enterprises*
*Source: Developed by the authors*

| Classification features | Innovative development types |
|---|---|
| 1. by content | product; resource; technological; managerial |
| 2. by scale | regional; branch; organizational; project; systemic |
| 3. by business environment | vector; functional |
| 4. by level | high; low |
| 5. by type | permanent; periodic |
| 6. by nature | evolutionary; revolutionary |

The identified features are a complete system of characteristics that reflect cause-and-effect relationships in the phenomenon of "innovative development". The other features of this concept should be interpreted as a superstructure to these basic, fundamental features.

Thus, innovative development of construction enterprises is a phenomenon of qualitative changes that occur due to the influence of creatively active construction enterprises on the growth and use of their innovative potential.

Classification features and innovative development types are a matrix of clarifying characteristics for each of the construction enterprises. It is advisable to use them for analytical purposes when identifying cause-and-effect relationships between factors that affect the effectiveness of innovative development, as well as for making managerial decisions.

Applying a systematic-functional approach in managing innovative development requires the practice of a certain set of principles.

Implying a set of these principles is focused on ensuring the effectiveness of the systematic-functional approach in managing innovative development of construction companies.

### *4.2. Analyzing of the Construction Services Market*

Applying official statistics, the changes in the construction services market in Ukraine during 2013-2019 are analyzed, in particular, the information on the number and structure of construction services market entities, the number of people employed in the construction sector, the volume of construction products produced, the nature of construction, the volume of value added by entities that carried out economic activities in the field of providing construction services, as well as the volume of capital investment in construction were taken into consideration. According to the results of the study, it was found out that:

- in 2013 there were in total 1 million 720 thousand business entities in Ukraine, 3.0% of which were the subjects of the construction services market. 70 % of the subjects of the construction services market accounted for entities that carried out economic activities as legal entities [12]. Due to the trends in optimizing the tax burden, which provided for the re-registration of the construction business of large companies to a few sole owners, as well as due to the phenomenon of takeover of some construction companies by others in 2019, the number of construction service entities increased, but their relative share decreased by 1.0%. At the same time, the relative share of legal entities providing construction services also decreased to 56.0 %.
- in general, the number of people employed in economic activities has decreased, but the number of individual entrepreneurs has increased. Therefore, the trend itself was typical for almost the entire sphere of construction and providing construction services.
- Thus, a decrease in the number of employees is observed in the construction of residential and non-residential buildings, structures, communications, pipelines, power supply and telecommunications structures, other structures, water structures, research and production structures, demolition and preparatory work on construction sites, preparatory work on construction sites, exploration drilling, electrical installation, water supply and other construction and installation works;
- the value of production was growing, but not steadily. Despite this, in 2019 it was 181697.9 ml. UAH unlike 58586.2 ml. UAH in 2013. Despite such a rapid increase in the volume of production of construction products, in general, the structure of construction has hardly changed. Thus, on average, the share of construction of buildings was 47.0%, and structures was 53.0%, among which 37.0% accounted for residential buildings and 63.0% for non-residential ones;
- due to a decrease in demand for new construction because of the population impoverishment, a decrease in the income of exporting enterprises due to the loss of markets in the temporarily occupied areas of Luhansk and Donetsk regions, the Autonomous Republic of Crimea by the Russian Federation, there was an unstable trend towards a decrease in the share of new construction, reconstruction and technical re-equipment (2013 – 81.2%, 2019 – 74.2 %) and to an increase in the share of capital and current repairs (2013 – 18.8%, 2019 – 25.8 %);
- in 2019, all business entities added 2973636234.2 thousand UAH of value, which is more than twice as much as it was in 2013. It should be recognized that this growth is not only a consequence of productive changes that led to an increase in production volumes, but also, largely, due to the depreciation of the national currency. It should be recognized that it was the growth of capital investment that became a factor of positive action, which provided an increase in added value in the construction sector and providing construction services.

This conclusion is confirmed by the fact that in activities in the construction services market, there was a decrease in the volume of capital investment (organization of construction of buildings, water structures, other structures of a scientific and industrial nature) and this is correlated with the increase in added value provided by them.

### *4.3. Identification of Problems of Assessing Innovative Development of Construction Enterprises and Disclosing the Essence of the Ways to Solve them*

Our empirical research conducted among Ukrainian construction companies has shown that, on the one hand, the rationality of innovation development management is usually assessed by comparing the actual values of innovation development indicators with the planned values of indicators (mainly it concerns such indicators as the number of innovative technologies and materials implemented, as well as the amount of innovation costs). Based on the analysis of deviations of actual values with planned one's management decisions are made on the need to regulate innovative development of a construction enterprise.

On the other hand, the study of empirical data of construction companies allows stating that: a full-fledged assessment of the rationality of applying a systematic-functional approach in managing innovative development of a construction enterprise cannot be carried out exclusively on the data of financial and statistical reports of enterprises; sources of information for assessing innovative development of construction enterprises should also be management reporting and, if necessary, expert assessments of subjects involved in creative search, implementation of creative projects, implementation of innovative processes, etc.

It is under such conditions of innovation management that development of construction enterprises will have a systematic-functional character, and the assessment results will be informative.

Based on the above mentioned, it is proposed to assess the rationality of applying a systematic-functional approach in managing innovative development of a construction enterprise taking into account two equivalent components – the creative activity of construction enterprises and the implementation of innovations by them. The importance of these components bivectorally reflects innovative development of a construction enterprise. For analytical purposes, the obtained values of these indicators will be uninformative, especially when it is necessary to compare two or more companies with each other to make an investment decision.

The content of such an assessment will also decrease if the analyst does not consider the size of the enterprise during the comparison.

To avoid these disadvantages, it is necessary to switch from absolute values to relative ones. In addition, to get a complete picture of innovative development of an enterprise, the most informative is to identify the relative increase in the values of indicators that characterize innovative development of a construction enterprise.

So, we propose an assessment method based on considering the relative increase in the values of indicators that characterize innovative development of a construction enterprise:

$$\because (R_k \wedge R_v) \sim \bigcup_{m=1}^{2} R_m \therefore (\Delta R_k \wedge \Delta R_v) \sim \Delta \bigcup_{m=1}^{2} R_m : \Delta \bigcup_{m=1}^{2} R_m \equiv \bigcup_{m=1}^{2} R_{m_z} \setminus \bigcup_{m=1}^{2} R_{m_b},$$

where $R_k$ – creative activity level, unit shares; $R_v$ – level of innovation implementation, unit shares; $\bigcup_{m=1}^{2} R_m$ - a set of values of indicators that characterize the level of innovative development of an enterprise; $\Delta R_k$ - relative increase in the level of creative activity of an enterprise, unit share; $\Delta R_v$ - relative increase in the level of innovation implementation by an enterprise, unit share; $\Delta \bigcup_{m=1}^{2} R_m$ - a set of growth values of indicators that characterize the level of innovative development of an enterprise; $\bigcup_{m=1}^{2} R_{m_z}$ - a set of values of indicators that characterize the level of innovative development of an enterprise in the reporting period; $\bigcup_{m=1}^{2} R_{m_b}$ - a set of values of indicators that characterize the level of innovative development of an enterprise in the base period.

After processing the primary data obtained from the heads of construction companies, the level of innovative development of a few construction companies for the period 2013-2019 was identified (Table 2.).

*Table 2. Level of innovative development of construction enterprises, unit shares*
*Source: Collected by the authors*

| N | Construction companies | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 |
|---|---|---|---|---|---|---|---|
| 1 | CC "integral Bud" | 0.35 | 0.38 | 0.42 | 0.42 | 0.44 | 0.45 |
| 2 | CC "Kyivmiskbud" | 0.22 | 0.21 | 0.24 | 0.27 | 0.27 | 0.31 |
| 3 | LLC "K. A. N." | 0.27 | 0.27 | 0.27 | 0.31 | 0.32 | 0.35 |
| 4 | CC "DIM" | 0.31 | 0.37 | 0.37 | 0.39 | 0.38 | 0.41 |
| 5 | LLC "Cityconsult | 0.29 | 0.31 | 0.32 | 0.35 | 0.37 | 0.35 |
| 6 | Edelburg Development | 0.33 | 0.35 | 0.37 | 0.37 | 0.39 | 0.41 |
| 7 | LLC "A.V. S" | 0.35 | 0.38 | 0.38 | 0.39 | 0.39 | 0.41 |
| 8 | LLC "OMOX" | 0.22 | 0.21 | 0.25 | 0.26 | 0.29 | 0.31 |
| 9 | Trust Zhylbud-1 | 0.27 | 0.30 | 0.31 | 0.32 | 0.32 | 0.39 |
| 10 | CC "NOVBUD" | 0.30 | 0.35 | 0.39 | 0.38 | 0.39 | 0.44 |
| 11 | CC "Komfort Life" | 0.28 | 0.32 | 0.35 | 0.37 | 0.38 | 0.42 |
| 12 | CC"REAL" | 0.31 | 0.32 | 0.33 | 0.32 | 0.35 | 0.37 |
| 13 | CC "Yarkovitsa" | 0.39 | 0.38 | 0.36 | 0.38 | 0.32 | 0.35 |
| 14 | CC "Martynov" | 0.35 | 0.37 | 0.38 | 0.37 | 0.37 | 0.39 |
| 15 | CC "MZHK Express-24" | 0.27 | 0.27 | 0.29 | 0.32 | 0.35 | 0.36 |
| 16 | CC "KAN Development" | 0.28 | 0.27 | 0.33 | 0.38 | 0.41 | 0.41 |
| 17 | SK "Creator-Bud" | 0.25 | 0.30 | 0.35 | 0.37 | 0.35 | 0.39 |
| 18 | CC "Saga Development" | 0.44 | 0.45 | 0.44 | 0.46 | 0.47 | 0.47 |
| 19 | CC "Avalon" | 0.27 | 0.31 | 0.32 | 0.30 | 0.31 | 0.35 |
| 20 | CC "Lev development" | 0.32 | 0.35 | 0.37 | 0.37 | 0.39 | 0.4 |

Based on the calculation results, it was found out that more than half of the analyzed construction companies had a stable increase in the values of indicators that characterize innovative development.

During the analyzed period, the maximum value of indicators of innovative development level was in "Saga Development" (0.455 shares of a unit).

The minimum value of indicators of innovative development level was in "Kyivmiskbud" (0.253 shares of a unit).

In general, for the studied population, the average value of the increase in the values of indicators of innovative development was 0.345-unit shares.

It should be recognized that the average growth value is quite high, which indicates the innovation and creativity of enterprises in the sample made.

Analyzing the experts' positions in construction business representatives of companies that are members of the Confederation of developers of Ukraine, allowed coming to the following conclusions:

- innovative initiatives that arise in the construction market of Ukraine, on the one hand, are caused by global trends, which are in the emergence of new materials, often characterized by energy saving, moisture resistance, lightness, etc., and on the other hand, the need to find competitive advantages that provide for a compromise between price and quality;
- the most creatively active and innovatively effective are those construction companies that fight for the market and try to create a competitive offer in the price range that is acceptable to the average consumer.

It is proved that the effectiveness of applying a systematic-functional approach in managing innovative development of construction enterprises is influenced by a number of factors: the type of organizational management structure of a construction enterprise; the size of a construction enterprise; the level of qualification of managers of a construction enterprise; the presence of an automated information and communication management system at an enterprise; the number of activities that the construction enterprise conducts; the presence of an organizational structure of management of the division for the innovations development and implementation; the creativity of the management subjects of a construction enterprise; the emotional and psychological climate in the labor collective of a construction enterprise; the belonging of a construction enterprise to statutory or contractual associations; the level of labor discipline and subordination in the presence of a developed system of rules and procedures in a construction enterprise; the presence of a quality management system in a construction enterprise.

As it turned out from the list of these factors, the most significant are the emotional and psychological climate in the labor collective of a construction enterprise.

Given this, considering these factors is a priority when managing innovative development of a construction enterprise.

### *4.4. Forecasting the Indicators that Characterize Innovative Development*

Managing innovative development of construction enterprises strategic management requires forecasting its economic efficiency.

The systematic-functional approach requires that forecasting is based on indicators that, on the one hand, are aggregated, and, on the other hand, reflect the functional vectors of managing innovative development of construction enterprises.

With an increase in the number of indicators of the predictive model, there is a risk of its statistical inadequacy to the established criteria.

To avoid this threat, it is proposed to apply the pair correlation coefficient to select indicators with the highest level of close relationships.

The selection of indicators was chosen considering the possibility of their quantitative measurement, as well as their relationship with the resulting parameter.

Important conditions for constructing a predictive model are also the following: the number of factors should be minimal, and their values should be reliable; the factors should not be functionally related to each other, and their influence on the resulting parameter should be direct.

In addition, to avoid the phenomenon of multicollinearity, which reduces the accuracy of the forecast, it is necessary to assume that the factors should not be characterized by a high level of close communication with each other.

Considering this, to ensure the adequacy of constructing a predictive model, it is necessary to avoid multicollinearity and eliminate autocorrelation.

Considering these conditions, the return on sales was chosen as the resulting parameter, and the number of employees, the number of innovative solutions, the cost of innovative raw materials and materials, as well as the cost of fixed production assets was chosen as factor features (Table 3.).

*Table 3. Indicators of innovative development of construction enterprises for 2005-2020*
*Source: Developed by the authors*

| **Year** | **Return on sales ($y_i$)** | **The number of employees ($x_1$)** | **The number of innovative solutions ($x_2$)** | **Cost of innovative raw materials and supplies ($x_3$), ml. UAH.** | **Cost of fixed production assets ($x_4$), ml. UAH.** |
|---|---|---|---|---|---|
| 2005 | 7.32 | 180 | 7060 | 4645.46 | 1296.15 |
| … | … | … | … | … | … |
| 2020 | 13.64 | 326 | 10536 | 6112.45 | 2090.57 |

Based on Table 3. the following linear model is:

$$y = -2,48 + 0,0086 x_1 + 0,0008 x_2 + 0,00113 x_3 - 0,0014 x_4.$$

As you can see, the factors $X_1$ and $X_2$ turned out to be insignificant due to temporary inconsistencies.

However, due to their temporal discrepancy, they should not be ignored, because they directly affect the value of the resulting parameter. The above given model is tested with using the three criteria of Pearson, Fischer, and Student to detect multicollinearity of factors, as well as with using the criteria of von Neumann-Hart and Darbin-Watson to detect autocorrelation.

To do the first task, the Farr-Glober method is applied, it provides: 1) normalizing variables; 2) designing a moment matrix of a standardized system of normal equations; 3) determining the Pearson criterion; 4) designing the inverse matrix; 5) calculating the Fischer criterion; 6) finding partial correlation coefficients; 7) calculating the Student criterion.

The tabular value of the Student criterion for the number of freedom degrees 15-4=11 and the probability 0.95 is 2.201, so the interdependence between the factors is not significant. Thus, the model is statistically adequate. Now let's go down to checking the model for autocorrelation detection with using the von Neumann-Hart criteria (Tabular value of this criterion with a sample size of 15 and a probability of 0.95 equal to 1.29) and Darbin-Watson:

1) $$NH_1 = \frac{n}{n-1} \frac{\sum_{j=1}^{n-1} \left(x_{j+1} - x_j\right)^2}{\sum_{j=1}^{n} \left(x_j - \bar{x}\right)^2} = 0,76;$$

$$NH_2 = 0,57; \qquad NH_3 = 1,24; \qquad NH_4 = 0,295;$$

2) $$DV = \frac{\sum_{j=1}^{n} \left(c_{j+1} - c_j\right)^2}{\sum_{j=1}^{n} c_j^2} = \frac{16,3}{6,24} = 2,611;$$

$$DV\left(2,611\right) > DV_{\mathrm{H\,tabl}}\left(1,97\right) > DV_{\mathrm{L\,tabl}}\left(0,69\right).$$

As you can see, there is no autocorrelation of the model residues, so this model is adequate.

This model is used to analyze the effect of a certain factor. That can be done with using the formula:

$$\Delta y_{z_i} = z_i\left(x_{ik} - x_{il}\right),\ k,l \in N,$$

where $\Delta y_{z_i}$ - the effect of factors $X_1$ - $X_4$ on the resulting parameter $y_i$.

$z_i$ - a regression coefficient.

Table 4. shows the necessary calculations with using this formula for two construction companies ("Saga Development" and "Kyivmiskbud").

In Table 4. the value $y_i$ is larger for construction company N2 under the influence of factors $X_2$ and $X_3$.

*Table 4. Comparative analysis*
*Source: Calculated by the authors*

| **Factors** | **$y_i$, mln UAH** | | $x_{ik} - x_{il}$ | $z_i$ | **$\Delta y_{z_i}$, mln UAH** |
|---|---|---|---|---|---|
| | **Construction Company N1** | **Construction Company N2** | | | |
| $X_1$ | 198 | 207 | 9 | 0.008555 | 0.076991 |
| $X_2$ | 7766 | 8119 | 353 | 0.0008 | 0.282541 |
| $X_3$ | 5110.008 | 5342.281 | 232.2731 | 0.001138 | 0.264251 |
| $X_4$ | 1425.767 | 1490.574 | 64.80758 | -0.0014 | -0.09072 |
| *In* | 9.243234 | 9.776298 | 0.533064 | | 0.533064 |
| | | | | | |

While studying these factors' influence on the resulting parameter with applying the Cobb-Douglas function, it is convenient to convert to log function:

$$\ln y = z_0 + z_1 \ln x_1 + z_2 \ln x_2 + z_3 \ln x_3,$$

where $z_0$, $z_1$, $z_2$, $z_3$ - the model parameters.

Let the following indicators' values of innovative development of construction enterprises be given (Table 5.).

*Table 5. The indicators' value of construction enterprise development for constructing a logarithmic model based on the Cobb-Douglas production function*
*Source: Calculated by the authors*

| **year** | $y_i$ | $x_2$ | $x_3$ | $x_4$ |
|---|---|---|---|---|
| 2005 | 7.32 | 7060 | 4645.46 | 1296.15 |
| … | … | … | … | … |
| 2020 | 13.64 | 10536 | 6112.45 | 2090.57 |

Because of applying the Farr-Glober method, it is possible to come to the following conclusions: a high value of the Pearson criterion indicates that the absence of multicollinearity is achieved with logarithming the original data; by the values of the Student criterion, the interdependence between the factors is not significant, since the tabular value of the Student criterion for the number of freedom degrees 15-3=12 and the probability 0.95 is 2.18.

Given this, the model is statistically adequate.

The check for autocorrelation according to the von Neumann-Hart and Darbin-Watson criteria is done:

$$NH_1 = 0{,}78;\quad NH_2 = 0{,}864;\quad NH_3 = 0{,}058.$$
$$DV_{\mathrm{L\,tabl}}\left(0{,}82\right) < DV\left(1{,}174\right) < DV_{\mathrm{H\,tabl}}\left(1{,}75\right).$$

At the significance level and sample 15, the tabular value of the first of the criteria is 1.29, which indicates that there is no autocorrelation, but there is an assumption that there is an autocorrelation of residuals.

After calculating the second criterion, the calculated value is observed to be in an indefinite zone. That requires calculating the cyclic autocorrelation coefficient:

$$r_{AC} = \sum_{j=2}^{n} c_j c_{j-G} \Big/ \sum_{j=1}^{n} c_j^2 \approx 0{,}435.$$

At a probability of 95% and a sample of 15, the table value is 0.322. Comparing it with the calculated value, there is a certain autocorrelation of residuals.

It can be ignored because the model has a stable set of parameters and is significant, because by the coefficient of determination (0.886), this model considers the influence of 88.6% of all the factors. In addition, the factors considered have a positive effect on the resulting parameter (increasing the value by 0.3366% contributed to $X_2$ by 1%.

Increasing $X_3$ by 1% caused an increase of by 0.49%. Increasing $X_4$ by 1% caused an increase of volume by 1.26%) since the sum of the interdependence coefficients of the studied factors and the resulting parameter is more than 1.

The increment of the value is defined with considering the changes in values $X_1$–$X_3$ with using the ratio:

$$\Delta y = \sum_{i=1}^{m} z_i \Delta x_i \Rightarrow \frac{\Delta y}{y} = \sum_{i=1}^{m} z_i \frac{\Delta x_i}{x_i}.$$

Thus, the left part of the ratio is transformed into a logarithmic dependence, the economic meaning of which is that the weighted sum of the growth rates for all factors is equal to the growth rate of the parameter under study.

The influence of factors is assessed on the resulting parameter (Table 6.).

*Table 6. Influence of factors $X_1 – X_3$ on the growth rate $y_i$*
*Source: Calculated by the authors*

| **Symbols** | **Average annual growth rate, %** | **Coefficients, $z_i$** | $z_i \frac{\Delta x_i}{x_i}$, **%** |
|---|---|---|---|
| $y$ | 3.378954 | | 0.750411 |
| $x_1$ | 2.189443 | 0.346636 | 1.096353 |
| $x_2$ | 2.266161 | 0.481138 | 1.599345 |
| $x_3$ | 1.23449 | 1.295298 | 3.383109 |

Thus, the average annual growth rate $y$ is 3.389%. The value of the resulting parameter was mostly affected by factor $x_3$. The absolute value of the influence of each factor is calculated using the formula:

$$\overline{\Delta y_{x_i}} = \overline{\Delta y}\, \frac{\frac{\Delta x_i}{x_i} z_i}{\frac{\Delta y}{y}} = \frac{\overline{\Delta y}\, \Delta x_i z_i y}{x_i \Delta y}.$$

$$\overline{\Delta y_{x_1}} = 84,83, \quad \overline{\Delta y_{x_2}} = 125,27, \quad \overline{\Delta y_{x_2}} = 177,52.$$

Now, the average annual absolute change in the values of factors $x_1$ and $x_2$, which will be 231.73 and 132.13, respectively, is calculated. In this case, the interchangeability coefficient of these factors is equal:

$$K_{31,2} = \frac{\Delta x_2}{\Delta x_1} = \frac{132,13}{231,73} \approx 0,57.$$

This indicator for other factors is calculated:

| | | |
|---|---|---|
| 1 | 0.572168 | 0.167998 |
| 1.75787 | 11 | 0.294397 |
| 5.96953 | 3.397931 | 1 |

The value of the factor interchangeability coefficient indicates that the change in the factor value $x_1$ by 1 gives the same effect as changing the value of the factor $x_2$ by 0.57 ml. UAH. Now a prediction of the value $y$ provided that the company plans to increase the value of the factor $x_2$ by 2 %, the value of the factor $x_3$ by 1.5% and the value of the factor $x_3$ by 122 ml. UAH is made. Then accordingly, the forecast change will be calculated as follows:

$$\Delta y = 0,3366 \cdot 2 + 0,4911 \cdot 1,5 + 1,2653 \cdot \left(1 + \frac{122}{10536}\right) \cdot 100 = 4,14\%$$

Since the change in the studied indicators is not known, the additional forecast models based on using the time trend models for factors in the logarithmic model is made and the forecast values for one period ahead for each factor are calculated:

$$\begin{cases} x_1(t) = 5979 + 258,4t \Rightarrow x_1(t+1) = 5979 + 258,4 \cdot 16 = 10113,4; \\ x_2(t) = 4245 + 102,9t \Rightarrow 4245 + 102,9 \cdot 16 = 5891,4; \\ x_3(t) = 2553 + 38,88t \Rightarrow 2553 + 38,88 \cdot 16 = 3175,08; \\ \Delta y = -1,73\%. \end{cases}$$

To interpret the obtained result, the confidence interval is defined:

$$\hat{\hat{y}} - t_{tabl} S_{y,\hat{y}} \le \hat{\hat{y}} \le \hat{\hat{y}} + t_{tabl} S_{y,\hat{y}},$$

where $S_{y,\hat{y}} = \sqrt{\sum_{j=1}^{n} \left(y_j - \hat{y}_j\right)^2 \Big/ n - m - 1}.$

As a result of constructing a predictive model, it is proved that with a probability of 95%, it can be argued that for the given values of factor indicators, the forecast value of the resulting parameter will not be less than 10934.89 ml. UAH. and not more than 15201.75 ml. UAH.

The obtained results are statistically significant guidelines for planning indicators of innovative development of a construction enterprise and applying the measures to manage risks associated with the innovations implementation.

### 4.5. Monitoring and Regulating the Indicators that Characterize Innovative Development

Implementing the strategy and tactics of innovative development of a construction enterprise, formed and implemented on the basis of scientifically based forecasts, requires permanent monitoring the indicators that characterize innovative development. Monitoring requires considering the causal relationships between factor and performance indicators that characterize innovative development. Identifying and analyzing these relationships are the most appropriate based on morphological analysis. The systematic-functional approach in managing innovative development of construction enterprises obliges to observe decomposition and polyvectoricity during monitoring.

Therefore, three morphological levels and three monitoring vectors are identified (Table 7.).

The selected monitoring levels and vectors allow designing causal morphological graphs and identifying the reserves to improve the performance indicators as accurately as possible.

At the level of a construction enterprise, as an integral indicator of innovative development, the share of innovative technologies in the total number of technologies used by the enterprise or the increase in this share can be considered. This integral vector, on the one hand, reflects innovations that specific divisions of the enterprise and employees worked on creating, and, on the other hand, a reflection of specific innovative developments, which, together, are innovations.

*Table 7. Parameterized morphological levels and monitoring vectors*
*Source: Calculated by the authors*

| Levels | Vectors | | |
|---|---|---|---|
| | Integral | Local | Factor |
| nterprise (X) | $P_x$ | $P_x \supset (a_1, a_2 ... a_n)$ | $a_1 = f(i_1 ... i_n)$; $a_2 = f(j_1 ... j_n)$; ....... |
| Division (Y) | $P_y$ | $P_y \supset (b_1, b_2 ... b_n)$ | $b_1 = f(k_1 ... k_n)$; $b_2 = f(l_1 ... l_n)$; ....... |
| mployee (Z) | $P_z$ | $P_z \supset (c_1, c_2 ... c_n)$ | $c_1 = f(q_1 ... q_n)$; $c_2 = f(p_1 ... p_n)$; ....... |

Note: $P_x$ – integral economic indicators that characterize the development of a construction enterprise; $P_y$ – local economic indicators that characterize the development of certain types of construction enterprise development activities; $P_z$ – the amount of funds spent on innovation activities, the amount of time spent on developing innovative technologies in construction, the amount of costs spent on attracting specialists, consultants, managers to master and implement innovations on an outsourcing basis, etc.

To deepen the analysis of the possibilities of improving the value of an integral indicator, it is necessary to identify and carefully analyze the factors that influenced the values of both integral and local indicators. When constructing morphological graphs, it is possible to trace the emergence of the topology of integral indicators into local ones. In this case, integral indicators are supersets that include a set of local and factor indicators. In this case, there is an intersection of super-sets with sets of factor indicators at the local level. It is the very fact that indicates the causality of the monitoring process, which takes place based on morphological analysis. At the decision-making stage, it is necessary to design a mutual consistency matrix to identify the probability of pairs of alternatives to solve the identified problem or the inserted goal. As a result, an argument is obtained in favor of choosing a particular scenario to achieve the expected value of the integral indicator. With the Bayes equations, it is possible to recalculate the probability of alternatives. The systematic-functional approach to managing innovative development of construction companies requires that the regulation has signs of both consistency and functionality.

Signs of consistency are the presence of an object, subjects, regulatory methods, as well as communication channels that connect all these components into one whole, into a system (Figure 1.).

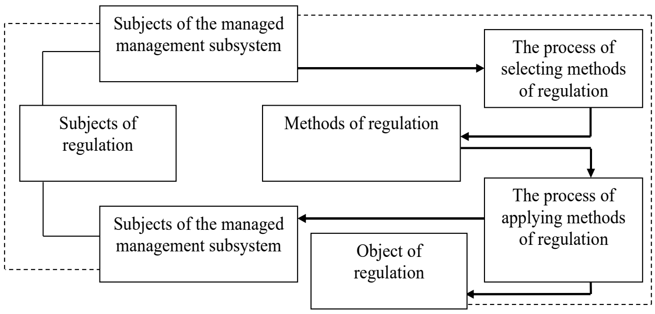


*Figure 1. Model for regulating the effectiveness of applying a systematic-functional approach in managing innovative development of construction enterprises*
*Source: Developed by the authors*

The dashed lines in the figure show communication channels, bold lines indicate the sequence of interaction of the control system components, thin lines show that individual blocks belong to a higher-order block.

As for the features of functionality, regulation is a specific management function, which is based on a specific object – the effectiveness of applying a systematic-functional approach in managing innovative development of construction enterprises.

Regulation is functionally related to other management functions, and most of all to the control function, since only after identifying certain deviations of the actual values of indicators from the expected values, regulatory decisions are made. As for regulating efficiency, regulatory decisions can be aimed at: strategic, tactical and operational adaptation of innovative development plans of a construction enterprise to environmental conditions; timeliness, completeness and quality of performance of their duties by performers of strategic, tactical and operational plans of innovative development of a construction enterprise; timeliness, completeness and quality of performance of their duties by performers of business partners of a construction enterprise who are involved in implementing projects of innovative programs (projects); rationalization of engineering and technological and management processes to identify reserves to reduce the cost of funds and time. Nowadays, at the methodological and applied level, it is problematic to track and consider causal relationships between factors that bring this model into a dynamic state that provides the expected results within the required time parameters. To transform a model from static to dynamic, it is necessary to perform several operations, the operations of combining, cross-section, and relative addition (difference) of sets.

Table 8. depicts empirical data of a few construction companies in Ukraine, which characterize the current practice of regulating the effectiveness of a systematic-functional approach in managing innovative development. Collecting and processing primary data were based on the conditions of the designed model. Comparing the data in Table 8. with the data in Table 2., it is possible to see that during the analyzed period the most differentiated models of regulation were used by those companies that are the most innovative and stable.

*Table 8. Empirical data of construction companies*
*Source: Calculated by the authors*

| Companies | **2015** | **2016** | **2017** | **2018** | **2019** |
|---|---|---|---|---|---|
| CC "integral Bud" | *** | ** | *** | *** | *** |
| CC "Kyivmiskbud" | * | *** | ** | *** | *** |
| LLC "K. A. N." | *** | *** | ** | *** | *** |
| CC "DIM" | * | * | ** | ** | * |
| LLC "Cityconsult | * | ** | * | * | * |
| Edelburg Development | *** | *** | *** | *** | *** |
| LLC "A.V. S" | *** | *** | *** | ** | ** |
| LLC "OMOX" | ** | *** | ** | *** | ** |
| Trust Zhylbud-1 | *** | *** | *** | ** | *** |
| CC "NOVBUD" | *** | *** | *** | *** | ** |
| CC "Komfort Life" | *** | *** | *** | *** | *** |
| CC"REAL" | ** | ** | ** | * | ** |
| CC "Yarkovitsa" | * | ** | *** | ** | * |
| CC "Martynov" | ** | *** | * | ** | * |
| CC "MZHK Express-24" | ** | *** | *** | *** | ** |
| CC "KAN Development" | *** | *** | *** | *** | *** |
| SK "Creator-Bud" | *** | *** | ** | ** | * |
| CC "Saga Development" | ** | *** | ** | *** | ** |
| CC "Avalon" | *** | ** | *** | * | ** |
| CC "Lev development" | ** | *** | *** | *** | ** |

Symbols * regulation was based on using one of the three possible operations (combining, cross-section, addition); ** regulation was based on using two of the three possible operations (combining, cross-section, addition); *** regulation was based on using all three possible operations (combining, cross-section, addition).

Despite this, it should be recognized that all the analyzed companies, without exception, a regulated innovative development and have a practice of using alternatives in regulating innovative development. That indicates a high level of management systems development in these companies, as well as the informative nature of the monitoring mechanisms used by them.

## 5. Conclusions

It is proved that innovative development is a phenomenon of qualitative changes that occur due to the influence of creative and active subjects on the growth and use of an innovative potential.

Based on clarifying the essence of this concept and specifying the features that characterize it, the classification of innovative development types is formalized.

According to the fact that the classification considers only those features that are significant to choose the optimal solution from a few alternative ones, it is of practical importance and can be used to develop automated information systems for managing innovative development of construction enterprises in terms of forming algorithms to sort innovative solutions.

Based on clarifying the components and essence of the set of principles for managing innovative development of construction enterprises, the recommendations and improvement of the method for assessing innovative development of construction enterprises are formulated.

Their essence is in the need for an integral assessing innovative development, which provides for considering the components of creative activity in a construction enterprise and the components of an innovation implementation by a construction enterprise. These innovative development components complement each other and can be reduced to a common denominator based on applying a system of relative growth indicators.

It is proved that forecasting the economic efficiency of applying a systematic-functional approach in managing innovative development of construction enterprises should provide for a specific forecasting technology and a mechanism to select the factors that ensure the adequacy of the model, provides for avoiding multicollinearity and eliminating autocorrelation.

The author's recommendations made it possible to improve the forecasting method in such a way that its results are acceptable to form sound strategic management decisions in terms of implementing engineering, technological, product, and other innovations.

Based on using tools of morphological analysis, identifying topological-metric spaces, designing and solving a system of bees' equations, it is argued that the improved mechanism to monitor the economic efficiency of applying a systematic-functional approach in managing innovative development of construction enterprises is advisable to apply during the implementation of the function of monitoring the progress of innovative projects, which is a prerequisite to make regulatory decisions.

The further research should be carried out in the direction of forming algorithmized systematic-functional complexes for managing innovative development, which can become the basis to create integrated information support systems for managers of construction enterprises.

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