A Study of a Comprehensive Quality Indicator of Multi-Storey Residential Buildings While the Indicators of the Groups Factors are Changing

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Abstract. The most significant eight parameters that affect the quality of a multi-story building object are identified. In the form of a regression model, a linear, quadratic, and general quadratic model are used. Based on the results of the studies, it was concluded that the most adequate model is the general quadratic model. The dependence of complex quality indicators of residential multi-storey buildings of the specific group of factors is studied. A three-dimensional surface graph of the regression equation is constructed based on the various groups of factors. A series of 6 dependencies in a graph describes the alternating effect of 2 groups of factors on changes in a comprehensive quality indicator.

1. Introduction

After analyzing Russian and foreign literature, the author identifies the main parameters that affect the quality of a multi-story building object.

Further, according to the results of a survey of experts, the most significant of them the following are 8 parameters:
- technical specifications for the facilities (P1);
- A reliable and complete volume of materials, including all sections on engineering surveys (P2);
- compliance with organizational and technical decisions (P5);
- compliance with the sequence of work (P6);
- geotechnical monitoring (P7);
- the presence of lifting mechanisms (P8);
- application of industrial formwork systems (P10);
- the use of modern equipment with high performance (P11);

In the course of further studies, for the selected eight factors, according to the calculation results, an intercorrelation matrix was compiled.

Based on the results of the analysis of the intercorrelation matrix, 4 groups of well-interconnected variables (z₁, z₂, z₃ and z₄) were identified.

Due to the fact that this experiment is multifactorial, it is necessary to search for a mathematical model that is a regression equation that adequately describes the results of the experiment.
2. Analysis parametrical indicators

To find the coefficients of the regression equations, one should use the mathematical theory of experimental design. It makes it possible to control the course of the experiment as efficiently as possible in order to obtain the most possible information, based on the minimum allowable amount of experimental data.

Planning an experiment is the procedure for selecting the number of experiments and the conditions that are sufficient to solve the problem with the necessary accuracy.

In the form of a regression model, a linear model is used. Here, the factors z1, z2, z3, and z4 are selected as factors.

The dependence is obtained:

\[ Y = 60.37 + 5.94z_1 + 8.69z_2 + 7.13z_3 + 5.9z_4 \]  

With a confidence probability of 0.95 (p-value is less than 0.05), all the coefficients are significant (by Student's criterion).

The coefficient of determination of the model is 0.879, which confirms the high adequacy of the model.

The next model under consideration is quadratic. Here, the groups z1, z2, z3, and z4, as well as their squares, are also taken as factors.

The dependence is obtained:

\[ Y = 54.67 + 5.94z_1 + 8.68z_2 + 7.125z_3 + 5.90z_4 - 4.41z_1z_2 + 7.78z_2z_3 + 1.15z_3z_4 + 3.40z_4^2 \]  

Only the coefficients of the linear terms are significant (coefficients at squares according to the Student criterion have a confidence level less than the generally accepted 0.95).

The coefficient of determination of the model is 0.925, which confirms the high adequacy of the model (according to the Fisher criterion, the significance is 2.0448E-05).

Next, the dependence of the general quadratic model is obtained:

\[ Y = 54.83 + 8.89z_1 + 9.45z_2 + 5.83z_3 + 5.83z_4 + 0.2Z_1^2 + 5.2Z_2^2 + 2.7Z_3^2 + 2.7Z_4^2 - 2.5Z_1Z_2 - 1.25Z_1Z_4 - 1.86Z_2Z_4 - 1.86Z_2Z_3 + 3.12Z_2Z_4 \]  

Only the coefficients of linear terms are significant (coefficients for squares and products of factors by Student's criterion have a confidence level less than the generally accepted 0.95).

The coefficient of determination of the model is 0.965, which confirms the high adequacy of the model (according to the Fisher criterion, the significance is 0.000481547).

The conducted studies allow us to conclude that the most adequate model is the general quadratic model, although not all estimates of the regression coefficients are highly significant (p-values are not all less than 0.05).

A detailed study of the dependence of complex quality indicators of residential multi-storey buildings on the considered group of factors was carried out graphically.

Here it is required to construct a three-dimensional graph of the surface of the regression equation based on various groups of factors.

Taking into account that the number of factors is 4, it will be convenient to study the resulting surfaces with a variable combination of 2 acting factors when the other two are in a fixed position. In this situation, it will become a series consisting of 6 dependencies in the chart.

The resulting combination is as follows:

CRC = f (z1, z2); CRC = f (z1, z3); CRC = f (z1, z4); CRC = f (z2, z3); CRC = f (z2, z4); CRC = f (z3, z4).
For example:

\[
CRC = f(z_1, z_2) = 54.83 + 8.89z_1 + 9.45z_2 + 0.2z_1^2 + 5.2z_2^2 - 2.5z_1z_2
\]

Figure 1

The combined action of factors \(z_1\) and \(z_2\) has a moderate effect on the value of \(P_{kach.}\). Stimulating the linear nature of the processes.

\[
CRC = f(z_1, z_3) = 54.83 + 8.89z_1 + 5.83z_3 + 0.2z_1^2 + 2.7z_3^2
\]

Figure 2

In the study of the combined effect of factors \(z_1\) and \(z_3\) on the value of the complex parameter \(CRC = f(z_1, z_3)\), the linear dependence on \(z_1\) and \(z_3\) prevails, although a more pronounced quadratic dependence on the factor \(z_3\) is observed.

\[
CRC = f(z_1, z_4) = 54.83 + 8.89z_1 + 5.83z_4 + 0.2z_1^2 + 2.7z_4^2 - 1.25z_1z_4
\]

Figure 3
The response surface $f(z_1, z_4)$ is not linear in the entire studied range. Moreover, the degree of non-linearity has a pronounced zonality. Three zones with different non-linearity are clearly distinguished on the graph.

Similar graphs were obtained for the remaining variables. A series of 6 dependencies in the graph describes the alternating effect of 2 groups of factors on changes in CRC (a comprehensive quality indicator).

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