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EVALUATION OF ORGANIZATIONAL AND TECHNOLOGICAL DESIGN INDICATORS OF THE OBJECT USING MODERN DIGITAL MODELS

Avaliação de indicadores de design organizacional e tecnológico do objeto usando modelos digitais modernos

Said Alvi Murtazaev[1], Magomed Elmurzaev[2,3], Salambek Aliyev[1], Imran Said Murtazaev[1], Aleksey Akulov[4]
[1]Grozny State Oil Technical University named after Academician M.D. Millionshchikov, Grozny, Russia,
[2]Complex Research Institute named after Kh.I. Ibragimov, RAS, Grozny,Russian Federation,
[3]LLC SibTekhProekt, Grozny, Russia, [4]State University of Management, Moscow, Russia.
E-mail: samurtazaev@mymail.academy, magomed.elmurzaev@mymail.academy,
salambek.aliyev@mymail.academy, imran.murtazaev@mymail.academy, aleksey.akulov@mymail.academy

ABSTRACT

The study aims to develop a methodology for assessing the efficiency of design parameters in organizational and technological design using digital models. The methodology is tested on a learning model imitating optimization process. The authors develop an algorithm for using information modeling tools to estimate organizational and technological indicators, such as labor intensity, the number of specialists and mechanisms, and the duration of work performance. The resource allocation and turnaround time by facility indicators are visualized and analyzed. Visual filters and color schemes allow one to identify elements with the highest load and potential areas for optimization. The proposed visual programming methodology proves effective in improving the visual clarity and flexibility of assessing organizational and technological indicators. This allows us to speed up the design process and improve the accuracy of planning construction works.

Keywords: Information modeling, Visual programming, Efficiency assessment, 4D Modeling

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AVALIAÇÃO DE INDICADORES DE DESIGN ORGANIZACIONAL E TECNOLÓGICO DO OBJETO USANDO MODELOS DIGITAIS MODERNOS

Evaluation of organizational and technological design indicators of the object using modern digital models

Said Alvi Murtazaev[1], Magomed Elmurzaev[2,3], Salambek Aliyev[1], Imran Said Murtazaev[1], Aleksey Akulov[4]
[1]Grozny State Oil Technical University named after Academician M.D. Millionshchikov, Grozny, Russia,
[2]Complex Research Institute named after Kh.I. Ibragimov, RAS, Grozny,Russian Federation,
[3]LLC SibTekhProekt, Grozny, Russia, [4]State University of Management, Moscow, Russia.
E-mail: samurtazaev@mymail.academy, magomed.elmurzaev@mymail.academy,
salambek.aliyev@mymail.academy, imran.murtazaev@mymail.academy, aleksey.akulov@mymail.academy

RESUMO

O estudo visa desenvolver uma metodologia para avaliar a eficiência dos parâmetros de design em design organizacional e tecnológico usando modelos digitais. A metodologia é testada em um modelo de aprendizagem imitando o processo de otimização. Os autores desenvolvem um algoritmo para usar ferramentas de modelagem de informações para estimar indicadores organizacionais e tecnológicos, como intensidade de trabalho, número de especialistas e mecanismos e duração do desempenho do trabalho. A alocação de recursos e o tempo de resposta por indicadores de instalação são visualizados e analisados. Filtros visuais e esquemas de cores permitem identificar elementos com maior carga e áreas potenciais para otimização. A metodologia de programação visual proposta se mostra eficaz em melhorar a clareza visual e a flexibilidade da avaliação de indicadores organizacionais e tecnológicos. Isso nos permite acelerar o processo de design e melhorar a precisão do planejamento de obras de construção.

Palavras-chave: Modelagem de informações, Programação visual, Avaliação de eficiência, Modelagem 4D

INTRODUCTION

Information modeling uses advanced digital tools to solve various tasks (Ilyushin et al., 2020; Nosova et al., 2018; Panasenko et al., 2024). Information modeling tasks include model creation, testing (validation and verification), assessment, and effectiveness analysis of the decisions taken (Aliev et al., 2023; Khakimov et al., 2024; Bondarenko et al., 2024).

A common practice is to use special "views" in the environment of information modeling software (Nikandrova, Evtushenko, 2020; Burak, 2020; Kirkolup, Polzunov, 2020). Such views include not only two-dimensional (2D) and three-dimensional (3D) model display positions, but also its representation in the form of a 2D database (Matvienko et al., 2022). This type of view is a "specification" tool. With the help of graphics override filters on the view, the designer can set certain conditions. Depending on whether these conditions are met or not, the elements can be colored in different shades, become transparent, or be hidden entirely (Akhmetshin et al., 2024).

For example, the designer can set the following condition: if parameters of the real element location (block, section, storey) are not filled in, the elements are colored red. In this way, the necessary elements for which the necessary attributes need to be filled in are highlighted. For the convenience of reusing such techniques, various kinds of templates are created for the views, and the view templates themselves are embedded in project templates.

In turn, 4D modeling includes the use of conditional visualization tools. Elements are assigned different colors depending on the type of workflow. For example, objects under construction at the start of operations can be assigned one color, objects under processing – another color, and objects under demolition – a third color (Hosseini et al., 2021). Moreover, during the construction period, the 4D model can be used to compare the design and the actual completion times of structures. For example, elements that have a lead time margin, elements that have a potential risk of delay and those that are delayed can have different colors (Brito, Ferreira, 2015).

Particular attention is paid to the question of optimizing the use of different colors for different states. For instance, blue is believed to reflect calmness and the absence of problems (Chang et al., 2013). In addition, a special role is attributed to the issue of standardizing the colors used by different participants in the construction industry (Chen et al., 2013).

The insufficiency or deficiency of the systems described lies in the following:

1. The practice of using specialized types of verification of parameter values, which is common in architectural and construction design, unfortunately, does not apply to organizational and technological design. This mainly owes to the fact that organizational and technological models are rarely developed in information modeling programs.
2. The design of the information modeling environment may not be sufficient to compare a large number of values. In this scenario, the instrument of conditional filters boils down to the following principle: if the parameter value is less than A, it is colored in color 1; if the parameter value is less than B but more than A, it is colored in color 2, and so on. Thus, this method appears to be cumbersome and cannot meet the requirements for model flexibility.
3. A 4D modeling environment offers the means to visualize a ready-made imitation model and can include conditional visualization tools similar to information modeling software (Khrapkin, Artamenko, 2021; Glebova et al., 2022). However, 4D modeling is one of the final stages of organizational and technological design. For this reason, at this stage, it can be challenging to make fundamental decisions on changing the organization of construction operations and to conduct proper assessment to make these decisions. In this connection, the main objective of the study was to develop a methodology for evaluating the effectiveness of design parameters.

1 METHODOLOGY

The process of developing the methodology involved an overview of existing models and visualization tools to identify their strengths and weaknesses. At the heart of the proposed approach is the use of information modeling methods to create a 3D model, which is then subjected to various types of analysis.

The first stage of the study was the development of a system of assessment criteria including such parameters as labor intensity, the number of involved mechanisms and specialists, as well as the duration of work execution. These parameters were embedded in the model attributes, allowing for their automatic extraction and analysis using visual programming in the Dynamo environment.

In the second stage, the usability of the model was tested on an educational model with imitation of the optimization process. The testing process included several steps: filtering the data, grouping the elements according to specified criteria, and visualizing the results with a color gradation, which enabled a visual assessment of the distribution of parameters across the object.

This last step involved testing the sequence of operations to assess such organizational and technological parameters as labor intensity and the number of workers required at different construction stages. Attributes were specified for each element in the model, allowing to clearly visualize the work performance process.

2 RESULTS

2.1 Methodology development

To overcome the difficulties described, it is proposed to adopt the following set of principles in designing the solution:

1. The development of an organizational and technological model should begin with the creation of a model in information modeling programs. This model will connect all the models included in the summary model except for the elements that are not required for calculating organizational and technological characteristics, for display in the model of construction site organization (Zaitseva, Starostin, 2019; Caldart, Scheer, 2022), and in the development of the 4D model (Boton et al., 2013m Brito, Ferreira, 2015). This principle will allow to freely adjust the initial model for the subsequent creation of the organizational and technological model, to perform calculations, as well as to simplify the process of creating a construction site organization model.
2. The primary analysis of organizational and technological characteristics should be carried out in information modeling programs. This principle will reduce the number of iterations to optimize the organization of construction operations at the stage of 4D modeling. This principle is justified by the greatest resource intensity of creating 4D models and preparing for this stage.
3. The proper specification of parameters and the correspondence of attributes to fixed values should be verified in information modeling programs with the help of standard tools. Visual programming tools are proposed for comparing values with each other.

The practice of using visual programming tools to change the geometric and visual attributes of the model is common in the creation of expressive architectural forms (Shumilov, Gureva, 2022). The distribution of color hues is determined by a system of random or specified values (Denis, 2014).

Organizational and technological modeling involves the assessment of the following parameters:

− Distribution of the values of the labor intensity of work performance by mechanisms and manual labor by individual structures, work zones, tiers, storeys, sections, and blocks in machine-hours and man-hours;

− Distribution of the values of the number specialists and mechanisms involved in performing works by work zones;

− Distribution of the values of work performance duration by individual structures, work zones, tiers, storeys, sections, and blocks.

Apart from the examples, it is possible to compare any other evaluated parameters. The means of visual programming allow flexibility in adapting to different value variability.

The key requirement for assessing the distribution of organizational and technological parameters by means of visual programming is the presence of these parameters in the model for extraction and processing. The required values are recorded in the attributes of model elements under a certain mane, which is used to extract them.

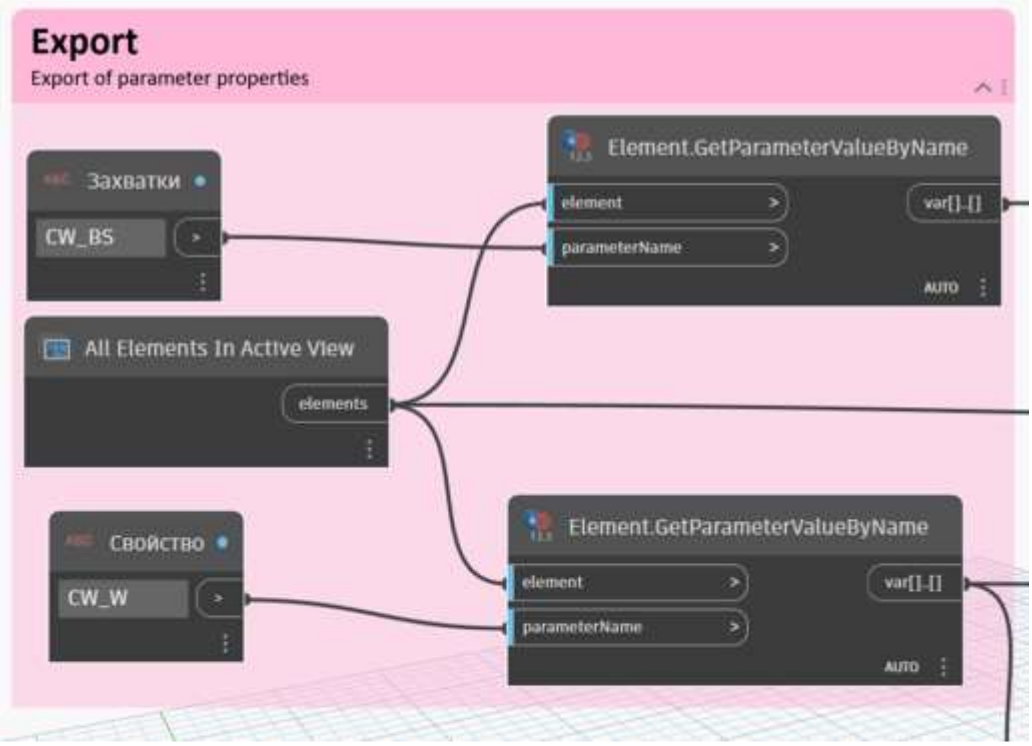
The proposed assessment algorithm consists in the following sequence of actions:

1. "Open" the view in such a way that it is "active" until the end of the algorithm;
2. Use standard visualization tools to verify that all the parameters involved in the assessment are filled in;
3. Prepare the view in such a way as to hide all elements that are not required for the specific task (e.g., when assessing only the work on reinforced concrete structures);
4. Run the script.

A visual programming script to color all active elements will perform the following sequence of operations:

1. Extraction of parameter values. In this process, the values of parameters filled in advance by the developer from the selected group of model elements are extracted (Figure 1). The elements themselves are also loaded into the Dynamo visual programming environment for further color assignment operations;

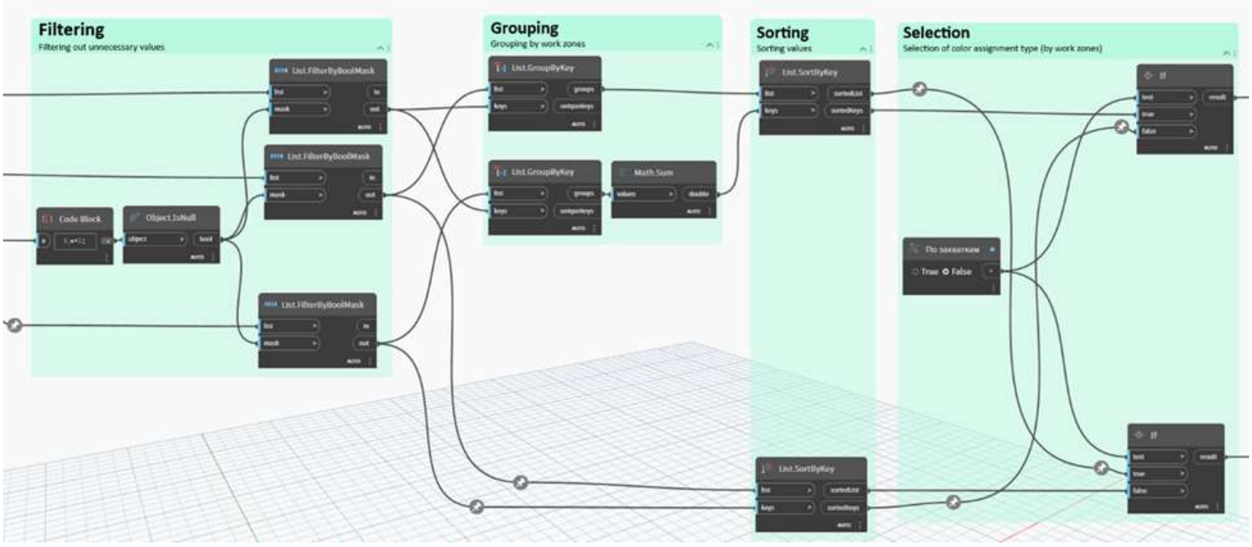
Figure 1 - The operation of attribute value extraction in the Dynamo visual programming environment: "CW_BS" – grouping criterion, "CW_W" – the organizational and technological parameter to be assessed (in this case, the number of workforce involved)



Source of data: compiled by authors

2. The filtering, grouping, and sorting of the values based on assessment requirements (by elements, work zones, etc.). In this, the filtering operation discards blank values from elements for which attributes have not been filled in (e.g., component parts). The grouping operation groups the elements and the values of their properties according to the grouping criterion (Figure 2). Individual values form the total of each group they belong to;

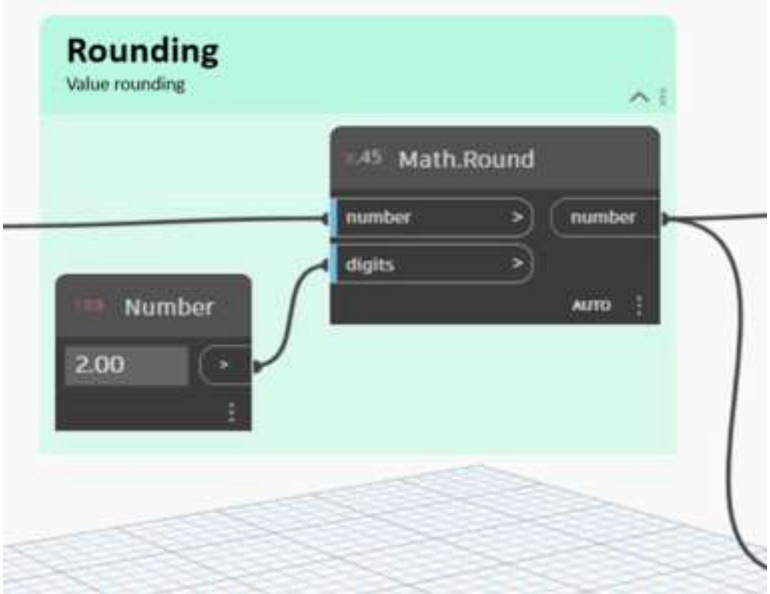
Figure 2 - Filtering, grouping, sorting and conditional selection of grouping criteria blocks in the Dynamo visual programming environment



Source of data: compiled by authors

3. The processing of values consists in rounding to reduce the total number of hues obtained. This operation defines the accuracy of the distribution (Figure 3);

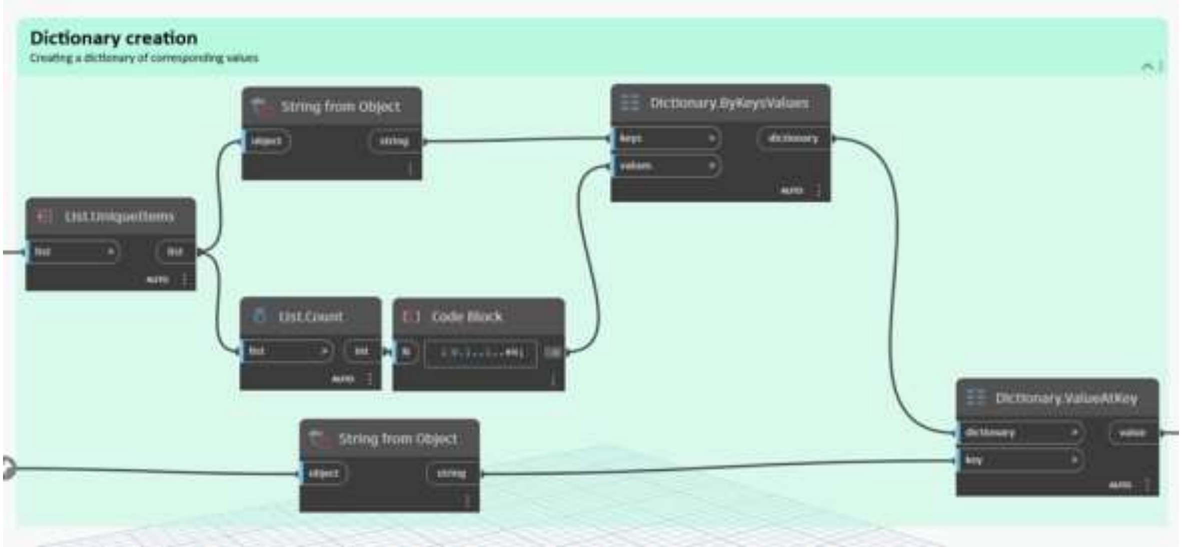
Figure 3 - The operation of rounding initial attribute values in the Dynamo visual programming environment: the developer adjusts the number of units after the decimal point



Source of data: compiled by authors

4. Creating a dictionary of correspondence of the evaluated indicators to the range of colors assigned to them. The creation of a dictionary. In this case, creating a dictionary ensures that a set of appropriate color assignment range values is created for each attribute value or a sum of attributes of an individual element or group (Figure 4). The set of color range values is sorted similarly to the set of the list of source values, as well as the corresponding elements;

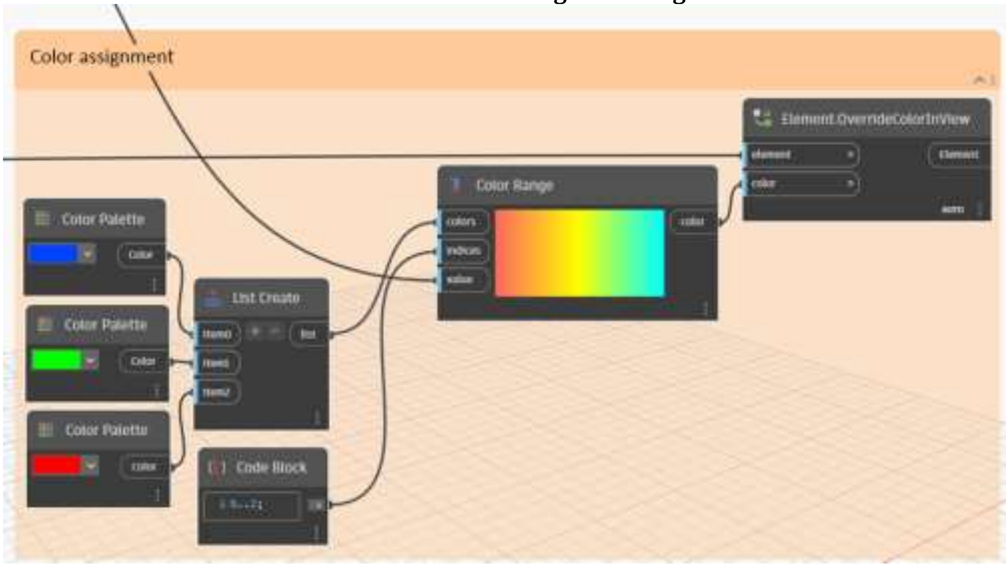
Figure 4 - The operation of creating a color assignment range dictionary in the Dynamo visual programming environment



Source of data: compiled by authors

5. Assigning visual attributes to elements. The assignment operation is performed in the visual programming environment when the visual attributes of elements are changed for elements in the open view space in the information modeling environment (Figure 5).

Figure 5 - The operation of assigning colors to elements in the Dynamo visual programming environment: assigning colors based on the consecutive range of blue-green-red



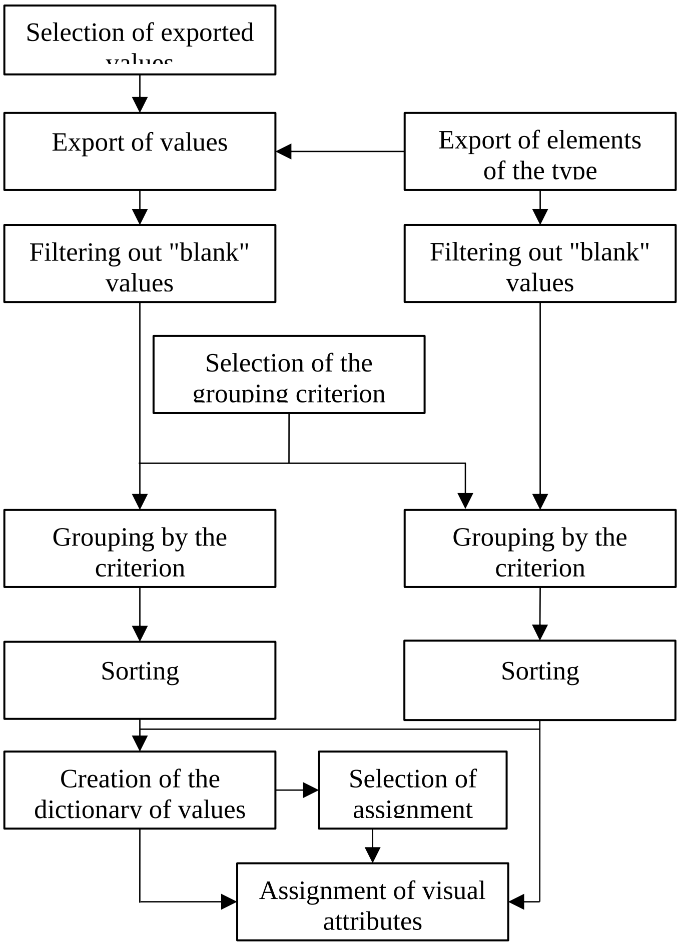
Source of data: compiled by authors

The general structural diagram of the script takes the form shown in Figure 6.

Launching the script is mandatorily preceded by specifying its settings, which includes the following steps:

1. Selection of exported values (labor intensity, the number of machines or workers involved, duration, etc.). This step consists in selecting the name of the desired parameter with the values to be exported filled in;
2. Selection of the grouping criterion (no grouping or grouping by work zones, storeys, sections, etc.). In this case, the name of the required parameter identifying the real position of the element by the product breakdown level is selected;
3. Selection of assigned parameters (color hues and their number, the presence of additional visualization effects); in this process, visualization effects are selected using special tools.

Figure 6 - Diagram of the script for assigning visual attributes by value range



Source of data: compiled by authors

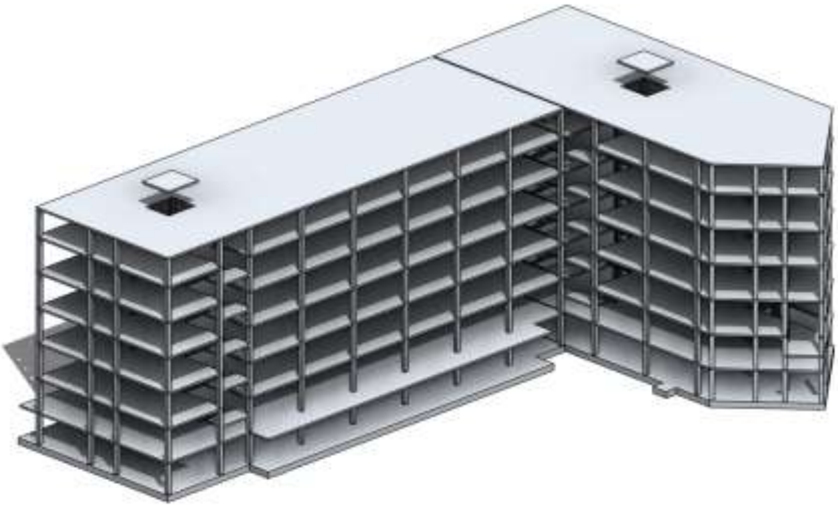
Aside from the actions that directly affect the outcome, it is also important to shed some light on indirect operations. For instance, the rounding of input values plays an important role. This operation decides the precision of the produced distribution. Rounding to more units after the decimal point will make it possible to assign close, yet different color tones.

A particular challenge in the hypothesized application of the proposed methodology is the difficulty of assessing the parameters of internal elements in the model. When viewing the building in the space of the 3D model from the front (as is most often the case), it is easy to overlook the structures hidden underneath the finishing layer. This circumstance may become critical because the bearing structures can constitute a significant amount of construction work. The same problem also arises in the creation of 4D models, so it is possible to deploy some similar solutions (Brito, Ferreira, 2015).

There can be no single solution in this case since the approach to solving the problem can be significantly influenced by architectural, planning, and construction solutions and the need to assess specific types of works. The possible solutions are as follows:

1. Isolated consideration of a specific type of work to be evaluated. This option examines a separate type or types of work and the corresponding group of structures. For example, on the considered view, the specialist can isolate the load-bearing frame structures (slabs, load-bearing walls, and beams) or, in the case of examining masonry works, the masonry wall structures. This view does not allow one to assess the general picture to compare the parameters but examines a specific type of works in more detail. The latter is justified by the fact that a single type of work typically corresponds to a single construction flow involving one brigade or several brigades of the same type. Thus, it is possible to calculate the workload of these workforce units.

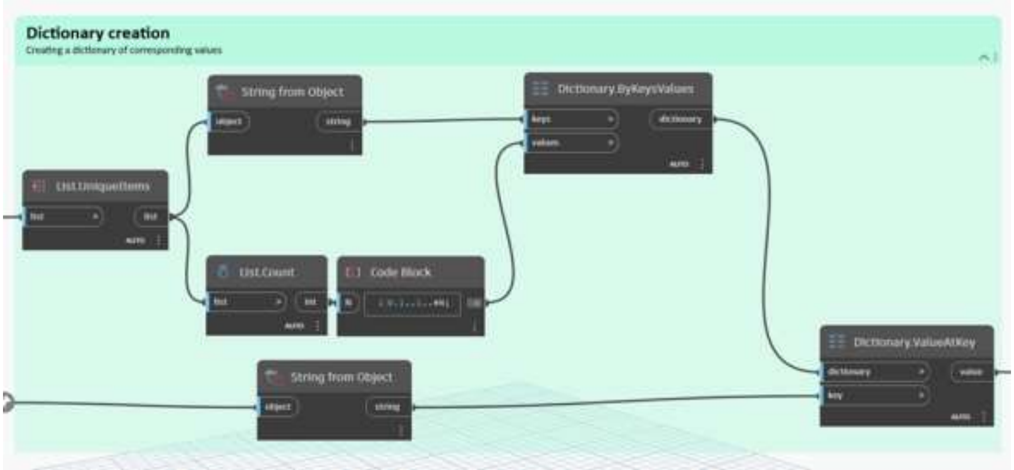
Figure 7 - 3D view of the space in the information modeling environment displaying the bearing frame structures: isolation of elements using standard visualization tools



Source of data: compiled by authors

2. Isolated analysis to assess distribution across the focal elements of the project (e.g., at a particular tier or along axes). In this case, the script will process structures depicted in 2D planes (e.g., plans, sections, nodes). This solution greatly limits the needs fulfilled by the results, but this method can still be useful in certain situations.
3. Consideration of structures along the symmetry of the building or structure. In this case, the building or structure will be cut in the 3D view by a volumetric figure along the symmetry axis (Figure 8). Thus, the internal layers will become visible and the organizational and technological characteristics of the structures of the symmetrical side will remain the same.

Figure 8 - 3D view of the space in the information modeling environment displaying the model of a two-section building: the use of the 3D boundary tool



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When using the last two methods, it is necessary to supplement the visual attributes assignment block with additional elements to color the dissected surfaces.

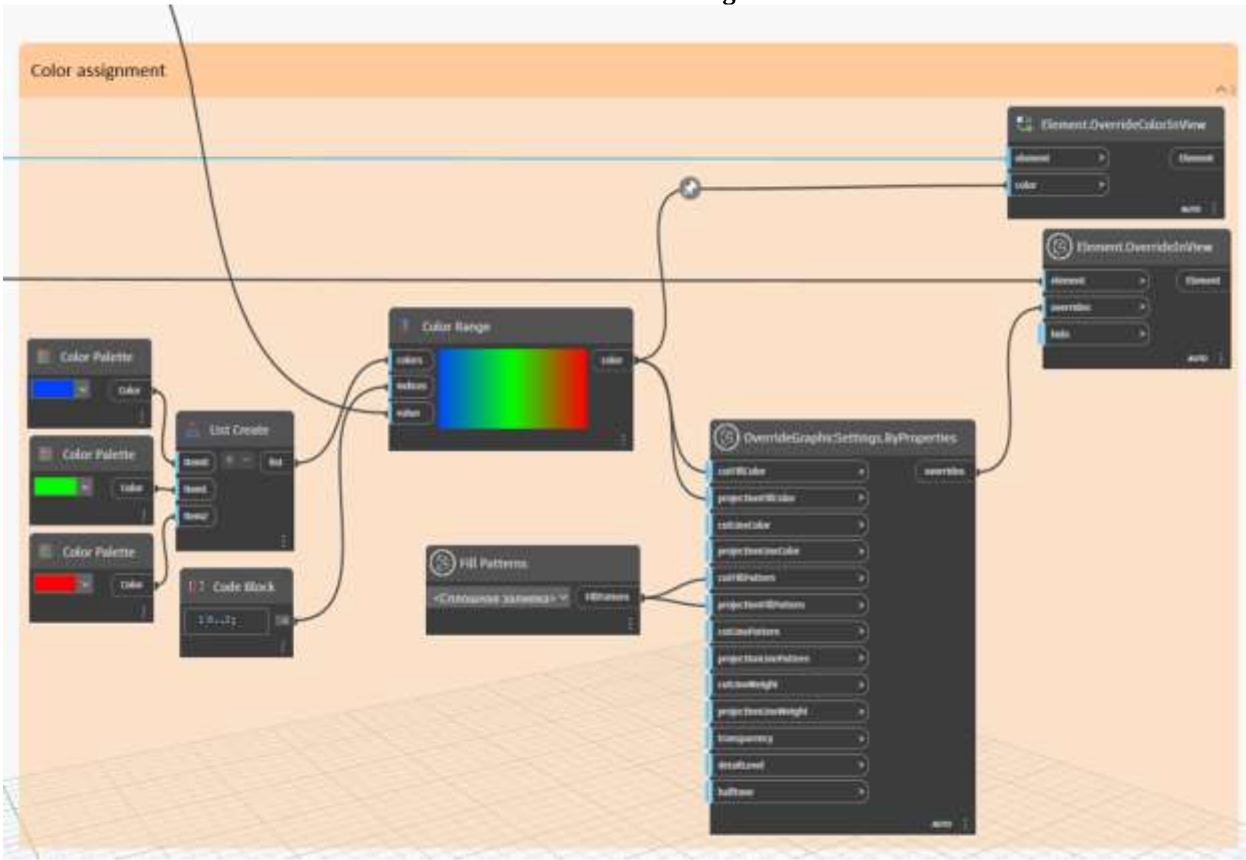
2.2 Testing the proposed methodology

The effectiveness of the proposed methodology was tested based on the object "Construction of a complex of buildings of the Grozny State Petroleum Technical University named after Acad. M.D. Millionshchikov (3rd start-up complex – Construction of dormitories and training and laboratory blocks), 100 Kh. Isayev Ave., Grozny, Chechen Republic". The object includes:

1. Projected dormitory buildings (blocks F and G);
2. Projected educational building (block R);
3. Projected underground parking lot with a superstructure (block S);
4. Projected on-site utilities for the operation of these units.

For educational purposes, the study object was limited to analyzing the organizational and technological indicators of the dormitory building (blocks F and G).

Figure 9 - The operation of assigning colors to elements in the Dynamo visual programming environment: assigning colors to the outer and dissected surfaces and setting a solid fill for the latter



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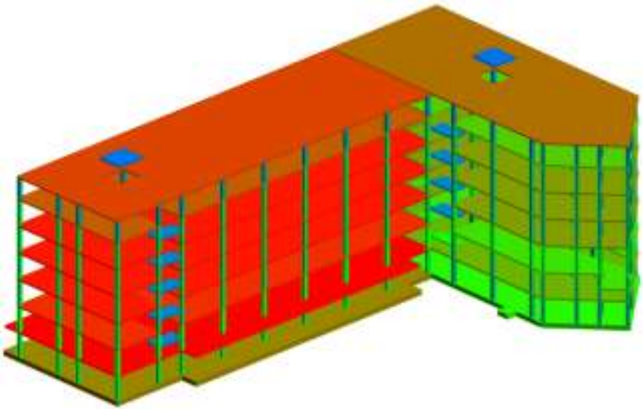
For each element in the model, the attributes of labor intensity, the number of mechanisms and specialists involved, and the duration of work execution are filled in. In addition, each element has an attribute identifying the element location and the work zone number.

We decided to perform the following operations to analyze the indicators:

1. Analysis of the distribution of manual labor intensity values by work zones in isolation for the bearing frame of the building;
2. Analysis of the distribution of the number of involved specialists by model element structures in isolation for the bearing frame of the building;
3. Analysis of the distribution of work duration values by work zones in isolation for the bearing frame of the building;
4. Analysis of the distribution of manual labor intensity values by work zones with dissection along the symmetry axis;
5. Analysis of the distribution of work duration values by work zones with dissection along the symmetry axis.

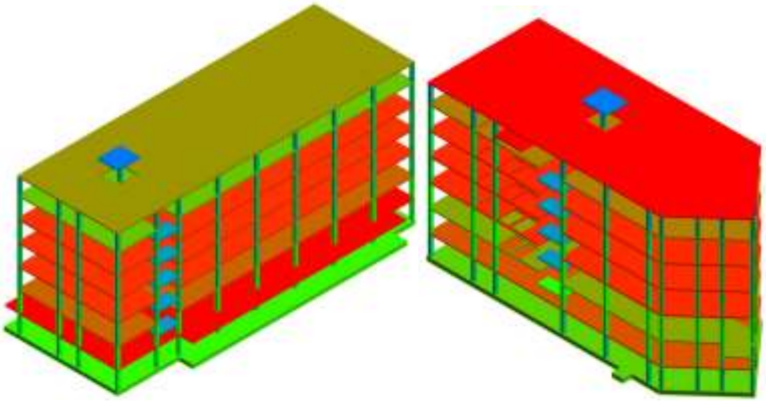
The first analysis operation was performed in several steps, in which the object's block sections were considered together (Figure 7) and separately (Figure 8).

Figure 10 - Distribution of the values of manual labor intensity in the range of ascending values blue-green-red: blocks F and G together



Source of data: compiled by authors

Figure 11 - Distribution of the values of manual labor intensity in the range of ascending values blue-green-red: blocks F and G separately

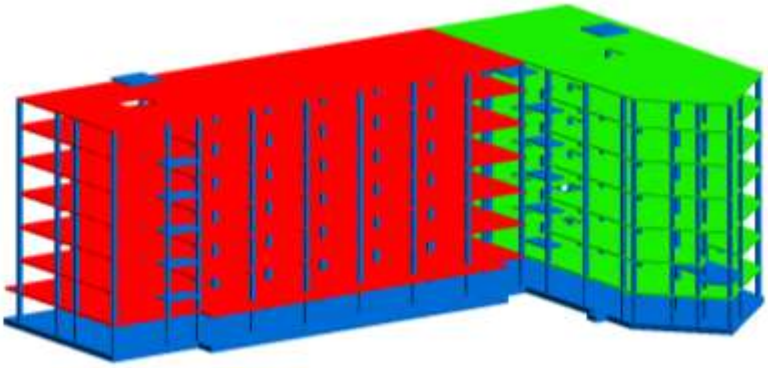


Source of data: compiled by authors

The first operation visually highlighted the elements of the model that might potentially require more workforce.

After the attribute of the number of involved specialists was filled in, the assignment distribution across the entire object was analyzed (Figure 9).

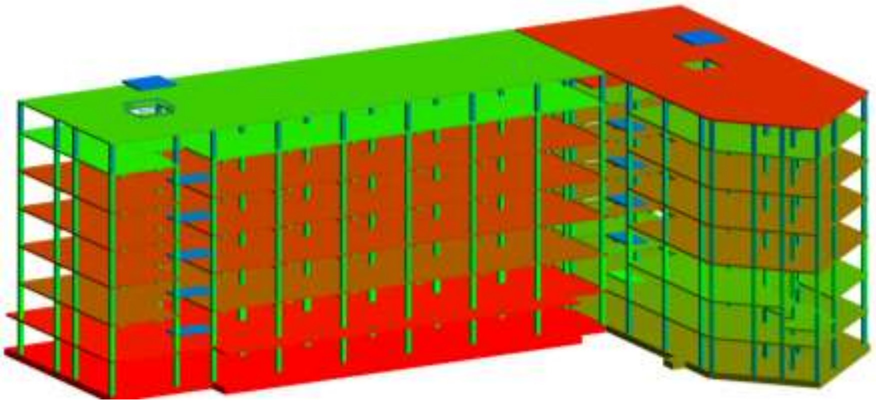
Figure 12 - Distribution of the values of the number of involved specialists by model element structures in the range of ascending values blue-green-red: blocks F and G together



Source of data: compiled by authors

After calculating the duration of work for each element, a distribution analysis operation was performed. Thus, the sets of elements that require more work shifts were identified (Figure 10).

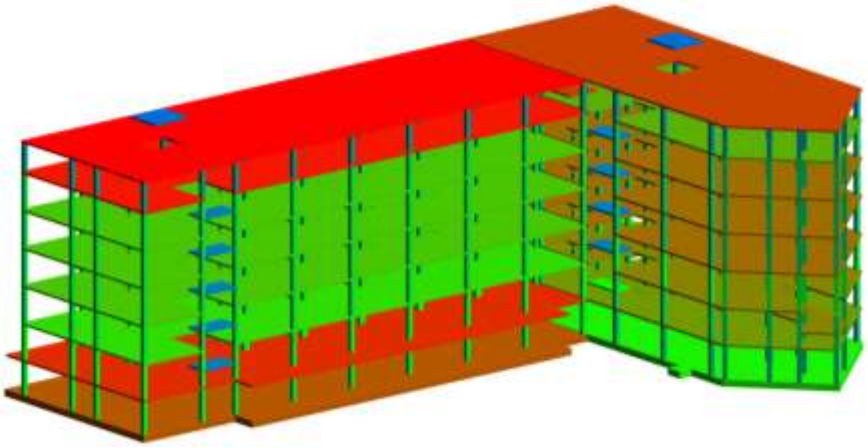
Figure 13 - Distribution of the values of work execution duration by model work zones in the range of ascending values blue-green-red: blocks F and G together



Source of data: compiled by authors

Relying on the results of the three operations, the specialist can draw a set of conclusions in the design process and take appropriate measures to optimize the organizational and technological parameters of the object. The adopted approaches to optimization can vary depending on the conditions set by the client. If there are no constraints on labor force engagement, and the priority is to perform a specific volume of work in a timely and uniform manner, then action can be taken to increase the number of workers involved and reduce the number of elements with critical differences in the color range (Figure 11).

Figure 14 - Optimized distribution of work duration values by model work zones in the range of ascending values blue-green-red: blocks F and G together



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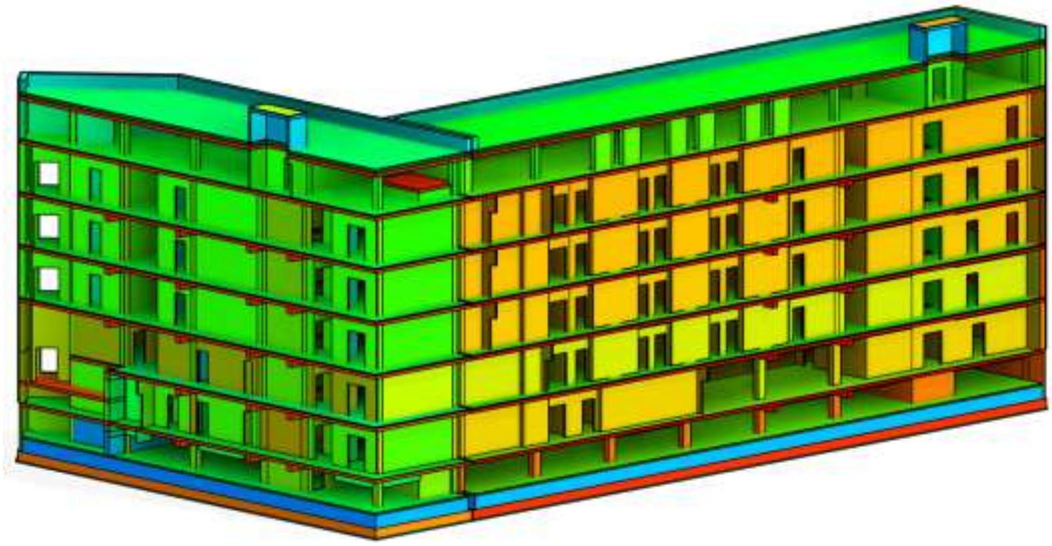
The main objective of the fourth and fifth operations was to assess the distribution of organizational and technological parameters across the entire object regardless of the type of work performed. In this case, optimization is particularly challenging due to the need to consider a multitude of factors arising from the combination of different types of works. Nevertheless, in this study, the last analysis operations were performed to demonstrate the mechanism of the script and its applications.

In the analysis of labor intensity distribution, blocks F and G were analyzed in 3D view from two sides: the dissected (Figure 15) and the front (Figure 16).

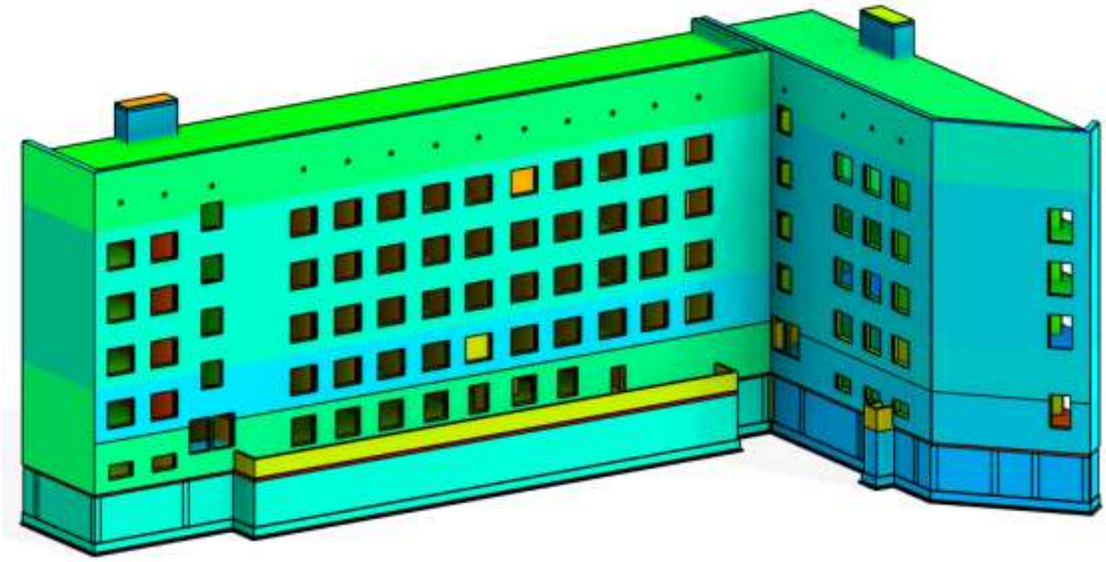
The analysis demonstrates that the greatest labor intensity is characteristic of works on monolithic reinforced concrete structures, whereas masonry, insulation, and facade finishing works are the least labor-intensive. Interior finishing works demonstrate the medium intensity of manual labor.

Figure 15 - Distribution of the values of manual labor intensity in the range of ascending values blue-green-red: blocks F and G from the dissected side



Source of data: compiled by authors

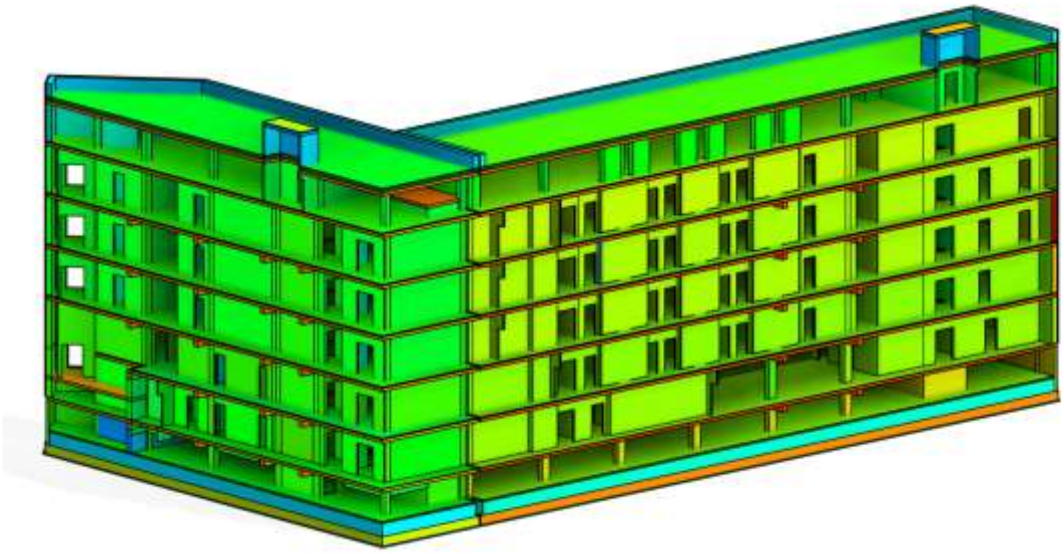
Figure 16 - Distribution of the values of manual labor intensity in the range of ascending values blue-green-red: blocks F and G from the front side



Source of data: compiled by authors

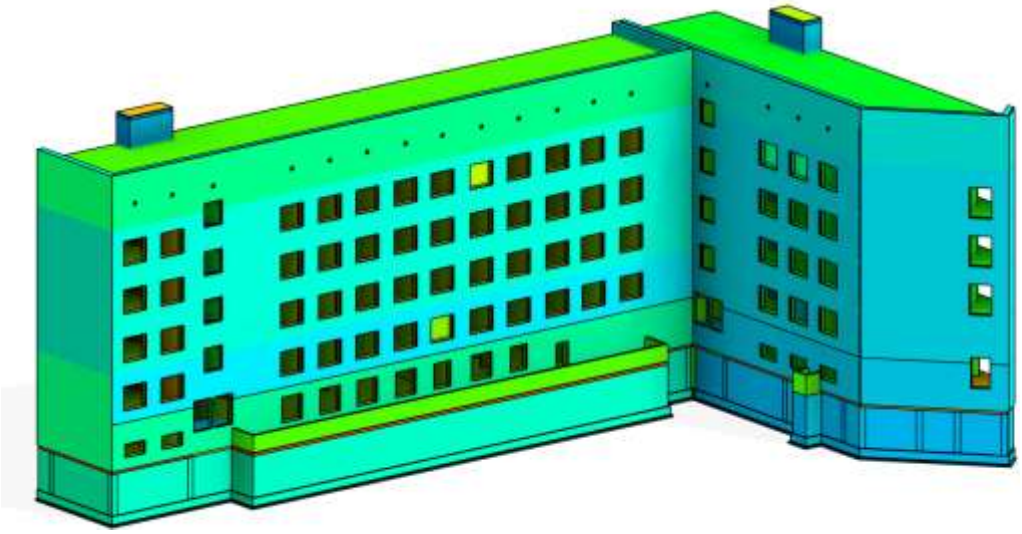
Similarly to the analysis of manual labor intensity, the building model was approached from the dissected side (Figure 17) and the front side (Figure 18) in the work duration analysis.

Figure 17 - Distribution of the values of work execution duration by model work zones in the range of ascending values blue-green-red: blocks F and G from the dissected side



Source of data: compiled by authors

Figure 18 - Distribution of the values of work execution duration by model work zones in the range of ascending values blue-green-red: blocks F and G from the front side



Source of data: compiled by authors

The analysis demonstrates that the greatest labor intensity is characteristic of works on monolithic reinforced concrete structures, whereas masonry, insulation, and facade finishing works are the least labor-intensive. Interior finishing works demonstrate the medium intensity of manual labor.

CONCLUSION

The existing methods for assessing organizational and technological parameters have several significant drawbacks that limit the optimization process’ flexibility and clarity. We propose a progressive method utilizing visual programming tools.

The proposed methodology ensures visibility of the distribution of organizational and technological design characteristics across the object and by specific work zones.

The key limitations of our study include the limited complexity of the educational model, which may reduce the method’s applicability to more complex projects. In addition, the disadvantages of existing visualization tools do not always allow one to consider hidden or complex structural elements. The grouping of data and filtering based on fixed criteria limit the flexibility of the method when faced with changing conditions. Furthermore, the software limitations of visual programming and scalability may make it difficult to process large models, and adapting the methodology for other industries would require refinements. The influence of the human factor also plays a significant role in data interpretation.

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