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Improving of Digital Construction Management with the Use of Automated Technology "Building Manager"

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Abstract: *The construction sector is one of the economy's main engines. A high proportion of construction in the gross domestic product and the construction industry's high multiplicative effect can provide citizens with significant economic growth and prosperity. Construction involves the results of almost all extractive and processing industries, and the sustainable growth of related industries depends on the sustainable development of the construction sector.*
However, several systemic problems have accumulated in the construction complex, which does not allow the full realization of the existing potential. Long planning terms for the implementation of large investment and construction projects, high risks of significant deviation of large projects from planned cost and time indicators, a large volume of manual labor, and low productivity are negative factors. They are manifested quite often in construction projects. All these negative factors indicate that the project management system operates insufficiently reliably and efficiently. In this regard, this work analyzed the current state of the management system, identified negative reasons, and proposed measures for their change using the automated technology of construction management "Building Manager".

Keywords: *automated technology of construction management; artificial intelligence; Organizational and Technological Model of Construction; BIM.*

I. Introduction

1.1. General statement of the main problems

Problem 1. Significant deviation of major construction projects from planned cost and deadlines

The percentage of major projects in the oil and gas industry that end with significant overspending is about 64% [1]. The percentage of major construction projects with a significant budget overrun in the mining industry averages 71% [2]. The average deviation from planned indicators of major projects in construction is [2]:

- 20 months from the original deadlines and 80% from the original cost;
- budget or cost overrun occurs in 98% of cases.

In transport projects: "Underestimation of expenses and overspending have not decreased over the past 70 years. No lessons seem to be learned from this phenomenon [3]." These, as well as other studies, speak of the dominance of significant budget and deadline overruns over forecast indicators in major investment and construction projects. There is also a correlation - the larger and more complex the project (or group of interrelated projects), the higher the probability of deviation from planned indicators and the greater the magnitude of the deviation. With a significant volume of investment in the construction industry and current average deviations in cost and terms, the task of increasing planning accuracy and keeping construction projects within target boundaries comes to the fore.

Problem 2. Low labor productivity growth dynamics

Productivity in construction has generally remained unchanged for decades, while productivity in the manufacturing industry has doubled over the same period [2]. Meanwhile, in construction during this time:

- New construction equipment and tools have appeared, leading to a 6-52% increase in labor productivity for certain types of work [4].
- There has been a transition from 2D design to BIM with the ability to automatically check design solutions for collisions, resulting in fewer reworks and deviations from the original plan.
- Collaborative work tools in the cloud space have been actively used, allowing specialists from around the world to connect.
- Virtual and augmented reality systems, laser scanning, and photogrammetry have been used.
- Mobile devices have appeared, allowing information to be instantly delivered to the consumer and receive feedback.

However, the integral indicators of projects are not improving, despite the presence of the following development factors:

- A significant increase in the productivity of machines and mechanisms.
- More technological equipment and more functional tools.
- The appearance of modern materials and products of high factory readiness.
- The development of project management and process management in organizations.
- The rapid development of information technologies and tools.

1.2. Root causes of the main problems

The analysis of the reasons for such a state of affairs shows that the root of the problems lies not in the technical, but in the organizational-technological plane. The following problems can be identified in the management system:

- Planning by the "rolling wave" method initially lays down planning errors in the project, does not consider multiple constraints (spatial, technological, resource, climatic, etc.), and therefore does not describe the construction process with the necessary accuracy.
- Poor communication of participants in the planning process, losses, and incompleteness of information on the project during its implementation lead to asynchronous and arrhythmic execution of work on the project.
- The inconsistency of the actions of many project participants leads to multiple downtimes of construction machines and work crews, and excessive movement of crews and materials, which ultimately leads to low output, delay in the timing of work on the project, and exceeding the budget.
- Barriers between project participants (owner, operator, regulator, designer, suppliers, subcontractors) do not contribute to the achievement of project goals, often project participants have divergent vectors of interest. This leads to delays in decision-making, not providing the necessary speed of response in the project, and accumulated mutual claims in the process of work often leading to antagonistic relations, disputes, and claims.

The imperfection of the management system in large projects, their uniqueness, high variability, and a large number of communications, lead to information losses and the inability to obtain accurate and reliable forecast estimates. As a result, a reactive management style (reacting to problems that have occurred) prevails instead of proactive management (timely removal of all project constraints with the adoption of corrective measures), and even more so the reactive management style prevails over predictive management (with statistical control of project processes and operations, identification of negative trends and taking preventive measures).

1.3. Main objective and expected outcomes of the study

Necessity of changes in construction planning

The Building Information Modeling (BIM) technology, actively used in design, is a good source of information for planning construction and commissioning works. However, the currently used approaches of aggregated 4D/5D modeling in the design process mostly visualize the sequence of work execution in an aggregated manner, but do not reproduce construction production with due accuracy, and therefore also contain planning errors.

For the successful implementation of a construction project, it is necessary to create a reliable construction production system capable of rhythmically producing the planned volume of construction products of the necessary quality in the presence of many restrictions (technological, spatial, temporal, logistical, climatic, resource) in dynamically changing conditions, it is necessary to create a construction conveyor and ensure its uninterrupted operation.

To build a system that meets these requirements, it is necessary at the design stage to plan construction flows for individual types of work for the entire project implementation period: monolithic work, finishing, installation of water supply and drainage systems, heating and ventilation, power supply and lighting, etc., providing appropriate conditions for the installation of technological systems and organizing unimpeded synchronous work on each stream, removing emerging restrictions in the process of work.

In this case, when organizing construction flows, it is necessary to consider the sequence of commissioning of technological systems, laying down the necessary work on commissioning and commissioning of systems within technological nodes.

For accurate forecast estimates of work deadlines, a high level of work detail is required - up to the level of simple work processes, for example: reinforcement, formwork, concreting, concrete care, dismantling of formwork for general construction work, or: installation of a heat exchanger, pump, installation of pipelines, supports and suspensions for technological systems. It is at the level of simple work processes, characterized by the uniformity of work performed, a well-established set of used mechanization means, and one involved specialty of labor resources, that an accurate estimate of the duration of work based on the physical volume, labor resource consumption rates and existing restrictions (technological, spatial, temporal, logistical, climatic, resource) is possible. Each scheduled task should contain a physical volume of work, and have a calculation of the need for machines and mechanisms, and labor resources at the level of a team of workers. The resulting workflows must be leveled (should not have peaks exceeding the availability of resources).

The construction model formed in this way during the design process will give accurate forecast estimates of the timing of work and the necessary resources for their implementation, and the overall system will provide project participants with accurate and reliable data at all levels of decision-making: strategic (until the end of the project), tactical (year/quarter) and operational (month/week/day).

To keep the project within the target indicators, it is necessary to ensure timely accounting of all emerging and forecasted deviations, proactive and inertia-free decision-making based on data, and effective coordination across all types of work at all decision-making levels using a data-centric approach.

II. Method

2.1. Use of Expert Systems in Construction Planning

Detailed planning of construction work for the entire project implementation period, with resource allocation (physical volume, labor resources, machines and mechanisms, including their cost), requires processing a large amount of information. Accordingly, it is necessary to use another class of calendar-network planning systems - expert systems, capable of automatically planning all work and resource flows for the entire project implementation period based on a digital information model.

Before calculating the calendar network schedule, it is necessary to form a construction digital information model from the BIM model, adding additional information necessary for work planning. Using the construction digital information model, you can form a Product & Work Breakdown Structure (PBS/WBS), see the example at Figure 1.

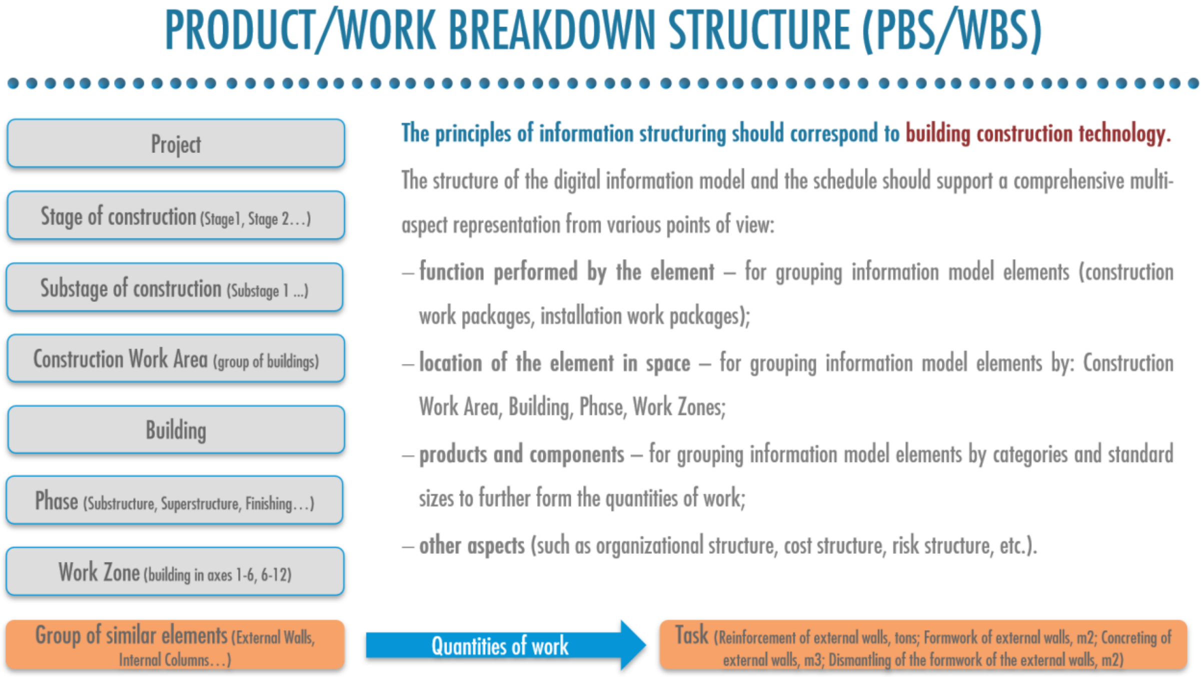

Figure 1. Product & Work Breakdown Structure (PBS/WBS)

The elements of the construction digital information model, grouped at the lower level of the WBS, allow for the calculation of work volumes and the formation of a calendar-network schedule sufficient for the organization of flow construction (construction conveyor) - Figure 2.

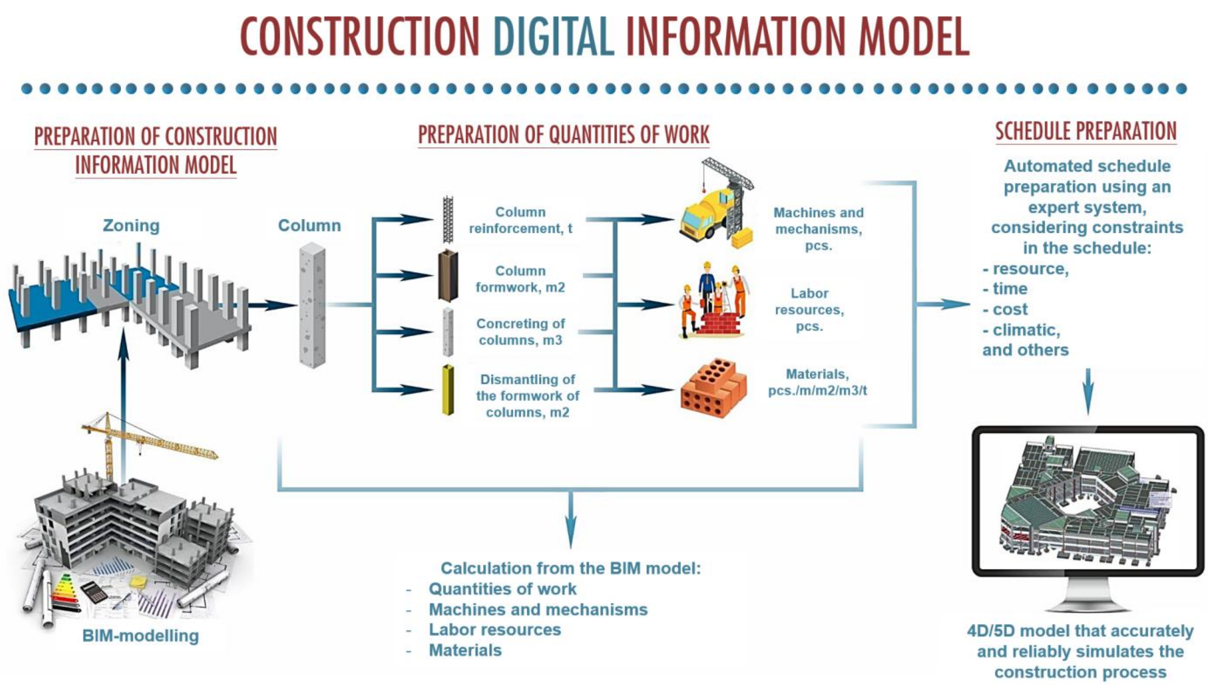

Figure 2. Construction digital information model

The construction digital information model serves as the basis for planning: equipment, products, and materials deliveries; labor resources, machinery and mechanisms provision; working documentation, and financial resources. The composition of information models used for construction project management is shown in Figure 3.

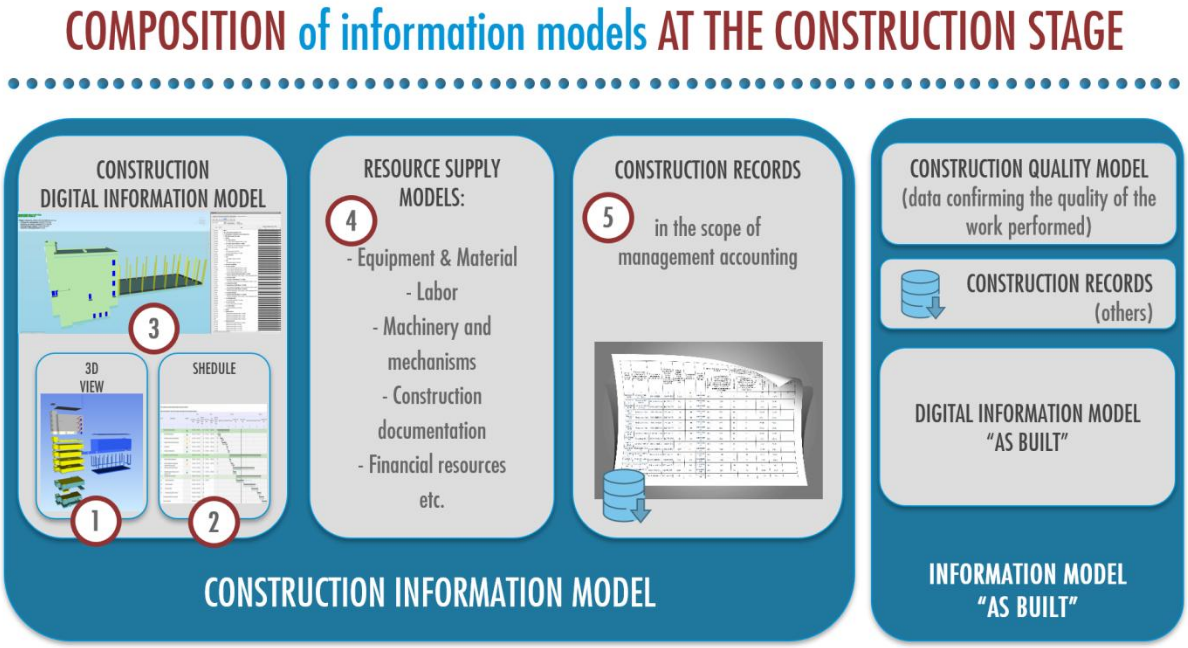

Figure 3. Composition of information models

For detailed work planning, the authors of this study propose using the "Building Manager" expert system, which automatically generates a network model and schedule based on the bill of quantities. Automated technology of construction management "Building Manager" allows to automatically create a network model using a knowledge base that includes routings and rules for their application. The schedule is formed taking into account various restrictions (spatial, temporal, resource, cost, climatic). This allows you to create a more precise work schedule.

III. Results and Discussion

3.1. Transition to a Proactive Project Management Approach with the use of Automated Technology "Building Manager"

The theoretical and practical research of the authors of this article confirms that in traditional technologies, the main obstacle is the huge labor-intensiveness of preparing initial data for detailed calculations. Therefore, in practice, under time constraints, aggregated, often statistical calculation methods are used, which fundamentally have significant errors. That in the end leads to inconsistencies in project financing: lack of resources, including financial resources at some stages of project implementation and dead finances at other stages. In addition, inaccuracies in project implementation plans have a negative multiplying effect on the development of production plans of related subcontractors and equipment manufacturers, and a significant "manual" labor intensity determines the presence of a large number of "human" errors.

The use of BIM in design, in dynamic conjunction with the modeling of construction production using the expert system "Building Manager", as well as the operational accounting of the statuses of all components of the work schedule (the status of procurement, manufacturing, and delivery of each unit of equipment, products, materials, availability of construction equipment, the presence of teams in the necessary volume on the site, the beginning and end of work, achieved productivity) together provide the necessary speed of data preparation for making effective decisions in the mass of existing and expected constraints[5], [6].

The adoption of AT "Building Manager" yields tangible economic benefits, including a notable reduction in labor intensity and construction costs. Empirical evidence from successful implementations underscores its efficacy in delivering substantial cost savings and operational efficiencies across a spectrum of construction and reconstruction projects.

AT "Building Manager" stands as a testament to the transformative potential of automated technology in reshaping the landscape of construction project management. By fostering collaboration, innovation, and efficiency, it empowers organizations to navigate the complexities of modern construction projects with confidence and precision.

The information collected in a unified database of statuses enables:

- Promptly updating the schedule network plan of production activities.
- Seeing the completeness of work fronts for each stream.
- Removing constraints from work fronts, preventing bottlenecks from forming.
- Providing all project participants with accurate and reliable data from a single source.
- Making management decisions based on data with the ability to flexibly model alternative scenarios.
- Executing the project within planned deadlines and budget constraints.

It should be noted that such an approach requires, before or during the design phase:

- Organization of a common data environment (CDE) for all project participants.
- Defining requirements for all information models and the information modeling process.
- Configuring informational dashboards for each participant using business intelligence (BI) systems.
- Describing processes of information exchange among project participants, including centralized project planning and management processes.

Applying this approach - Proactive Project Management Approach - to construction management requires specialized skills in information management[7]. Therefore, to effectively utilize proactive project management methods, engaging a specialized company - Project Management Contractor (PMC) - is advisable, as illustrated in Figure 4.

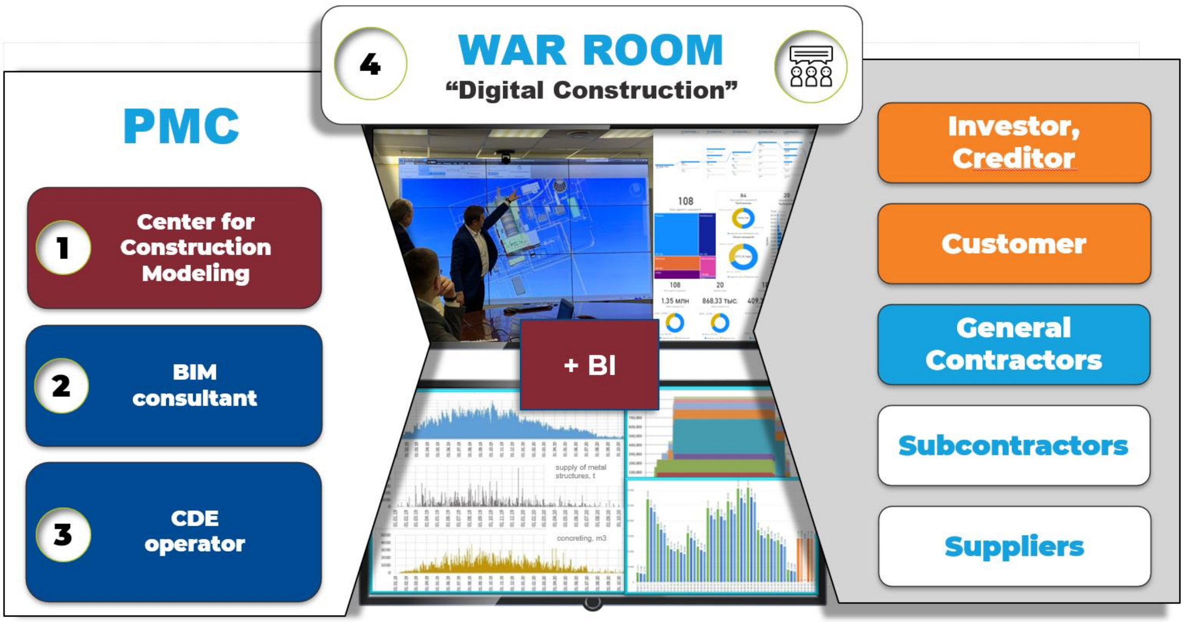

Figure 4. Proactive Project Management Approach

For successful implementation of this approach, it is necessary to drastically reduce the labor intensity of preparation of initial data for calculations. This principle is the basis for the development of the automated technology Building Manager. This technology is based on the principles of expert systems - systems with elements of artificial intelligence. The basis of automation is the use of the system of rules replenished and corrected in the process of operation (training - fixation and logical processing of trivial knowledge in the Rule Base of the system). This serves as a basis for the automation of such labor-intensive processes:

- formation of the list of works with the calculation of their physical volumes directly from the complex of the project BIM models;

- formation of a network model of work interrelations as a basis for calculating the schedule;

- formation of resource and organizational-technological characteristics of works.

Organizational and technological characteristics of works are also automatically formed using the database of contractors' capacities. Thus, the time required to prepare and calculate a dynamic model (calendar plan associated with a set of BIM models) with a sufficiently trained system, regardless of the volume - design solutions, is reduced to a few hours instead of weeks and months - in the case of traditional systems. Training the system is also not a complicated process. It is enough to process an object of a certain type once, regardless of its volume, and all the new knowledge necessary for calculation will replenish the Rule Base of the system. Such processing is reduced to the input of several new system concepts and their characteristics and relations. This information is entered and corrected in the most convenient perception form.

AT "Building Manager" encompasses a myriad of cutting-edge functionalities designed to revolutionize project management practices within the construction industry. These include:

- BIM Integration and Structural Description: Leveraging Building Information Modeling (BIM), AT "Building Manager" facilitates the precise formulation of work lists and scopes, augmented by comprehensive structural descriptions of construction objects.

- Construction Network Modeling: Employing advanced approaches akin to expert systems, AT "Building Manager" automates the formation of construction network models, optimizing resource allocation and scheduling.

- Resource and Cost Estimation: Drawing upon a diverse normative base, AT "Building Manager" generates accurate resource and cost characteristics, informed by production standards and regulatory methodologies.

- Organizational and Technological Profiling: By delineating key parameters such as performers, equipment, and composition, AT "Building Manager" enables meticulous organizational and technological profiling of construction projects.

-Dynamic Work Scheduling: Through sophisticated scheduling algorithms, AT "Building Manager" orchestrates the execution of work orders, offering real-time monitoring, recalibration, and 4D visualization of construction progress (Example - Fig. 5)

- Financial Monitoring and Reporting: Facilitating comprehensive financial oversight, AT "Building Manager" monitors actual costs, mitigates risks, and generates detailed reports, ensuring fiscal transparency and accountability(Example - Fig.6).

3.2. Case study

One such project, in which the expert system Building Manager was used for work planning, was the “Hanhikivi-1” nuclear power plant project. With the help of the Building Manager, several options for the construction of the NPP were modeled. Thanks to variable modeling, finding the most rational way of constructing the NPP was possible, which allowed to reduce the planned construction period by 12 months.
The expected savings from reducing the construction time for objects costing more than 1 billion euros is 7-10% of the construction cost.

Modeling using the expert system Building Manager made it possible to find a variant of construction of NPP "Hanhikivi-1" (Finland) 12 months earlier than the planned work schedule and to justify the technological feasibility of this variant. This was achieved in the following way:

1. The nodal method of construction (AWP- Advanced Work Package) was applied with the help of which structurally and technologically separate parts were allocated in the information model of the nuclear power plant, allowing the adjustment of separate technological units taking into account the order of their commissioning[8].

2. A variant of the main building construction using Open-Top technology was adopted - when the installation of heavy and large-size equipment was carried out together with general construction works.

3. To perform construction and installation works in parallel, a decision was made to create a zone with completed finishing works and climate control in the premises of the main building, which was half built.

4. The performed preparatory works determined the order of erection of buildings and structures. For the formation of the calendar-network construction model, the automated technology Building Manager was used, with the help of which the flows of works and resources (machines and mechanisms, labor resources by specialties) were modeled and synchronized.

5. Work and resource flows were analyzed, ways of their optimization were determined for the entire complex of buildings and structures, taking into account all project constraints (technological, spatial, climatic, resource, organizational) - and appropriate changes were made to the technology of construction of buildings and structures. Taking these changes into account, work, and resource flows were remodeled and synchronized with each other by using the automated technology Building Manager.

6. Ways of local optimization of works that are on the critical path of the calendar-network model of construction were found. Optimization of workflows with the help of automated technology Building Manager was performed. The resulting construction variant was shorter by 12 months of the planned work schedule and used the project resources more rationally.

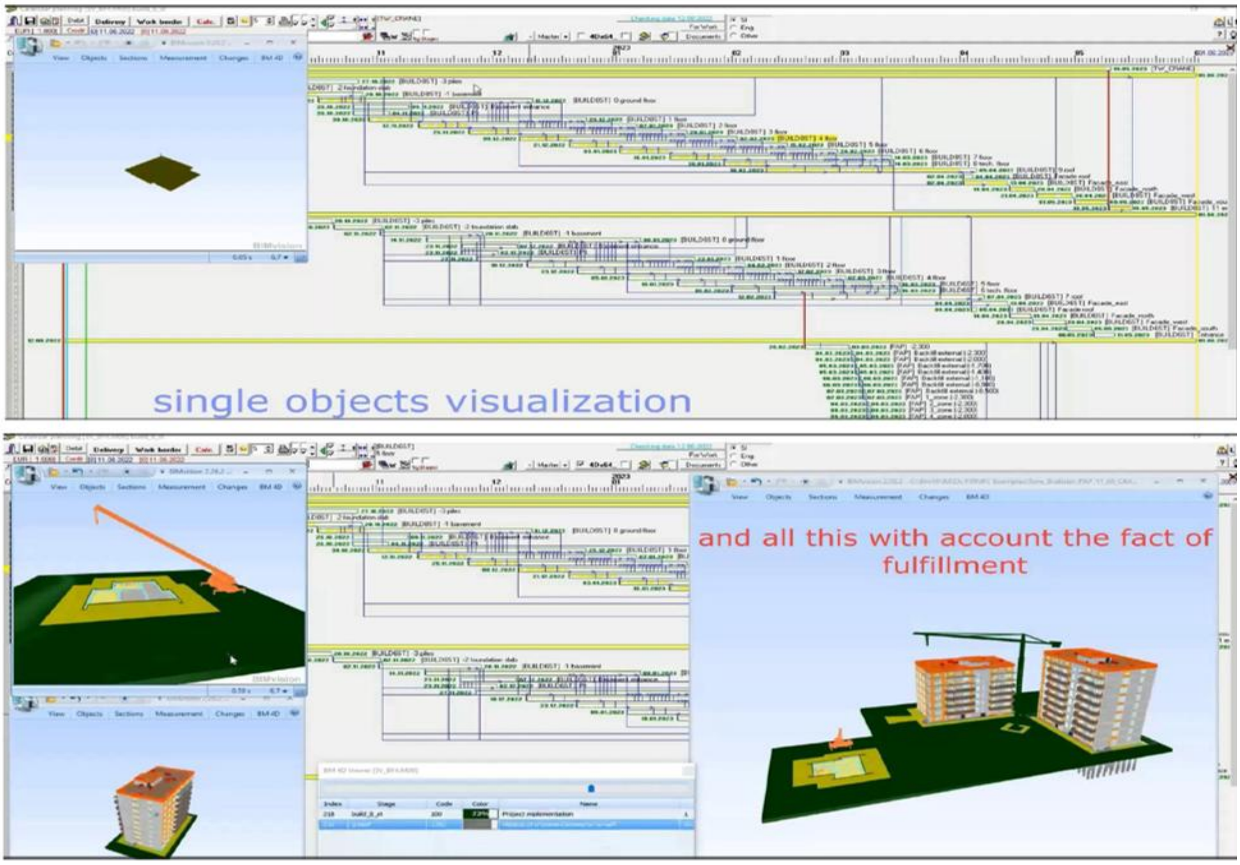

Figure 5. Exampleof Dynamic Work Scheduling with 4D-visualisation of calendar plan by AT "Building Manager"

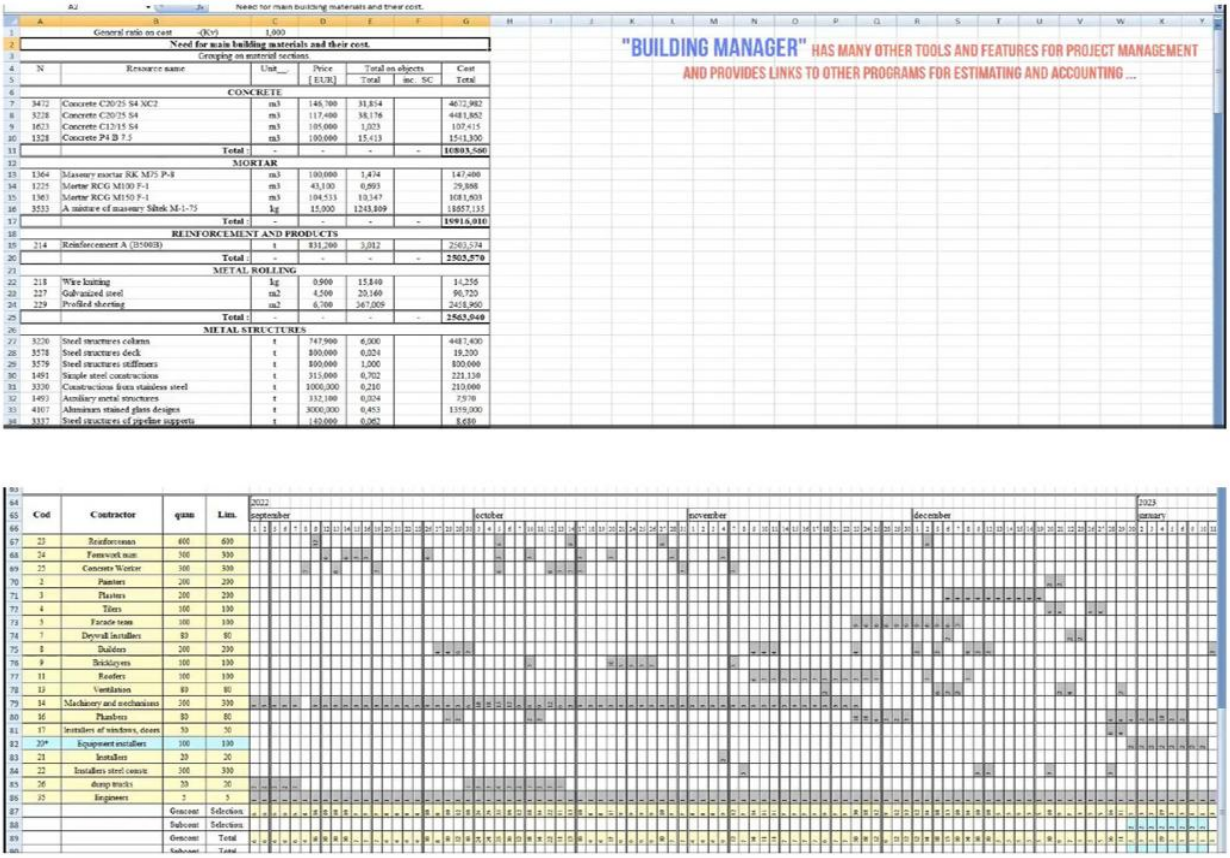

Figure 6. Exampleof Financial Monitoring and Reporting withcost estimation by AT "Building Manager"

IV. Discussion

What problems can complicate the application of Building Manager Automated Technology?

It should be noted that for the successful application of automated technology "Building Manager" requires a certain level of standardization of a limited list of parameters of elements of BIM-models used to determine the type of work and in the calculation of their volumes. Anarchy in this matter may require additional labor costs in the process of preparing the BIM model for use. In case of non-compliance with the list of parameters to the standard one, the total labor intensity of preparation of initial data for calculations increases, but it is still much less than the labor intensity when using traditional technologies. Standardization of the list of parameters of elements of BIM models can be local (within the group of project participants) or within the firm or industry standard. To a large extent, bringing the names of an arbitrary list of parameters of BIM model elements to the standard (accepted in the system) is automated by a special software module of the system.

V. Conclusion

Detailed planning at the design stage of buildings and structures with expert systems allows:

- To find the best way to implement the project by reducing the construction time by 15-20%.
- Reduce the volume of manual labor, and increase productivity by 20-25% due to the organization of flow production.
- Reduce the cost of construction by 7-10%.
- Significantly reduce the risks of implementing investment and construction projects and increase the profitability of construction projects.

The use of such technology in construction management allows to keep the project within the planned indicators and not allow deviations described in section 1.

Application in "Building Manager" of the technology of merging dynamic models of construction of individual objects into a common dynamic model of construction of a complex of objects along with the use of a unique algorithm for calculating the calendar plan, taking into account all possible conditions and constraints allows to form several variant calculations, balanced by all capacity, organizational, technological and resource parameters, plans with minimum labor input. Realization of feedback "Production - Planning" allows constant (daily) to keep the dynamic model up-to-date and make necessary corrections with variant calculations of the results of regulatory and control actions with visual support.

AT "Building Manager" caters to enterprises within the construction complex seeking to optimize project development and management processes. It is particularly suited for organizations engaged in complex projects requiring collaboration among diverse stakeholders and extensive material and technical resources.

The trajectory of AT "Building Manager" is characterized by continuous innovation and refinement. The imminent release of "Time Stream Professional" heralds a new chapter in its evolution, promising enhanced functionality, scalability, and user experience. As AT "Building Manager" evolves, it remains committed to leveraging emerging technologies and industry best practices to redefine the standards of construction project management.

Acknowledgments

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