

# Green building investment control system based on a three-dimensional parametric model of the green building

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**Abstract.** Investment in construction projects is a rather complex process. The customer of construction product, as a rule, is also its investor and for him the systematization of information about the construction process is a necessity. Construction investment control (CIC) is an integral part of the building construction process. Such control is a separate service that is necessary for the customer to objectively understand the installed work volumes and forecast deadlines. Completed construction and installation works are confirmed by acts of acceptance of the completed works, which are subsequently the basis for payment for the work done. In this paper, we developed a methodology for managing investments in construction, as well as their control using modern BIM technologies. The effectiveness of using 3D modelling in investment control was demonstrated on the example of a residential complex. In addition, the volume of work obtained from the 3D-model was compared with the volume of work calculated manually. As a result, the exact amount of work and schedules for forecasting investment of funds were obtained.

## 1 Introduction

Investment in construction projects is a rather complex process. The customer of construction product, as a rule, is also its investor and for him the systematization of information about the construction process is a necessity [1-3]. The control process itself is closely related to the construction site, because the acceptance of installed structures and completed works must be carried out continuously at all stages of construction. The quality of the work done indirectly affects the functioning of the building and it must meet the stated requirements and meet all necessary requirements [4].

Construction investment control (CIC) is an integral part of the building construction process. Such control is a separate service that is necessary for the customer to objectively understand the installed work volumes and forecast deadlines [5-8]. Completed construction and installation works are confirmed by acts of acceptance of the completed works, which are subsequently the basis for payment for the work done [9].

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Nowadays, the design process is in the process of switching to so-called BIM (Building Information Modelling or Building Information Model) technologies, which allow you to improve the quality of the received documentation, contain attribute data and subsequently apply such data and element geometry to obtain accurate specifications, calendar schedules, renderings, demonstration materials and design projects [10-13].

In addition to the above-mentioned ways of using BIM technologies, it is proposed to introduce them into the CIC process, which will simplify the interaction of technical supervision, the General Designer, as well as the construction organization and management Department, the economic Department [14-16]. As a rule, in such a chain of document flow, inaccuracies and errors may occur in determining the mounted volumes, which accordingly affects the financing and remuneration of labor [18-20]. The accuracy and correctness of such data is primarily necessary for the customer, the investor [21].

The purpose of this article is to increase of level of control of investment in construction and quality control documental process of completed construction works during the reporting period, based on accurate data on the composition and scope of work of a parametric model of the object.

As part of the goal, we are dealing with tasks such as:

1. Develop a methodology for managing investments in construction, as well as their control using modern BIM technologies
2. Formation of acts of acceptance based on information about the implementation of the construction and installation work and data on the volume of materials and structures obtained from the BIM model.

## 2 Methods

Construction control is performed in the Revit software environment. You can work with elements both from individual models and from assembled files. An assembly file is an information model that contains nested models. The volume of work in the BIM model corresponds to the actual volume (the error is not more than 1%). The BIM model is one of the source data for investment control of construction. The BIM model is generated in the Autodesk Revit CAD system. Below are the stages of the CIC and responsible persons.

The use of sections to divide the text of the paper is optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in Table 2 should be used.

**Table 1.** CIC stages and responsible persons.

<b>№</b>	<b>Stage</b>		<b>Responsible</b>
1	Acceptance of the model for compliance with the BIM standard and elimination of comments		Customer's BIM manager/designer
2	Approval of construction control requirements for the project/conclusion of a contract		Customer's BIM manager
3	Preparing a model for construction control		BIM construction support
4	Entering planned dates for construction and installation works into the model		BIM construction support
5	Monthly cycle:	Dates of the month	
5.1	Construction and installation works	01-25	Contractor
5.2	Reflection of the construction fact in the model (volumes planned to be presented by the contractor to the Customer for the reporting period) - assigning dates and statuses to the	Until 20	BIM construction support together with the contractor

	model elements		
5.3	Preparation of the cumulative statement of the with the fact of construction and installation works	Until 21	BIM construction support
5.4	Preparation of the detailed form of Act of Acceptance – transfer to the customer's technical supervision	Until 21	BIM construction support
5.5	Control over the implementation of the construction and installation works volumes (determining the volume of construction and installation works that the Customer is ready to accept)	From 21 to 24	Technical supervision of the customer, contractor, BIM construction support
5.6	Update of the journal of the construction works accumulative statement with the fact of construction and installation works	Until 24	BIM construction support
5.7	Preparation of detailed form of Act of Acceptance – with the fact and forecasting the implementation of future accounting periods	Until 24	BIM construction support together with the contractor
5.8	Preparation Of the enlarged form of first construction acceptance certificate	Until 24	BIM construction support
5.9	Preparation of an Enlarged form of second construction acceptance certificates	Until 24	BIM construction support
5.10	Creating and transmitting to the customer a summary report for the month: documents on acceptance of works types PDF	Until 24	BIM construction support
5.11	Approval of the consolidated report for a month	Until 25	Technical supervision of the customer
5.12	Making a forecast of future accounting periods in The customer's cumulative statements		BIM construction support
5.13	Signing paper versions of the documents of acceptance of works		Director for construction
5.14	Analysis of monthly performance and forecast of future periods		Director for construction
6	Completion of construction		Contractor

### 1. Check BIM models for compliance with the BIM standard

Such verification is an essential part of the chain of work, because it significantly reduces the likelihood of errors at subsequent stages and, accordingly, improves the quality of the information that is being worked with. It is divided into 2 stages: checking for the correctness of the geometry and the tools used for modeling such geometry, as well as checking for the attribute content of elements, the availability of necessary parameters and their occupancy.

### 2. Creating a list of non-modeled jobs

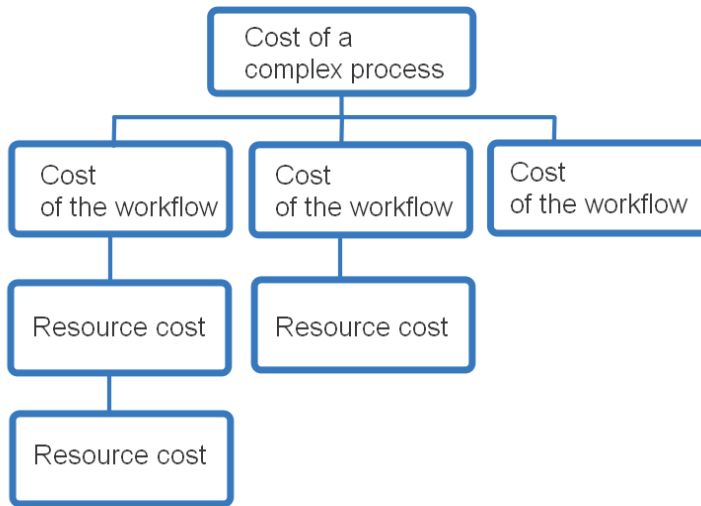
The list of non-modeled works is necessary to include them in the General list of performed works (in the list of work volumes), followed by assigning prices for such types of work. The list of non-modeled works must be previously agreed with the customer and specified in the project implementation plan.

### 3. The creation of the bill of quantities

- Define scope of work
- Calculation of the duration, volume and cost of work
- Maintaining a hierarchical structure of types of construction and installation works
- Maintaining standard indicators of construction processes:

- Time standards for estimating the duration of work
- Norms and prices for various details of the construction and installation work processes
- Labor costs
- Resource consumption per unit of work volume
- Maintaining a resource database
- Integration with calendar and network planning programs and other external systems

Figure 1 shows a tree of work types that displays the composition of complex and work processes.



**Fig. 1.** Tree of types of work.

#### 4. Uploading unit prices and planned dates to the BIM model.

Entering the agreed prices into the element parameters specially created for this purpose is also one of the most important stages of preparing the model for the CIC. Planned dates should also be included in the model elements.

Individual prices are loaded after Selecting and Contracting a contractor. Before that go:

- Formation and approval of tenders
- Conducting tender procedures. Comparison of submitted offers and selection of the winner
- Mapping of normative documents on the progress of the contractual relationship with the contractor

#### 5. Unloading a bill of quantities

After all the parameters are filled in, the filtered elements are exported to Excel. The monthly cycle of investment control

Stages of the monthly cycle

- Photo recording of the construction site
- Entering data on work performed by the General contractor into the BIM model
- Approval of Completed works by the Customer's technical supervision service
- Formation of construction acceptance certificates forms
- Preparing a monthly report

#### 6. The completion of the

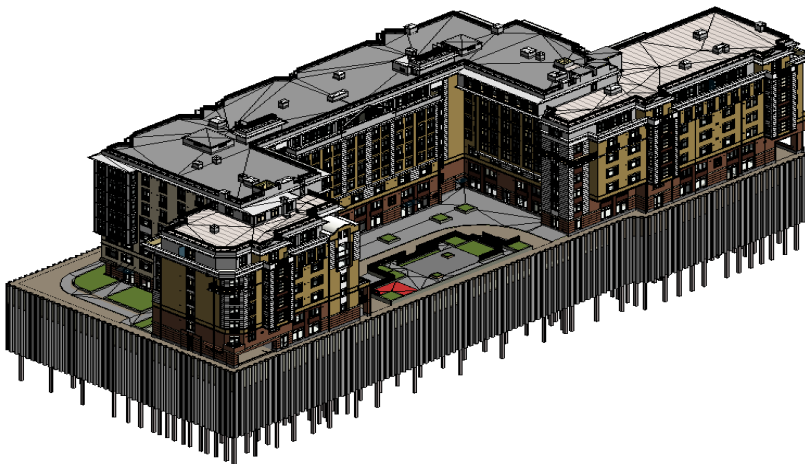
During the control process, the so-called "status" is added to the model elements, which reflects the current status of the type of work on the construction site. Table 2 below shows the proposed statuses, their description, and color display in the model.

**Table 2.** Statuses of model elements defined in the CIC process.

Statuses defined in the framework of construction con		Description	Color display
NOT STARTED		Work not started	Grey/transparent
STARTED	NOT BUILT	Work has started, the front of subsequent work is not formed	
	BUILT	Readiness IS less than 80%, 0% is accepted for the act of acceptance certificate	Red
		Readiness from 80% TO 99%, 95% is accepted for the act of acceptance	Yellow
		100% ready, 100% is accepted for the act of acceptance	Green

### 3 Results and Discussion

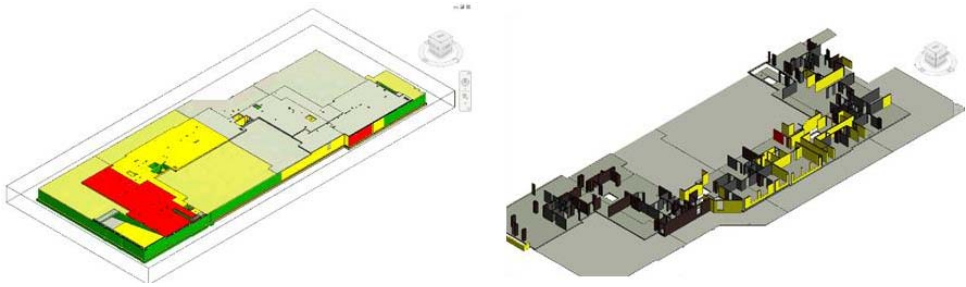
As an example, we consider the project of a residential complex, which is made in the level of detail LOD400. Figure 2 shows the General view of this building.



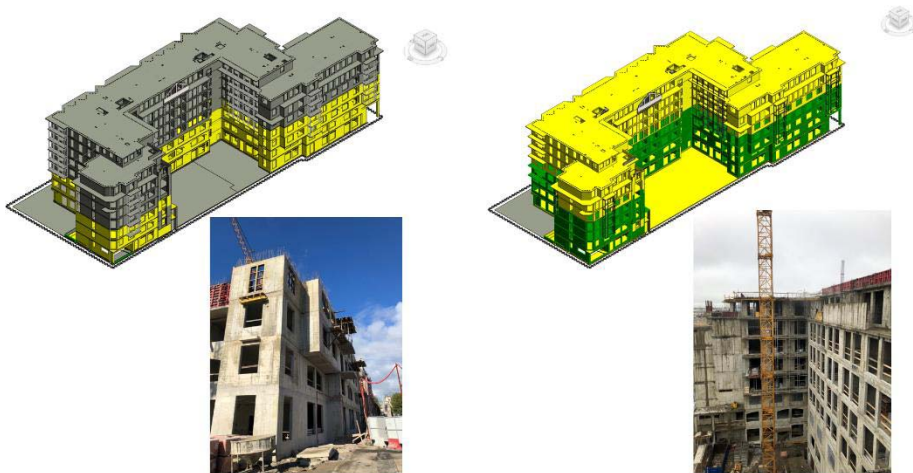
**Fig. 2.** General view of the building for the CIC.

Model elements are related to their attribute content. Redefining the graphics in the view depends on the item's status value. The division into "statuses" is shown in table 2.

Thanks to the proposed CIC method, the customer can clearly see the installation process and the condition of the building elements. By updating the model after each check, you can monitor the construction process online. Figures 3 and 4 show the entire layout and building in accordance with the actual installation process on the site.

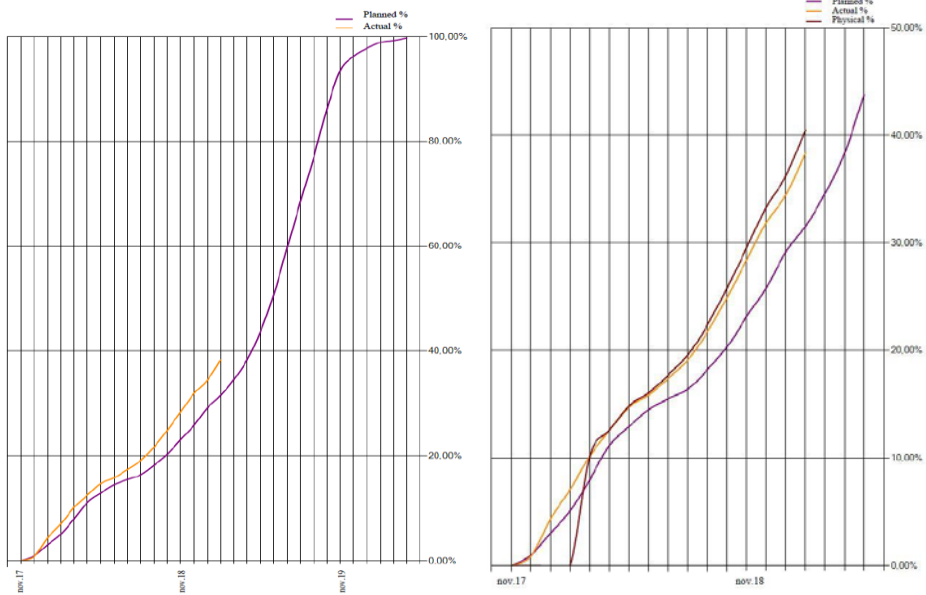


**Fig. 3.** Floor plans of the building in the process of conducting the CIC.



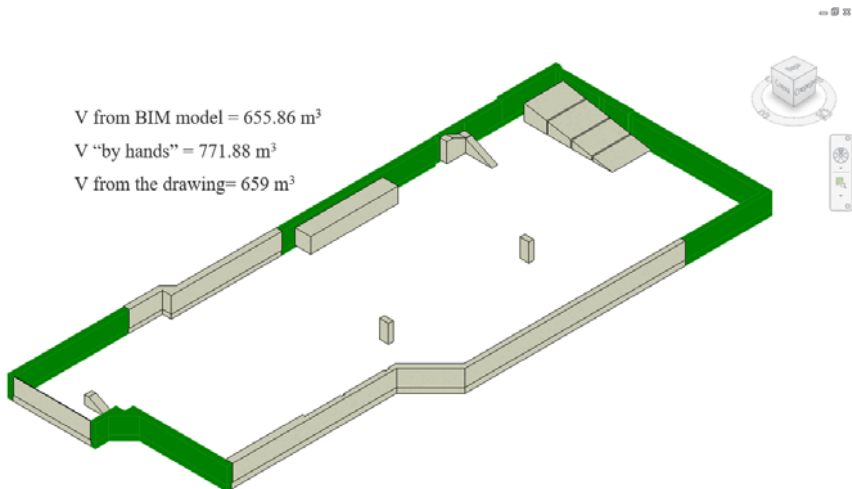
**Fig. 4.** Relations between elements in reality and the information model.

Another important result of the method of investment control of construction through the use of 3D models is the ability to plan the financial side. In the graphs in figure 5, you can see the dependence of the cash flow on time. This approach allows you to plan how much money you will need to invest in the next month. Such forecasting helps the customer determine the amount that they need to have in stock, which makes it possible to better control the economic component of the construction project.



**Fig. 5.** Diagrams of dependence of investments from time to time.

Another advantage of using information modeling in CIC is an accurate estimation of the volume of structures and materials. Backfill was considered as an example. As shown in figure 6, the volume of sand obtained from the model differs significantly from the volume calculated by "hands".



**Fig. 2.** Backfill volume data.

In figure 8 , we can see a comparison of data on the volume of backfill sand obtained from the construction site, from the model and from the drawing. As can be seen from figure 9, the data obtained from the model are most accurate as they take into account all the "bumps" allow "rounding" of volumes in favor of the contractor, which is an advantage for the customer, as he has the right to refer to the volumes calculated automatically from the model as the most reliable because there is no influence of the so-called human factor.

On April 25 (Wednesday) from the General Contractor, an executive scheme for the work "Backfilling" was received, the data in which differed from the data received on April 23:

- according to the data sent on April 23 - 771.88 m<sup>3</sup>
- the next data, from April 25 - 659 m<sup>3</sup>
- data obtained from the model - 655.86 m<sup>3</sup>

**Fig. 3.** Data on the volume of backfill sand obtained from the construction site, from the model and from the drawing.

## 4 Conclusions

BIM technologies can be successfully applied to the most important stage of construction – investment control. As it was shown, the 3D model allows you to continuously monitor investment in construction, manage monetary resources, and predict their availability for the successful next closing of the reporting period.

The CIC methodology using the building information model was successfully developed and applied in the construction of a residential complex. accurate data from the BIM model allowed reducing the amount of money paid for the amount of work.

Advantages of using BIM for investment control:

- Reducing the risk of financial losses from unreliability of information about the actual volume of work performed;
- Increase the speed of preparation of work completion reports and investment control reports for construction;
- Getting reliable information about changes made to BIM models and project documentation;
- Creation of infrastructure for carrying out investment control procedures for construction to control subcontractors;
- Project cost estimation at each stage;
- Detailed calculation to the final structural element of the BIM model;
- Increasing the speed of building cost estimation;
- Reducing the impact of the human factor.
- The use of BIM technologies for CIC allows you to:
  - Enter into a contract for a fixed price-minimizing the risks of additional work
  - Build an accurate financial forecast and plan/fact comparison
  - Automatically generate acts, keep cumulative records
  - In the monthly report, you can clearly see the progress of construction ahead or behind (based on physical volumes and development of financial re-sources).

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