UDC624

ANALYSIS OF THE CONSTRUCTION CONTROL PROBLEMS AT THE SITE USING BIM RESOURCES

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Introduction

The organization of the worksite is the fundamental phase of the construction process. It consists of works that have to be aligned and coordinated with the previous phases (conception, planning, programming, design). And it requires rational use of resources (machines, tools, materials), people (manpower), time, and money. The constant need to cover lower costs while maintaining an environmentally sustainable approach that produces as little waste as possible, with the best quality end product, is the new trend of the construction task.

The progress of construction work, whether it is behind or ahead of schedule, the ratio of construction phases to costs - this information is the most important for making accurate and timely management decisions. It is primarily in the interest of the Client and the Investor.

The proliferation of new information technologies and discoveries in this field are driving a change in the view of construction. Due to the developments of software companies in the field of programming and parametric design, 4D (time), and 5D (cost) technologies, it is possible to directly prepare an estimate for each material used and a schedule of works. The ability to manage project phases in terms of operational planning and site management will be ensured

The development of BIM comes from the growing need for simplifying the construction process regarding project implementation and management by optimizing the various phases of work planning: design, construction, exploitation, and demolition.

CAD and BIM

CAD (computer-aided design) applications simulate the traditionally manual process of drawing with paper and pencil in two dimensions. The CAD drawings are created independently from each other, just like in the case of a manual drawing. Therefore, each file modification has to be reviewed and edited manually on each drawing. If we modify an element in the plan, we have to modify it also in other views (elevations and sections). It makes a lot of time-consuming and risks possible errors in the modification process.

On the other hand, BIM modeling applications simulate the real building process. Instead of creating drawings with 2D lines, the application generates a virtual building by virtually simulating real building elements: such as walls, windows, floors, columns, roofs. That, in turn, contains information about materials, specifications, manufacturers, and prices. So, since all data are held in a central virtual model, design changes are automatically detected and applied to all individual drawings generated by the model. This system prevents unexpected design changes caused by errors made during the construction phase.

Figure 1 shows the "MacLeamy Curve" which summarizes the usefulness and impact of BIM in the construction industry

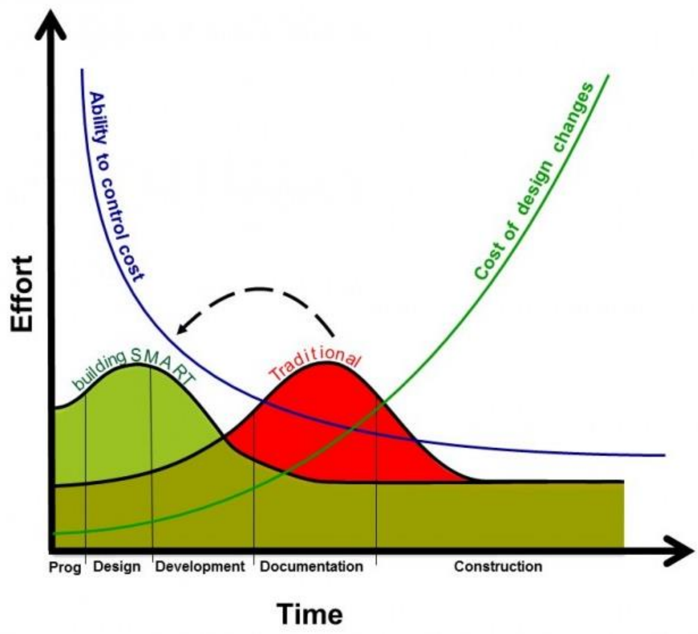


Figure 1 MacLeamy Curve

This curve represents the normal distribution of the design process with a peak of effort and resources located in the middle of the documentation phase and shows how BIM moves this peak closer to the beginning of the project. The curve also demonstrates that effective design changes are most easily and cheaply made early in the process, but least effective and most expensive later in the process (1).

Obviously, in traditional methodology (red), most of the required effort occurs during documentation implementation. With BIM (green), the curve moves to the left, which means that the most effort is required earlier in the process. In contrast to the traditional method, where changes to the project that have not been previously defined will occur during the construction phases. This will lead to a significant increase in costs and labor costs.

Methodology

The metric calculation was done for the architectural part of the Administrative Building of the Embassy of Belarus in the Republic of Kazakhstan (2).

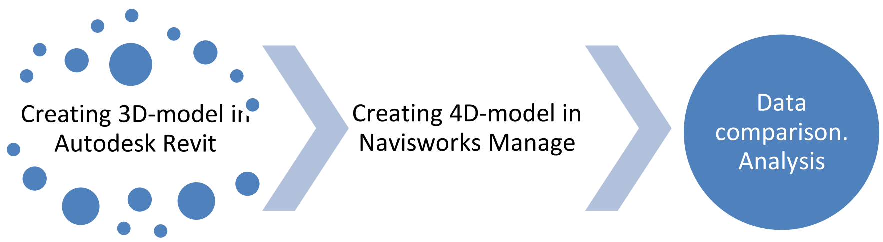


Figure 2. Methodology stages

The purpose of this work - to determine whether the use of BIM methodology, compared with traditional, can achieve significant savings in time and resources, maintaining the reliability of the project, prepare a method of automating of scheduling development, and evaluate the result of its application. (Figure 2)

The task is to check whether the two found calculations coincide. Otherwise, if they diverge, we will deepen the possible reasons that may lead to this inconsistency. We will also check for interoperability between Autodesk Revit 2021 and Navisworks Manage 2021.

Building concept

The project is designed administrative three-story building with a basement floor and engineering space for air conditioning on the roof. The above-ground part of the building has dimensions in the axes 28,875x28,375m. (Figure 3)

Structurally, the building is designed in a monolithic reinforced concrete frame with load-bearing walls and flat slabs.

Structurally, the building is designed in a monolithic reinforced concrete frame with load-bearing walls and flat slabs. The spatial stability is ensured by the joint work of the columns, walls, and slabs which form horizontal disks at the floor level

Figure 3. Administrative Building of the Embassy of Belarus

*Stage 1**.** Creating 3D-model. From CAD to Revit*

The 3D model is created from 2D drawings using Autodesk Revit software, and the construction schedule (duration and coordination of work on the worksite) is based on the existing "paper" schedule.

Based on the building plan we proceed the modeling of the architectural part with the Revit software. We implemented our BIM model with a level of development (LOD) equivalent to LOD400.

Each structural element is defined in the identification process, covering quantity, size, location, and material. The model also provides analytical data related to material properties such as heat transfer coefficient, thermal resistance, absorption.

Traditional calculation

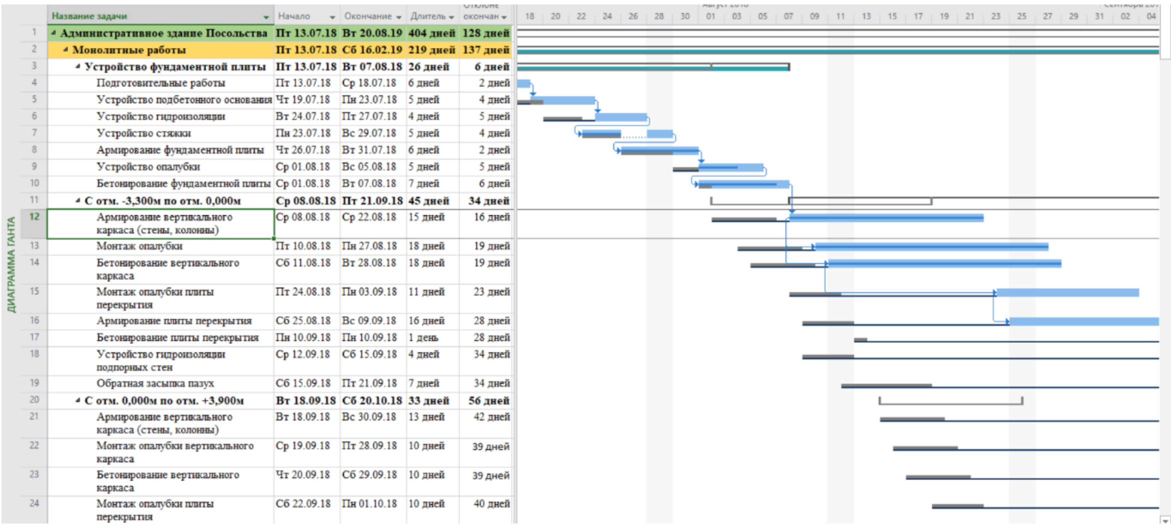
According to the PCO (the project of the construction organization) (3) duration of construction takes according to SP RK 1.03.102-2014 Timeframe rates for construction and pre-construction work in construction of enterprises, buildings and structures. Part II, Section B.5.1 "Residential buildings," Table B.5.1.1 p 4 "Three-story monolithic building" with the standard 1800 m2 with a construction period of 8 months (4).

The duration of construction of the Administrative Building of the Embassy of the Republic of Belarus is 8 months. Including preparatory period - 0.6 months, underground - 1 month, above-ground part - 5 months, finishing - 1.5 months.

According to the approved schedule, construction of the administration building was done in 9 months.

Stage 2. Creating 4D-model. From Revit to Navisworks

- The first step was to export the Revit model in NWC (Navisworks Cache) format. The format is designed to describe the data and objects of the model, making it compatible with Navisworks Manage 2021. It is essential to check the model for collisions and correct them.
- Create a progress schedule with a predefined work duration from paper in the MS-Project program and export it to Navisworks



	Название задачи	Начало	Окончание	Длитель	Отклоне окончан
1	**Административное здание Посольства**	**Пт 13.07.18**	**Вт 20.08.19**	**404 дней**	**128 дней**
2	**Монолитные работы**	**Пт 13.07.18**	**Сб 16.02.19**	**219 дней**	**137 дней**
3	**Устройство фундаментной плиты**	**Пт 13.07.18**	**Вт 07.08.18**	**26 дней**	**6 дней**
4	Подготовительные работы	Пт 13.07.18	Ср 18.07.18	6 дней	2 дней
5	Устройство подбетонного основания	Чт 19.07.18	Пн 23.07.18	5 дней	4 дней
6	Устройство гидроизоляции	Вт 24.07.18	Пт 27.07.18	4 дней	5 дней
7	Устройство стяжки	Пн 23.07.18	Вс 29.07.18	5 дней	4 дней
8	Армирование фундаментной плиты	Чт 26.07.18	Вт 31.07.18	6 дней	2 дней
9	Устройство опалубки	Ср 01.08.18	Вс 05.08.18	5 дней	5 дней
10	Бетонирование фундаментной плиты	Ср 01.08.18	Вт 07.08.18	7 дней	6 дней
11	**С отм. -3,300м по отм. 0,000м**	**Ср 08.08.18**	**Пт 21.09.18**	**45 дней**	**34 дней**
12	Армирование вертикального каркаса (стены, колонны)	Ср 08.08.18	Ср 22.08.18	15 дней	16 дней
13	Монтаж опалубки	Пт 10.08.18	Пн 27.08.18	18 дней	19 дней
14	Бетонирование вертикального каркаса	Сб 11.08.18	Вт 28.08.18	18 дней	19 дней
15	Монтаж опалубки плиты перекрытия	Пт 24.08.18	Пн 03.09.18	11 дней	23 дней
16	Армирование плиты перекрытия	Сб 25.08.18	Вс 09.09.18	16 дней	28 дней
17	Бетонирование плиты перекрытия	Пн 10.09.18	Пн 10.09.18	1 день	28 дней
18	Устройство гидроизоляции подпорных стен	Ср 12.09.18	Сб 15.09.18	4 дней	34 дней
19	Обратная засыпка пазух	Сб 15.09.18	Пт 21.09.18	7 дней	34 дней
20	**С отм. 0,000м по отм. +3,900м**	**Вт 18.09.18**	**Сб 20.10.18**	**33 дней**	**56 дней**
21	Армирование вертикального каркаса (стены, колонны)	Вт 18.09.18	Вс 30.09.18	13 дней	42 дней
22	Монтаж опалубки вертикального каркаса	Ср 19.09.18	Пт 28.09.18	10 дней	39 дней
23	Бетонирование вертикального каркаса	Чт 20.09.18	Сб 29.09.18	10 дней	39 дней
24	Монтаж опалубки плиты перекрытия	Сб 22.09.18	Пн 01.10.18	10 дней	40 дней

Figure 4. Progress schedule in MS Project

* A Gantt chart is planning, task management tool invented by American engineer Henry Gantt. It looks like horizontal bars located between two axes: a list of tasks vertically and dates horizontally. The diagram shows not only the tasks themselves but also their sequence, duration (5) (Figure 4)

- For comparison, enter the actual construction time taken from the engineer's reports and revisions.
- Synchronize the complex three-dimensional model (3D) with the project schedule, which allows you to analyze the model for conflict in space and time and inconsistencies in the workflow sequence
- Attach objects to the schedule in automatic and manual mode

Stage 3. Data systematization and analysis

From the engineer's reports, we can see that due to weather conditions and design adjustments (which resulted in a lack of construction readiness for subsequent work), the building took about 404 days to construct, 128 days longer than planned. Errors in the design could have been corrected at the initial design stage on the digital twin building.

Having collected enough examples of this type of report and having a ready estimate in hand, it is possible to anticipate the cost of production delays. And eliminate them at an early stage.

Results

Given the specifics of the project, the estimated metric calculation was made first using the traditional model and then using the BIM model made with Autodesk Revit. We obtained a parametric model using Navisworks software and, as a result, compared the planned work schedule with the actual deadlines.

Let's compare, for example, the timeframe for the monolithic works - the installation of the vertical frame and floor slabs - according to the approved schedule and the actual timing. (Figure **5**)

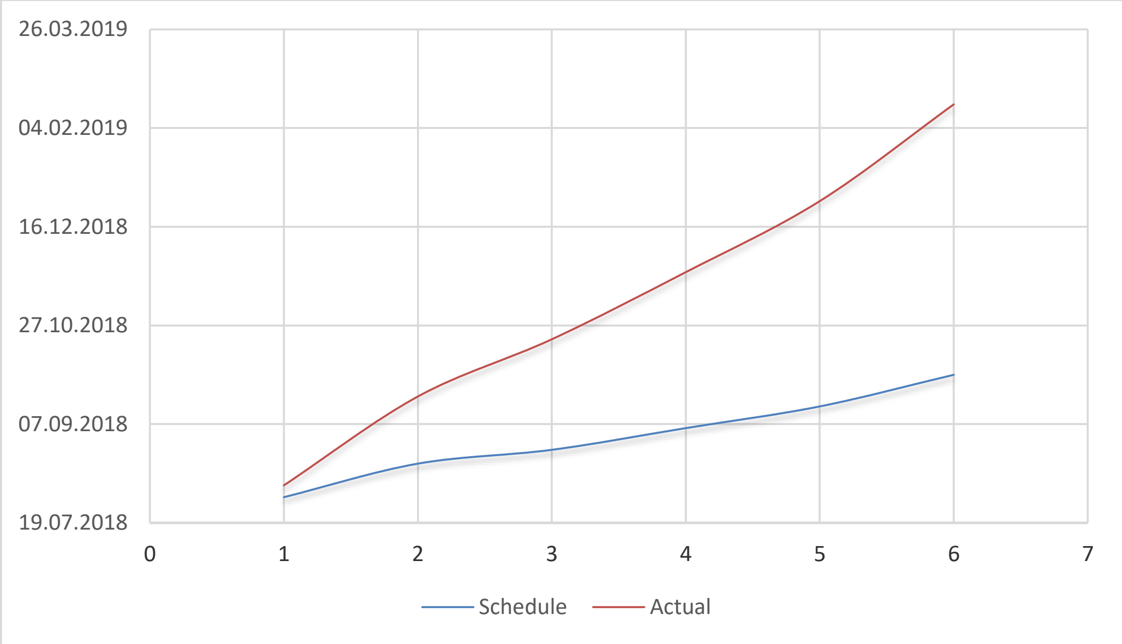


Figure 5. Comparative diagram of the timing of monolithic works

Here we see that the monolithic work lasted 137 days longer than the approved plan. Among the main reasons were changes in the project, which required the approval of the design institute, the Customer, the General Contractor, and Subcontractors. And each part of this link takes time - to send an official letter, wait for a response, if it is rejected, then come up with a new solution. So there were changes in the design decision of the building frame of permanent formwork with cement - chipboard on a monolithic frame with precast concrete formwork, nodes on the adjacencies of the vertical frame were introduced. Double-shift works of monolithic operations were organized for reducing delays.

Also from the reports and minutes of the meeting, we can see that disruptions in the supply of materials and equipment frustrated the order and duration of the work.

Uncoordinated work of warehouse managers and site supervisors led to the fact that unused formwork, lying in the building, prevented the start of masonry work on time.

Conclusion

In general, the visual model of the construction organization allows to solve 4 main problems:

- Develop a schedule of works coordinated in time and space
- Check the feasibility of organizational and technological solutions, identify conflicts, and find solutions to overcome them
- Optimize use of available resources
- Reduce construction time and costs through optimization of organizational and technological solutions and logistics at the worksite.

Can all these problems be solved using only the network model in the form of a Gantt chart with resource diagrams? Well, you can, but it requires more qualification and experience of engineering and technical staff and management. The visual model improves the quality of decisions and reduces the timing and approvals by several times. This is the reason for the economic effect of using the 4D model.

Reference

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