# BIM FOR EFFECTIVE PROJECT MANAGEMENT DURING THE EXECUTION PHASE

**Nikola Knežević[1], Marija Grujić[2]**

*[1]Faculty of Civil Engineering, University of Belgrade, Serbia; [2]Faculty of Civil Engineering, University of Belgrade, Serbia*

**Abstract**: Construction projects always involve a large number of participants, and managing a vast amount of information is necessary. Additionally, each project is unique, further complicating management challenges. Construction projects are exposed to a wide range of risks. These problems have been recognized, leading to the emergence of the need for new project management systems using information technology. The fundamental idea of Building Information Modeling (BIM) is to create a digital model of a building, which also serves as a centralized database to be used in all project lifecycle stages. This paper aims to present the achievements so far in the context of 4D and 5D BIM, demonstrating its capabilities through an example in the construction phase of a building.

**Keywords**: 4D BIM, 5D BIM, Construction Management, Planning, Cost

## 1. INTRODUCTION

Project management in large real-estate investments requires an extensive organizational resource base. Project management is continuously a very demanding job, since it is managing a large number of project stages and many teams from different disciplines that are involved in project implementation (designers, subcontractors, equipment suppliers, material suppliers, consultants, etc.).

Project management requires interdisciplinary knowledge. Designing projects and creating technical documentation are the most complex activities because these processes are pathways from an idea to the beginning of building construction. The modern approach to project management is based on information technologies that provide an integrated work concept, an integration of all phases of building development, from an idea to the design, construction and maintenance of the facility.

Not so long ago, project management in building construction was a significantly more difficult process. Designs and management schemes were created manually, hand drawn on paper, which required a lot of time. Also storing this technical documentation required large infrastructure (spaces). Since different involved disciplines required different kinds of drawings, adjustment of one to another and coordination in-between required a lot of back and forward communication processes. It often resulted in a lack of accuracy and many disharmonized details. During the implementation (construction) of the building design, these problems stood out, not only because of the problems mentioned above, but also because of the lack of its understanding.

The progress of information technologies has significantly changed many industries, among them the construction industry. Computer-aided drawing, such as well-known AutoCad software, appeared during the 1990is, but many problems remained the same. Certain progress was obvious, drawing speed improved, speed of revisions and changes in design, easier checks to see if the drawings are consistent,... Although today it doesn't seem like it, this was a significant improvement. With upgrades of these solutions, 3D modeling was introduced. It offered new possibilities in design and in projects. Technical documentation (floor plans and cross-sections) is extracted from the 3D model, thereby shortening the design time and facilitating the process of harmonizing different projects.

New challenges appeared in information technology in construction after the introduction of the 3D model. It was challenging to upgrade 3D models in n-dimensional space including 4D, 5D, 6D,... Modeling started from 3D where it is possible to assign additional information to the geometry, from defining the category of the element (column, window, door) to its characteristics, functions and properties. After that, the model is expanded by assigning the duration of certain activities and linking them to the schedule, which results in 4D. Upgrading the model with a financial plan leads us to 5D, the energy efficiency of the building in exploitation leads us to 6D, maintenance of the building in the exploitation period to 7D,... This is the basic idea behind the creation of the Building Information Model (BIM), which is continuously developing.

The goal is that BIM contains all the necessary information about the building, that is, to be a centralized database of a building, and to perform all the necessary analyses and extract all the necessary information within its framework, and as such provides excellent conditions for project management from conception to demolition.

Given that the benefits of using 3D BIM have already been recognized and a large number of construction companies use it for the creation of project documentation (floor plans, sections, and quantity take-off), the focus of this paper is to point out the benefits brought by the fourth and fifth dimensions of BIM, in order to get the most out of it.

## 2. BIM USE IN THE CONSTRUCTION PHASE

Time and costs are important for all participants during the implementation of the project, which is why in order for the construction project to be successful, it is necessary to make adequate schedules and financial plans. Well-known schedule planning methods are: network plan, Gantt chart and line of balance, while for cost control, cash flow and Earned Value Method (EVM) are used. Because of the importance of these analyses and plans, BIM has a time dimension (4D) (Martins et al., 2022) and a cost dimension (5D) (Abdel-Hamid & Abdelhaleem, 2017; Mukkavaara et al., 2016; Smith, 2016).

### 2.1. DIMENSION OF TIME (4D BIM)

Software such as Microsoft Project, Primavera, etc. are often used for the creation of schedule plans. The difficulties that occur when using only this software are strongly related to the individual operation of the building design software and the schedule design software, without the possibility to update new project data, which may arise during the execution phase, simultaneously in both software, after changes have been made. Also, in the before mentioned schedule design software, in order to clearly define the tasks, in addition to naming and describing them, it is usually necessary to create additional sketches, after which there may be omissions. 4D BIM integrates these existing approaches by creating schedule plans and adds the ability to link them to the 3D model (spatial dimension of the building) and thus overcomes these problems.

It is also necessary to mention the possibility of generating an animation or simulation of building construction, which, in addition to its commercial capabilities, provides the planner with an additional tool for checking the quality of the schedule plan. In this way, the planner can immediately see if the tasks, their connections and dependencies are well set, and if the construction order of the schedule plan is correct.

## 2.2. COST DIMENSION (5D BIM)

Reviewing project costs is one of the most important analyses of construction projects. In order for the contractor to be able to form his prices, the contractor needs to look at the direct and indirect costs of the project, as well as the scope of work. Construction projects are complex and have a large number of work positions, and therefore it is necessary to carry out this analysis in a systematic way in order to achieve the highest possible accuracy. The fifth dimension of BIM provides the tools for the contractor to create his own project control, that is, to create his Quantity take-off based on the existing 3D model and then, similar to the fourth dimension, to define the costs and assign them to the appropriate elements.

## 2.3. ANALYSIS OF 4D AND 5D BIM WITH EXAMPLES

Now certain possibilities which are offered by 4D and 5D BIM will be analyzed and presented through Bexel Manager software (Bexel Consulting, 2023).

At the beginning, we can define all the necessary resources within the project, which will later be needed for the execution of our tasks within the schedule, with their unit cost per unit of measurement (Figure 1).

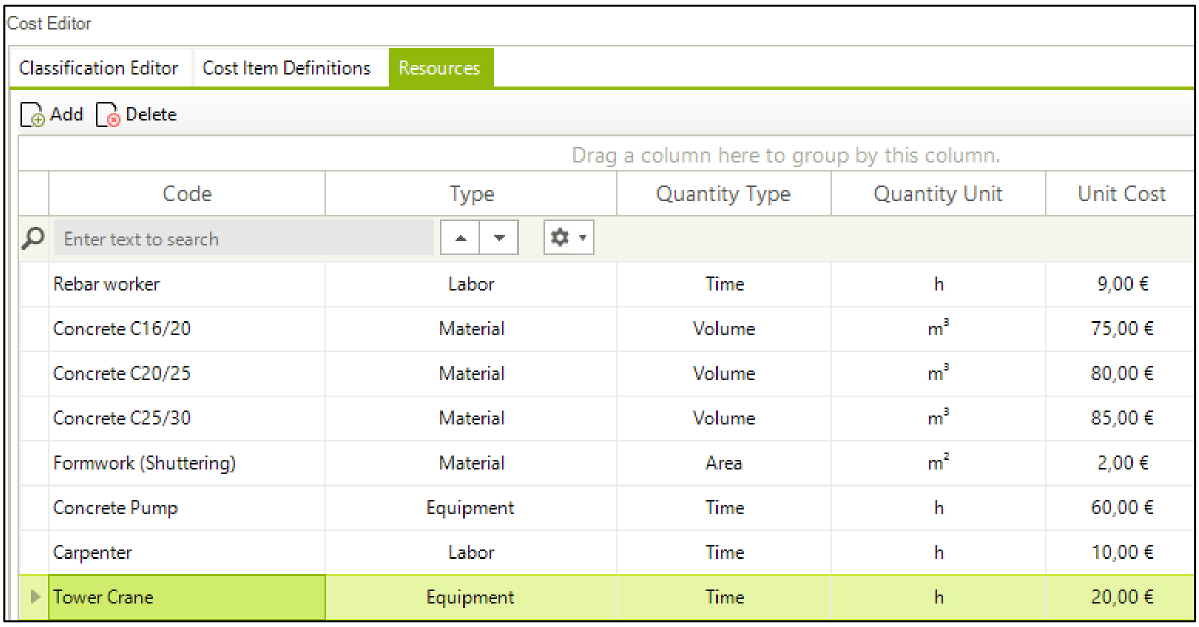
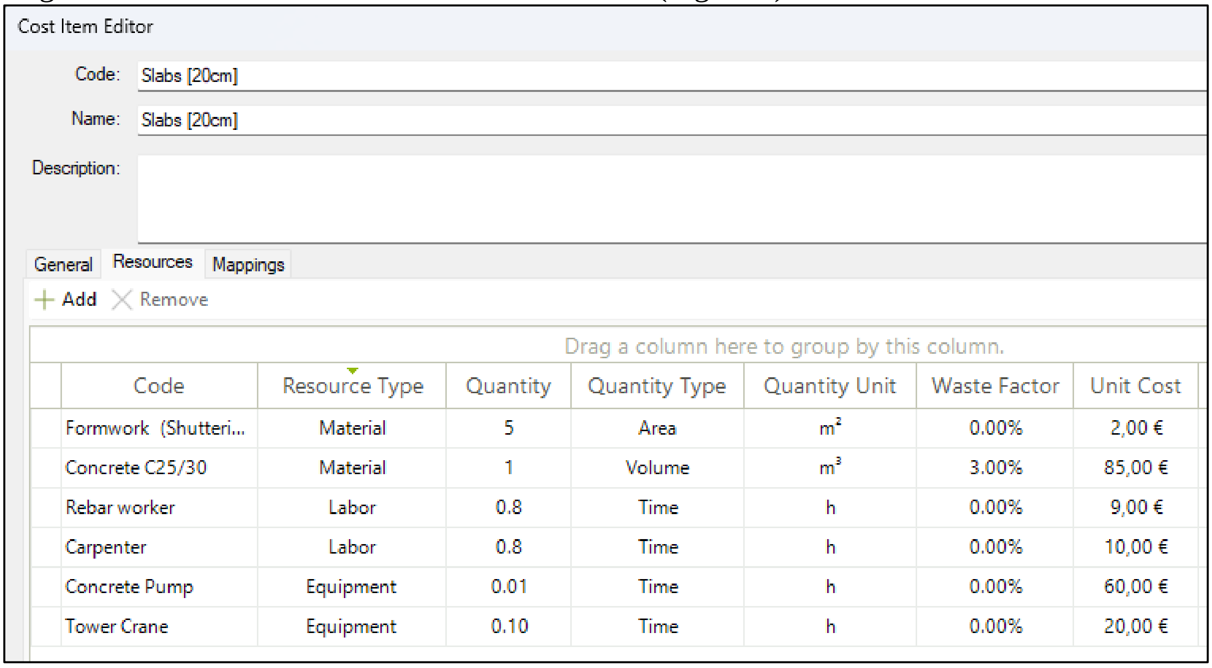



**Figure 1.** Defining resources

Then, for each type of work, the resources required for its execution are selected from the previous database (Figure 1), and the average quantity of resources required to complete a single unit of measurement for the work is defined (Figure 2).




| Code | Resource Type | Quantity | Quantity Type | Quantity Unit | Waste Factor | Unit Cost |
|---|---|---|---|---|---|---|
| Formwork (Shutteri... | Material | 5 | Area | $m^2$ | 0.00% | 2,00 € |
| Concrete C25/30 | Material | 1 | Volume | $m^3$ | 3.00% | 85,00 € |
| Rebar worker | Labor | 0.8 | Time | h | 0.00% | 9,00 € |
| Carpenter | Labor | 0.8 | Time | h | 0.00% | 10,00 € |
| Concrete Pump | Equipment | 0.01 | Time | h | 0.00% | 60,00 € |
| Tower Crane | Equipment | 0.10 | Time | h | 0.00% | 20,00 € |

**Figure 2.** Adding resources to types of works

This way, we have defined the cost of this item per unit of measure - "Unit Cost" (Figure 3). It is also possible to add other costs that are not expressed through a specific resource: "Subcontractor Cost", "Other Cost",... (Figure 3). Costs should always be defined through resources if possible, so they can be used later for further analysis (Figure 6 and Figure 7).

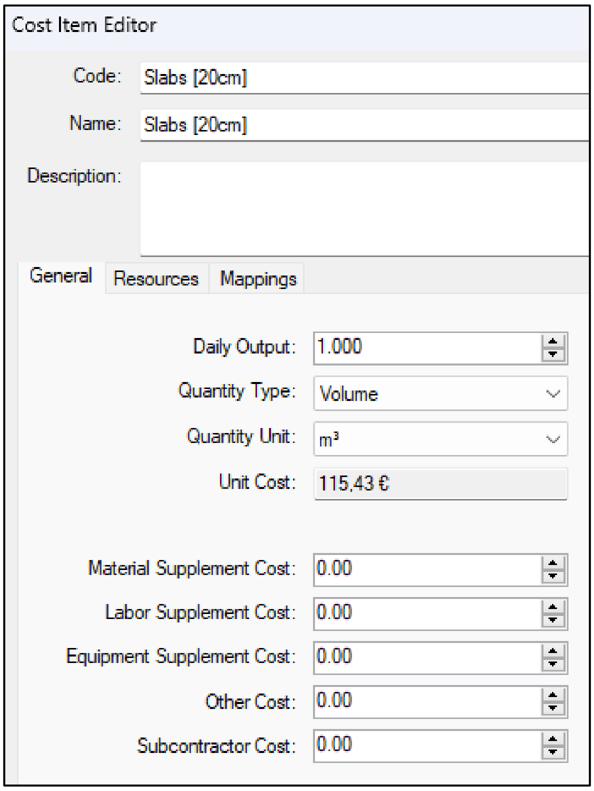



**Figure 3.** Defining unit costs for types of works

This can now be linked to the elements of the 3D model and its geometry, through which the cost estimate is calculated (Figure 4).

| Name | Quantity | Unit | Unit Cost | Material Cost | Labor Cost | Equipment Cost | Base Construction Cost |
|---|---|---|---|---|---|---|---|
| Classification | | | | 89.199,91 € | 13.943,58 € | 2.591,95 € | 105.735,44 € |
| Types of works | | | | 89.199,91 € | 13.943,58 € | 2.591,95 € | 105.735,44 € |
| Reinforced concrete works - Reinforced concrete works | | | | 89.199,91 € | 13.943,58 € | 2.591,95 € | 105.735,44 € |
| Beams - Beams | | | | 9.757,40 € | 1.519,15 € | 259,85 € | 11.536,40 € |
| Beams 25x40 - Beams 25x40 | 99.944 | $m^3$ | 115,43 € | 9.757,40 € | 1.519,15 € | 259,85 € | 11.536,40 € |
| Columns - Columns | | | | 989,51 € | 204,25 € | 215,00 € | 1.408,76 € |
| Columns [25x25cm] - Columns [25x25cm] | 10.750 | $m^3$ | 131,05 € | 989,51 € | 204,25 € | 215,00 € | 1.408,76 € |
| Foundations - Foundations | | | | 158,59 € | 30,40 € | 32,00 € | 220,99 € |
| Footings [50x50cm] - Footings [50x50cm] | 1.600 | $m^3$ | 138,12 € | 158,59 € | 30,40 € | 32,00 € | 220,99 € |
| Slabs - Slabs | | | | 78.294,40 € | 12.189,79 € | 2.085,09 € | 92.569,28 € |
| Slabs [20cm] - Slabs [20cm] | 801.960 | $m^3$ | 115,43 € | 78.294,40 € | 12.189,79 € | 2.085,09 € | 92.569,28 € |

**Figure 4.** Cost Estimate

Now we can read this information from the model itself (Figure 5). It is also important to note that if we decide to make a change about a resource (for example add or remove a resource), our cost estimate will be updated.

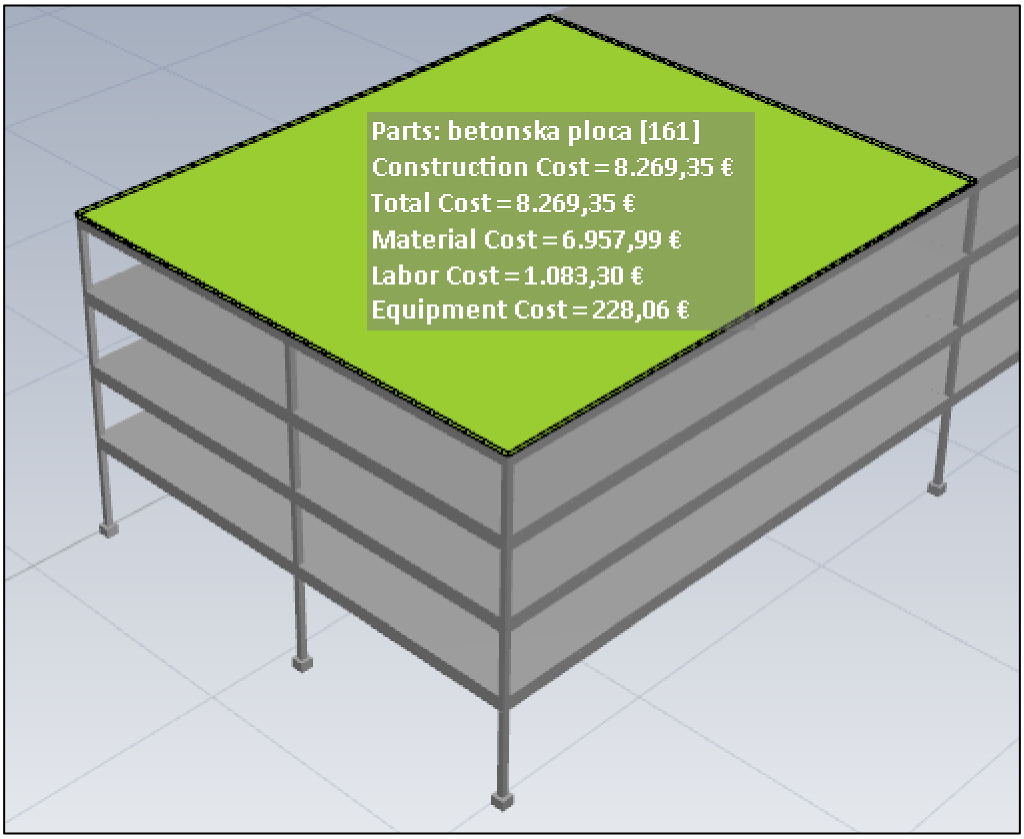



**Figure 5.** Preview of cost estimate on the 3D model

Here we can already highlight certain advantages of this approach, and they appear in the process of creating the schedule. The schedule consists of tasks, and by assigning elements from the 3D model to those tasks, we have a cost estimate for that task and the quantity of required resources.

Depending on the duration of the task, the resource requirements change. In order to be able to create a precise schedule, it is necessary to make an adequate resource allocation. Figures 6 and 7 show the required quantity of resources for the same task. In Figure 6 the task lasts 5 days, while in Figure 7 the task lasts 4 days. Analyzing only the carpenters, we can see in Figure 6 that we need an average of 1.14 carpenters to complete this task by the planned deadline. If one worker were to be adopted, there would be two outcomes: either the worker would have to achieve 14% higher performance within the work shift or he would have to work longer. In Figure 7, we have an average of 1.45 and we can ask the question, of whether to adopt one or two workers. In a similar way, we can look at other resources and make certain decisions.

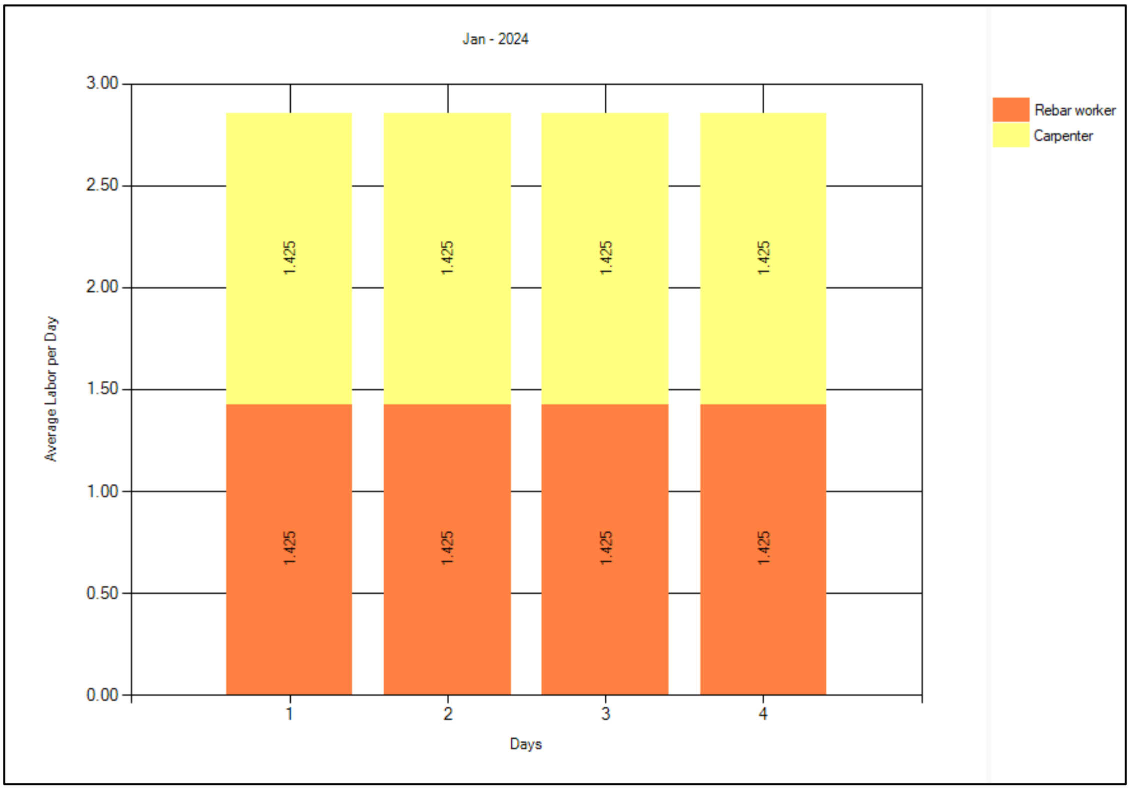



**Figure 6.** Required labor for the task that lasts 5 days

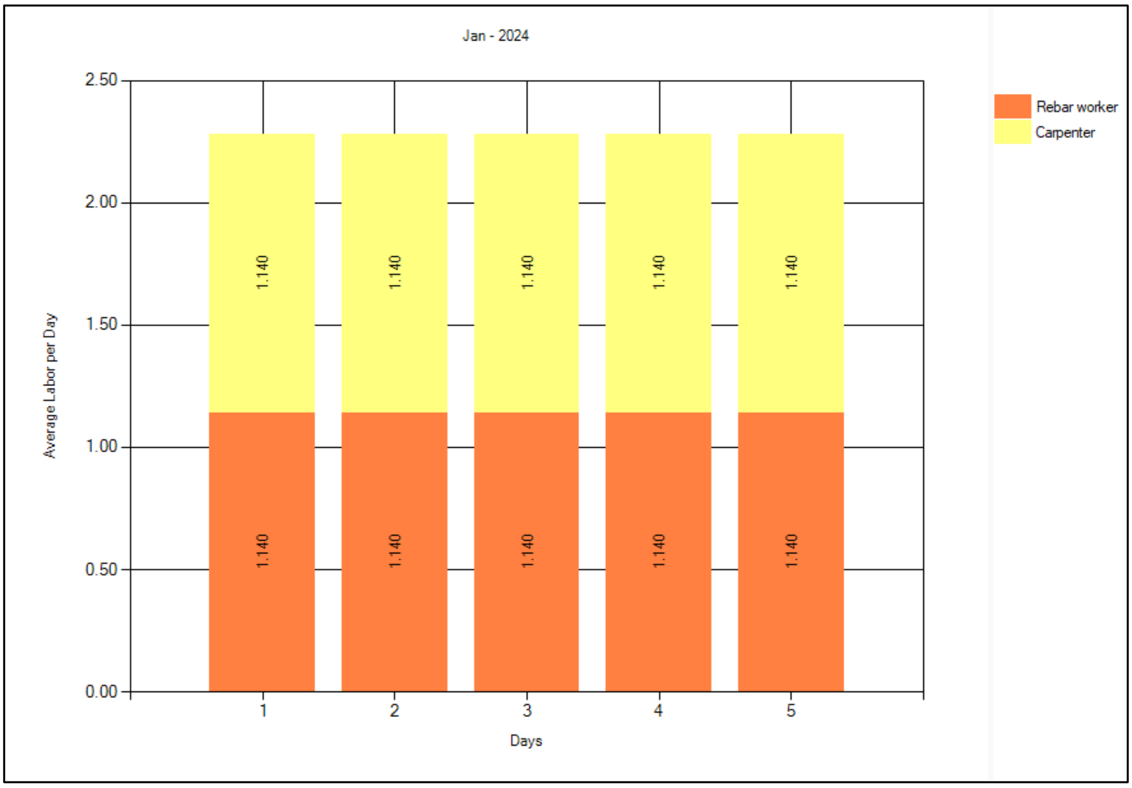



**Figure 7.** Required labor for the task that lasts 4 days

Finally, once the construction on site begins, the progress can be tracked by selecting and marking elements from the model which were executed, with adding additional information about the actual quantities and costs. Based on this data, work trends can be established and monitored through the Earned Value Method (EVM).

## 3. CONCLUSION

In the end, it can be concluded that BIM brings numerous advantages to construction management due to the well-organized structure of data, and because of that it is easier to make cost and time optimizations among others. Also, errors can be found more easily and eliminated faster. The use of BIM in all phases of the project's life cycle brings a comprehensive approach, where 4D and 5D give greater control over the project during the execution phase.

The obvious advantages are:

- The comprehensiveness of the virtual model, which describes the project in detail, including geometry, materials, costs, planned time for its completion…,
- more effective collaboration and communication of the participants on the project due to easy access to information which allows us to minimize errors,
- the possibility of thorough analysis and simulations of the project, both before and during the execution phase,
- cost optimization possibilities and easy monitoring of costs during construction.

Finally, BIM has significant advantages over traditional design and planning methods and has proven to be a necessary tool for modern and efficient construction management.

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