



## BIM-Based tool for visualizing the EVM technique

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### ملخص البحث

عملية المراقبة والتحكم تشرف على جميع المهام والمقاييس اللازمة لضمان أن المشروع المعتمد والمخول هو ضمن النطاق وفي الوقت المحدد وعلى الميزانية المحدد لها، بحيث يستمر المشروع بأقل قدر من المخاطر، و تتم عملية الرصد والتحكم بشكل مستمر طوال عمر المشروع، و أصبح الرصد والتحكم صعبا بسبب زيادة تعقيد المشاريع في الأيام الحالية، وقد عجلت تكنولوجيا BIM من الاستجابة لضغوط التعقيد المتزايد للمشاريع، واحدة من أهم الفوائد لتكنولوجيا BIM هو التصور لجميع العناصر ومكونات المبنى، وبالتالي، في هذا البحث هو تصور لأداء المشروع باستخدام تقنية إدارة القيمة المكتسبة (EVM)، وفقا لنظام رمز الالون المعينة.

### Abstract

The Monitoring and Controlling process oversees all the tasks and metrics necessary to ensure that the approved and authorized project is within scope, on time, and on budget so that the project proceeds with minimal risk. Monitoring and Controlling process is continuously performed throughout the life of the project. Monitoring and control became difficult due to the increase of the complexity of projects in now days. BIM technology has accelerated the response to the pressures of the increasing complexity of projects. One of the tremendous benefits of the BIM technology is the visualization of all the models elements and components, therefore, in this paper is to visualize the project performance using the Earned value Management technique (EVM), according to a certain color code system.

**Keywords:** Monitoring, Control, BIM, Visualization, EVM, AC, PV, EV, Dynamo.

### 1. Introduction

The construction manager is the key figure of the execution of a construction project. He has the crucial responsibility of guaranteeing the fulfillment of the project scope within the allocated budget and timeframe (Koster et al., 2011). Another aspect he has to take into account is quality. According to the Project Management Institute (PMI) (2013), a successful project is the one in which the manager is able to execute it within the allocated time and budget while fulfilling the quality requirements. The manager must therefore find the balance between these three constraints. During project construction, procedures for project monitoring, recording and control are essential elements for project managers. Monitoring is the process of tracking various operations during the construction stage. Cost control indicates the direction of the changes in

preliminary planning variables compared with actual performance with the aim of avoiding unacceptable variations. Cost control includes “monitoring” costs and recording data, then analyzing the data in order to take appropriate corrective actions. Once the project starts; control becomes the major task of the contractor, because contractor’s profit depends to a great extent on the effectiveness of its cost monitoring and control system (Olwan 2004). Project control system indicates the direction of change in preliminary planning variables compared with actual performance (Rozenes et al. 2006). It assures that all changes to the scope baseline are controlled in a structured manner. This prevents the baseline plan from becoming obsolete. Several research have focused on cost and schedule variances (eg., Li 2004).

BIM is a revolutionary technology and Process that has transformed the way buildings are designed, analyzed, constructed, and managed. Currently, an overwhelming amount of information is available about BIM, such as theories on where BIM can go, the vast array of tools available, and how BIM seems to be the answer to all the problems facing a construction manager (CM). Although some of this information is useful, often it inundates potential users because the information all seems to meld together. BIM has become a proven technology. What it can do and the concepts associated with BIM taken out of context, however, can become misleading and frustrate users and owners alike to the point of not wanting to use this technology again on future projects. This not only hurts the future growth of BIM technology, but it inhibits users from getting involved and sharing their experiences with other in the BIM community to further refine lessons learned and best practices. (Brad Hardin., 2009). BIM assists planners in making crucial decisions by enabling visualization of the details of the prospective work at any specified time (Chau et al. 2004). When a project is planned and built virtually, most of its relevant aspects can be considered and communicated before the instructions for construction are finalized (Li et al. 2006). BIM technology also offers the possibility of having a 4 Dimensions (4D) model, where the 4th dimension is the time. 4D BIM model is developed for better visualization and removing flaws before the commencement of the work at site. There are several problems on construction site to be faced, for the same 4D BIM is the tool which can be helpful for managing and finding the several alternatives, which can optimize the results and give best possible solution by its better visualization. 4D BIM provides a graphical simulation that allows planners for identification of problems in early stage. 4D BIM shows project schedule in visual format. It can also be used to coordinate in work with engineers, clients and subcontractors (Harshal S Shimpi, 2015).

BIM tools can integrate a 5th dimension which is the cost, and even more within the context of the n-dimensions (nD) modeling. Lee et al (2003) define n-D model as an extension of the BIM model which incorporates multi-aspects of design information required at each stage of the lifecycle of a building facility. Each dimension corresponds to an additional design attribute or perspective such as time, cost, accessibility, sustainability, maintainability, acoustics or energy (Aouad, Lee & Wu, 2005). Thus, it enables a design decision based on a variety of design perspectives (Aouad et al., 2005).

Earned Value Management (EVM) is a management technique used in different areas such as Information Technology project or construction projects, which aims to monitor cost, schedule and technical performance of a project (Fleming & Koppelman, 2005). One of its main uses is the forecast the project time and cost through the apply of the

performance indices (Kenley & Harfield., 2015). It constitutes an early caution of performance problems when properly used (Abba, 2001).

EVM is based on the interpretation of three S-Curves in a time cost diagram (Figure 2). Each curve represents a cumulative data of a specific parameter. The Project Management Institute (PMI) (2005) defines three input parameters: The Planned Value (PV), The Actual Cost (AC), and the Earned Value (EV).

Dynamo is a visual programming tool that works as a plug-in to Autodesk Revit, using the Revit Application Programming Interfaces (API) and built using the Windows Presentation Framework. It is designed to extend Revit's parametric modeling capabilities (Keough, 2011). Autodesk defines it as a visual programming extension that allows manipulating data, sculpting geometry, exploring design options, automating processes, and creating links between multiple applications.

### **1.1 Problem Statement**

The process of construction monitoring and control gets more sophisticated, complex and challenging due to the huge amount of information that need to be measured and analyzed. An effective monitoring and control system should include a data management system to cover the large sets of data associated with the different project components. Therefore, developing an integrated visualized cost estimate and control models to track construction projects performance would be an important advance in the area of construction project monitoring and control. This research aims to introduce a model that integrates cost estimate and monitoring processes with the advances in data visualization to provide decision makers with a tool for better monitoring and control of their construction projects.

## **2. Integration between BIM Model and EVM**

Several researches have proved the potential of combining the two concepts in construction management. For example, in Japan, Kim et al (2010) programmed a 5 Dimensional (5D) tool based on EVM which allows determining real-time schedule and real-time cost by managing schedule and cost simultaneously. It has been used within the context of the construction of a bridge in Seoul (2nd Guemgang bridge: 2008-2011). Another approach by Marzouk & Icham (2014) tried to implement EVM in Bridge Information Modeling (BrIM) which they defined as an intelligent representation of bridges gathering all information needed about bridges through their whole lifecycle. They presented a BIM-based cost estimate application which integrates the EV concept to control cost and time during the execution phase of the project. Figure 1 shows the framework of the main processes.

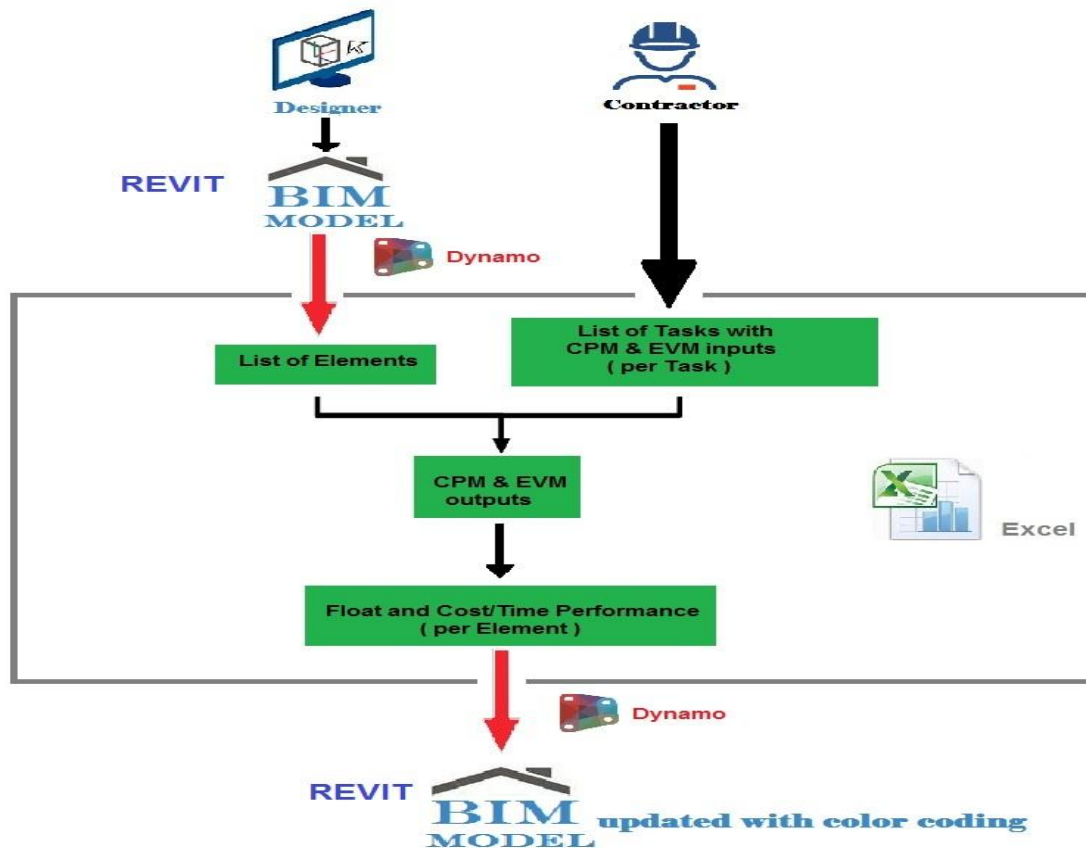


Figure 1 – The framework of the processes.

The tool consists of an Excel file that is the main user interface, and of a Dynamo code that allows the connection between the Revit BIM-model with this Excel file. The EVM Calculation sheet is also to be completed by the user with the EVM input data. The reference time unit is up to the user's choice. It can be per day or per month or per week for example. So in this sheet, the PV corresponds to the Planned Value, will be calculated automatically. Then, the task budget and the task duration. Then the AC corresponds to the Actual Cost of the project at the given date. The user must fill the real cost for each task at the corresponding day. After that the EV corresponds to the Earned Value, is to fill with the Earned Value of each task at the given date, i.e. the actual percentage of execution progress per activity also at the corresponding day. The connection between the list of activities and the list of elements constitutes a major challenge. There is still no automated process to link objects to the tasks (Kim et al., 2013). In fact, this is a consequence of a lack of organization in BIM information management. BIM models contain indeed an important volume of data, which has been very challenging to cope with until the present day (Nepal and Staub-French, 2016). In the tool, this connection is required because when the performance per task is obtained in the Excel spreadsheet the elements have also to be credited of a performance value in the sheet so that they are colored afterwards. This requires each task to be allocated a hierarchic number such as "1.2." named "Task Number". The task number of an element corresponds to the hierarchic number of the task in which it is involved. It implies that the connection between elements and tasks is univocal i.e. to each element corresponds only one task. This new parameter does not exist in Autodesk Revit

software. Therefore, the solution for this is to create in Revit a shared parameter called “Task number”.

The next step involves transferring the list of elements with their respective ID number and task number from the 3D model to the Excel sheet. The column in the spreadsheet corresponding to the performance has a predefined formula in the cells. This formula allows the cell to take the value of the performance of a task in the Excel sheet.

## **2.1 Monitoring using the BIM-based tool**

The Earned Value Management technique is considered as a powerful project management tool that supports the management of project scope, time, and cost (Leu et al. 2005). Using the earned value process, contractors can easily compare how much work has actually been completed with the amount of work planned to be accomplished. Earned value provides work progress status, and the relationship of planning to the actual cost. Jung and Kang (2007) developed a system to standardize progress measurement. Shen et al. (2005) developed a scoring system to measure the environmental performance done by the contractor. Barraza et al. (2000) developed a model based on stochastic S-curve to monitor project performance.

There are three key indicators that are used in performance measurement: (1) Planned Value (PV), (2) Earned Value (EV), (3) and Actual Cost (AC). The performance measurement computes variances from baseline.

### **Planned value (PV)**

This is sometimes also called as Budgeted Cost of Work Scheduled (BCWS). This is the budget allocated for an activity, WBS component, or control account and can be expressed as the amount for a certain period, or cumulative amount to date. The figure of PV represents work authorized and the budget authorized for that work.

Planned value is calculated by multiplying percentage of work planned to have completed and the Budget at Completion.

$$PV = \text{Planned \% Complete} \times BAC$$

### **Earned Value (EV)**

This is at times called as Budgeted Cost of Work Performed (BCWP). This is the value of work completed at any given point in time, expressed as value of budget assigned for the work. Again, this is expressed for an activity, WBS component, or control account. Can be expressed as a value for certain time period, or cumulative amount to a certain date.

Earned value is calculated by multiplying percentage of actual work completed and the Budget at Completion.

$$EV = \text{Actual \% Complete} \times BAC$$

### **Actual Cost (AC)**

This is sometimes called as Actual Cost of Work Performed (ACWP). Quite simply, this is the actual cost of work done at any point in time. Can be expressed as the value for certain time period, or cumulative amount to date. There is no formula for this. This figure should come from cost accounts maintained for the project, can be derived from control accounts.

The variance is calculated using the above 3 metrics.

### **Schedule Variance (SV)**

Schedule variance indicates the extent to which an activity is ahead (or behind) as compared to its estimated time. SV can be calculated for an activity, WBS component or control account. When done for all activities on a project, this metric tells us whether the project is ahead (or behind), and if so by how much (hours, person-days – based on unit of measure used).

**Schedule Variance = Earned Value – Planned Value**  
**SV = EV – PV**

If you discover a negative schedule variance, you need to think of possibilities of shortening duration of few other tasks. Schedule compression techniques (discussed as part of Develop Schedule process) will be useful.

### **Cost Variance (CV)**

Cost variance tells you how you are doing on cost front against the budget allocated for project. If you have spent more than authorized budget for an activity, this metric will tell you that. This can be calculated for a period of time, or at the end of project.

**Cost Variance = Earned Value – Actual Cost**  
**CV = EV – AC**

If you are calculating CV for the end of project, it will be the difference between Budget at Completion and actual amount spent on project till then. If there is a negative cost variance then that amount is gone; it cannot be recovered. So you can only plan for corrective action by which you can save money on other tasks (if such a plan is possible).

The image below shows cost and schedule variance at any given point in time. All above concepts are summarized here.

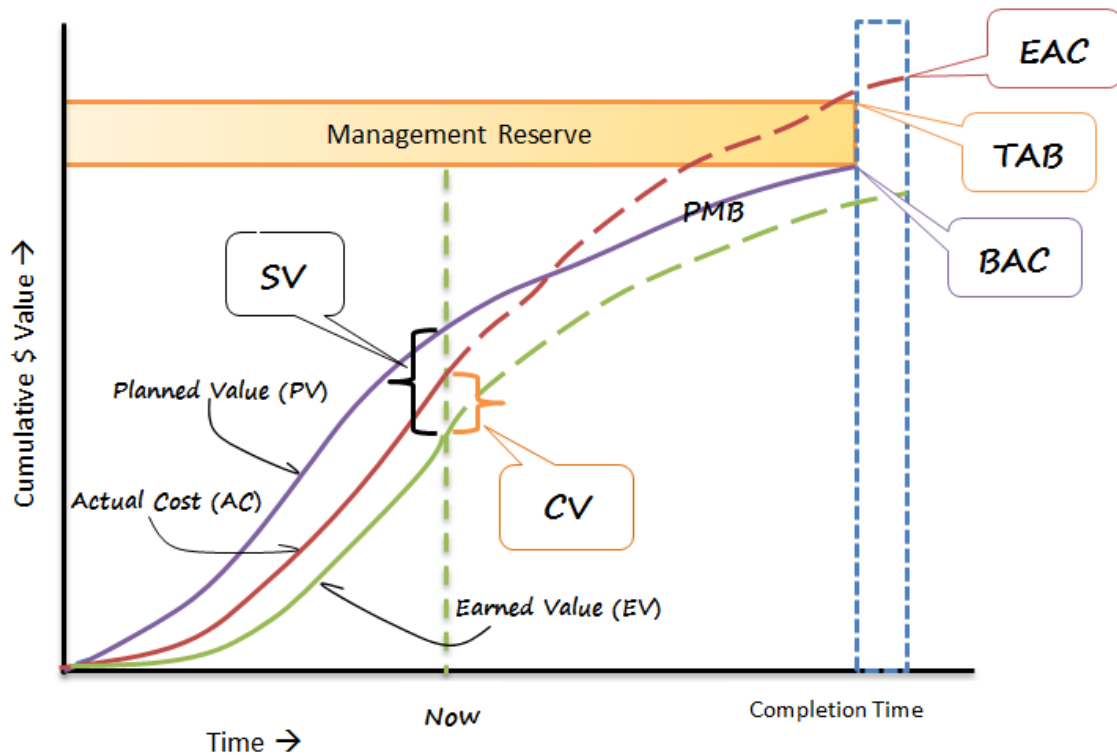


Figure 2 – Earned Value Management concept

### 3. Model implementation

This section describes a computerized system that is developed to automate the monitoring process. The implementation process depends on using commercial software packages such as Microsoft Excel provides the capabilities needed to analyze the inputs data and output results, Information exchange is required from the Autodesk Revit BIM model to MS Excel and vice versa to visualize the EVM status on the BIM model through a colors code system. Dynamo is the interface chosen to perform this exchange of data. Dynamo will allow firstly to extract the element ID automatically in each element in the Revit Model itself, Then extracting data from a Revit file to an Excel sheet and read Excel data and change the Revit model according to each task status per element.

Firstly a scheduling module for the project is developed, the project has been tested on a Revit model of a residential house. It has 2 floors and an area of 263 m<sup>2</sup>. By developing an initial schedule and integrate it with the cost estimating module, the total cost of the project is calculated as well as the detailed cost for all activities. Then, actual cost data is add manually in the excel sheet, Detailed project cost variances are computed in the background based on the previously discussed equations. Actual cost data and detailed variances are then automatically transferred to the model.

The Schedule Variance allows one to know if the project is ahead, on or behind schedule; the Cost Variance if the project is under, on or over budget. So after calculating those indicators, the EVM performance is obtained for each task. For each performance is attributed a number and a color as shown in (Figure 3).

		Performance with Colors	Code	R	G	B
-	-	Not Started Yet	0	Transparent		
SV>0	CV>0	Ahead of Schedule and Under Budget	1	135	206	250
SV>0	CV=0	Ahead of Schedule and On Budget	2	123	104	238
SV>0	CV<0	Ahead of Schedule and Over Budget	3	238	130	238
SV=0	CV>0	On Schedule and Under Budget	4	64	244	208
SV=0	CV=0	On Schedule and On Budget	5	0	176	80
SV=0	CV<0	On Schedule and Over Budget	6	244	164	96
SV<0	CV>0	Delay on Schedule and Under Budget	7	255	215	0
SV<0	CV=0	Delay on Schedule and On Budget	8	119	136	153
SV<0	CV<0	Delay on Schedule and Over Budget	9	255	0	0
	TF=0	Critical Path	10	139	0	0

Figure 2 – Performance and colors code system

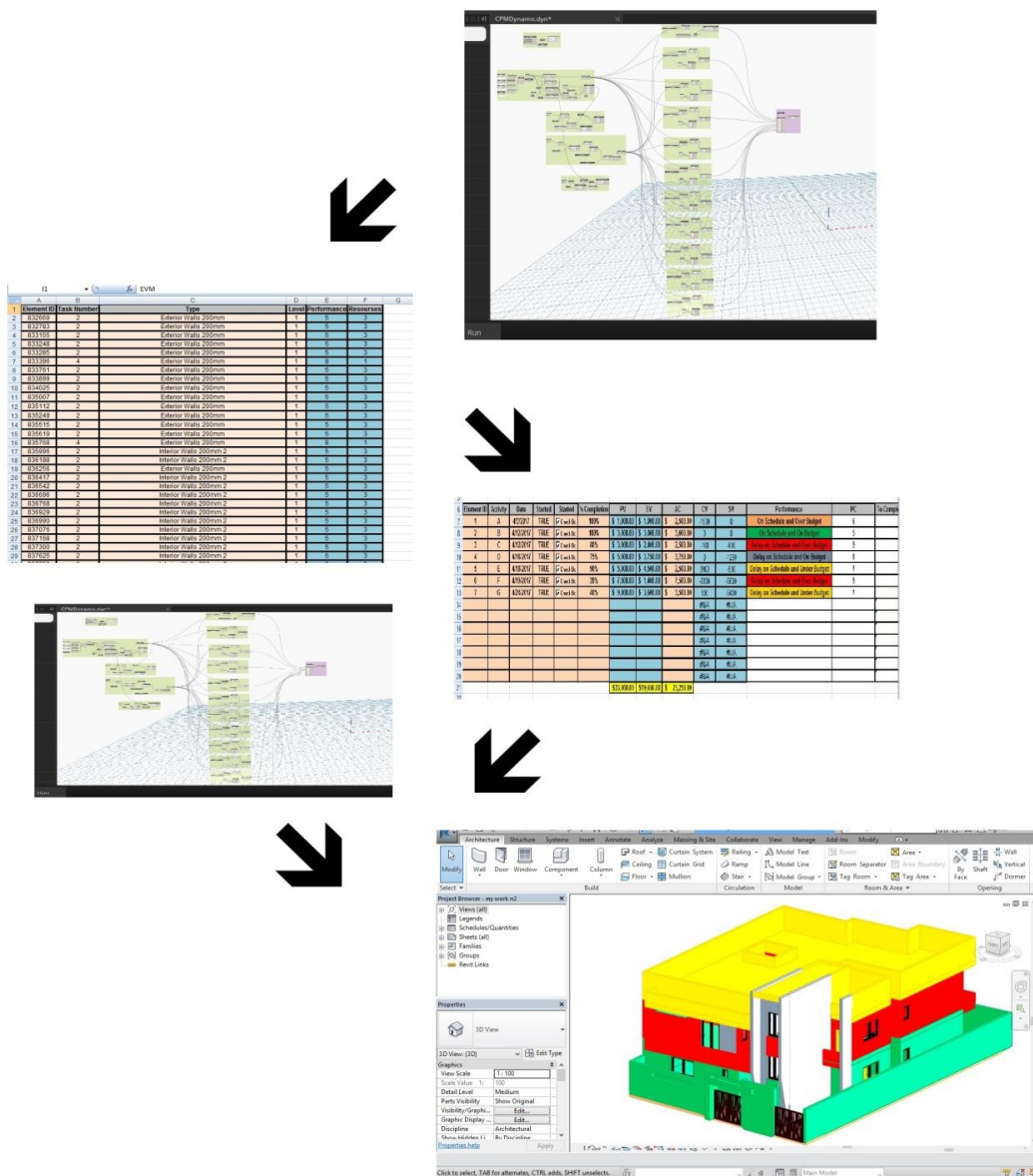


Figure 3 – BIM-Based Visualized tool process



### 3.1 Model benefits and limitations

Computerized automated model could support decision making by enabling project parties to test and evaluate any alternative rapidly for the purpose of reaching an optimum solution. A visualized monitoring/control model provides reliable features to architects, owners, engineers, contractors, and all participants involved in the construction industry. It creates a single building model that act as a repository for all elements of the building. The model provides many features that help project construction team to avoid costly errors during construction of the project. Element clashes can be detected from the design phase saving considerable time delays and cost overrun, in case of any discrepancy. At the same time, visualization helps construction team to absorb and understand project information. A methodology for evaluating and visualizing construction performance with respect to cost has been developed. A BIM based visualization system has been introduced to facilitate tracking and monitoring construction progress. The proposed model can be effectively used in controlling small to medium projects. The main advantage of the system is that it enables nD visualization of the construction progress along with the geographical conditions. This paper emphasizes the importance of integration between project cost estimate, cost monitoring/control techniques and BIM platforms. The integration will add other dimensions to construction progress visualization. The developed framework can be considered as an effective tool for monitoring construction projects and providing decision makers with a visualization aid to enable them to take cost and progress related decisions in a timely manner.

As for the limitations, the use of the tool during this pilot case emphasized several drawbacks. Firstly, the manual entry of task numbers in the Revit file is inconvenient because it is long and mainly prone to error, even if Dynamo use eases the process. Moreover, the non-automated connection between tasks and elements requires that the schedule, or more specifically the order of tasks, does not change. Otherwise, the entry of task numbers has to be repeated, and for big projects it can be time-consuming. The ideal is to enter the data during the design of the Revit model. However, it requires that the definitive schedule is ready before the design, which is in reality nearly impossible because a project construction schedule is usually made after the design.

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