

# Building Information Modeling Based Time And Cost Planning In Construction Projects

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**THIS PAPER PRESENTS TIME AND COST PLANNING IN CONSTRUCTION PROJECTS USING BUILDING INFORMATION MODELING (BIM) APPROACH. THE BIM TECHNIQUE CAN BE INCORPORATED INTO THE TIME AND COST PLANNING PROCESS THROUGH SEVERAL STEPS.**

At the beginning, a 3D model of the construction object is developed using an adequate modeling application. After that, the 3D model is imported into suitable BIM construction management software. Thereupon, the project costs are estimated on the basis of quantities of required resources, consumptions, production rates and unit costs. The project activities are then defined and linked to the construction elements of the 3D model as well as updated with allocated resources and costs. The activities with established durations are mutually connected together into a project network plan by taking into account relevant precedence relationships. The project duration is automatically determined from the generated network plan. Finally, the BIM model of the construction object is completed by upgrading the 3D model with defined scheduling and cost data. An application example is presented in the paper to demonstrate the advantages of BIM implementation in architecture, engineering and construction industry.

## Introduction

The main stream for development of software, that can simultaneously manage building, scheduling and cost data as well as to be suitably applied in architecture, engineering and construction (AEC) industry, originated in the year 2004 with the introduction of BIM (Building Information Modeling) (Eastman et al., 2011). At the beginning, the BIM was used to form virtual 3D building models that were able to visualize the construction objects and make their design more understandable. For this purpose, different modeling software, such as AllPlan, ArchiCAD, Bentley Architecture, Revit Architecture, Tekla etc., were put forward and successfully applied in practice (CAD Addict, 2013).

Over the years, the modeling software has been upgraded with different modules for handling structural design, analysis of reinforced concrete, mechanical design, energy and environmental issues, visualization, facility management, product and technical information for manufacturers and distributors, etc. Today, some of them use external applications in which the interoperability is often enabled by statical work with import and export of data. Synchronization of multiple data formats, for the purpose of executing the work between the modeling software and other applications in a

dynamical manner, is still a great challenge of managing the construction projects using BIM.

Scheduling plans for the construction object frequently represent an outcome of common work of different experts. They may incorporate into schedules various information about execution of project activities, application of materials, assignment of workers, employment of machinery, etc. Classically used software for project scheduling includes computer applications such as MicroPlanner, MS Project, Planisware, Primavera, SuperProject, Teamwork, X-Pert among others. On the other hand, the basic aim of the BIM is to combine 3D building models with scheduling data to produce 4D models in which the fourth dimension is time. The results may include an animation of the construction execution as well as the scheduling data connected to the 3D model.

Nevertheless, accurate estimation and planning of actual project costs are also very important for success in construction business. Handling the project cost data by BIM approach give us an opportunity to manage the construction project costs more efficiently. As soon as the construction costs are identified and connected to the construction elements and scheduling data, the 5D building information model is created.

Over the past few years, the BIM applications have been successfully combined with scheduling and other software (Rundell, 2006; Brisk, 2007; Rundell and Stowe, 2007; Tulke and Hanff, 2007; Muhič, 2008). However, the combinations between different software were oftentimes unique and hardly generally applicable. It was also reported in mentioned references that the converter must be applied for data synchronization between BIM and scheduling software.

Research papers were also published in the field of BIM based cost management of construction projects (Heinisuo et al., 2010; Shen, 2010; Shah, 2011; Mitchell, 2012; Haapio, 2012; Cheung, 2012). Similarly, as in cases of combinations between BIM applications and scheduling software, the combinations between BIM programs and cost estimation tools also yielded acceptable results, but they were mostly matchless and difficult for wider use. Another limitation was also a lack of appropriate costing methods that are transparent enough and include all required cost components (i.e. labour, material, investment, energy, consumables, overhead, profit, life cycle, etc.) for detailed calculation of construction cost in BIM applications.

A step forward to enable the combinations between BIM applications, scheduling tools and cost estimation programs more employable for wider use was recently done within the Vico Office R4 (2012) software. The purpose of this paper is to give an insight into the construction project time and cost planning process using the BIM approach. The contribution presents a step by step implementation of BIM on an actual construction project using the Vico Office R4 software application as an interface for project time and cost planning. The example demonstrates the advantages of BIM approach and possibilities for its wider integration in AEC industry.

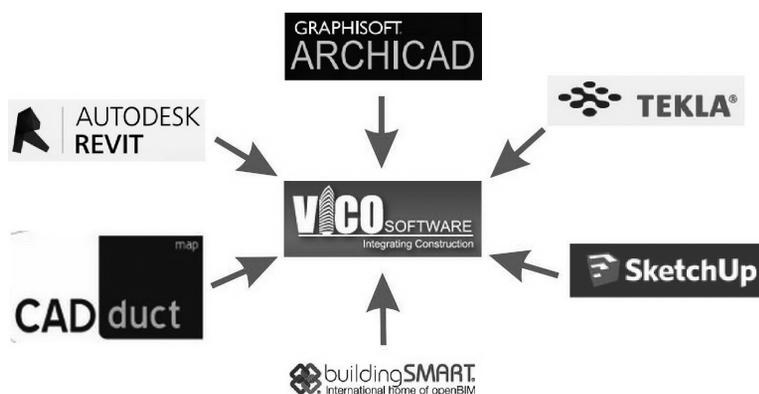


Figure 1. Vico Office R4 format support



**Figure 2. Flowchart of work steps for BIM based time and cost planning of construction project**

### Project Time And Cost Planning By Bim

BIM based time and cost planning of the construction project can be performed through several steps using Vico Office R4 software. At the beginning, a 3D model of the construction object is developed using an adequate modeling application. Here, the 3D model can be formed in multiple formats such as Revit, Tekla, ArchiCAD,

CAD-Duct, IFC files, SketchUp and 3D DWG files that are supported by Vico Office R4 system, see Figure 1.

When the 3D model of the construction object is formed, the project time and cost planning can be executed employing the BIM approach through work steps demonstrated in the flow-chart of Figure 2.

By the start of BIM implementation in the project time and cost planning process, the 3D model is imported into the Vico Office using an installed add-on of appropriate modeling software (e.g. Revit, Tekla, ArchiCAD etc.) or by additional importers for Google SketchUp, CAD-Duct, 3D DWG, and IFC files. After that, the module Takeoff Manager is applied to determine the geometrical properties of the 3D model. The Takeoff Items are created automatically and can be rearranged in different groups of building elements. The geometrical properties of Takeoff Items are then employed as source quantities for further time and cost planning of the project.

As soon as the 3D model is successfully imported and the Takeoff Items are correctly determined, the project costs can be estimated within the module Cost Planner on the basis of defined quantities of required resources, consumptions, production rates and unit costs. Hence, the source quantities from previous step can be used to calculate the appropriate components or subcomponents of project costs as functions of geometrical properties. All components and subcomponents are hierarchically structured for the purpose of providing the level of cost estimation either for basic or detailed cost calculation. Different versions of estimated costs can be stored and compared within the Cost Planner. The cost components and subcomponents can be newly estimated or imported into the system from previous projects as references.

It is recommended to define locations of building model in order to avoid wastes on time and to have better

overview on moving of work crews. For this purpose, the work locations can be defined within the module LBS Manager. The work locations enable the planner to allocate the location-based quantity takeoffs for further use in scheduling, to determine adequate labour force, material and equipment, as well as to set the number of work hours per location. In this way, the required works in construction project can be done more continuously.

The project activities are then defined and linked to the construction elements of the 3D model employing the module Schedule Planner. The quantities, that were determined during cost estimation process, can now be linked to the construction project activities. At this point, it is important to define the construction project activities correctly because the main scheduling method employed within Vico Office R4 represents the flowline theory and not classical critical path method (CPM). Namely, when the project scheduling is handled by the CPM, the durations of activities are known and they are treated as input data. On the other hand, in the flowline theory, the durations of project activities are calculated and this means a calculation of quantities per location divided by the productivity rate of the work crew.

During the process of project scheduling, the construction activities are mutually connected together into the project network plan by taking into account relevant precedence relationships. Furthermore, the defined links between construction activities also enable the planner to obtain an appropriate flowline diagram or Gantt chart. In the context of Vico Office R4 modeling system, this step can be made in the module called Vico Office Schedule Planner.

Thereupon, the resources and the crew sizes are allocated to the construction project activities. As soon as the work crew productivity rates are appropriately established, the durations of construction activities are calculated



**Figure 3. Location of Medical Faculty shelter building in Maribor**

and the project duration is automatically determined from the generated network plan. BIM applications represent location-based systems (LBS) for project management which are oriented on planning, scheduling and controlling the project by the location. In this way, it is significant to achieve the work crew's productivity rate by moving from location to location and to minimize the wastes on time, possibility of conflicts etc.

In the final step, the BIM model of the construction object is completed by upgrading the 3D model with defined

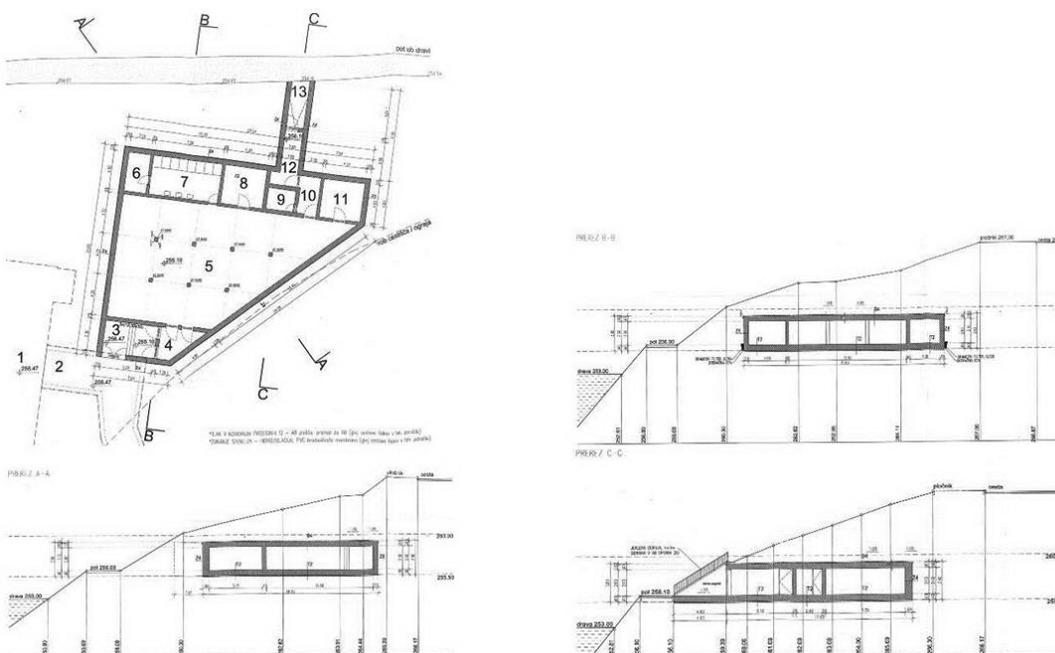
scheduling and cost data. At the end of the step, the project time and cost planning process is completed and the 5D BIM model of the construction object is developed. Note also that the module 4D Simulation, a part of Vico Office R4 software, enables the execution and presentation of an animation of the scheduled construction.

### Application Example

In this section, an application example is presented to demonstrate the advantages of BIM technique implementation

in AEC industry. The considered example is based on the Vico Office R4 software application. Here, the BIM based project time and cost planning was performed for a shelter building of the Medical Faculty that was recently built in Maribor, see red shaded area in Figure 3.

The shelter building is a part of Medical Faculty complex that also includes the main building and the corridor to the University Clinical Centre of Maribor. It is a reinforced concrete structure composed from the foundation



**Figure 4. Architectural design of shelter building (Razpet et al., 2009)**

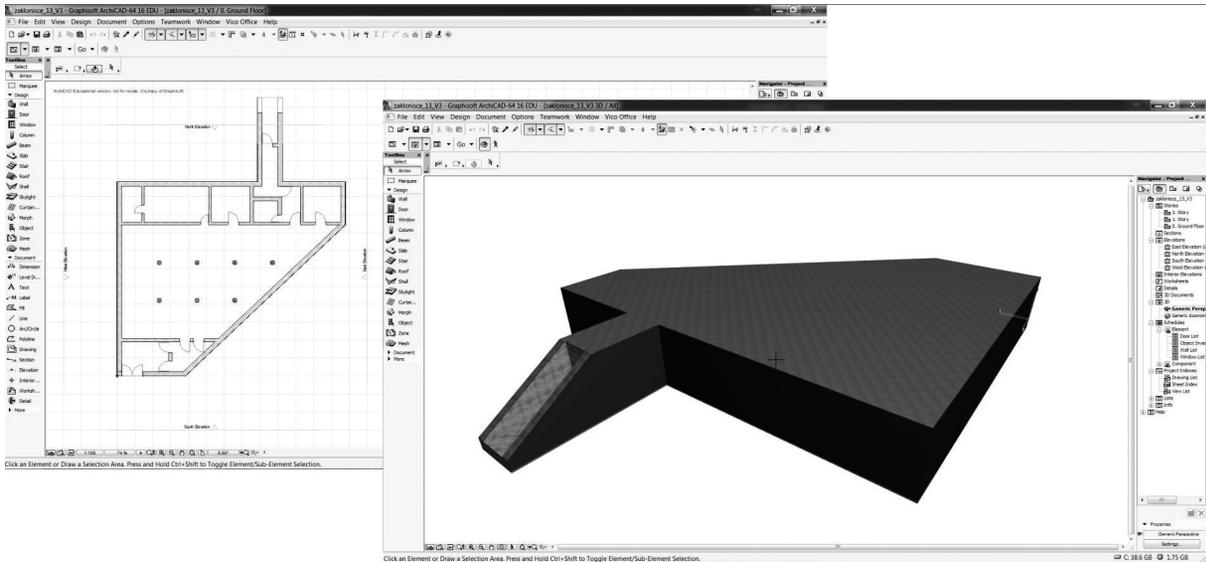


Figure 5. Ground floor plan and 3D model of shelter building

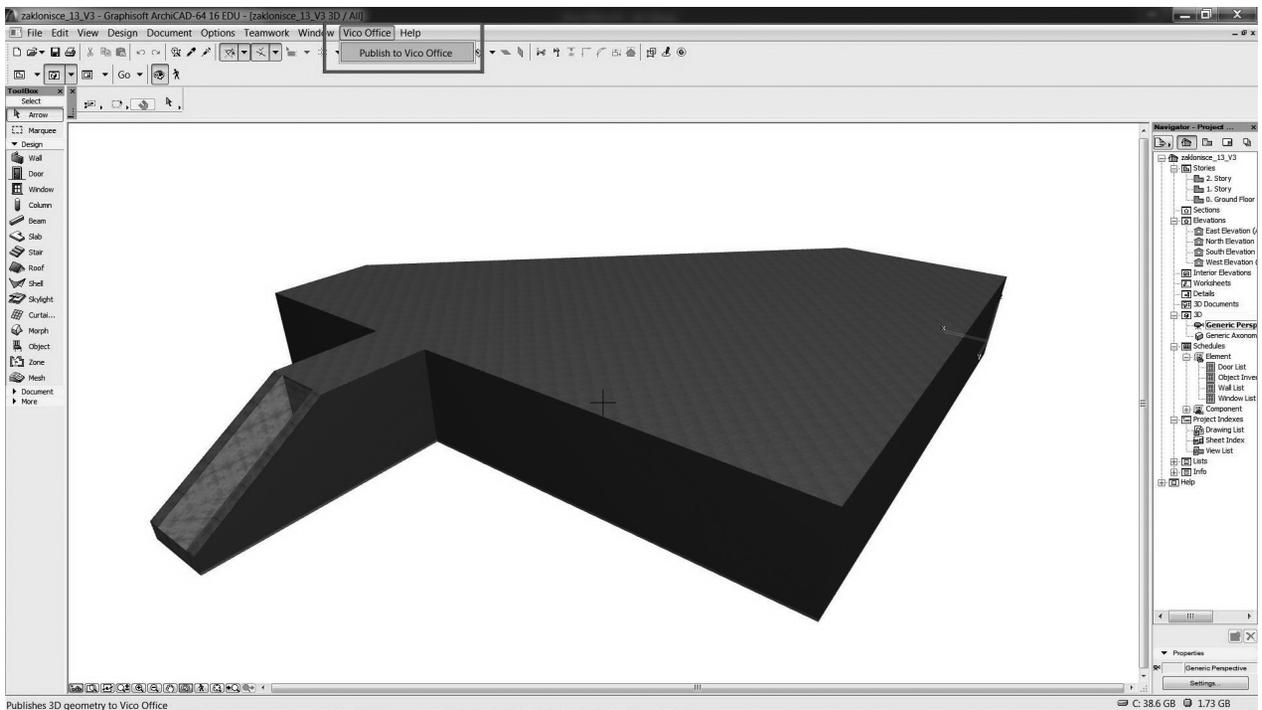


Figure 6. Published 3D model of shelter building

concrete slab, the ground slab, the retaining external walls, the internal walls, the internal columns and the roof slab. Figure 4 shows the architectural design of the shelter building with main construction elements.

The BIM based project time and cost

planning for the shelter construction was executed through several steps. In the first step, the 3D model for the shelter building was developed using ArchiCAD modeling software. Figure 5 shows ground floor plan for the shelter building and its 3D model.

Afterwards, the next task was to import the 3D model of the shelter building into the Vico Office R4 system over the added menu in the main modeling software ArchiCAD, see Figure 6.

As soon as the import procedure has been completed, the 3D model

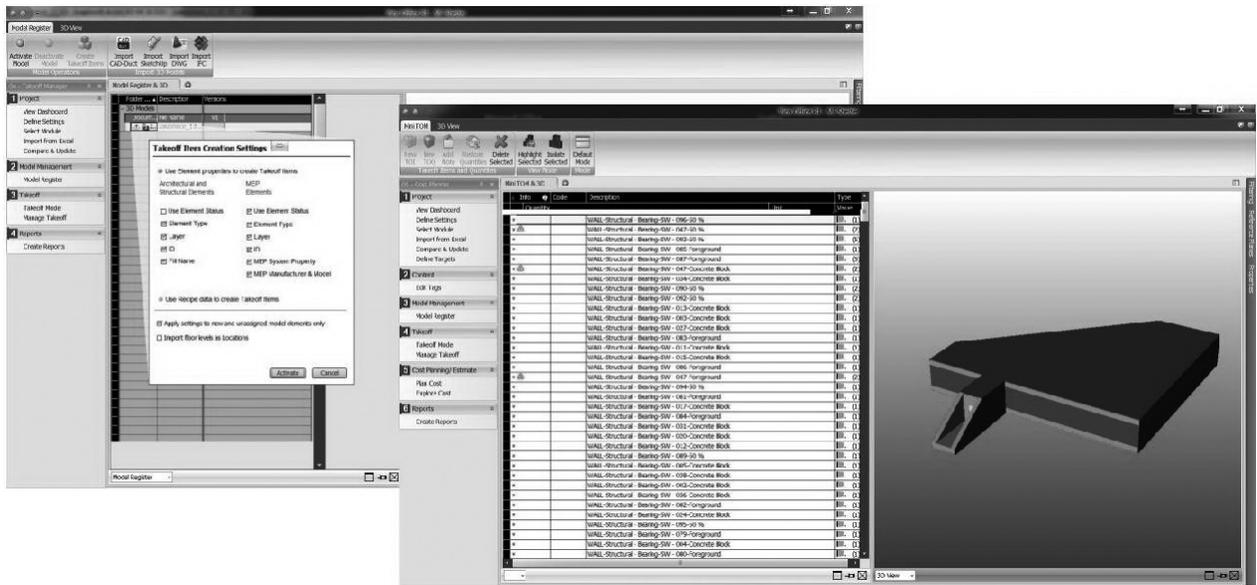


Figure 7. Activated 3D model, building elements and 3D model of shelter building in Vico Office R4

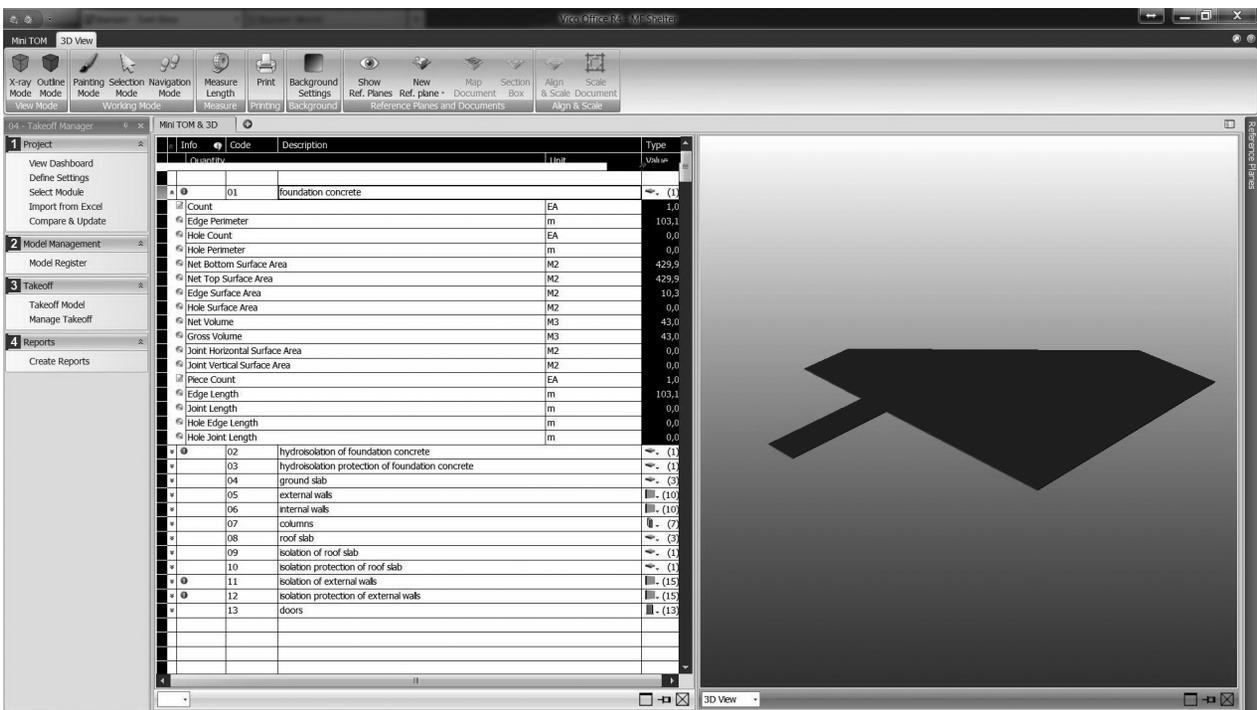


Figure 8. Grouped building elements and information about their geometrical properties

was activated within the Vico Office R4. The activation process employed the selected element properties (e.g. Element Type, Layer, ID, etc.) to create Takeoff Items, see left side of Figure 7. Afterwards, the shelter building elements were listed in the Takeoff Manager

module and the developed 3D model appeared in the Vico Office R4 as it is shown on the right side of Figure 7.

In order to define the construction project activities correctly, the shelter building elements were rearranged into several different groups. Figure 8 shows

determined groups of shelter building elements and information about their geometrical properties.

In the module Cost Planner, the construction costs were estimated for each building element by adding the appropriate components or subcomponents

Code	Description	Source Qty	Consumption	Waste	Qty	UOM	Unit Cost	Cost/Parent As.	Net Total	%Parent Assembly
MFS EN	MF Shelter	1.0	1,000	1,000	1.0		195,927.33	NA	195,927.33	NA
001	Foundation concrete	42.8	1,000	1,000	42.8	m3	55.74	2,385.67 /	2,385.67	1.22%
002	Hydroisolation of foundation concrete	1,286.6	1,000	1,000	1,286.6	m2	0.76	977.82 /	977.82	0.50%
003	Hydroisolation protection of foundation concrete	856.9	1,000	1,000	856.9	m2	1.88	1,610.97 /	1,610.97	0.82%
004	Ground slab	287.1	1,000	1,000	287.1	m3	264.22	67,931.60 /	67,931.60	34.67%
4.100	Formwork for reinforced and unreinforced concrete structures	61.8	1,000	1,000	61.8	m2	16.34	3.93 / m3	1,009.77	1.49%
4.110	Formwork for straight concrete walls and foundations	61.8	1,000	1,000	61.8	m2	16.34	16.34 / m2	1,009.77	100.00%
4.111	One sided panels with boards	61.8	1,000	1,000	61.8	m2	16.34	16.34 / m2	1,009.77	100.00%
4.1111	Boards	61.8	0.008	1,000	0.5	m3	159.30	1.27 / m2	78.76	7.80%
4.1112	Beams	61.8	0.004	1,000	0.2	m3	176.22	0.70 / m2	43.56	4.31%
4.1113	Couplings	61.8	0.070	1,000	4.3	kg	8.00	0.56 / m2	34.61	3.43%
2031	KV formwork man	61.8	0.300	1,000	18.5	hr	17.00	5.10 / m2	315.18	31.21%
2032	PK formwork man	61.8	0.580	1,000	35.6	hr	15.00	8.70 / m2	537.90	53.26%
2021	KV concrete man	257.1	1,000	1,000	141.4	hr	17.00	9.35 / m3	2,403.89	11.88%
2022	PK concrete man	257.1	1,000	1,000	141.4	hr	15.00	8.25 / m3	1,121.08	10.49%
2.200	Manufacture and placing of reinforced concrete	287.1	1,000	1,000	287.1	m3	181.81	181.81 / m3	46,893.21	69.77%
2.250	Placing a pre-made reinforcement networks	428.4	8,000	1,000	3,427.2	kg	0.92	12.24 / m3	3,146.93	6.74%
2.251	Placing a pre-made reinforcement networks for reinforced concrete	428.4	8,000	1,000	3,427.2	kg	0.92	0.92 / kg	3,146.93	100.00%
2.2511	Concrete reinforcement networks	3,427.2	1,005	1,000	3,444.3	kg	0.65	0.66 / kg	2,254.49	71.66%
2.2427	Wire	3,427.2	0.004	1,000	13.7	kg	1.14	0.00 / kg	15.08	0.46%
2001	KV reinforce man	3,427.2	0.008	1,000	27.4	hr	17.00	0.14 / kg	466.10	14.81%
2002	PK reinforce man	3,427.2	0.008	1,000	27.4	hr	15.00	0.12 / kg	411.26	13.07%
2.240	Hand cutting, bending and placing reinforcement of ordinary	287.1	1,000	1,000	287.1	m3	169.37	169.37 / m3	43,546.27	93.26%
2.245	Medium complicated reinforcement bars Ø 4-12mm	287.1	80,000	1,000	20,568.0	kg	1.36	108.49 / m3	27,891.98	64.06%
2.2421	Concrete reinforcement bars Ø 4-12mm	20,568.0	1,030	1,000	21,185.0	kg	0.65	0.67 / kg	13,827.48	49.58%
2.2427	Wire	20,568.0	0.004	1,000	73.0	kg	1.10	0.00 / kg	80.32	0.29%
2001	KV reinforce man	20,568.0	0.023	1,000	466.9	hr	17.00	0.39 / kg	7,937.19	28.46%
2002	PK reinforce man	20,568.0	0.020	1,000	403.1	hr	15.00	0.29 / kg	6,046.99	21.69%
2.245	Medium complicated reinforcement bars Ø 14mm and thicker	14,140.5	1,050	1,000	14,847.0	kg	0.65	0.68 / kg	9,598.63	67.32%
2.2427	Wire	14,140.5	1,000	1,000	56.6	kg	1.10	0.00 / kg	62.22	0.46%
2001	KV reinforce man	14,140.5	0.012	1,000	170.4	hr	17.00	0.20 / kg	2,896.68	18.50%
2002	PK reinforce man	14,140.5	0.015	1,000	206.5	hr	15.00	0.22 / kg	3,096.77	19.78%
005	External walls	80.9	1,000	1,000	80.9	m3	326.00	26,373.40 /	26,373.40	13.46%
006	Internal walls	13.3	1,000	1,000	13.3	m3	312.00	4,149.60 /	4,149.60	2.12%
007	Columns	3.1	1,000	1,000	3.1	m3	412.00	1,277.20 /	1,277.20	0.65%
008	Roof slab	248.5	1,000	1,000	248.5	m3	325.12	80,792.32 /	80,792.32	41.24%
009	Isolation of roof slab	414.1	1,000	1,000	414.1	m2	1.33	550.75 /	550.75	0.28%

Figure 9. Estimated costs with integrated components and subcomponents of building element Ground slab

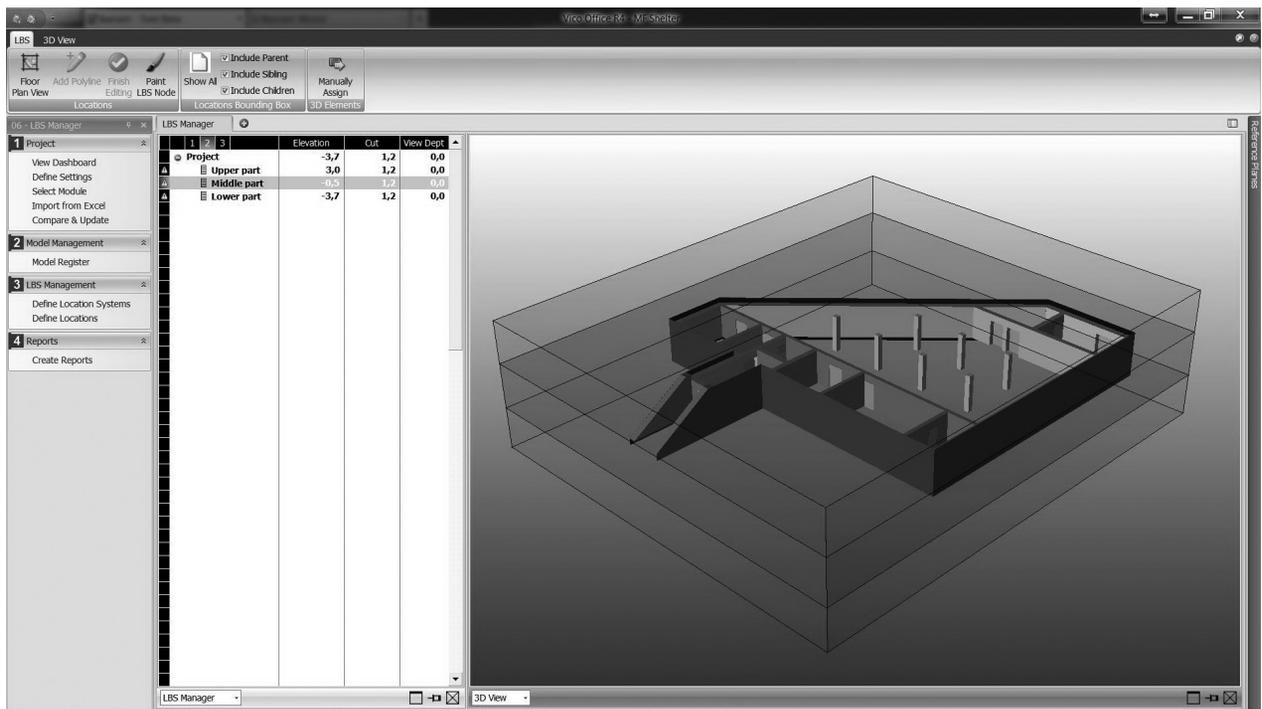


Figure 10. Locations of shelter building in LBS Management module

according to the work that should be done to complete the building with allocated resources (i.e. workers, materials, machinery etc.). It was significant for this step that the appropriate

geometrical properties of building elements were used as source quantities. The source quantities were determined using the function with a link to the Takeoff Item and its appropriate

geometrical properties. The source quantities were then calculated in accordance with consumptions for the aim of correct cost estimation. The total project cost was defined by adding the

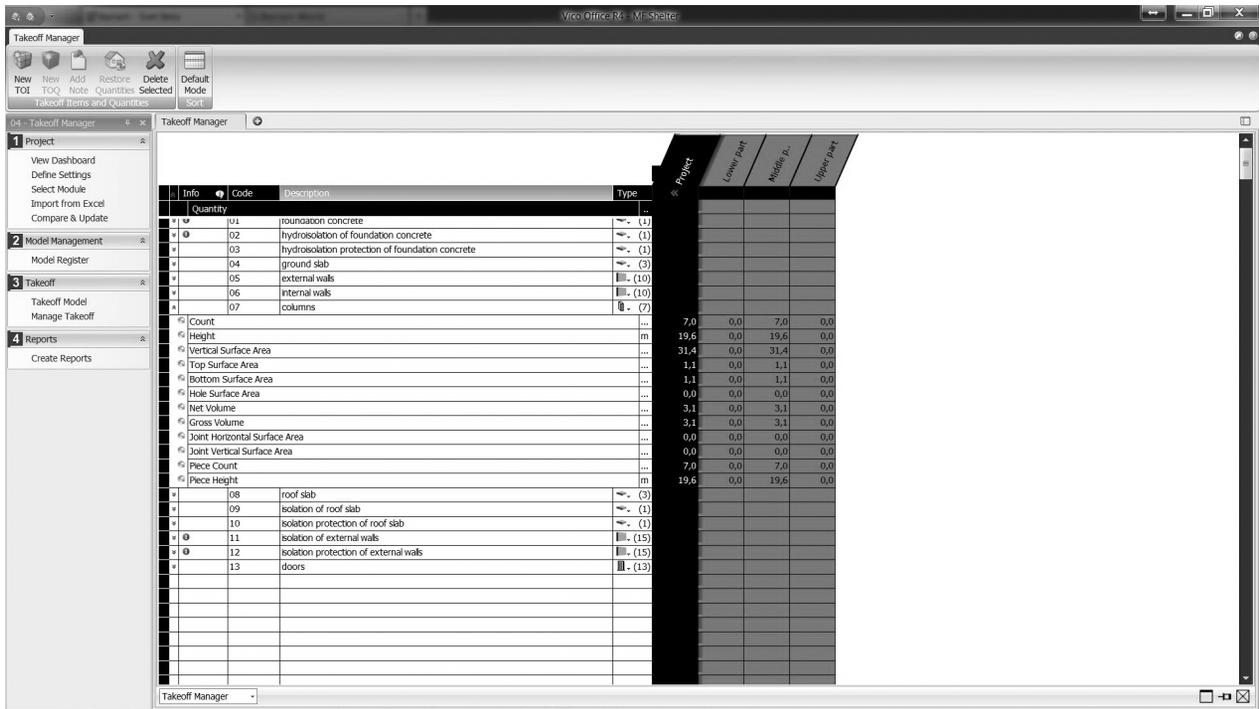


Figure 11. Building element Columns and geometrical properties in location Middle part

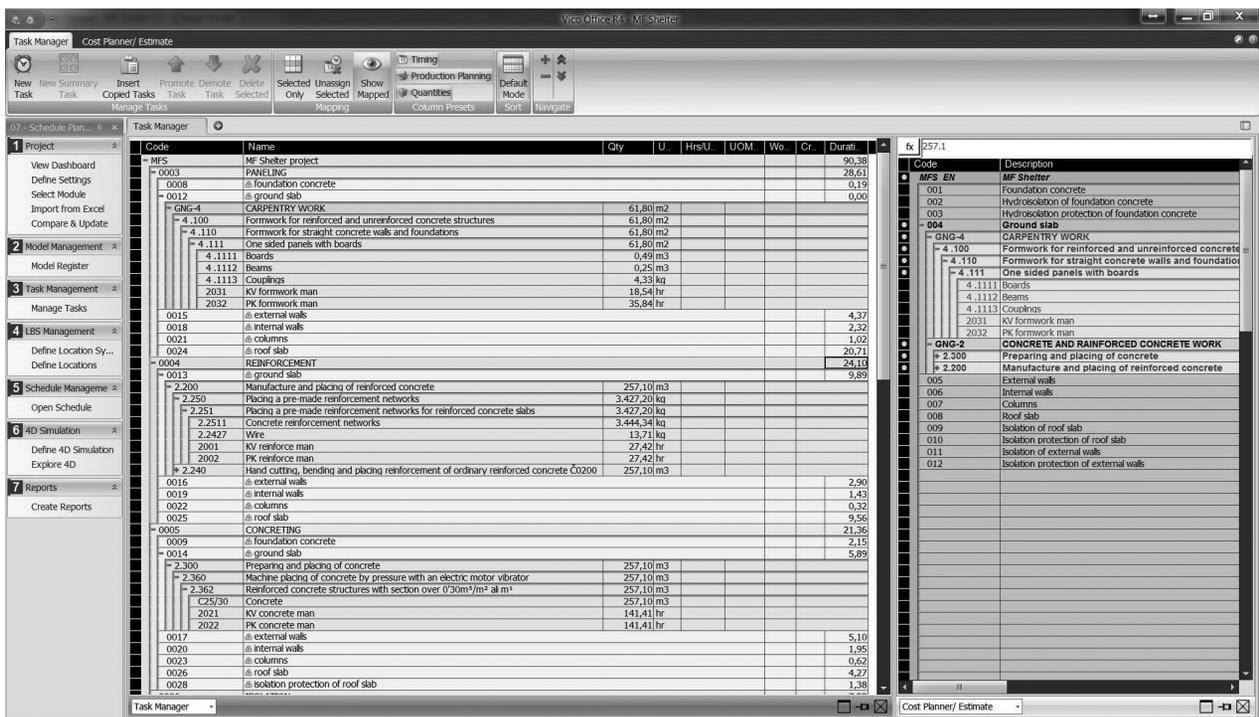


Figure 12. Activities on building elements in module Task Manager and integrated components and subcomponents for the building element Ground slab

units of measurements and unit costs into the model. For example, Figure 9 shows estimated costs with integrated

components and subcomponents of building element Ground slab.

As described in section 2, the main

project scheduling method of the Vico Office R4 application is based on the flowline theory. Thus, it was important

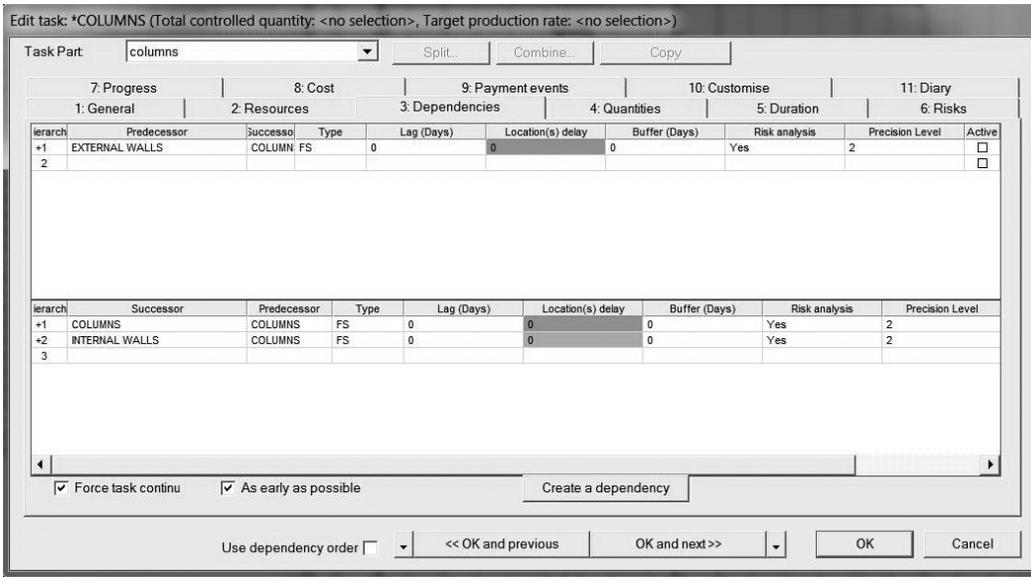


Figure 13. Construction work Paneling on element Columns with Successor and Predecessor

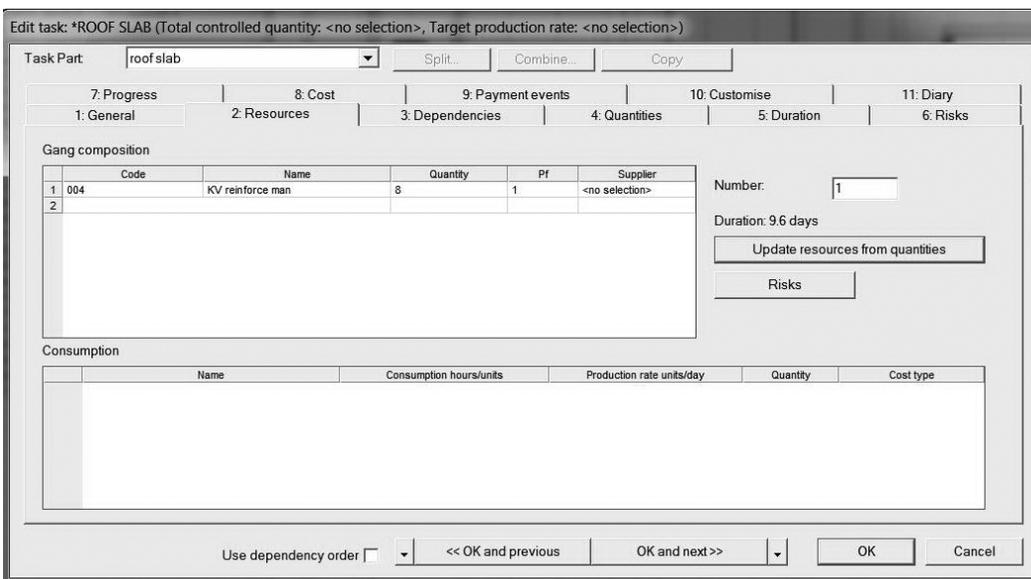


Figure 14. Allocated workers for construction work Reinforcement on element Roof Slab

to include the building locations in the project scheduling process. In the 3D model of shelter building, the three different locations were defined in the module LBS Management, i.e. Upper part, Middle part and Lower part, see Figure 10.

As an example, Figure 11 presents the building element Columns with

information about geometrical properties incorporated into the location Middle part.

Thereupon, the project activities were determined in the module Task Manager in accordance with the construction works that should be executed. The calculated cost data from the Cost Planner was linked to the construction

project activities. Figure 12 shows activities on building elements in the module Task Manager and integrated components and subcomponents for the building element Ground slab.

The Schedule Planner, a module in Vico Office R4, was activated to define the precedence relationships between activities for the purpose of project



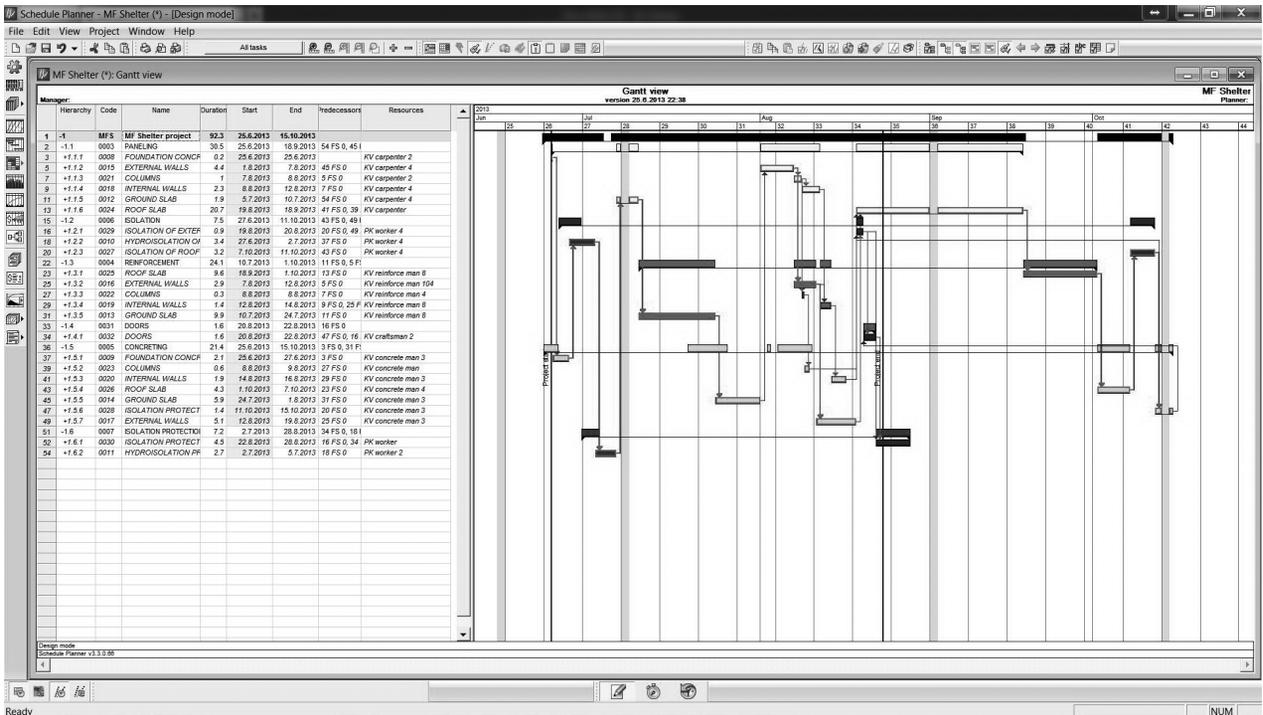


Figure 17. Gantt chart for shelter building construction project

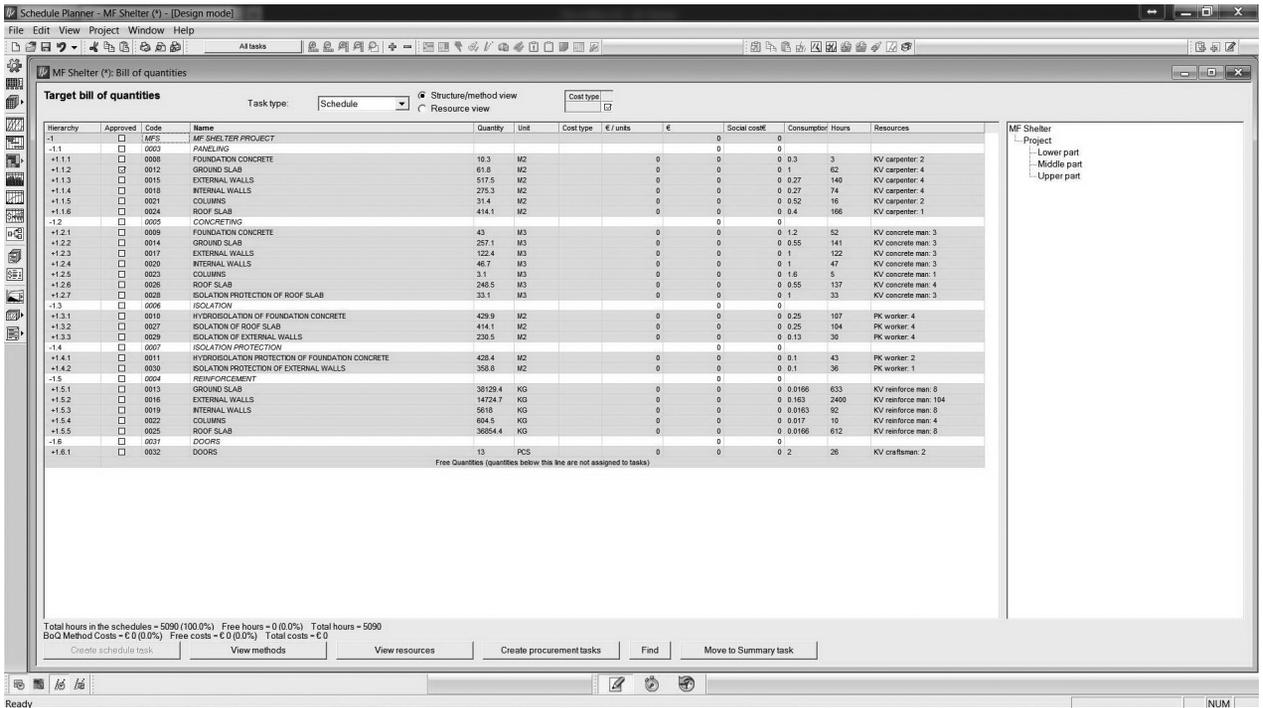


Figure 18. Target bill of quantities for shelter building construction project

scheduling. Figure 13 demonstrates the construction work Paneling on the building element Columns with defined Successor and Predecessor.

After that, the resources and the work crew sizes were allocated to the construction project activities. For example, Figure 14 shows the

construction work Reinforcement on the building element Roof Slab with allocated eight reinforce man.

After the work crew productivity

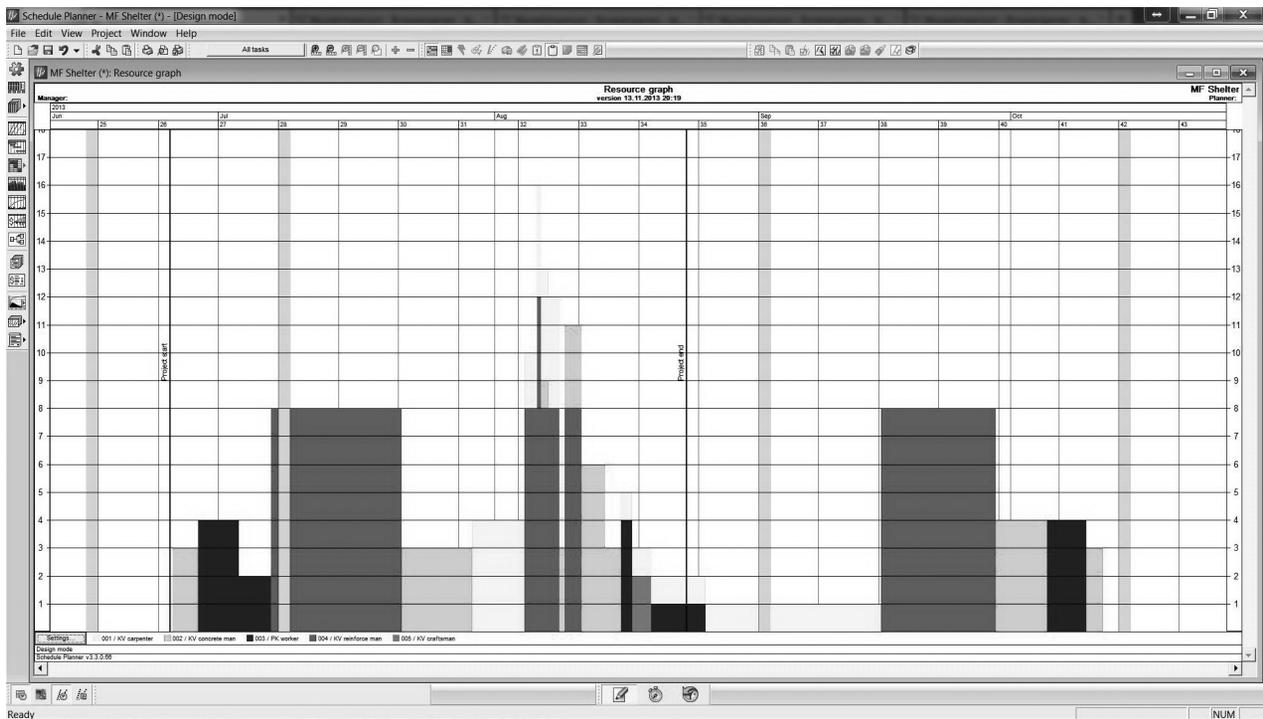


Figure 19. Resource graph for shelter building construction project

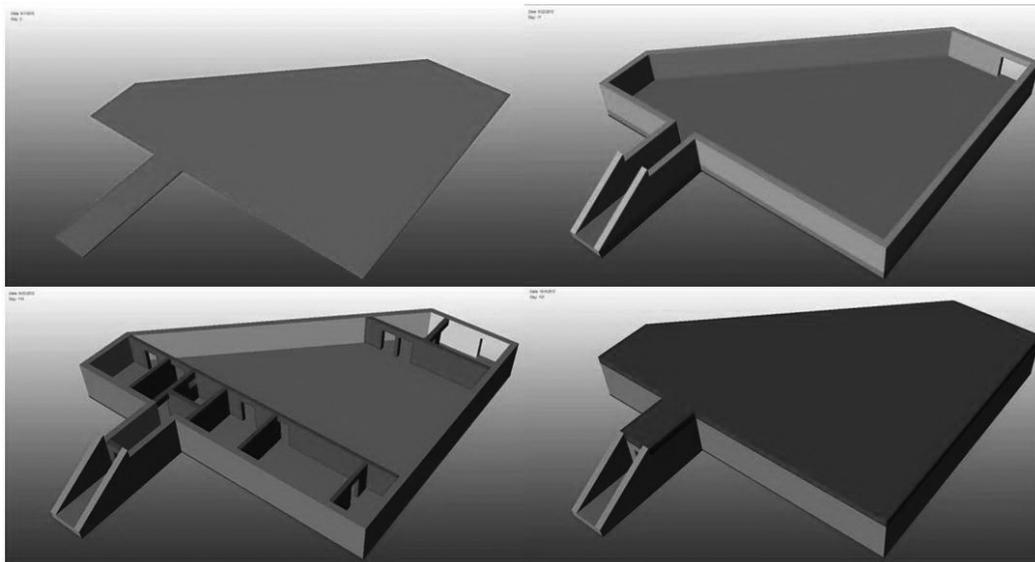


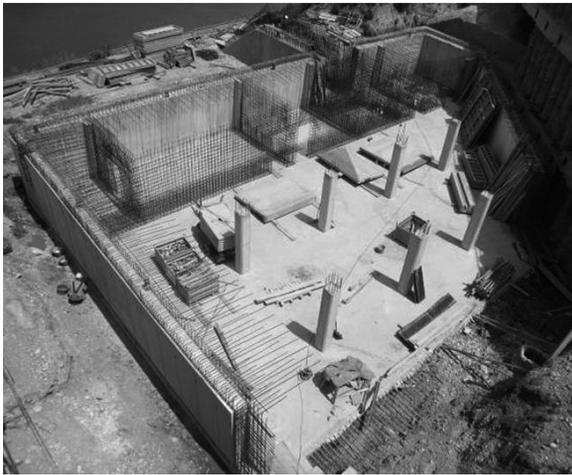
Figure 20. Construction process animation for shelter building in 4D Simulation module

rates have been defined, the durations of activities and the project duration were calculated. Figures 15–19 demonstrates the developed project network plan, flow-line diagram, gantt chart, target bill of quantities and resource graph, respectively. The considered activities of this particular example project as well as

colours used to label the construction works and assigned workers in output graphical reports were defined as follows:

- paneling (yellow)
- reinforcement (red)
- concreting (green)
- isolation (blue)
- isolation protection (violet)

The final step was to upgrade the 3D model of shelter building, which was incorporated within the Vico Office R4, with the scheduling data from the Schedule Planner and the cost data from the Cost Planner as well as to develop the 5D model. This task was executed automatically due



**Figure 20. An actual construction phase and finalization of shelter building (Proplus, 2013)**

to dynamical link that was established between the Cost Planner, the Schedule Planner and the Vico Office R4. In the 4D Simulation module, a part of Vico Office R4, an animation of the construction process for shelter building was made. A part of the construction process animation for shelter building is presented in Figure 20.

Different manually selected colours were defined within the 4D Simulation module and used for animation to achieve better visualization of single building elements. Moreover, the actual dates were continuously reported during animation in the left upper corner of the screen. Figure 21 demonstrates an actual phase of shelter building construction and its finalization.

The presented application of Vico Office R4 software indicates possibilities for project participants to contribute to a better management of construction process by implementing BIM technique in their practice. However, the project participants must be willing to make changes in their current work methods and to adopt new approaches. The main advantages of incorporating BIM approach into the construction project scheduling can be summarized as follows: i) all of the information is collected in one place and kept up to date, ii) the conception risk is minimized, iii) all changes in construction automatically

influence on other related parts of the model data, iv) all of the information is dynamically linked to the building model, v) the geometrical quantities, the number of items, the required resources, the execution times of project activities, the costs and other data are available to be used in any time. The advantages of construction time and cost planning using BIM may significantly improve the project management, especially in cases of large and complex construction projects in which the project goals are usually related to the quality of the building, short construction time and cost effective realization of the project.

### **Conclusion**

The aim of this paper was to give an insight into the construction project time and cost planning process using the BIM approach. For this purpose, the steps of the time and cost planning of the construction project employing BIM were introduced. An example based on the application of Vico Office R4 software was presented in the paper to demonstrate the advantages of the proposed approach.

In cases when initial design phases are executed to be incorporated into the BIM application, the architects have to develop the 3D building model and to determine required works. However, the design work should not be executed

through classical 2D drawings, but the 3D model of the construction object must be created on the basis of geometrical and material properties of building elements. The setup of geometrical characteristics of building elements result in basic quantities such as side length, object surface area, and object volume.

Thus, the 3D model of the building can be modified in a user-friendly manner during the design process because the basic quantities will be automatically updated. After the architectural design is completed, the engineers can upgrade the 3D model with a wide variety of different information related to structural analysis and design, HVAC, energy and environmental issues, visualization, facility management, product and technical information for manufacturers and distributors, etc.

As soon as the 3D model of the construction object is completed, the contractors may execute the cost estimates and the project scheduling. When the building model is upgraded with suitable input data, the contractors may obtain in each moment, for each building element, all relevant information for the execution of works. Such model of the construction object can contain information about the type of building elements, the geometrical quantities, the number of items, the resources needed for implementation, the execution times of project activities,

the technology implementation, the costs, etc. The biggest advantage of BIM is that the information about the construction object is stored in one place and kept up to date.

Hence, the use of modern software that allows BIM in construction projects represents a technological progress with many advantages for all participants. In this way, this paper intends to provide new valuable information for construction management experts as well as it will serve as the basis for further research in the field of BIM based construction project management.

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