The conformity of the tools of selected software programs for 4D building modeling

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Abstract. 4D modeling is a part of the BIM (Building Information Modeling) platform. It represents the design approach, when the building is designed not only in space (3D) but also in time (3D + time). The aim of the article is to compare Autodesk Navisworks and Synchro Pro in terms of the conformity with the requirements for creating and using 4D building models. The introduction represents the resource search where the advantages and ways of using 4D modeling for construction and the situation of its applying in Slovakia and abroad are summarized. Besides, the 4D model of the building Water World, created in Autodesk Navisworks and Synchro Pro, is introduced there. In the conclusion, there is a comparison of the tools of this software in user's several points of view.

1. Introduction

Today is not the first year that the era of the fourth industrial revolution (Industry 4.0). "Construction 4.0" is a branch of Industry 4.0. This term is used to refer to the digitalisation of the construction industry. BIM is one of the elements of Construction 4.0. The AEC (architecture, engineering, and construction) industry is in a constant search for new methods and technologies that will reduce costs and project implementation time, increase productivity and quality. Building information modeling (BIM) offers ways to achieve these objectives [1]. BIM provides a technology information of all elements of the building that can be used in designing, planning, and managing the project in collaboration and coordination environment. Building information modeling is a digital representation of all kinds of building data, and is used as a shared knowledge resource to make resolutions on a facility throughout its lifecycle [2].

Today BIM is the most popular and promising technology in AEC industry. The usage of BIM is growing in most countries. UK has become one of the world’s leaders in the implementation of BIM thanks to the government support, more than two thirds of the country's firms use BIM. Since 2016, all government construction projects in the UK are required to achieve BIM Level 2 [3]. In Singapore 80% of the construction industry uses BIM (compulsory for practitioners to submit architectural or engineering plans in the BIM format for regulatory approval). In Spain BIM used to be mandatory in public construction projects from December 2018 and in infrastructure projects by July 2019. More and more governments support the BIM initiative. Since 2014, according to EU Directive 2014/24/UE, the member states are invited to encourage and require the usage of BIM in construction projects financed by EU public funds as of 2016. Year by year the usage of BIM increases [3].

The basis of the BIM model is a geometric 3D model; in addition, information on time (4D BIM model), finances (5D BIM model) or other project resources depending on need can be provided.
2. 4D modeling in construction

The four-dimensional model was recognized as an approach that improves the methods of planning and construction management [4]. The usage of 4D adoption is increasing within the construction sector and upper management starts realizing the potential benefits of using it as a viable planning tool [5]. 4D models can be used to understand the relationships between the various stages and processes of construction work [4], identify and eliminate errors in the project before they occur at the construction site, coordinate work and improve the management of the work of teams and subcontractors, provide information on the current status of the project for hour plan adjustment and other important decisions, in addition, it can be used to create simulations and animations of the construction process for presentation her purposes.

2.1. The level of detail for 4D modeling

The level of detail (LOD) shows with what accuracy and how detailed the data provided in the project is developed. The level of detail of the information in a building model depends on the functions it will be used for. For 4D CAD schedule analysis model must contain temporary works (scaffolding, excavation) and show how the construction will be phased (how deck pours will be made, the sequence of wall erection, the reach of tower cranes, and so forth) [7].

Since the 4D model presents graphical and temporal data, it has the graphical level of detail and the temporal level of detail (or temporal resolution).

The graphical level of detail of a simulation is entirely reliant on the detail contained within the preliminary 3D CAD model. If a 3D model contained little graphical detail some tasks were overlooked in the simulation, while if the 3D model had too much detail the project planner was not interested in many aspects, but the work got complicated due to the large file sizes [6].

The temporal level of detail relates to the interval of time that is shown between state changes in the 3D model and how often the 3D model is updated to show the progress of construction operations. The construction process is highly dynamic and that’s why the state of the construction ‘product’ can change hourly. Conversely, some construction operations are slow to evolve and in this case it may take a week for any significant state change to occur in relation to the 3D model [6].

Both graphical and temporal detailing of 4D modeling should be such that it can contribute to the adoption of effective management decisions and, consequently, the construction processes during the project. As such, the LOD for 4D is still not well defined, and there is no way to develop a simulation with a specific approach to LOD management [8].

2.2. Current 4D software applications

Today there are enough software for 4D modeling that provide different levels of capabilities and toolkits. Consider some of them.

Vico Schedule Planner and 4D Player. That’s a part of the platform Vico office from company Trimble. The building model is imported from 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 [9]. Scheduling can be created in Vico Schedule Planner or schedule dates can be imported from Primavera or MS Project. Changes in the scheduling system are automatically reflected in the 4D visualization [7].

Innovaya Visual 4D Simulation. Innovaya Visual Simulation associates Building Information Models (BIM) objects with scheduling activities, performing 4D construction planning and constructability analysis. The building model can be imported from any 3D design program. It doesn’t have tools for scheduling, but schedule dates can be imported from Primavera or MS Project [10][11].

Navisworks (Autodesk). Navisworks technologies enable us to assemble all project data into a single model that enables us to make design decisions more effectively, manages the project, reduces errors. The building model can be imported from any 3D design program thanks to the support of the IFS format. Navisworks allows you to import a schedule from Primavera, MS Project and Microsoft Excel. It has a module that allows collision detection in real time [11].

Synchro Pro. Software created by Synchro Software. Ltd., purchased in 2018 by Bentley Systems Incorporated. This is a well-developed, complicated stand-alone 4D BIM tool [7]. Synchro has tools for
creating schedule (uses the CPM method) or you can import data from specialized software (Primavera or MS Project). Import of 3D models is possible using the IFC format or special plugins.

**Powerproject BIM (Elecosoft).** Powerproject BIM is an extension for Powerproject which allows you to import IFC data into the project plan and to associate 3D model elements with a schedule. The construction schedule is created in Powerproject, the 3D model is imported in IFC format.

### 3. Comparison of selected software programs for 4D modeling

The article will compare two programs for 4D modeling - Autodesk Navisworks and Synchro PRO. Most often these programs can be found in the literature over the past ten years. The main characteristics that the requirements for 4D modeling software should have will be considered. Comparisons are made based on the compliance with the above requirements and specifications.

#### 3.1. Characteristics of the software for 4D modeling

For comparison, we will use characteristics that are important for representatives of programs in this area, affect the construction process or simplify the use of these products and / or their functions.

##### 3.1.1. Level of Scheduling

Planning and scheduling the project is one of the most important part of construction phase. Because it depends on this plan and schedule how quickly and efficiently the project will be completed, as well as the financial part. In general, planning is the organization and distribution of work, depending on the availability of resources. Gantt charts are great for managing various kinds of task relationships. For example, the task sequence, the dependency of tasks, the completion time of tasks, the duration of every single task and more. In this case, a construction Gantt chart offers a great network based on a logical progression toward the final success of the project.

From the point of view of Scheduling, it is possible to divide programs for 4D modeling into two categories: programs that have functions for creating a schedule and programs that do not have such functions, but use graphics created in other programs. Programs of the first category also often use graphics from third-party programs, but even in this case they can edit data without resorting to the programs from which the import was performed. Representatives of the second category are deprived of these advantages. An important role is played by what formats the program supports for importing schedule and whether it’s possible to update the data if it was changed in the program from which the import was made. The level of scheduling in programs for 4D modeling is usually lower than that which is needed to draw up a high-quality construction schedule.

##### 3.1.2. Work with 3D models

Since 4D models consist of graphic and temporal data, the ability of the program to work with graphic data of the project is important. It is also important which formats can be imported. Of course, you can import models using the IFC format, but with this approach quite often errors occur (incorrect display of objects, bindings, etc.). The number of files that can be downloaded and which you can work with simultaneously, updating the model when making changes, the ability to adjust the model directly in the program, and the user interface are of great importance.

##### 3.1.3. Linking of 3D model/s with schedule

Linking 3D objects to the construction plan can be done manually or automatically. Automatic linking is possible when names of the object match the items in the construction plan. Automatic linking is only relevant for simple projects, and even in this case the result of such a link needs to be modified. However, this feature sometimes allows you to reduce the time to create a 4D model.

##### 3.1.4. Clash detection

One of the functions of 4D modeling is collision detection. Standard clash detection identifies clashes between static objects such as beams, columns, pipes, and ducts. 4D clash detection can detect clashes between permanent and temporary objects, whether static or moving (such as tower cranes and trucks), clashes of equipment and material delivery [7]. A systematic step-by-step phasing in 4D BIM eliminates the possibility of encountering any workflow clash and avoids site downtimes to keep up the man-efficiency of the task force.
3.1.5. Simulation and animation. To search for 4D collisions, we need information about all objects and their movement (location and time of temporary objects, the movement of machines and mechanisms, for example, the movement of cranes and others). To do this, the software must distinguish different types of objects (temporary, permanent, demolition objects, and so on) and be able to simulate movement at a construction site. Also, one of the reconciliations of 4D modeling is the use of materials as presentation materials. And the possibility of creating animation and its export plays a role here.

3.2. Comparison of Navisworks and Synchro Pro based on the characteristics of the software for 4D modeling

Based on the categories presented above, comparisons were made between the Synchro Pro and Navisworks software. The comparison results are shown in table 1.
### Table 1. Comparison of Navisworks and Synchro Pro based on the characteristics of the software for 4D modeling.

| Characteristics of the software | Navisworks | Synchro Pro |
|---------------------------------|------------|-------------|
| **Level of Scheduling** | It has no tools for network process analysis (Gantt chart). It allows you to create a hierarchically structured list of construction processes and assign the start and the end date to the process, displaying a line schedule of processes. The construction schedule can be imported from MS or Primavera or downloaded in CSV format. You can easily update the data if it has been changed in MS Project or Primavera. You can load several charts at the same time and work with them. | He has tools for creating a Gantt chart. It has tools for summarizing resources (histograms). It does not have tools for analysing labor and material resources. It uses a network analysis method with only simple links for time scheduling of processes that does not meet the requirements for quality tools for planning construction processes and resources in time and space. Synchro allows you to import a schedule from Primavera, MS Project, Safran Project and Microsoft Excel. It has more options for editing schedule in its software environment than Navisworks. |
| **Work with 3D models** | Models created in any product from the Autodesk family can be imported. Simple update of the 3D model. It is possible to work with several 3D models at once. Supports import using IFC format. | To import a 3D model into the Synchro software environment, IFC format or plugins can be used, for example, for import from Revit (There is an API interface that allows you to write your plugins). Data can be updated when a change is made in the source file of the 3D model. It is possible to work with several 3D models at once. You can also attach equipment and mechanisms to tasks from the schedule. |
| **Linking of 3D model/s with schedule.** | Automatic or manual linking of 3D objects and schedule is possible. Convenient filter system for manual connection. | Only manual connection of 3D model objects and construction schedules is possible. |
| **Clash detection** | The program is one of the best for searching for 3D collisions and preventing them. Automatic check for 4D collisions is not available. | Automatic search for spatial collisions is possible. Automatic check for 4D collisions is not available |
| **Simulation and animation** | It is possible to assign a certain type of task to an object (creation, temporary objects), you can also create your own types of tasks, for example, to designate different subcontractors. The movement of machines and mechanisms cannot be tied to tasks, for example, moving a | It is possible to assign a certain type of task to an object (creation, temporary objects), you can also create your own types of tasks, for example, to designate different subcontractors. The movement of machines and mechanisms can be tied to tasks, for example, moving a |
4. Conclusion
In this article, the state of 4D modeling, possibilities and capacities of software tools for 4D modeling were analysed. A comparison was made between two Synchro Pro and Navisworks products. For comparison, the possibilities and tools that are important in creating and working with 4D models have been analyzed. Each of the programs has its weak and strong points, and the choice between them should be based on the analysis of the tasks that are being implemented. For example, if the source data were developed in a product from the Autodesk family or you do not need to display the operation of machines and mechanisms, but only the construction process itself, then it may be better to use Navisworks. If you need to model the construction site, the operation of machines and mechanisms and the like in more detail, then Synchro Pro is probably the best option. The choice of program should be based on the analysis of the source data, available resources and desired results. It is also impossible not to notice that both of these programs do not have the function of automatic detection of 4D collisions. This function is very important and would significantly increase the efficiency and level of demand for this software. These programs have a sufficient number of useful functions and methods of application, but in addition to this there is a great potential for development.

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