

## SOFTWARE FOR 4D MODELLING OF CONSTRUCTION PROJECTS

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Most complex projects in the Architecture, Engineering, and Construction industries involve multidisciplinary collaboration and the exchange of large building data set. Traditionally, the collaboration efforts across the disciplines have been based on the frequent exchange of 2D drawings and documents. However, during the past decade, the widespread adoption of object-oriented Computer-aided Design (CAD) tools has generated more interests in Building Information Modelling (BIM). Idea of Building information modelling (BIM) concept consist on creating and managing data of whole building lifetime cycle in virtual model, where all information are stored. For managing of those data we need software for 3D, 4D and 5D modelling. This article is information about 3D and 4D software are collected and presented. The Civil Engineering Faculty Technical University of Košice provides relevant bachelor, master and doctoral level of the university study. In article is information, which area of Building Information Modelling was main aim in solution of master theses. The number and proportion of the student's work in Technology and Management in Civil Engineering which focused on BIM technology for the last 6 years is presented.

**Key words:** Building information modelling (BIM), 3D and 4D modelling, software tools, master diploma theses.

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## ПРОГРАМНЕ ЗАБЕЗПЕЧЕННЯ ДЛЯ 4D МОДЕЛЮВАННЯ БУДІВЕЛЬНИХ ПРОЕКТІВ

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Найскладніші проекти в галузі архітектури, техніки та будівництва передбачають міжгалузеву співпрацю та обмін великими наборами будівельних даних. Традиційно, зусилля зі співпраці в усіх дисциплінах ґрунтувались на частому обміні 2D-рисунками та документами. Однак протягом останнього десятиліття широке впровадження інструментів об'єктно-орієнтованого автоматизованого проектування (САПР) посилило інтереси в побудові інформаційного моделювання (BIM). Ідея концепції побудови інформаційної моделі (BIM) полягає у створенні та управлінні даними про весь цикл будівельного циклу у віртуальній моделі, де зберігається вся інформація. Для управління цими даними нам потрібне програмне забезпечення для 3D, 4D та 5D моделювання. Ця стаття містить інформацію про зібрані та представлені 3D та 4D програмне забезпечення. Технічний університет м. Кошице на факультеті будівництва забезпечує відповідний рівень бакалавра, магістра та докторантури університету. У статті наведено інформацію про те, яка область інформаційного моделювання будівництва була головною метою у вирішенні магістерських робіт. Представлено

**кількість і частку студентської роботи в галузі технологій та менеджменту в галузі будівництва, яка зосереджена на технології BIM протягом останніх 6 років.**

**Ключові слова: інформаційне моделювання будівель (BIM), 3D and 4D моделювання, програмні засоби, магістерська кваліфікаційна робота.**

**Introduction.** Building information modelling change today's view on construction process management during lifetime cycle of building. These assess management mostly used 2D project documentation. Building Information Modelling (BIM) represents a digital model of physical and functional characteristics of building and its facilities, which creates a source of shared knowledge and its basis for information exchange. This creates a solid base for decision making through the whole lifetime of building, from the first idea to the demolition (Sinclair, 2012). By Eastman (Eastman et al., 2011) BIM is not only a change of technology, not just a thing or software type, but human activity, which is a major change in processes in building design, construction and facility management. Parametric 3D models of buildings based on information systems change fundamentals of project documentation from documentation that can be readable only by human to documentation that can be readable by computer. 3D model in virtual space contains accurate information about building. From virtual 3D model is possible to generate automatically quantity take-offs of constructions and materials. Software tools for BIM also allow clash detection of construction design. By using of clash detection in early stage of design can be clash detected and corrected in project documentation and that helps to decrease of costs and time required to construction process. Suggested data about construction or their parts can be distributed directly to production. Virtual model allows automatic planning of products, processes, supply and costs needed for construction in time and space. Better understanding of design structure by 3D model helps also with managing of construction process directly on construction site. BIM technologies improve preparation and processes needed to construction and their energetic and ecologic requirements. Data created in realization phase will help facility manager at use phase of building for maintenance of facilities and at stage of building disposal.

Implementation of BIM technologies into construction process goes through some levels 0, 1, 2, 3:

- Level 0: unmanaged CAD files, cooperation between stakeholders in construction is in form of text or 2D documentations.

- Level 1: CAD files in 2D or 3D format with tools for cooperation, which offers shared data environment and standard data structure and formats too. Financial data are managed by isolated software without possibility of integration. 3D views of objects are used as tool of conceptual design in early stages of project and for visualization and presentation of final design.

- Level 2: Today most used level. On this level are used coordinated 3D BIM environment. Models from each profession are created from objects, which carry information about construction process. Costs are managed by Enterprise resource planning systems. This level can use 4D and 5D planning too. Level 2 require split design team into small parts.

- Level 3: Full open process. Integration of data is managed by help of server for cooperation, where is saved virtual model of building and stakeholders in construction got free access to model. This level is called iBIM (integrated BIM).

**Software for 3D modelling and 4D modeling.** Construction management requires smart planning, constant progress tracking, and getting critical information to the right people fast. Comprehensive solution for Digital Prototyping for 3D design, 4D and 5D modelling, visualization and simulation tools is help make construction project. In BIM platform 4D software tools are for integrated solution of analysis and management for conflicts and structural safety problems during construction (Zhang and Hu, 2011).

**The students software license for 3D and 4D modelling of constructions.** Those interested in software for team-based projects can combine options as needed:

- Perpetual license with Maintenance Subscription,
- Perpetual license whit Maintenance Subscription and Desktop Subscription,
- Desktop Subscription.

Schools and universities have at their disposal a comprehensive free EDUCATION package containing almost all the major software provided by more computer companies. A positive example is Autodesk. In the Student Community, Autodesk can do the following Learning, Support, Design Showcase, Community, Spotlight and Competitions. Computer companies developing BIM software allow students to have 1 – 3 year student license. Student allows:

- Use individual programs for FREE or buy programs at the seller and get benefits,
- Buy full bundles at the ultimate vendor, and convert with a discount on a commercial license when you go into practice.

**Software for 3D modeling.** Engineered Models for Construction (3D modeling) can reduce construction costs during all stages of construction. The 3D modeling offers savings through greater accuracy, efficiency, and reduced resource cost. 3D data not only enhances design through clash detection and better visual representation of the completed project prior to breaking ground, but it also can be used for facility management of building. The representatives of software for 3D modelling of building constructions are shown in table 1.

*Table 1*

**Software for 3D modelling**

Software Name	Creator	Commercial license
Revit	Autodesk	Payed
ArchiCAD	Graphisoft	Payed
Tekla Structures	Trimble	Payed
Microstation	Bentley	Payed
Allplan	Nemetschek	Payed
Sketchup	Trimble	Payed
VICO Virtual Construction	Trimble	Payed
Blender	Blender Foundation	Free
Designshark	DesignShark inc	free
FreeCAD	FreeCAD inc	free

**Software for 4D modeling.** 4D technology allows you to connect the spatial structure of the building structure with time. This connection carried out by linking business operations with 3D objects that correspond to a given activity. The result is a simulation of 4D construction work to simulate the construction process in time. The representatives of software for 4D modelling of building constructions are shown in table 2.

Expected start and expected end for given planned work for 3D object of building project are the inputs information for 4D modelling. This information is obtained by modeling the construction schedule. The representatives of the software for modeling the construction schedule are: Primavera Project Management 4-6, Microsoft Project 2000-2017, Microsoft Project MPX, Primavera P6 etc. For given planned work that correspond to 3D object of building project you need to enter for 4D modeling information about a type of 3D object that can be construct, demolish or temporary.

Table 2

### Software for 4D modelling

Software Name	Creator	Commercial license
Synchro	Synchro Ltd	Payed
NavisWorks	Autodesk	Payed
Constructsim	Bentley	Payed
VICO Virtual Construction	Trimble	Payed
Allplan	Nemetschek	Payed

4D simulations can be used at different stages of the construction process for design analysis or the suitability of the design of the structural point of view and also for planning and monitoring the construction process. 4D construction simulation process helps in increasing the reliability of the schedule reduces the risk of different interpretations schedule and minimize communication problems. Opportunity to communicate effectively between the parties to the construction and coordination of changes in the timing and method of construction is crucial for the construction management from the perspective of managers. Visualization Build allows the management personnel of responding promptly to any problems and take decisions that will repair schedule before building. The elimination of scheduling problems will reduce costs that would be incurred downtime and delays in completion of works.

Diploma thesis whit 4D modelling construction projects. The Civil Engineering Faculty TUKE provides relevant bachelor, master and doctoral level of the university study. In table 3 is information, which area of BIM was main aim in solution of master theses.

Table 3

### Areas of Building information modelling

A	Building design with use of BIM technology (3D model of selected construction and building equipment).
B	Time-space planning of resource and time simulation of construction (4D construction model).
C	Modelling of construction process condition (3D, 4D and 5D modelling of construction site)
D	Calculation of building construction costs from virtual model (quantity takeoff from 3D model, 5D modelling)
E	Facility management (3D model of exists building construction and technical equipment of building)
F	Planning and managing of construction process (work with projects in BIM environment)
G	Modelling and simulating of virtual model parameters from different views

Bachelor and master theses in Architectural Engineering programs in Civil Engineering Faculty TUKE are mostly thematically focused on architectural and construction solution of building. Analysis of projects shows that project documentation for master thesis from Architectural Engineering study programs are usually created in 2D software. In 3D software are only architectural visualization models. The occurrence of project design in software support BIM technology is unique. This 2D documentation cannot be used for solution of tasks in specific area of BIM.

Students from Structural and Transportation Engineering study programs got thesis focused on construction solution of engineering buildings or on building construction static assessment. Mostly used BIM tool in educational process is Tekla Structure, SCIA and AutoCAD Civil 3D, which supports BIM for civil engineering design and documentation for transportation, land development, and water and wastewater projects. Active use of software tools for solution of assigned tasks within technical subjects is good basics for use of BIM technology in thesis.

In Technology and Management in Civil Engineering study programs was main motivation for bachelor and master thesis focused on BIM technology, solution of PhD thesis regarding with themes of research projects on Institute of Construction Technology and Management.

Table 4 show the number and proportion of diploma work of students in Technology and Management in Civil Engineering study program which focused on BIM technology for the last 6 years. Analyzes show that most of the BIM work is on this program (table 5).

Table 4

**Number and percentage of thesis focused on BIM technology**

Academic year	Number of students	Diploma theses in BIM		Area of BIM (by table 2)
		number	%	
2015/2016	33	4	12.1	A-B; A-B-F; C; E
2014/2015	54	3	5.6	B; F; A-G
2013/2014	36	2	5.6	B; B
2012/2013	26	-	0	-
2011/2012	28	3	10.7	A-C-D; D; A-F-G
2010/2011	35	3	8.6	A-B-D; C; C-D

Table 5

**Diploma theses in 4D modelling**

Academic year	Student	Diploma theses	Software for 4D modelling
2015–16	Andrej Ňarjaš	Use of software for 4D modelling of construction	Navisworks (Revit)
2015–16	Michal Homza	Use of BIM environment for scheduling of construction projects	Synchro (ArchiCAD)
2014–15	Michal Bulko	Planning and optimization of construction resources	VICO Control
2013–14	Karol Urbán	Time-space planning in construction project	VICO Control
2010–11	Štefan Mandzák	Processes 4D modelling of reinforced concrete structures realization	VICO Control (VICO Constructor, VICO Estimator, VICO Presenter)

For final thesis topics focusing on 4D modelling of a building and its structures, it is desirable that the architectural documentation of the construction be made in software environments supporting the 3D information model of building structures.

Conclusion. Students of any school can use listed software for education purpose for free. Whether student will spend study period to acquire not only knowledge but skills in work with BIM software, it is on student personal judgement. In 2017 Civil Engineering Faculty Technical University of Kosice (TUKE) filled for accreditation the educational lifelong learning program focusing on BIM technology. Within 16 program modules focused on special BIM software, every lasting for 12 – 36 hours, absolvent can get skill and knowledge about 3D (4D, 5D) modelling. Lifelong learning for designer, subcontractor, developer, building owner and facility manager offer another organization and training center too. For example BIM association Slovakia (BIMAS, created in 2013) offers courses and trainings in design in BIM software, work with projects in BIM technologies and analysis appropriateness of modelled project or already build construction. Lifelong learning courses organized by TUKE track two main goals. First is increase educational and practice competences of own education employee. Second is to provide opportunity to increase knowledge and skills for construction industry workers.

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