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Building Information Modelling – 4D Modelling Technology on the Example of the Reconstruction Stairwell

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Abstract

Building Information Modelling (BIM) is a process that involves creating, generating, managing and using a digital representations of physical and functional characteristics of building. The use of the term 4D is intended to refer to the fourth dimension: time, i.e. 4D is 3D + schedule (time). The role of 4D BIM is to add a new dimension to 3D CAD or solid modelling—that is, 4D BIM adds a fourth dimension of Time to the 3D Space of CAD solid modelling on computer. In the paper show the project entirely made using 4D BIM

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Keywords: Building Information Modelling (BIM); 3D design; CAD; architectural engineering and construction (AEC) software

1. Introduction

The main goal of this paper is investigation of the BIM programs' abilities in regards to projects with various design options and with necessity to phase tasks.

The effect of this work is three-dimensional model of a staircase, with a few design options, “compatible” with BIM. On the base of this model, building documentation is created.

On the example of the staircase, the survey of Autodesk Revit 2015's effectiveness of creation of project with various design options will be undertaken. There will also be examined the possibility to exchange data with some other programs (e.g. Autodesk Navisworks). One section of this paper will also shortly introduce the idea of BIM – its foundations and terminology.

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2. Description of existing building and its documentation

2.1. Provided documentation

The provided documentation of the existing building consists of 2D architectural plans and one section of the staircase. All of them are created in traditional CAD 2D work system.

2.2. Description of existing building and its planned modernization

The effectiveness of the program will be examined on the example of a few decades old building. The access to each apartment is provided by only one staircase, which will be crucial in the planning of its extension.

The building consists of 7 floors – cellar, 5 residential storeys and attic. The cellar's height is 268cm. Other floors are about 335cm high. Fig. 1 demonstrates existing geometry of the stairwell.

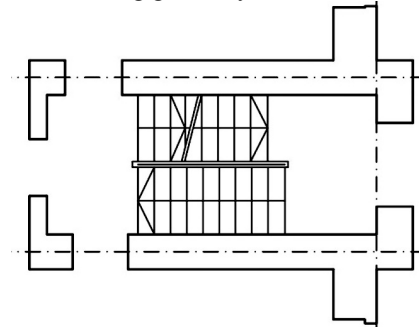


Fig. 1. Existing geometry of the staircase.

The aim of the modernisation is to add the elevator to the stairwell. There are 3 different conceptions of the upgrade:

- Building the elevator's shaft outside of the staircase, see Fig. 2.
- Building the shaft inside and moving the stairs out, see Fig. 3.
- Creating the lift at the place of one of the stairs' run and building additional stairs outside, see Fig. 4.

The first option will be the cheapest one, but the usefulness is limited because the elevator would have to stop at the mid-floors.

The second option provides better usefulness but the construction would be much more inconvenient. In order to provide the access to the flats there is necessity to phase the tasks very carefully.

The third option seems to be optimal. Its usefulness is slightly worse than the second one but its construction demands just the same inconvenience for the residents as the first option.

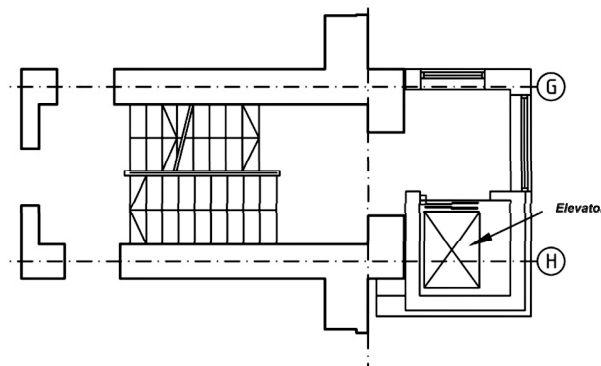


Fig. 2. 1st conception of the staircase's extension.

Important aspect of this work is to clearly present (with 3D visualisation), to all people concerned, the main features of all options without forcing anybody to read traditional documentation.

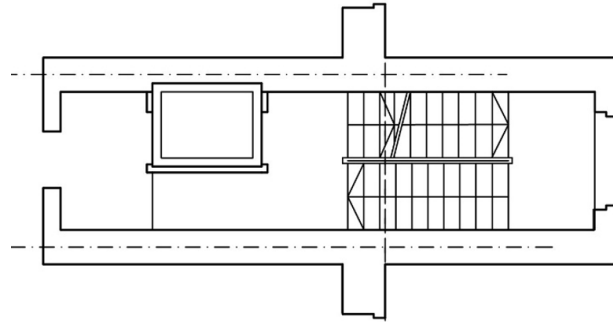


Fig. 3. 2nd conception of the staircase's extension.

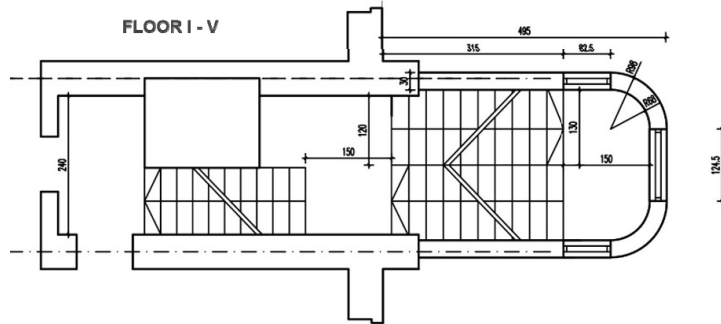


Fig. 4. 3rd conception of the staircase's extension.

3. Building Information Modelling

3.1. What is BIM?

BIM (Building Information Modelling) allows designing of the building in agreement to *from cradle to grave* approach. It is possible to model the build though its whole existence time, which means from the developers conception to the destruction of the building, [1].

The realization of this idea is possible by exchanging the traditional drawings with three-dimensional model enriched with various additional information. Such model consists of certain objects representing functional parts of the building like walls, slabs, doors, windows, etc. Each object has some associated set of properties, which, depending of the component's type, allow to create material schedules or help in creating the analytical model of the structure. The addition of these information takes some time, obviously, but it can later be used everywhere and its modification is visible in the entire model.

Typical feature of such design is that the collisions are easily perceivable. Sometimes it is impossible to add some component when the collision is too obvious. It is also not possible to cheat in dimensioning the plans – the change of dimension require change in the model.

3.2. Terminology of BIM

Depending of the usage of BIM in various phases of the building development process there are distinguished the following types of it [2, 3]:

- **BIM 3D** – it is the basic form of the BIM. Its use is constrained only to making building documentation with some material take offs or other schedules. It is important to differentiate it from CAD 3D. In BIM the building must be divided into functional components with particular properties.
- **BIM 4D** – in addition to functionality of BIM 3D, the fourth dimension is added – time. Every component in model contains information about its creation date and, possibly, destruction time.

- **BIM 5D** – information about cost of each task provides the fifth dimension
- **BIM 6D** – in addition to BIM 5D functionality, it offers energy analyses.
- **BIM 7D** – last dimension regards usage of model in maintenance of the building. Currently there is no software able to provide such functionality.

3.3. The IFC format

IFC (Industry Foundation Classes) – it is a platform neutral file format with open specification, developed by building SMART. Its aim is to provide data model able to contain as much information about building as possible. The IFC specification is registered by ISO and is an official International Standard ISO 16739:2013, [4,5,6].

Every proper BIM software should be able to read and write such a file format.

The structure of an IFC file is based on entity-relationship model. It can be imagined as relative database, in which certain entities are connected by various relations. These attachments are especially important, because they allow for very complex and flexible description of an object's elements by using many various entities capable of holding almost every important information. Thus, apart from saving such basic information about the element as its geometry and location, it is also possible to add information about materials, manufacturers, connections with other elements (e.g. type of connection between beam and wall), etc. It is very crucial to realize that these characteristics do not look like a list of properties attached to each element. The attachments are rather the references to other entities. It means that when e.g. a wall is considered, one of its properties is type of concrete used and it is indicated by the reference to other entity – *Class C30/37 concrete* in this example. Such structure allows later for very fast gain of information. Thanks to the references, it is immediately known in which components given material was used. The data organization in form of static properties of each element would require, in order to acquire similar set of data, checking every component's characteristics separately, one by one. It seems intuitive that such process would be much less effective, with the performance decreasing along with the growth of number of the elements. The usage of relation model also allows for avoiding the data redundancy and makes its validation easier.

4. Creation of the model in BIM

4.1. Creation of the building model

Creation of the building model in Autodesk Revit 2015 is very intuitive. The first thing to do is to import DWG files into Revit. This process is very easy to set up. Next step is to create levels for each story. It may be helpful to create levels also for stair landings.

Next step is to configure appropriate types of components (walls, slabs, stairs etc.). There is complete freedom in creations of partition layers. The only thing to remember is to choose certain materials, not to leave *<by category>*.

Afterwards it is possible to go ahead with the creation of the model. At first, the existing condition should be modelled. Then it is necessary to copy all elements into design options (it is due to inability to edit *Main Model* in options). After doing so the modelling of alternative realizations follows. At the beginning few phases shall be set up, because later each component will have creation and, optionally, destruction phase assigned.

While doing model of the building few obstacles emerge. The most important one is the inability to change component geometry during its lifetime (although it is possible when adding window or door to the wall). Hence, when some element will require cutting an opening in the wall in some phase, the opening will be visible in the model from the moment of creation of the wall. It is huge shortcoming of the program.

The process of the model creation is easily managed and verified thanks to the 3D view.

4.2. Solar study

Polish regulations require that at least one window in the room should be lit by the sun at least 1,5h in the autumn and spring equinoxes in the hours from 7 am to 5 pm, [7].

Survey of this regulation is easily conducted in Revit. It is just necessary to add the location and azimuth of the building and the analysis is ready to be made. There are different types of solar studies available, but I used just the

one-day analysis, due to the regulations. During the analysis Revit calculates the shadow range at each time of the day and the user assignment is to check when the shadow starts to cover the whole area of the window concerned. Fig. 5 shows the example of such study.

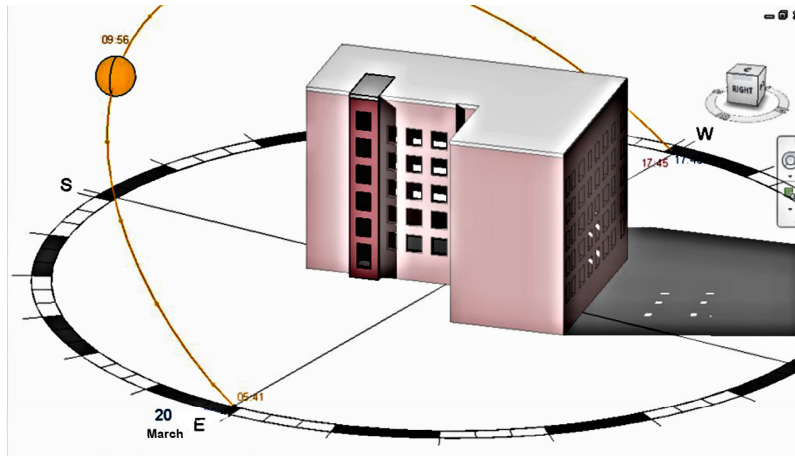


Fig. 5. Example of solar study undertaken in Revit.

4.3. Creation of the 4D schedule and the visualizations

The 4D schedule is prepared in Autodesk Navisworks. The creation of schedule starts with importing the data from Revit model. Next thing to do is to assign each component its task. The tasks are divided into categories. The basic ones are creation, destruction and temporary. Nevertheless, it is possible to define our own type. Such assignment is easy due to the possibility to filter elements on the base of their Revit's creation and destruction phases.

After creation of the tasks and attaching components to them, the only procedure left is to set the start and the end dates of each task. Having set all of them it is now very easy to make animation of the building construction. Visual settings of the materials are copied from Revit, hence if everything has been set properly there is not much more work to do. Two slides of such animation are presented in Fig. 6a and Fig. 6b.

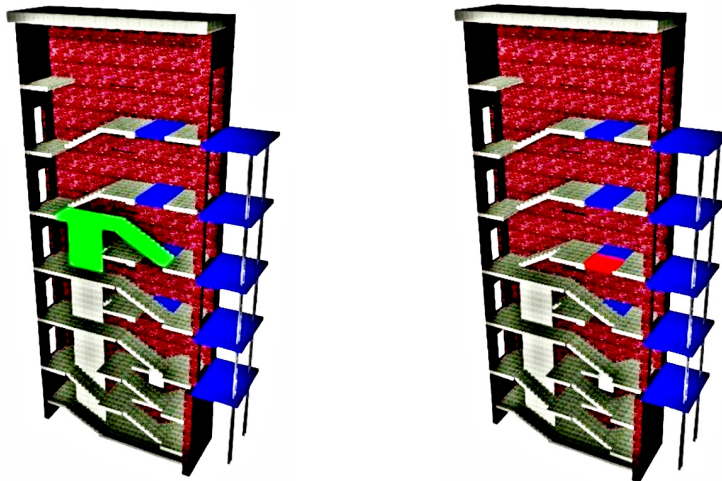


Fig. 6. (a) One of the construction tasks in Navisworks; (b) One of the demolition tasks in Navisworks.

4.4. Creation of building documentation

The creation of such documentation is very easy, because the floor plans, sections etc. are created automatically. The only thing left to do is to set up proper hatching, thickness of lines and so on. The creation of annotations is also automatized. The tags for each element are added by one click of the mouse. The most important job for the designer is to make the drawing tidy and readable.

Unfortunately, when it comes to tasks phasing, the creation of the documentation is painful, because each floor plan or section has to be copied to cover each phase we want to use on the sheet. It very fast becomes very tiring, even when there is only a few phases of construction.

The Revit's handling of design options in documentation is also underdeveloped. It is, e.g. impossible to make a sheet with two drawings concerning different conceptions. It is only possible to use only one design option on the sheet at the time.

5. Conclusion

Autodesk Revit 2015 is very convenient tool and proper piece of BIM software. It has its shortcoming, obviously, but it is very intuitive and yet powerful. When it comes to the modelling, the construction phasing is handled properly, but it cause some inconvenience when the documentation is created. Still, the time required to produce the paperwork seems to be significantly shorter comparing to traditional workflow – CAD 2D.

The functionality of design options seems to be made to support rather small variations of the project. The more changes each option adds to the project the more inconvenient the use of it becomes. It seems to be prepared to handle only some temporary options, which means that the designer should make an effort to choose one option as fast as possible and forget about the rest. When it is necessary to create different conceptions of the building, work in a few, separate models seems to be the better decision.

Autodesk made a suite of programs nicely covering the requirements of BIM 4D. The exchange of the information between this company's products is excellent. The cooperation with other firms' software is also very good through the IFC format [8].

BIM with no doubt allows for realization of every project and always the effect will be time savings comparing to the traditional workflow. The cost, though, is not necessarily lower, depending on the software own.

When working in BIM it is crucial to carefully choose software we would use and develop suitable workflow and information exchange system (e.g. IFC vs. native file formats).

It also very important to have in mind that the most important factor in the process is still the user. BIM simplifies many tasks and allows for many savings. Nevertheless, the creation of good, economical project requires much user experience and sensibility.

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