2D AND 3D BUILDINGS MODELLING BY USING GEODETIC MEASUREMENTS

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Introduction

Now buildings are more complex than ever before, because today we have greater telecom, security, electrical, data and energy requirements. Earlier documentation sets were hundreds of pages long. Load of work with these sets of drawings became huge, because people had to produce them, evaluate them or use them to build a building. But the computer-based technology has replaced pen and paper. Drawing and editing lines is faster and more efficient. However, these lines and text are not intelligent lines and text. They are still manually created collections.

Computer-aided design (CAD) is the use of computer technology for the design of real and virtual objects [1]. CAD is a 2D technology that outputs a collection of lines and text on a page. These lines have no inherent meaning in the computer or on the printed sheet [8]. Of course, CAD has its advantages over pen and paper, but it is still a digital modelling of the act of drafting. This form of drawing shows us how architects, engineers and designers have worked in the last century [7]. Earlier designers drew plans manually. It was inconvenient, because if any of the items changed, the designer had to modify each of the other drawings that were affected, in order to take the change into account. In our days we can use a *Delete* key, but the aim is the same. Thus, here BIM makes important departure from CAD platforms.

BIM is beginning to change buildings: how they look, the way they function, the ways in which they are built [5]. BIM is not a type or a thing of software but a human activity that involves wide process changes in construction. BIM must be: digital, spatial, measurable, comprehensive, accessible and durable. In BIM all elements are loaded with data that describe not only geometry, but also material, fire rating, cost, manufacturer, count, and just about any other metadata you can imagine.

Now we can have all disciplines involved with a project sharing a single database [5]:

- Architecture, structure, mechanics, infrastructure and construction now can be coordinated separately, not together.
- Models can now be sent directly to production machines.
- Energy analysis can be done at the outset of design.
- Construction costs become more predictable.

BIM regards how designers and constructors look at the entire building process: from preliminary design through construction documentation, into actual construction and even into post-construction building management [5]. With BIM a usual 3D model is used to generate traditional building abstractions: plans, sections, details, elevations and schedules. Drawings produced using BIM are not just collections of lines and coordinates but an interactive view of a model.

A work with a model-based framework is easier and very convenient because it guarantees that a change in one view will be transferred to all other views of the model [6]. If you remove a window from the model, it simultaneously is removed from all views and your window schedule is updated. If you move elements in plan, they change in elevation and section.

Research aim and objectives: to analyze advantages and disadvantages of 2D and 3D modelling using AutoCAD, Autodesk Revit Architecture and Autodesk Revit MEP software, and to compare BIM and CAD technologies.

Research methods:

I started my Project with measurements of Vilnius Gediminas Technical University. I measured the second floor. These measurements were not like usual cadastral measurements, because I had to measure this floor for a 3D model. It means that I had to measure not only length of walls, but every detail in all rooms: sockets, switches, lamps, all cords which we see and other things. In addition, I had to know all materials of walls, floors, ceilings. I obtained this information from my university. I had to gather all information needed for Building Information Modelling.

For measurements I did not use any coordinate system. I used a laser distance meter (Leica DISTO D2) and a tape-measure where there were no possibilities to measure with a laser distance meter. I wrote all the measurements on a paper. When I had measurements I drew a 2D model with AutoCAD software (Figure 1). I have more than three year experience of working with AutoCAD software, so it was not very difficult for me to draw a 2D model of one floor.

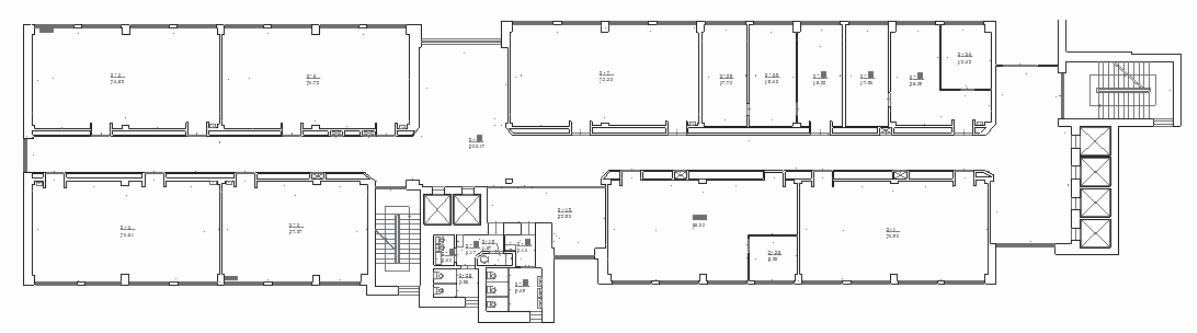


Fig. 1. 2D model

Research results

The greatest difference between BIM and CAD is that a CAD system, especially 2D, uses many separate documents to explain a building. For example, the wall view is represented with two parallel lines, and we cannot understand that those lines represent the same wall in a section. BIM assembles all information into one location. It is a centralized database model. In BIM all documents are interdependent and share intelligence. (Figures 2 and 3).

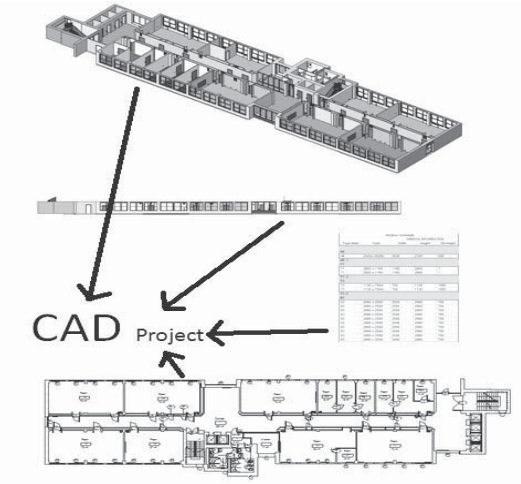


Fig. 2. A CAD project consists of many uncorrelated, independently created files

The best thing in BIM is that it manages changes for you. If we do a change in one place of the project, the system will change all relevant views and documents of the project. If we change size of a window opening, this change is made throughout sections, floor plans and schedule tables.

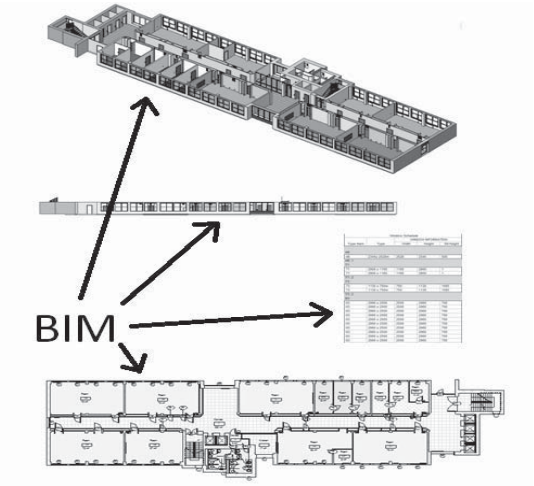


Fig. 3. The BIM model is a centralized database in which all documents are dependent

Here are five big differences between BIM and CAD:

- *BIM as a task-oriented methodology is faster than an object-oriented one* [4]. In 2D drafting we draw a wall with two lines. In BIM, a wall is presented like an object named *Wall.* This wall has height, width, angle, fire rating, materials, is interior or exterior, demolished or new. If we add a door, in BIM it is more than four lines, in contrast to the case in 2D drafting. Adding a door to a wall automatically creates an opening in the wall in all views where the door is.
- *BIM keeps us honest* [4]. One of the advantages of BIM is that we cannot cheat design, because the elements have properties based on real-life properties. If we have a window in plan, it automatically appears in other associated views, such as an elevation or a section. In a CAD system this can be easy to overlook because we can forget to draw a window in the place or we can draw it in a wrong location.
- *BIM is more than a 3D modeller* [4]. Usual modelling does not have the ability to document a design for construction. But it is possible to bring a model into a BIM application and progress through design, analysis and documentation.
- *BIM is a data-driven design tool* [4]. BIM lets you create custom content and libraries. This content contains a rich amount of data that will inform schedules, quantity take-offs, and analysis. Therefore, it is not just 3D – it is 3D with intelligent information.
- *BIM is based on an architectural classification system, not "layers"* [4]. In CAD every line belongs to a layer. For this reason we can place, for instance, a window in the wrong layer. For example, in Revit, there is no way to accidentally place a window in the 'wall' layer.

For 3D modelling I chose Revit Architecture and Revit MEP software, because Revit is the most technologically developed BIM application (however, there are many pieces of software based on BIM technologies (Table 1) [2]). The name Revit comes from "Revise Instantly". Revit is built for managing change. This software was designed from the ground up as a BIM platform to specifically address problem areas of architecture, engineering and construction industry: communication, coordination and change management. In CAD users have to do a lot of manual updating, but Revit understands when a change happens and does it automatically.

Table 1**.** ***Software based on BIM technologies***

SOFTWARE	PRODUCER
Revit	Autodesk
Navit Works JetStream	Autodesk
ArchiCAD	Graphisoft
Constructor	Graphisoft
Bentley Architecture	Bentley Systems
Digital Project	Gehry Technologies LLC
Vector Works Architect	Nemetschek N.A
Tekla Structures	Tekla Corporation
SPIRIT	SOFTTECH GmbH
StruCAD	AceCAD Software Inc
IFC Engine Series	TNO

Revit has many advantages, but sometimes, if we are not careful, there may be disadvantages as well, especially for users who may be quick to make changes. Revit creates relationships between building elements in order to streamline the design process. For example, if we delete a wall, all windows, doors and other elements will be deleted. But a very attractive aspect of Revit is that it will not let you leave elements floating around.

Another attractive aspect of Revit is that we can import and export to a predefined set of layers. I have imported my 2D CAD model into Revit very easily and quickly.

A 'SlimBIM' is a digital model of the building without intelligence. A 'SlimBIM' consists of walls, floor, doors, stairs, windows, etc. In 'SlimBIM' we do not have any information about building, materials, communications, etc. We have only a 3D view (Figure 4).

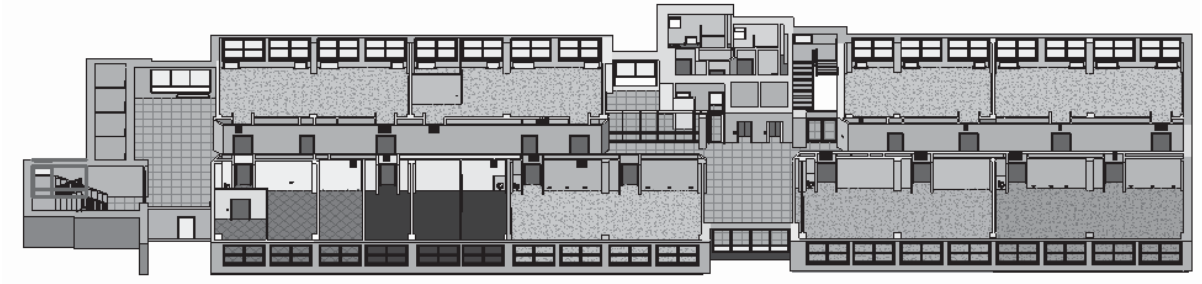
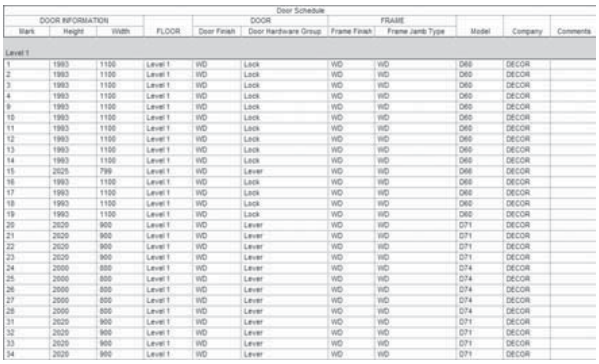


Fig. 4. SlimBIM

BuildingSMART is a digital model with intelligence. If we want to get a full BIM model, we have to put in all information about building, constructions, communications and other details. Type of information depends on the drawer, because he can put in, create all information which he needs and considers important.

I, for example, tried to put in and create all information so that everybody could find the information needed. For example: electrician – about electricity, plumber – about heaters, communications.

All information in Revit is in schedules (Figure 5). Creating schedules is very easy and quickly. We can choose fields and create new fields if we think that they are necessary.



Door Schedule

DOOR INFORMATION				DOOR		FRAME				
Mark	Height	Width	FLOOR	Door Finish	Door Hardware Group	Frame Finish	Frame Jamb Type	Model	Company	Comments
Level 1										
1	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
2	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
3	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
4	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
9	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
10	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
11	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
12	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
13	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
14	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
15	2025	799	Level 1	WD	Lever	WD	WD	D66	DECOR	
16	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
17	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
18	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
19	1993	1100	Level 1	WD	Lock	WD	WD	D60	DECOR	
20	2020	900	Level 1	WD	Lever	WD	WD	D71	DECOR	
21	2020	900	Level 1	WD	Lever	WD	WD	D71	DECOR	
22	2020	900	Level 1	WD	Lever	WD	WD	D71	DECOR	
23	2020	900	Level 1	WD	Lever	WD	WD	D71	DECOR	
24	2000	800	Level 1	WD	Lever	WD	WD	D74	DECOR	
25	2000	800	Level 1	WD	Lever	WD	WD	D74	DECOR	
26	2000	800	Level 1	WD	Lever	WD	WD	D74	DECOR	
27	2000	800	Level 1	WD	Lever	WD	WD	D74	DECOR	
28	2000	800	Level 1	WD	Lever	WD	WD	D74	DECOR	
31	2020	900	Level 1	WD	Lever	WD	WD	D71	DECOR	
32	2020	900	Level 1	WD	Lever	WD	WD	D71	DECOR	
33	2020	900	Level 1	WD	Lever	WD	WD	D71	DECOR	
34	2020	900	Level 1	WD	Lever	WD	WD	D71	DECOR	

Fig. 5. Door schedule

One more power of Revit is that when we place a door in the model it is automatically assigned a sequential door number. The same is with windows. In Figure 5 we can see a door schedule. The dimensions of the doors are created automatically, so I did not have to write one by one. But, for example, I had to write in a model, a company. But this is natural, because software cannot know these things. This schedule can help everybody. For example, if we break a door, we can open the door schedule and see the model of the door and company producing these doors. So, we just go to the shop and say that we need this door, with these dimensions, etc.

But schedules do not end with doors and windows. We can schedule almost any item that goes into the model.

Next step of creating buildingSMART is creating material takeoffs. It is similar to creating a schedule. The only difference is that we are now breaking components down and scheduling the smaller pieces (Figure 6). For example, we could get a schedule of all the doors. But with material takeoff, we can quantify the glass within the doors, the area of door panels.

Door Material Takeoff

Mark	Material: Area	Type	Width	Height	Door Finish	Family
4 m²: 1						
5 m²						
1	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
2	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
3	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
4	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
9	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
10	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
11	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
12	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
13	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
14	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
16	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
17	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
18	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
19	5 m²	1100 x 1993m	1100	1993	WD	M_Single-Flush
5 m²: 14						
6 m²						
36	6 m²	2400 x 1900m	1900	2400	PL	M_Double-Glass
6 m²: 1						
7 m²						
36	7 m²	2400 x 1900m	1900	2400	PL	M_Double-Glass
7 m²: 1						
7 m²						
41	7 m²	2400 x 2900m	2900	2400	PL	M_Double-Glass
7 m²: 1						
11 m²						
41	11 m²	2400 x 2900m	2900	2400	PL	M_Double-Glass
11 m²: 1						
Grand total: 71						

Fig. 6. Door material takeoff

One more thing in Revit which I like very much is that we can preview our drawing and see how, for example, a corridor will look in reality (Figure 7).

Fig. 7. Corridor rendering

So, I can say that all information in buildingSMART can be sorted into: 'must-have', 'should-have', or just 'nice to have' [3].

Conclusions

1. Both pieces of software are suitable for building modelling. They have a lot of properties to create a model as real as possible. They both produce the main objects, such as walls, doors, windows, etc. But it was noticed that when using AutoCad there was no possibility to create families. With the help of families we can easily change various minor details as desired.
2. 3D design is easy to understand because we see and know what windows, doors, and other details look like. It is not just lines like in a 2D

model. In addition, not everyone can understand 2D, because we have to know how we draw windows, doors, and what the symbols mean.

3. 3D design gives us an ability to show a variety of design options to the team and the client. For example, if the client can see a 3D buildingSMART model of his future house, he can change the colours of walls, the style of doors and other things and preview the result.
4. In Revit automated schedules of building components can be automatically produced and improve the calculation of costs and quantities.
5. In Revit material quantity take-offs allow for better planning and predictability, because in the table we can see which kind of materials we need, how much materials we need and where we need them.
6. Popular AutoCAD software with 2D modelling is universal, it is good to learn to draw, to do small-scale projects. But Building Information Modelling lets us not just do, but create and model projects. The goal of BIM is to control calculations and interaction of elements for software system, because it is faster, more accurate and easier for us.
7. 2D modelling has one advantage: drawing a 2D model is very fast. Disadvantages are that in a 2D model (CAD technologies) we have only a drawing (lines and text) without information about building. Certainly, in AutoCAD we have layers, for example stairs layer, windows layer, doors layer. But we cannot see how they look visually. However in Revit in 3D model we can see every detail of doors or other parts.

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Summary

Many scientists, inventors and companies still use 2D drawings and only start to realize a 3D modelling that can save time and money. My primary aim is to compare peculiarities of 2D and 3D modelling based on CAD and BIM technologies. To achieve the aim, distance measurement device Leica 2D was used to measure the second floor of Vilnius Gediminas Technical University. Using these measurements I made a 2D model by using AutoCAD software, then I imported this model into Autodesk Revit Architecture software and drew a 3D model. As to the theoretical aspect, this work also required analysing, understanding what a BIM model is and how it differs from CAD model.

Keywords: CAD, BIM, 2D modelling, 3D modelling.

2D IR 3D STATINIŲ MODELIAVIMAS NAUDOJANT GEODEZINIUS MATAVIMUS

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Santrauka

Daugelis mokslininkų, išradėjų ir kompanijų vis dar naudoja 2D brėžinius ir tik pradeda realizuoti 3D modeliavimą, kuris gali sutaupyti laiko ir pinigų. Pagrindinis straipsnio tikslas yra palyginti 2D ir 3D modeliavimo ypatumus, remiantis CAD ir BIM technologijomis. Šiam tikslui įgyvendinti atstumų matavimo prietaisu Leica D2 buvo matuojamas Vilniaus Gedimino technikos universiteto antras aukštas. Naudojant šiuos matavimus nubraižytas 2D modelis AutoCAD programine įranga. Šį modelį importavus į Autodesk Revit Architecture programinę įrangą, nubraižytas 3D modelis. Be to, šis darbas taip pat reikalavo išanalizuoti, suprasti, kas yra BIM modelis ir kuo jis skiriasi nuo CAD modelio.

Prasminiai žodžiai: CAD, BIM, 2D modeliavimas, 3D modeliavimas.

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Fiziniai mokslai