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Metodology of building passportization from laser-scanned point clouds

Lukáš Vojta
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Vedoucí bakalářské práce: Ing. Michal Kovářík

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V Praze 15. ledna 2018

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Lukáš Vojta

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Abstrakt

Tato diplomová práce pojednává o metodologii tvorby pasportu budovy pomocí mračna bodů. V první části je tato problematika popsána z obecného hlediska. Nejprve je provedena obecná rešerše, kde jsou popsány jednotlivé oblastim BIM, laserového skenování, mračna bodů atd. Dále jsou v práci uvedeny problémy, které jsou s touto problematikou spojeny. V poslední části je popsána metodologie postupu tvorby pasportu budovy hotelu Hausalpin z mračna bodů, s jakými problémy je možné se během pasportizace budov setkat a jak tvořit rodiny v softwaru Autodesk Revit z mračna bodů.

Abstract

This master thesis focuses on methodology of passport building using a cloud of points. The first part describes issues in general terms. At first a general search is performed where BIM areas, laser scanning, point clouds, etc. are described. In next part, there are also problems which are related to this issue. The last part describes the methodology of how to create a passport of hotel Hausalpin from the cloud of points, what problems can be encountered during building passportization and how to create families in Autodesk Revit software from a cloud of points.

Klíčová slova: building information modeling, laserové skenování, mračno bodů, Autodesk Revit

Key words: building information modeling, laser scanning, point of clouds, Autodesk revit

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List of abbreviation

Abbreviation	**Meaning**
BIM	Building Information Modeling
HBIM	Historical Building Information Modeling
BEP	BIM Execution Plan
LOD	Level of development
LOI	Level of information
FM	Facility management
ifc	Industry Foundation Classes

1 Introduction

BIM is a new standard for the designing and construction of building structures. BIM is an abbreviation for Building Information Modeling or Building Information Model. It can be imagined as a new building contruction and operation method, in which part of the working process (for example, collisions during construction, moving, or reconstruction) can be simply simulated in a 3D model, and then realized properly. This approach leads to significant cost savings. By using BIM, it´s possible to design a completely new building or passport an existing one and convert it to a BIM model. It shows that the use of BIM will be a greatly desirable method in the future.

The Czech Republic can take note of examples in some European countries like Finland, Norway or Great Britain, which require a BIM model for the processing of a public contract handover [1]

2 Basic Concepts

2.1 BIM

Information modeling of buildings (shortly BIM) is the process of creating and managing building data during its lifecycle. [1]

BIM "is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward." [2]

A BIM can be created for the whole object or for individual parts. For example, you can create an informational model for a building interior installation or a significant historical part of a building - such as a chandelier or a staircase. The information model can be marked also as a model of a certain process during the building's lifecycle. The great advantage of modeling is its possibility of linking to other sectors of the lifecycle of buildings, such as building administration regarding future reconstruction and demolition.

2.2 HBIM

Historical Building Information Modeling is a process of creating project documentation in which parametric objects represent individual buildings elements. These are constructed from historical data, the laser–scan point cloud or another geodetic method. [3]

2.2.1 The Main Purpose of HBIM

- To obtain the current condition of the building
- To obtain documents for reconstruction
- For retaining information about the geometry of construction for future use [4]

2.3 IFC format

In the construction industry, there are a big number of different companies which are usually involved in the project. These companies need to exchange data among themselves effectively. In a 2D CAD environment, DXF format is used for such data exchange. In the field of BIM design, there is an internationally recognized industry standard class (IFC), which is used for exchanging data. It is developed and maintained by the non-profit organization called BuildingSmart. [5] [6]

2.3.1 The History of the IFC format

The IFC initiative was launched in 1994 when Autodesk established an industry consortium called Industry Alliance for Interoperability, which changed its name to the International Alliance for Interoperability (IAI) in 1997 and to BuildingSMART in 2005. BuildingSMART aims to develop and publish the Industry Foundation Classes (IFC) as a neutral model of AEC product design, according to the design lifecycle requirements. The IFC model allows you to describe all aspects of the construction and construction process. However, most of the applications do not use these options [5]

- Autodesk softwares which are support IFC format
- AutoCAD
- BIM 360 Glue
- Inventor Professional
- Navisworks
- Revit
- And many others

The following IFC classes are available for use in the IFC export mapping file, and with the "ifcExportAs" shared parameter.

- IfcAnnotation
- IfcBeam
- IfcBuildingElementPart
- IfcBuildingElementProxy
- IfcBuildingStorey
- IfcColumnType
- IfcCovering
- IfcCurtainWall
- IfcDoorType
- IfcFastenerType
- IfcFilterType
- IfcFooting

- IfcFurnishingElement
- IfcFurnitureType
- IfcLampType
- IfcLightFixtureType
- IfcMechanicalFastenerType
- IfcMemberType
- IfcOpeningElement
- IfcPile
- IfcPlateType
- IfcRailing
- IfcRamp
- IfcRoof
- IfcSite
- IfcSlab
- IfcStair
- IfcSystemFurnitureElementType
- IfcWall
- IfcWindo

2.4 Passport

The Passport of buildings and construction is defined in the Czech Republic by-law number 499 from 2006, then it was adjusted by-law n. 62 from 2013. According to by-law 62 from 2013, the requirements for drawing documentation are defined as Simplified drawings of the real state of structural details which match the kind and the purpose of the building, with a description of use of all spaces and rooms. [7]

That is the reason why we have to focus on requirements for documentation of actual state during the process of creating a passport. Unfortunately, all these requirements are related to 2D documentation. So it is necessary to define these requirements as an LOD parameter.

2.4.1 Passport from the Investor's Point of View

The passport can be used in many ways. For this reason it is important to set precise requirements and goals even before beginning to create it. It is necessary to set an amount of information to be reported and used. The next parameter is accuracy.

2.4.2 Models for reconstruction

- Precise measurement of construction
- The model should have distribution of construction by age

Model of historical building should contain a big amount of details and it is necessary to devided constructions by age and monument care (conservation). The model should also contained information about strength of individual structural and the other characteristics e.g. material, age, etc.

The important aspect of historical building is a modeling methodology of individual elements. Some of them, for example cornices or chandeliers have to be modeled in really high detail, because of restoration.

2.4.3 A Model for Facility Management

The final format should be in a compatible with FM software which is used for facility management. Requirements for a detail of the model is not to high as the e.g. commertial type of model.

2.4.4 A Commercial Model

This type of model is suitable for presentation of the object it self, 3D virtual tour. So the details of construstion has to be high.

Model vhodný pro prezentaci historického objektu. Model může obsahovat přidané popisné informace např. odkazy na externí reference o objektu a jejich bývalých uživatelích. Tento model může být také využíván pro další účely. Vhodným způsobem je využití u koncertních síní. Zde by bylo možné využít 3D model koncertního sálu pro návrh ozvučení případné posouzení akustických vlastností. Tento model by mohl být využíván také pro návrh scény.

2.5 Laser - Scanning

Laser–scanning, also called high definition surveying (HDS), is a method of high-accuracy mapping or reality capture that uses laser beams to quickly capture complete detail of the entire building construction project—much like a camera taking a 360-degree photo, but with an accurate position for every pixel. This detailed 3D representation of the building project is often called a point cloud. [8] The point of cloud can contain a huge amount of points, approximately hundreds millions of points. Today´s scanners can measure really fast, between half million up to 1 millions points/ second. This means that measuring with laser–scan is really fast and accurate. Accuracy depends on the type of scanner and scanner distance from the measured object. The shorter the distance, the higher the accuracy. The accuracy can be from 0.01 mm to 100 mm. The accuracy also depends on the geometry of object and the surface of the object. [9] In general, an extremely reflective surface (e.g. mirror) is possible to scan only if we make the surface dimmer. (e.g. cover it with dull white paper) On the other hand, a matt, white surface is ideal for scanning. Most actual objects are somewhere in between. [10]

The leading manufacturies are:

- Faro
- Leica Geosystems

Originally applied in the construction and maintenance of industrial plant facilities, laser–scanning has since been adopted for many other uses, including building construction and building information modeling (BIM). [8]

Laser–scanning is a powerful tool that can save thousands of dollars in rework, keep projects on schedule and provide valuable information for all stakeholders. For renovations or any construction project that lacks accurate documentation of existing conditions, the laser–scan data can be converted into models to provide the missing information. [8]

Most as-built drawings are inaccurate and incomplete. If a building renovation or retrofit is designed based on outdated or incomplete drawings, errors will be "designed in." These errors will be completely invisible until the construction phase, when they are very expensive and time consuming to resolve. The best way to avoid these unwanted surprises during construction is to perform 3D as-built scanning to capture comprehensive information about the space to be renovated. [8]

Capturing accurate as-built data for renovations or retrofits requires first scanning all areas of the building involved in the project, then registering or stitching together the point cloud data. If drawings or models exist, the pointcloud will need to be oriented to match the coordinate system of the drawing or model, so that both sets of data align. From there, the as-built scan data can be compared to the existing drawings or models. The models and drawings can be adjusted to match the scan data so the team can begin the design. If no models or drawings exist, the scan data can be utilized as a "template" to create the new documentation. The point cloud can be sliced horizontally to expose a plan view that can be traced to create very accurate floor plans, or it can be sliced vertically to expose elevation views for tracing. Isolating point cloud data is a great way to model or draft on point clouds. [8]

The other characteristic of laser–scanning, and it is very important one, is that the laser–scan can capture detail only of the surface of objects, constructions etc. It means if e.g. there are curtains in the room, they cover walls and windows. The same is true of the ceiling, which covers the installation, piping and the ceiling panel.

So if an investor wants to capture all of the above details, it is necessary to remove the curtains and ceilings before the laser–scanning starts.

2.5.1 Advantages

Laser scanning is:

- Fast
- Accurately (w comparing with photogrammetry)
- „ Inexpensive“ (except initial costs)

2.5.2 Disadvantages

- Huge initial costs
- It has bad automatization evaluation [11]

2.5.3 The Influence of the Surface of the Object being Measured

Material	reflectivity
White paper	**100%**
Timber for construction	**94%**
Snow	**80-90%**
White masonry	**85%**
Clay, limestone	**75%**
Printed newspaper paper	**69%**
Deciduous trees	**60%**
Conifers	**30%**
Beach, desert sand	**50%**
Smooth concrete	**24%**
Asphalt with pebbles	**17%**
Lava	**8%**
Black neoprene	**5%**

Table 1 - Influence of surface of the measured object being [9]

2.6 Point of clouds

As mentioned above, point of clouds is an output from 3D laser scanning and it can contain a huge amount of points, approximately hundreds million of points. These points represent a surface of measured object.

A point cloud is a set of data points in some coordinate system. In a this three-dimensional coordinate system, these points are usually defined by X, Y, and Z coordinates, and often are intended to represent the external surface of an object.

The final point clouds can used for many purposes, including to create 3D BIM models for creation passport of building or construction. It can also be used for creation of 3D model for manufactured parts, for example for 3D printer. Or it can be used for multitude of visualization, animation. [12]

Point clouds can also be used to represent volumetric data used for example in medical imaging. Using point clouds multi-sampling and data compression are achieved. [5]

In geographic information systems, point clouds are one of the sources used to make digital elevation model of the terrain. [6] They are also used to generate 3D models of urban environments.[7]

2.7 LOD (level of development)

The level of detail is affected by the size of the model, the time allotted for building it and what critical items need to be communicated. [13] The information model is divided into a graphics part (LOD) and an information (LOI) part. These two parameters must be defined before the creation of BIM begins. In the Czech Republic, there is no document which solves the LOD of the information model in individual phases of the project. We can say that the LOD parameter can be set based on the use of the model itself. But the requirements for the LOD and LOI are defined in PAS 1192, which is the British standard for BIM.

The name, Level Of Definition, which is used in the UK, contains just these two parts. The LOD represents a level of the graphical image of the element in the model. It moves in the range of LOD1 to LOD7 according to the level of geometrical detail of ascertainment of the model. It is a graphical and geometrical level, not an information level (LOI). The higher the number, the more detailed the element is.

In the USA, the name *Level of Development* is used. It moves from LOD 100 to LOD 500.

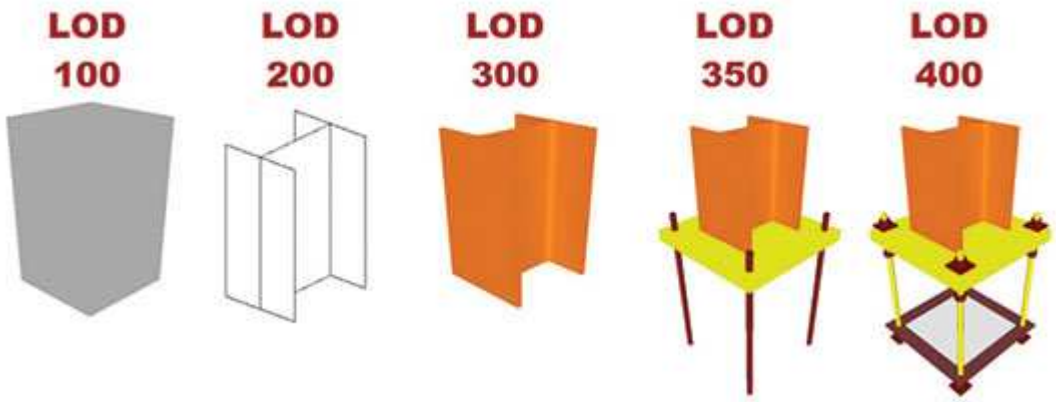


Figure 1 - LOD 100 through 400 of structural column, [14]

2.8 LOI (level of information)

LOI is the level of provided and connected non-graphics information. For example time schedule, properties of the partial element in the model. Only defining the graphical level of detail seems pointless. It doesn't matter how realistic a chair looks. If you don't have data on the manufacturer and model, it is impossible to cost or order it. LOI is defined by PAS 1192.

Performance

- Accuracy tolerances (for structural performance)
- Design submittals requirements (applicable where there is a contractor-designed component)
- Working life
- Fire performance
- Structural performance – impact, M&E services
- Heat loss (U value)

Execution

- Workmanship during adverse weather
- Cleanliness
- Reference and sample panel requirements (to monitor workmanship, materials quality)
- Specific product installation requirements (e.g. installing cavity wall insulation, installing lintels, block bonding new walls to existing, laying frogged bricks in mortar)

Product properties

- Thermal conductivity
- Freeze/Thaw resistance
- Recycled content
- Dimensional tolerances for masonry units
- Compressive strength

2.9 LOD matrix

The matrix is created for more precise specification of the individual parts of the model. It defines the boundaries between professions and other requirements:

- Who will model a certain element?
- When will the model be modeled?
- What alevel of LOD parameter will be reached?

LOI is the level of provided and connected non-graphics information. For example time schedule, properties of the partial element in the model. The purpose of an LOD table is that it tells others what information they CAN USE. To put it another way, it is a measure of the certainty, or confidence, of that information.

Individual elements	LOD 100	LOD 200	LOD 300	LOD 400	LOD 500
Element	Yes/No	Yes/No	Yes/No	Yes/No	Yes/No

Table 1 – LOD table, source: author

2.10 BIM coordinator

The BIM Coordinator's post is an indispensable part of the correct creation of the BIM. His post is really important and demands on quality are really high. For this profession, knowledge of the BIM modeling process is required. The BIM coordinator must be thoroughly familiar with the future use of the model. According to that, the workflow and type of native software must be decided before the project starts. The BIM coordinator should keep the BEP (BIM Execution Plan) and if there are any changes, he should put these changes in to BEP. [15]

The BIM coordinator´s main tasks:

- Preparation and implementation of the BEP (BIM Executive Plan)
- Definition of standards for exchangeable data formats for process participants who do not have recommended program tools
- Definition of the rights for work with the model
- Keeping the BEP document updated to date throughout the life cycle of the project
- Checking the compliance of BEPs by internal and external collaborators on the project
- Ensuring the responsibility of individual construction partners for entering data into the model according to requirements of this project
  [15]

2.11 BEP (BIM Executive Plan)

A document describing data requirements at each stage of development of building project including the responsibilities and relationships of the participants. [1]

It's a basic curriculum for creating a BIM model. The BEP is managed by the BIM coordinator. BIM coordinator is helping assemble the plan itself and he is authorized to change and edit it. The BIM Execution Plan is defined in British Standard AEC (United Kingdom) BIM Implementation Plan BIM.

2.11.1 BEP requirements:

- Set out of targets for stakeholders (for example, to take into account requirements subcontractors during reconstruction.)
- The taking into account of the future use of the model
- BEP may change with the modeling process. Required capture of changes in the BEP itself by the responsible person (BIM Coordinator)
- Definition of the LOD matrix.
- Identification of KPIs - Key Performance Indicators - they allow us to orient ourselves in time and the required qualitative demands on individuals part of modeling.
- Determination of the standard of modeling, material properties
- Definition of output formats for each part of the model.
- Definition of deadlines for control meetings - according to the nature of the construction.
- Establishment of basic units in modeling. [16]

3 Identification of main problem of work

Reference	Title	Jurnal name	Problem
Pingbo Tang, Daniel Huber, Burcu Akinci, Robert Lipman, Alan Lytle 7 June 2010	Automation in Construction Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques	Elsevier	Clutter
Revit Architecture Forum	Weeding LiDAR clutter	forums.autodesk.com	Clutter
Chao Wang, Yong K. Cho 2015	Performance Evaluation of Automatically Generated BIM from Laser Scanner Data for Sustainability Analyses	Elsevier	Time consuming
Sebastian Ochmann n, Richard Vock, Raoul Wessel, Reinhard Klein 2015	Automatic reconstruction of parametric building models from indoor point clouds	Elsevier	Clutter and time consuming

Dejan Skenderovic 2016	Making BIM Ready 3D Models from Point Clouds in Revit	Pluralsight	Laser scan can catch points only on surface of the objects
Pingbo Tang, Daniel Huber, Burcu Akinci, Robert Lipman, Alan Lytle 7 June 2010	Automation in Construction Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques	Elsevier	Automating the creation of as-built BIMs
Turkan, Y., Bosche, F., Haas, C.T., Haas, R	Automated progress tracking using 4D schedule and 3D sensing technologies	Elsevier	Time consuming
Klein, L., Li, N., Becerik-Gerber, B.	Imaged-based verification of as-built documentation of operational buildings	Elsevier	Time consuming

Table 2 - Identification of main problem of work, source: author

3.1 Clutter

- What is it?

  In addition, so-called noise occurs during scanning. Noise is reflected by a cluster of points in one line. This step also determines the accuracy of the model to some extent. Theoretically, it is possible to use individual cloudy points when modeling an object.

- Why is it problem?

  For floor approximation, for example, it is necessary to neglect floor trampling and scanning noise. Clouds contain huge numbers of points. When creating a model without the help lines, random errors would occur because of snapping objects to still different cloud points.

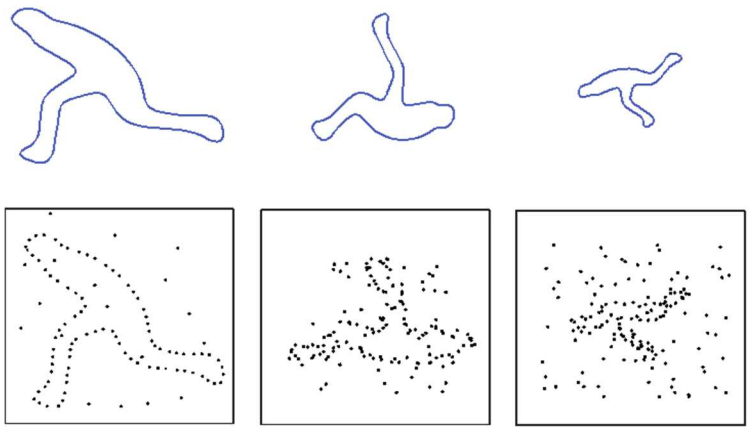
- 

Figure 2 – noise and clutter in point cloud [17]

Noise occurs most of the time, and is created by the use of poorly accurate scanning devices of the original object, and is also among the basic factors that affect the quality of the last surface. Therefore, it is an essential part of the test set. For these purposes, the Armadillo polygon was elected. The model was left in the basic quality and then three different noise levels were applied to it. For this purpose, a random filter was used moving points in the Meshlab application that takes each point of the cloud and moves it to another random co-ordinate in the circular vicinity of the original point with the specified radius. Three levels of 0.6 mm shunt noise (ArmNoise1) were applied to this model,1.2 mm (ArmNoise2) and 2.4 mm (ArmNoise3).

3.1.1 Detection and removal of noise

The first step is to remove the points that make up the sum. This body is situated behind the height and area of the area of interest. They could have been made by airborne laser scans by the action of clouds and aerosols, flying flocks of birds or, for example, a low-flying aircraft. These noises are automatically removed automatically by setting the height and position coordinate frames in which the aperture points are to be set for processing data sets. Other bodies not belonging to this selection group are removed. Follows manual result correction. In this operation, the dots are used to color the individual points according to the specified treble range. This feature offers a number of existing CAD systems. [18]

3.2 Flatness of Construction

In real objects, the wall, floors and columns are never perfectly straight and flat. So this has to be allowed for during passportization. In the LOD matrix, it is defined how the model will be made. For floor approximation, for example, it is necessary to neglect floor trampling and scanning noise. Clouds contain huge numbers of points. When creating a model without the help lines, random errors occur because of snapping objects to other cloud points.

3.3 The Time-Consuming Nature of Creation or Update BIM

Automating the creation of as-built BIMs

The manual process for constructing as-built BIMs is timeconsuming, laborious, tedious, and requires skilled workers. Ideally, a system could be developed that would take a point cloud of a facility as input and produce a fully annotated as-built BIMof the facility as output. This is a challenging problem for several reasons. Facilities can be complex environments, often containing numerous unrelated objects, such as furniture and wall-hangings, which obscure the view of the components to be modeled. These unrelated objects (known as clutters) typically are not required to be included in a BIM, and the surfaces that are occluded result in incomplete BIM representations unless assumptions are made about them(e.g.,walls extend until they touch the floor). Even without clutter and occlusions, the geometry of a facility can be very complex, geometrically, with window and doormoldings, light fixtures, and other components. [19]

3.4 The point cloud as reference model

First it is necessary to transfer the original survey data into the required BIM system. Currently there are only a few BIM systems, such as, for example, Autodesk Revit, that are capable of importing and displaying large point clouds. There, it is then possible to use the point cloud as a modelling reference, whereby sections from and planar views of the point cloud can be extracted. Point snapping allows the precise remodelling of the point cloud regions with 3D BIM elements (figure 1).

Besides the spatial display of the whole point cloud it is also additionally possible to use the scan view of the individual scans for modelling.

In the scan view all of the surveyed points from a single scanner set up can be displayed in a photo-like panorama view. This high resolution image of the observed situation offers in many cases advantages by way of simple and intuitive navigation over the 3D display of the whole point cloud. In this view each point contains the correct 3D information of the total referenced point cloud.

If the target system does not have the necessary point cloud functionality then there remains two alternatives: the creation of 2D intermediate results as modelling references, or the use of the scan view in an external piece of software with an interface to the BIM system.

In the first case, in the appropriate software, 2D CAD drawings, or also ortho images as planar projections, of the point cloud are created. These intermediate results can afterwards be attached as references in the BIM system (figure 3).

Disadvantage of this workflow: the valuable information density of the point cloud is reduced to a two-dimensional projection. This loss of information can later be reflected in incorrect 3D modelling.

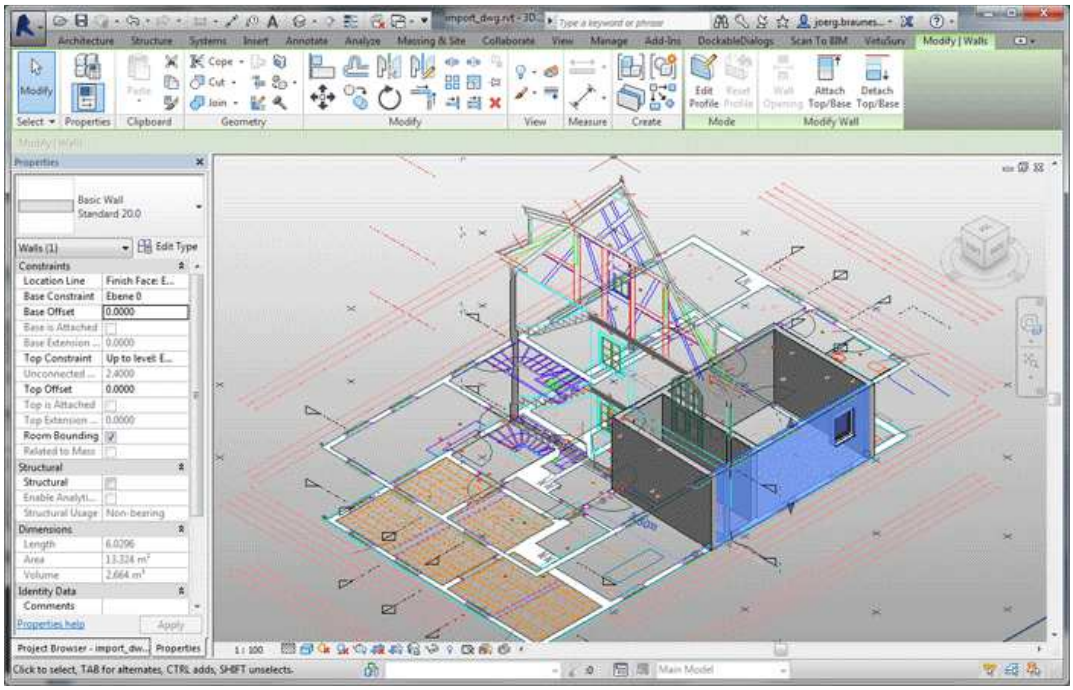


Figure 3 - Remodelling in the BIM system: 2D CAD drawings serve as model reference

As an alternative to this, the photo-like scan view of the individual scans can be used in an external piece of software for 3D modelling. Using an interface, the 3D co-ordinates in the scan can be obtained and transferred to the BIM system for object creation.

Despite the high quality data of the point cloud, this form of modelling remains, to a large extent, a manual and time consuming process that is very cost intensive. Thereby, there is an increasing need for an automated solution to create BIM models from point clouds.

3.4.1 Generalisations vs accuracy

It is indisputable that the purpose of the building survey determines the amount of detail and the accuracy of the model. For facility management purposes, the visualisation or the simple planning of alterations, certain generalisations are not at all problematic and are in many cases desirable, to simplify or as the case may be to first allow further work in the BIM system.

Built heritage conservation and building research projects or structural stability analyses, however, require a higher degree of accuracy and hence a lower level of generalisation of the model.

It is therefore necessary to enquire as to the purpose of the BIM model when the amount of work involved in creating the model increases significantly in respect to its purpose. It is therefore to be ensured whether the generalisation is necessary or desired, and if the variance between the BIM model and the point cloud remains acceptable.

3.5 Size of 3D Model Itself

How to reduce the size of rvt file

- Open the file with the Audit option selected.
- On the File menu, click Purge Unused.
- In the Purge Unused dialog box, delete all of the definitions not required for your projects.
- On the File menu, click Manage Links.
- In the Manage Links dialog box, remove all of the CAD, Revit and DWF files not required for your project.
- Go to Ribbon > Insert > Manage Images
- In the Manage Images dialog box, remove all raster images not required for your project.
- Save the project with a different name, so the file database can be recompiled.

4 Creating passport of hotel Hausalpin

4.1 Characteristics of the building

Hotel Hausalpin is a log-house built in the Tauplitzalm mountain resort of Austria. It is located at an altitude of 1650 meters above sea level. This hotel was built by Voestalpine as its corporate log-house in the 1970s. Until 2005, it was operated by different operators. The total capacity is 45 rooms with 110 beds.

It is devide to two parts. The easter part of the building was built in the 1970s and the western part was built after in the 1980s

It is a monolithic, reinforced concrete structure, mainly with a wall construction system. The building has three overground levels and one underground level. The dimensions of the object are 45m x 13m. On the south side of the facade, the building has a balcony on the 1st and 2nd floors.

4.2 The Main Goals of the Model

At first it is important to define the main goal of the model. The main goal of the model is to create an as-built drawing or in this case a BIM model. There will be changes in the building caused by, e.g., user changes or reconstruction, and these changes must also be taken into account in the model. Therefore, it should be determined with which tool the model will be created. After that, the investor himself can update the building development model. It is important to say that this model can be used for a deacade or more. For that reason it is necessary to update both the native file format and the ifc format.

For this work I chose the Revit tool for creating a model. Revit is BIM software from Autodesk for architects, structural engineers, MEP engineers, designers etc. Its native output format is rvt. The program itself also supports the ifc format and many others. The Revit project is composed of individual objects. These objects are called families. These are individual elements of certain properties (parameters). The family can be e.g. a window or furniture or a wall. It is also possible to create a special family for more detailed elements of structures, such as cornices, sculptures etc. [20] [21]

4.3 Creating LOD matrix

The LOD is always define by client. In this case is no client, so i define LOD according to future use of the model. The future use of the model is mainly for reconstruction. The LOD of individual elemets is define in table bellow.

According to the American Institute of Architects (AIA) document E203 BIM Protocol Exhibit (the AIA's original contract document for BIM), there are five levels of model development ranging from 100 to 500. If you examine excerpts from the model content requirements describing each level of development (LOD) for the design professions—LOD 100, LOD 200, and LOD 300—the evolution of modeling granularity becomes apparent. Although LOD 100 represents a conceptual level of information defined as "overall building massing," LOD 200 and LOD 300 are represented by "generalized systems or assemblies" and "specific assemblies," respectively. This chapter will help you create walls that comply with both LOD 200 and LOD 300. Four different kinds of walls can be created: basic walls, stacked walls, curtain walls, and in-place walls. In this chapter, you'll explore the skills you'll need to create and customize walls to meet the needs of your design. You will also dive into the new and exciting realm of complex curtain wall and panel generation made possible with the conceptual massing tools in Autodesk® Revit® Architecture software. In this chapter, you'll learn to: [20]

Which LOD is necessary for my model.

In which detail is going to create individuals parts of the model (walls, columns, windows, doors, furniture – if it is even necessary to model it.

Which is more important for my model?

- LOD
- LOI

4.4 Creating passport

The basis for the creation of model of hotel Hausalpin is the cloud of points, you can see in Fig. 1. The all folder with all scans is really huge. The point of clouds contain 325 scan stations and 850 milions of points. The total size of file and folder with all scans station is 26.5GB.

The point cloud was provided by company named Geoton. It is Czech geodetic company which provide:

- engineering geodesy
- laser scanning
- photogrammetry
- 3D models - BIM

The first task is to connect a point cloud to Revit. Revit itself offers to connect point cloud in rcp or rcs. These are native Autodesk ReCap formats. Recap itself allows basic work with clouds e.g. trimming, changing color mode, change size of points etc. and subsequent export.

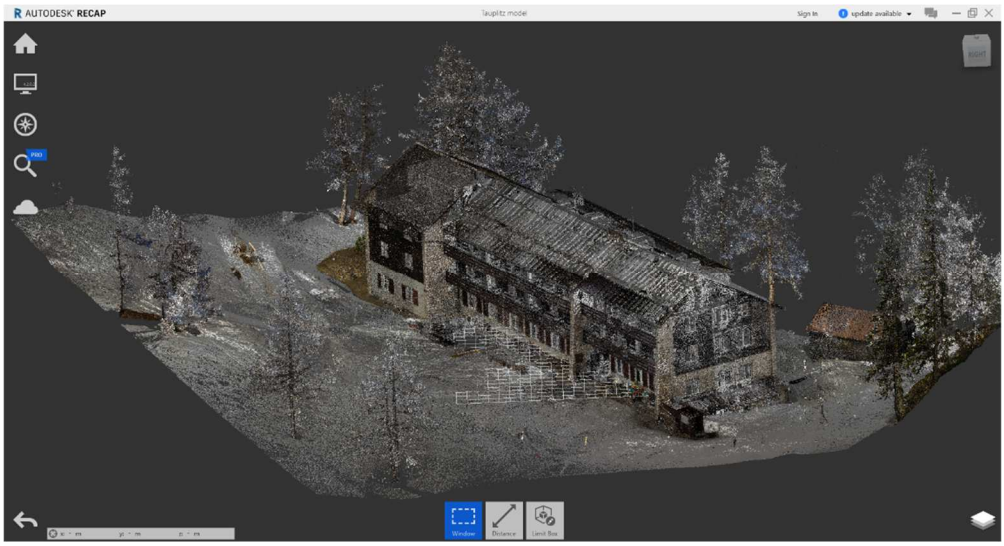


Figure 4 – point of cloud in Autodesk Recap, source: author

The other background for creating a model is an old as-build drawing from 1970s and in this documentation is not draw the new part of the building.

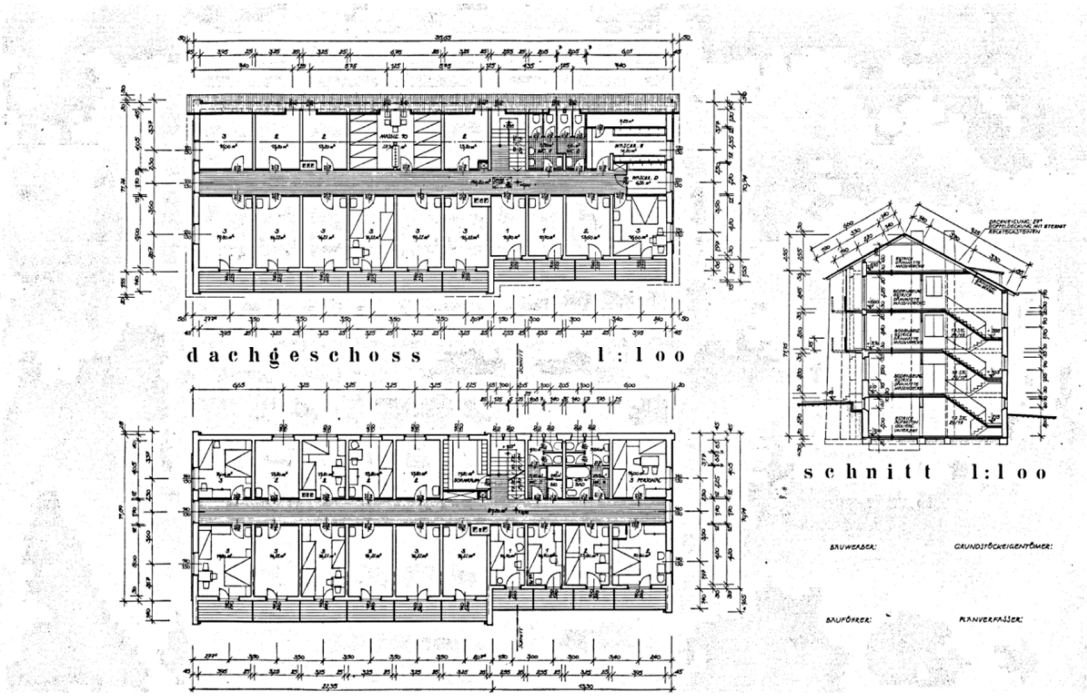


Figure 5 – as-biult drawings from 1970s, source: author

This old, as–build drawing can be really useful when there are some places in point cloud, which are confused or just missing. In this situation it is a change to find this missing information in this drawing.

4.4.1 Modeling principals

1	Importing of point cloud to Project	Recommennded	The point cloud should be imported into the project (Revit) as an external reference. This will allow faster work and fewer difficulties for the PC hardware. Or it is possible to import only parts of the point cloud.
1	Geometric accuracy	Required	The entire BIM model must coincide with both the geometric and the other properties of the reality as it was specified in the LOD in the pre-project phase.
2	Using of appropriate objects	Required	In terms of bill of quantities and subsequent use it is necessary that the wall will be modeled using the wall toolbar. The same thing applies for all other families e.g. windows, columns, doors etc. This is especially import for transport to ifc structure. It is important that the appropriate properties will be assigned to the individual families.

3	Creating of floor levels	Required	Before the start of the modeling it is necessary to divide the point cloud (model) into individual floor levels. Walls and columns will be created between these level floors.
4	Using the reference plane	Recommennded	The first step in making a model from point cloud is to define floor levels and walls with a reference plane. With this step we avoid mistakes during modeling e.g. walls or other objects. The wall will be grabbed on to the reference plane instead of points from the point cloud and all walls will be perpendicular.
			During the floor approximation, for example, it is necessary to neglect floor sagging and scanning clutter. Modeling without the reference plane would lead to randon errors, caused by grabbing of objects (famillies) and placing on to constantly different points.
5	Mounting of windows and doors	Required	Every family, e.g. windows or doors, will be modeled on the same floor as its host. This makes it easier to convert to FM.

		Required	Size and position of individual elements e.g. windows, doors, roof trusses etc. will be measured in the software for working with point cloud. • Autodes Recap • Trimble RealWorks Viewer
	Minimal amount of information	Required	Each object must at least contain information about: • Material • Dimensions of the object (thickness, height etc.) • Age of the the object (objects with different age of creation will be differentiated by different coloring.
			Maximal amount of information is not defined. Every element can be enriched by more information.

Table 2 - Modeling principals, source: author

4.4.2 Clean the Point Clound

For better work with the point, it is very useful to clean up the clutter and edit the point cloud before importing to Revit. It is also possible to reduce the size of point cloud, which is always better. The point cloud will be clearer and work with it will be easier.

There are many programs for editing point cloud e.g. Autodesk ReCap, Trimble RealWorks, Pix4D, 123D Catch etc. For this work I choose Autodesk ReCap.

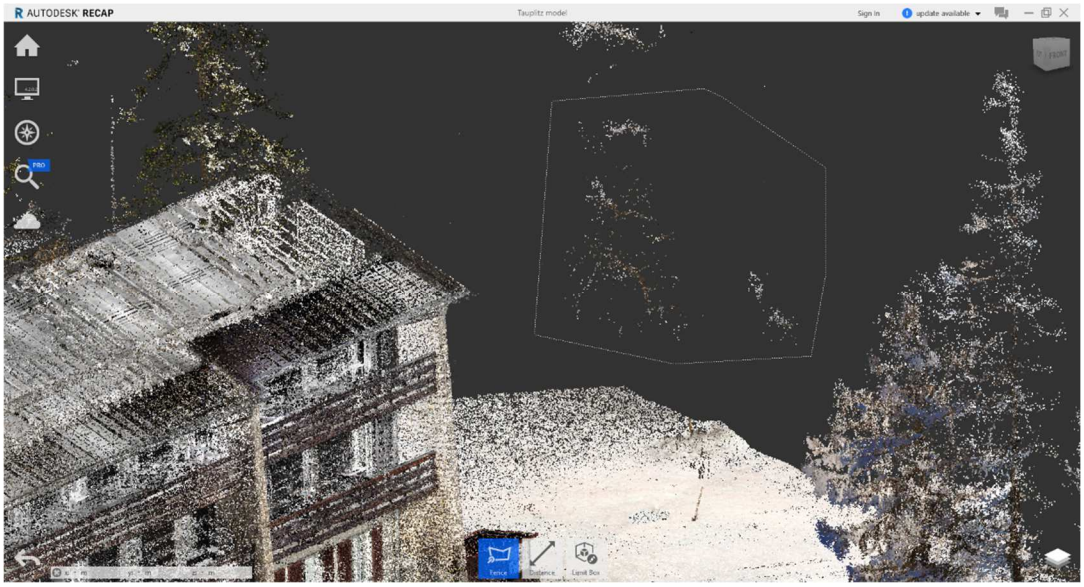


Figure 6 – point cloud with useless clutter, source: author

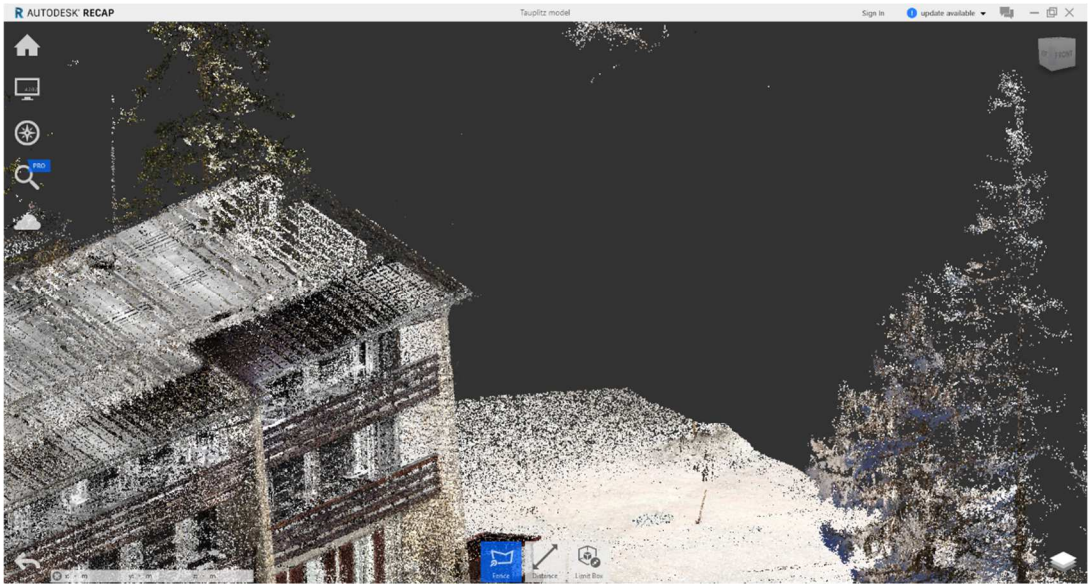


Figure 7 – clean point cloud (without clutter), source: author

4.4.3 How to import point of clouds in Revit

This step is very important. It is possible to import point cloud to Revit in two different formats. The first one is rcs format, and he second one is rcp format.

4.4.3.1 RCS and RCP format

When rcs format is imported into the Revit, Revit shows a warning that the point cloud file is large, which could lead to undesirable graphic behaviors.

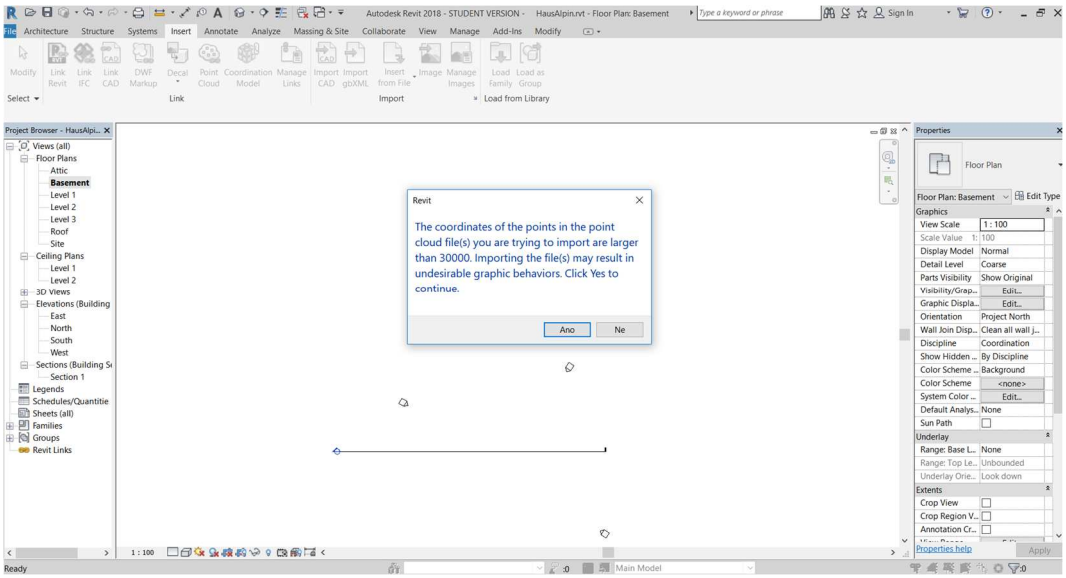


Figure 8 – importing rcs format point cloud to Revit, source: author

This means that the rcp file is better for working, because rcp format is much smaller than rcs format.

To begin using a point cloud that a user just received from a scanner, the user will need to insert the file into Revit. The first time you load a raw format point cloud file, Revit will need to convert your scan file to an RCS file type. This is a proprietary file type that will compress the original scan and optimize it for use in Autodesk software applications. Converting this file will create a new file on your disk, taking up more drive space (plan ahead!). The processing for converting this file can take some time based on your processor speed and the I/O speed of your hard drive, so be patient. It only has to happen once, but it will be once for every scan point you import.

For importing the point cloud to Revit exist three different ways how do it.

4.4.3.2 Centre to Centre

Revit places the center of the point cloud (it means the project base point) at the center of the bounding box of the model. If most of the model is not visible, this center point may not be visible in the current view. To make the point visible in the current view, set the zoom to Zoom View to Fit.

4.4.3.3 Origin to Origin

Revit places the origin of point cloud, i.e., (0,0,0) point, at the Revit project origin, which is known as a project base point in the site plan. If your Project North is rotated, Revit will also rotate the point cloud so that the point cloud's north direction (0,1,0) maps to the current Project North. This option makes sense to use if the point cloud is sampled in respect of the known point and known direction in the model. Usually, the point cloud which is provided by surveyor, contains this geographical/surveyor information.

4.4.3.4 By Shared Coordinates

Revit assumes that the coordinates in the point cloud file are specified in the shared coordinate system used in your model. As a result, the point cloud origin will be placed at the origin of the shared coordinates that can be accessed through the Survey Base Point. The point cloud will be oriented so that the north direction in the cloud file (0,1,0) will be mapped to the True North of the Revit model.

The point cloud with which I am going to work has coordinates which are provided by a surveyor. So for this work I used the option for importing the point cloud to Revit Origin to Origin.

- Coordinates of my point cloud

North	1540570942
South	-80368709
Elevation	3128927
Angle to True North	33°

Table 3 – point cloud coordinates, source: author

This step is very important for future work with point cloud, because it is necessary to import the point to the exact position, e.g. for other professions like ventilation, transport engineers etc. After importing cloud point, it is really important to pin the cloud point, to prevent the possibility of moving it.

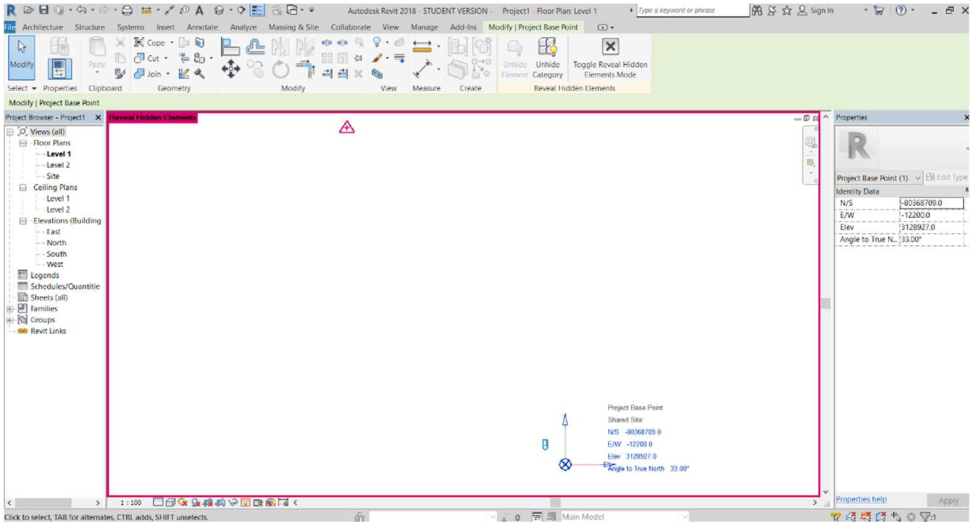


Figure 9 – inserting coordinates of the point cloud in to Revit, source: author

Preparation of point cloud for work

Revit allows a change in the graphical point display of the point cloud itself. It is possible to choose between five options. For creating the model from the point cloud, the first two options are most useful, esp. the second one (Single Color)

- RGB
- Single Color
- Elevation
- Intensity
- Normals

Revit sets the graphical point display of point cloud as the RGB by default , which is not really good for working. The individual elements such as walls, columns, doors, windows etc. are not really clearly visible, as is shown in Fig. 3.

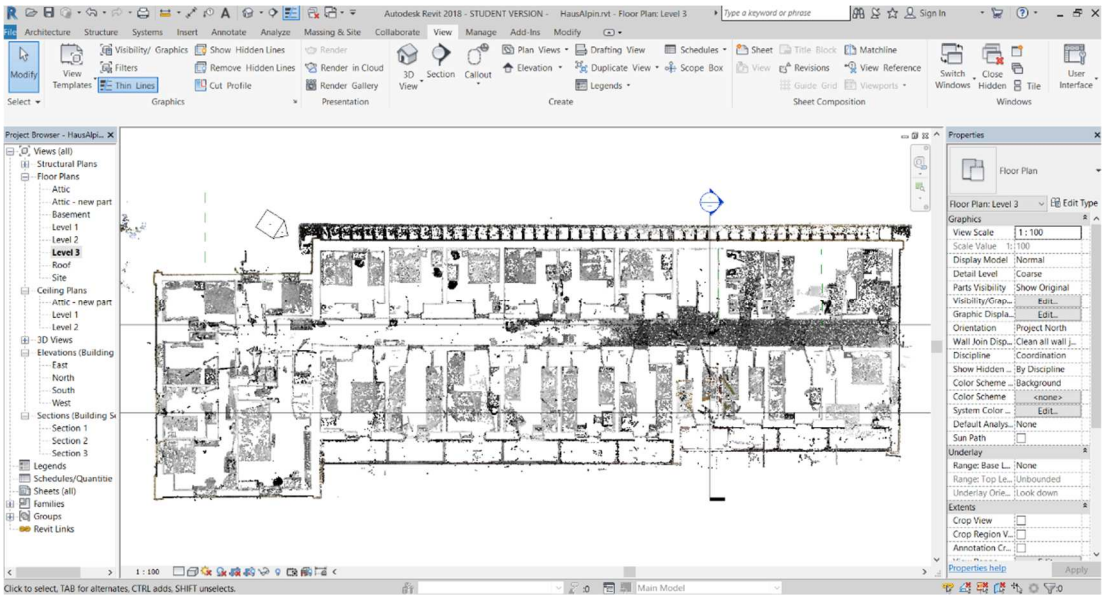


Figure 10 – Point Cloud Color Mode set as RGB, source: author

So, for better visibility it is really useful to set the color mode of the point cloud to a single color, specifically to black. In fig. 4 it is really nice to see the difference between the RGB Color mode and the Single color mode.

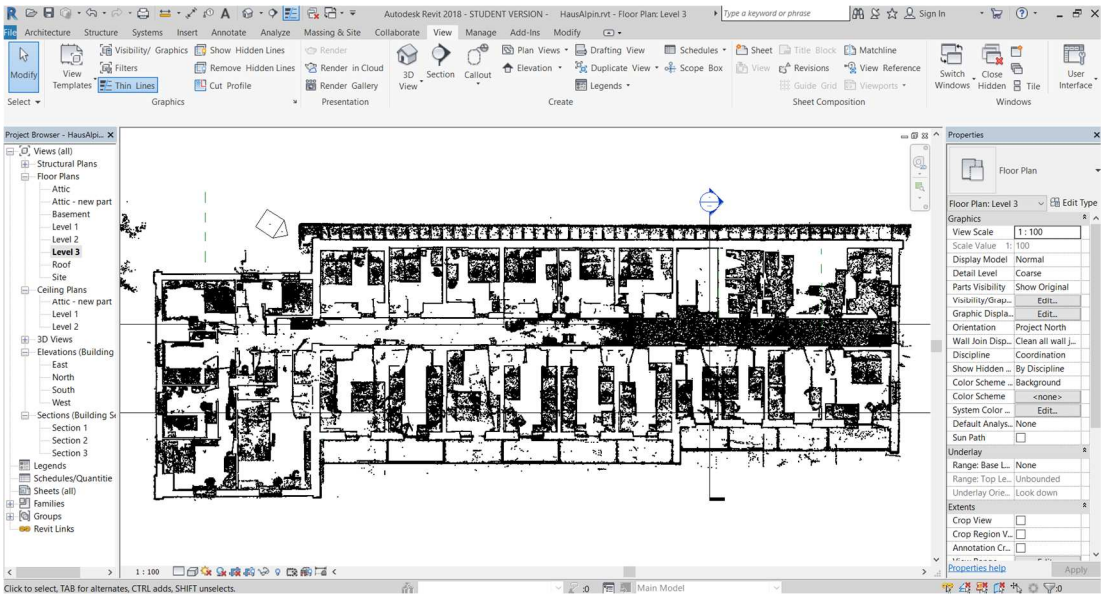


Figure 11 – Point Cloud Color Mode set as Single color (black), source: author

The first thing that we will do is to create a section view on Level 0. Right click and zoom to fit > Draw a section from the left to the right hand side of your screen to ensure you will be intersecting your point cloud. Once you have done this, go to your section. If your point clouds shared coordinates' file was set up correctly, you will now see your model in the section view. Unlike 3D views, section views allows you to add levels and elevation tags to your model.

4.5 Process of Creation of the Model

When a point cloud is imported correctly to Revit, the next step is the creation of floor levels. For the height and distribution, a level line is used, which creates an individual level. These level lines can then be linked to individual floors. It serves as the lower and upper boundary.

4.5.1 Flatness of Constructions

There is no construction which is perfectly straight and flat, especially in older buildings and constructions, and in combination with the laser–scan, which measures with an albeit low level of inaccuracy. In the final laser–scanned point cloud, there will always be non-straight and non-flat constructions (mainly floors and walls). For this reason, it is necessary to approximate the plane of the construction. In this step, we determine the accuracy of the model.

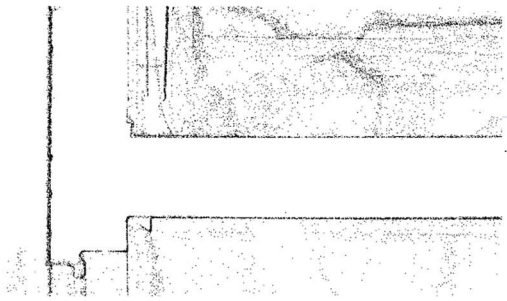


Figure 12 – aproximation of level line, source: author

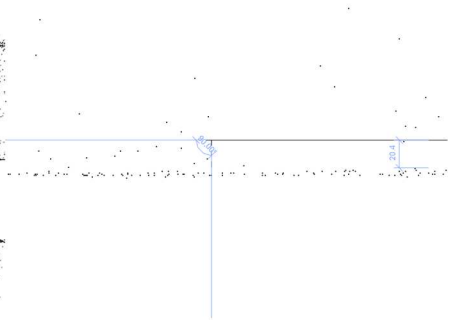


Figure 13 – determined accuracy of level line, source: author

On Fig. 7 and 8 it can be seen, that the level line is not throughout its length same as the point cloud. So it it necessary to define a tolerance of this distance.

4.5.2 Clutter

During scanning, a phenomeon known as a clutter emerges. The first step in making a model from the point cloud is to define floor levels and walls with the reference plane. With this step we avoid mistakes during the modeling e.g. walls or the other objects. The wall will be grabbed to the reference plane instead of points from the point cloud and all walls will be perpendicular.

During the floor approximation, for example, it is necessary to neglect floor sagging and scanning clutter.

Modeling without the reference plane would lead to random errors, caused by grabbing of objects (families) to constantly different points from the point cloud.

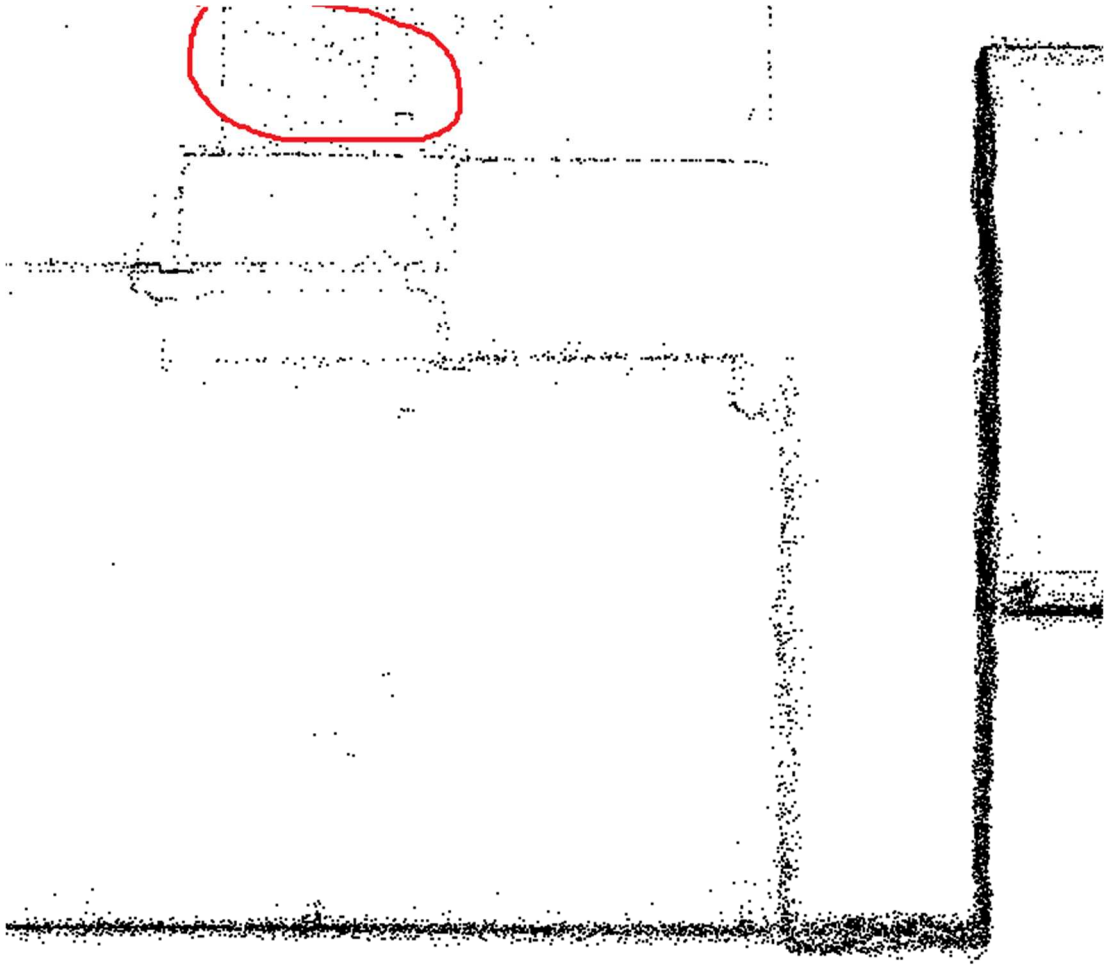


Figure 14 – exapmple of the clutter in point cloud

Object	Point cloud density
Main geometry: **Walls, floors, roofs**	High density of the point cloud is not really important. More important is a basic idea of the shape of the structure, which is necessary for approximation by lines.
Secondary objects: **Windows, doors**	High density of the point cloud is more important. The geometric accuracy of points is also very important

Table 4 – Types of point clouds according to types of objects, source: author

4.5.3 The Problem with Scanning (and thus limitation of my project)

As was mentioned in chapter 2.4. the laser–scan can capture detail only of the surface of objects, constructions etc. This can be a problem e.g. during modeling of the floor. Because from the point cloud, it is not possible to find out the depth of the floor. The reason for that is the laser–scanner's ability to scan only the surface of objects.

That means when the surveyors measure for example the first floor, the ceiling panel is covered by the ceiling and the laser–scan can not capture the bottom surface of the ceiling panel. When surveyors measure the second floor, the laser–scan captures the upper surface of the floor, which is usually a footprint layer.

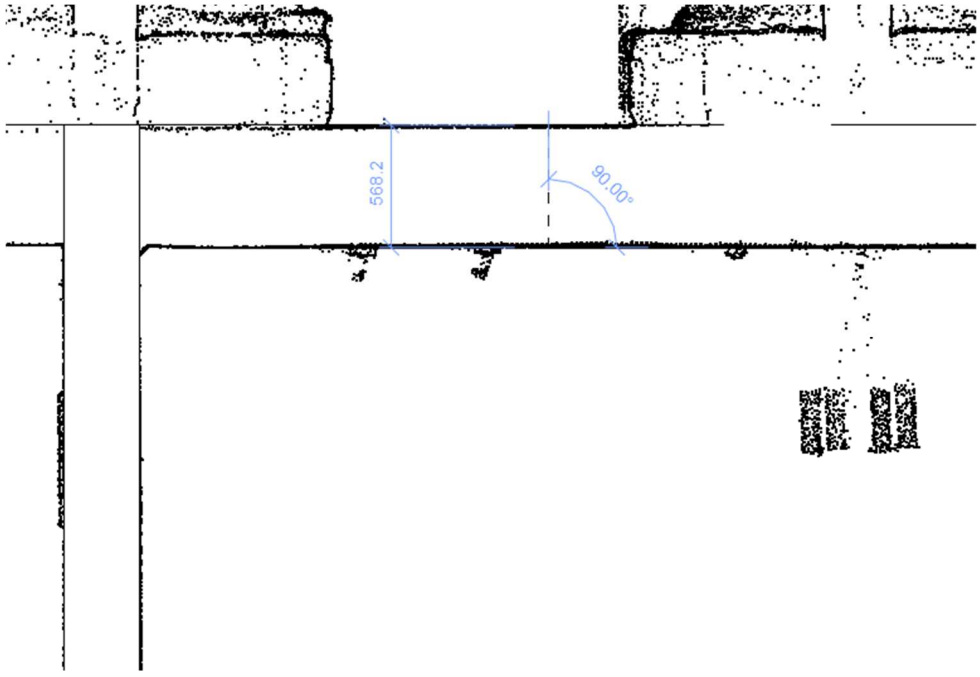


Figure 15 – ceiling panel covered by ceilings, source: author

Fig. 11 shows that the thickness of the ceiling measured from the point cloud is 568.2 mm, which is wrong. The correct thickness of the ceiling panel is thicker. There are two solutions for this state of affairs:

1. Use of the old as-build drawings
2. Removal of the ceiling before laser–scanning starts

In this case, when the point cloud is already made, the only way is to use the old as-built drawings to find out the depth of the ceiling panel.

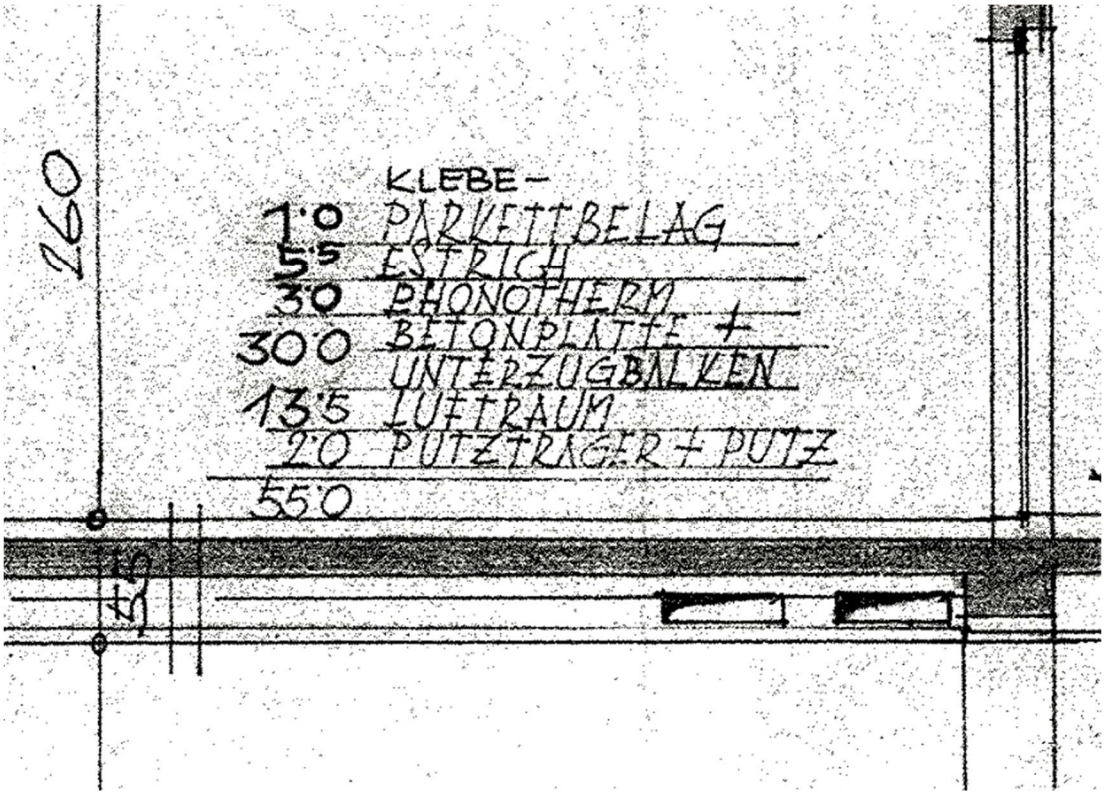


Figure 16 – thickness of the ceiling in first floor, source: author

In case of the old, as-built drawings not being available, it is necessary to remove the ceilings, curtains etc. before scanning starts.

It means if there are e.g. curtains in the room, they cover walls and windows in the room. It is the same situation with the ceiling, which covers the installation, piping and the ceiling panel.

So if the investor wants to capture all these details above, it is necessary to remove curtains and ceilings before the laser–scanning starts.

4.5.4 Creating of Windows and Doors Using the Trimble RealWorks Viewer

For modeling windows, doors or e.g. roof trusses it is necessary to measure the size, position and height of the parapet. For this a lot of software can be used. In this work, I used Autodesk Recap and Trimble RealWorks Viewer and compared these two softwares. Both programs were in trial or student version.

4.5.4.1 Autodesk Recap

As was said above, the version of Autodesk Recap is not a full version. In this version there is no tool like station based. So Recap is useful for measuring outdoor objects, but for measuring indoor objects e.g. windows, doors etc. it is not really useful.

In table n.3 is a comparison of tools and functions in Autodesk Recap and Trimble RealWorks Viewer

4.5.4.2 Trimble RealWorks Viewer

Trimble RealWorks Viewer, besides basic functions such as section box, tools for editing point cloud and different visual graphics of point cloud, also offers a function called station based, which is really used for measurements. With this tool, the user can see exactly the same view as the laser–scan captured during scanning. But the tool named Scan explore is even more useful, because the user does not see the point cloud, but the photo, which is more clear and it is better for work.

Scan explorer has a measurement tool, with which it is possible to measure the distance between individual points. So we can find out the size of a window or height of a parapet etc. These are the three measurement options:

- Distance (point to point)
- Distance along the Vertical axisDistance along the Horizontal axis
- The scan exploration can also show positions and names (numbers) of

every scan which the surveyor did. This is really useful for orientation around the whole object. It is possible to change the station based view by double clicking the icon.

Figure 17 – example of measuing window in Trimble RealWorks Viewer, source: author

Tool/function	Autodesk Recap	Trimble RealWorks Viewer
Color mode of point cloud	Yes	Yes
Change size of points	Yes	Yes
Navigation panel (flying mode, walking mode, orbit etc.)	Yes	Yes
View filters (hide backgrounds, see inside, oulines etc.)	No	Yes
Capture screen	No	Yes
Scan explorer	No	Yes
Measure	Yes	Yes
Show stations	No	Yes
Section box	Yes	No

Table 5 - comparison of tools and functions in Autodesk Recap and Trimble RealWorks Viewer, source: author

4.6 Creating of Families from Point Cloud

4.6.1 Revit family editor

In Revit family editor there is no tool or option which allows the importation of point cloud to family editor. But there are other ways to ´´import´´ point cloud to the Revit family editor or to create a family from point cloud.

The first step is by using a section box (for better orientation and ease of work) to create a section of our object. For this work, I chose a kitchen cabinet. On figure 15, it is possible to see that the point cloud is really confused. So this is the why the quality of laser–scanning is so important.

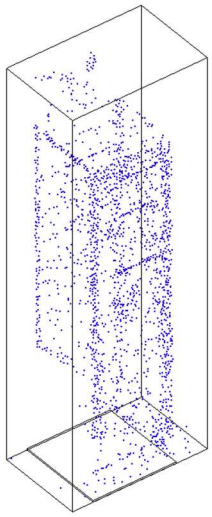


Figure 18 - point cloud of kitchen cabinet, source: author

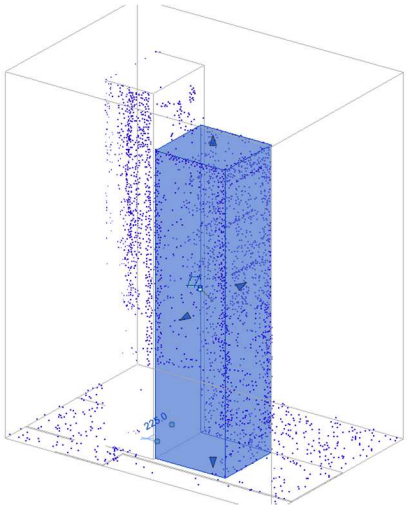


Figure 19 – modeled kitchen cabinet by component tool, source: author

When the shape of the object is clearly visible, the next step is to model the geometry of the object by using a tool named component (Figure 16). It means that instead of importing the real point cloud in to family editor, the geometry of the object (kitchen cabinet) will be imported to family editor.

When the geometry of the object is complete it is necessary to copy and paste it to family editor. Once this process is completed, it is possible to edit the family. E.g. we can attach some properties (geometry, price, size, date of arrival at the construction zone etc.) It is possible to see on the figure, that after all these steps have been taken, it is possible to save a new family and then load it into project.

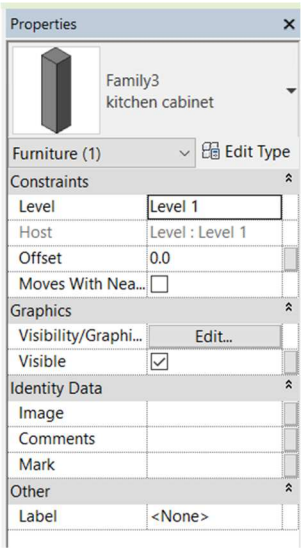


Figure 20 – new family of kitchen cabinet, source: author

4.6.2 Other Ways how to Create the Family

Other ways how to create the family is by using two more softwares, which are ReCap and Autocad. (both from autodesk, Inc) So it is obvious, that this method is much more coplicated and more time consuming. But also it has some advantages compared with first method in chapter 4.9.1

First step is to prepare a cutout in Autodesk ReCap (by using section box) of the object which will be modeled. In this case I also chose the kitchen cabinet for good comparison of these methods. When the cutout is ready, next step is the exporting of this cutoutted point cloud to rcp or rcs file. Other option which Autodesk Recap provides is the export of the point cloud to pts file.

The reason why it is necessary to do it, is because Revit's Family editor does not allow the linking of point clouds, but does allow the importing of DWGs files. So, after the exporting of rcp file from Autodesk ReCap, the next step is the importing of rcp file to Autocad and then saving it as DWGs file. Now it is possible to import point cloud in to Revit´s family editor as DWGs file and afterwards model the revit family of the kitchen cabinet.

4.6.3 Comparison of these method

Characteristic of these methods	4.9.1 -using only revit	4.9.2 – using autocad
Time consuming	This method is much more less time consuming than method 4.9.2, because using only one sotware	This method is much more time consuming than method 4.9.2, because it is necassary to use three sotwares and tranfering the point between them.
Amount of used softwares	• Revit	• Revit • Autocad • ReCap
Shape of the modeled object	This method is better for less complicated shapes (e.g columna, basic cabinets, etc.)	This method is better for more comlicated shapes, because the all object is import to Revit as a point cloud. So modeling of Revit family of the irregular shaped object is much more easier, thant method 4.9.1

Table 6 – comparison of the above mentioned methods, source: author

5 Conclusion

The main theme of my master thesis was the buildings passportisation, which will be in my opinion very developing field in the future. The first part describes issues in general terms. At first a general research is performed where BIM areas, laser scanning, point clouds, etc. are described

The second part describes the methodology how to create a passport of the building. The metodology was created from point cloud of hotel Hausalpin. As a source of the information were used the old as – building drawing from 1970´s and the point cloud which was created by 3D laser scanner. I was focused especially on the laser scanning. This method has been chosen as the key one, because it allows to obtain very precise information about the geometrical properties using laser scanning. It is a method which certainly has a great future and right now has a very fast development.

However like evething has its own advantages and disadvantages, this also applies to BIM creating from point cloud

Advatages:

- Data collection is really fast
- Today´s 3D laser scanners are very precise
- BIM is really useful for:
    - sharing information between the participants of the building
    - for facility management
    - building management

Disadvantages

- 3D laser costs are very high
- There is no defining standarts in the Czech Republic
- Creating a Revits family is pretty difficult

It is not possible to fully exploit the potential of information modeling. It will slowly become acquainted with HBIM experience. In the Czech Republic, this would

be very helpful in defining certain standards or standards governing the creation and output of information models. This is the reason for this work.

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