BIM within current building facilities and infrastructure

V Nyvlt

1Department of Civil Engineering, Institute of Technology and Business in Ceske Budejovice, Okružní 517/10, České Budějovice 370 01, Czech republic

E-mail: vlad.nyvlt@gmail.com

Abstract. One of the main reasons for introducing BIM into existing buildings is cost savings in the construction management and maintenance phase (operating phase). Operational phases have the biggest impact on the total life cycle costs. The introduction of BIM and the creation of a building information model, albeit at a higher price, will be counterbalanced several times by a more efficient way of managing the building during its life cycle, the possibility of creating a healthier indoor environment for building users and better access to necessary information, for example in the case of changes to completed buildings. The BIM model is a digital equivalent of a real construction – real digital twin. It contains geometric data in the form of a 3D model and non-geometry data, including construction management and support documents. The BIM model allows access to building usage information. The information obtained is more accurate. It keeps building element information up to date, enabling more informed decisions. It supports comparison of different solutions and their energy needs. Renovation can be done more efficiently. Construction information is up-to-date, so we can use the time needed to process different solutions instead of finding the necessary information about the construction.

1. Introduction

The building information model is not just a 3D model, but a database of information that is used throughout the construction lifecycle. All process participants contribute to this database during the construction and use of the object with up-to-date information. The advantage of this shared data is collaboration without losing data and maintaining access to their current version. The 3D model is only one way of presenting these shared data. By providing all the elements of the 3D model with structural, material and utility features, construction schedule positions, unit price, inspection and replacement schedule, investment and operating costs, etc., it is possible to create a model that also serves within operation and building maintenance phases.

The common "center" of the BIM method is CDE (Common Data Environment). This environment contains all the information like a 3D model technical data and other documents, but also communication between co-workers and individual processes in given phases of construction.

BIM's task is to bring together all the participants involved in the construction, implementation and operation of the building. Throughout the life cycle, the continuity of all individual phases can be maintained. The benefit of the BIM method to the builder (investor) is primarily to control the project and finance at each stage, or, for example, to process requests and changes to the building faster. For other workers, such as chief planners (architects, engineers, engineers), HVAC designers, structural...
engineers, budget workers, contractors, etc., the greatest advantage is the ease of communication with other participants, easier incorporation of changes, and better recording and editing requirements.

The BIM model data is destined for further use within building operations. In contrast, the current processing of data ends with the handover of the printed version of the actual construction. For example, when using BIM consistently and correctly, the facility manager may have all requirements for changes, defects, or backlogs. Data is available to all participants throughout the construction lifecycle. Facility management can thus use them not only to optimize operations, but also for timely planning of maintenance work, inspections and changes to completed structures (reconstructions).

2. Use of BIM for existing buildings
Models for existing buildings are made for rebuilding, reconstruction and maintenance. The detail and focus depends on the selection of the targeting method. The most widely used method and the roughest measurement is the measurement using a laser rangefinder. Furthermore, it is possible to use photogrammetric measurement or measurement using total station. The most accurate measurement is the combination of 3D laser scanner and photogrammetric measurement. This focus can be used both from the interior and from the exterior of the building. For photogrammetry of higher floors or a roof plane, it is possible to use a drone. Another aid to creating a model can be the original project documentation, where there is a risk that the project was not fully complied with during construction.

One of the first companies in the Czech republic that publicly showcased its experience with BIM's production of measured data was di5 architects and engineers. An example was creation of the Prague State Opera model (see Fig.1) The model was created in Revit 2011. To create the BIM model, data from existing documentation, historical documentation, photo documentation and geodetic surveying of the perimeter of the building were used. Furthermore, laser scanning and visual inspection of the building. First of all, source data was added to the project, the model itself was made up of walls, columns, and components. In addition to geometric information, the model also includes photographs and documents about the building attached to it, or information about the age of the individual structures (using the phase tool) [1].

![Figure 1. Model of Prague State Opera, source [1].](image)

3. Public sector and BIM implementation
Public procurement began to require BIM support in managing database of public buildings and infrastructure. This initiative started in northern European countries, USA, Australia, and according to
[3] it is a clear schedule till 2027 in Czech republic, too. This is also related to the development of modeling from measured data [4].

Taking data in this way is fast, accurate and detailed. Data is collected using a ground laser scanner or unmanned aerial vehicle. When using the Revit program, we have to pay attention to the fact that it is not a program directly designed for creating an existing object model and it is necessary to set boundaries when the point cloud deviation cannot be neglected. Other ways of focusing from scientific articles and manuals are known, such as manual rangefinder, photogrammetry, or tachymetry.

The BIM model is useful for maintaining and managing object data in one file. Unlike conventional documentation, where data is transferred to 3D and may be lost. If a change occurs in the object, the change is entered into the model. When you enter a model, the change appears in all parts at once and does not need to be corrected separately in each drawing. In a BIM model, there cannot be a situation where floor plans, cuts, and views are contrary to one model generation. Thus, the drafting documentation, tables and lists are updated when the change is made.

The existing building model is the best means of refurbishment or rebuilding and a designer tool to design the best solution. When redesigning and completing the original model, the model is transformed into a model for building construction, which once again has been completed as a model for building maintenance. Sometimes it can also be used to compare the original project with the actual design.

The model is not only used for generating drawings, but also for solving visual aspects (color variations of components, interior, exterior and other visual designs) and for virtual tours. Compared to photo inspections, the model is specific in that it can also show hidden installations, such as air conditioning, wiring and other building equipment.

It is best to use a laser scanner for historic buildings. With a fairly detailed model, conservationists can preserve all historical features. Thanks to the BIM model, the elements are thoroughly described. When performing a sufficiently detailed model, it is easier to carry out maintenance and reconstruction of the building.

4. Scanners for BIM model creation

3D scanners are devices for capturing the shape and texture of physical objects and then converting them into digital form for further processing on a computer. The principle is based on scanning individual points of the object surface. A point cloud is created after all points are scanned. The model is also reconstructed using points and simultaneously using a suitable polygon mesh. One of many camera technologies, X-rays, magnetic microtomographs, lasers and touch sensors is used to earn points. Depending on the technology used, methods such as X-ray, ultrasound, laser, optical or mechanical 3D scanners are called. The most common method is to use non-destructive methods. These methods do not destroy individual scanned elements. All methods have advantages and disadvantages in terms of limitation and price. Outputs from 3D scanners are not only used for construction. Difference between point cloud and completed captured picture is on Fig. 2 [5].

Laser Flight Scanners or ToF Technology Principles are very similar to sonar. The scanner points at the scanned object and the laser beam is directed through the object to the nearest sensor. We measure the flight time of the beam to the object and back to the scanner that is the track time. The point has a fully defined point position in three-dimensional space. This method helps us to use the laser beam scanner to record the entire body using rotating parts. The rotating portion may be the entire scanner head in the case of another scanner, or the rotating coupled two mirrors, or the more advanced rotating optical reflecting prism, typically has the shape of a regular n-angle. The density at which the laser beam covers the surface of the real body determines the quality of the digitized body. A color camera can also be included to capture solid body information. The measurement result is a cloud of points. The cloud is composed of thousands of points in three-dimensional space. It is a dimensionally accurate geometric imitation. The acquired data is further transferred to an information model that can be further processed in CAD software [6].
Today, 3D scanning occupies an important position in civil engineering. He also finds application in other fields such as archaeology, medicine, film industry and engineering. This technology evolves very quickly and provides users with many new possibilities. The scanner analyses and collects data about the object, gets information about its shape and possibly colour. For example, such data can serve as a very accurate and detailed basis for the creation of replicas of sculptures or other major cultural monuments. With digitized objects, you can work with different SW, including those commonly used by architects and designers. They have the opportunity to transfer any item to their project and visualization. At the same time, there is a possibility to print the scanned object with a 3D printer in a reduced form.

![Figure 2](image-url). Laser scanning, left part is completed picture, right part just scanned point cloud [5].

5. BIM Implementation Process for Existing Buildings and Infrastructure

Owners / Facility Managers / Administrators perform site maintenance activities according to legal requirements and provide routine activities. Such activities became so complex that without the appropriate systems that support the facility managers' work, they are virtually impossible. If a properly trained facility manager takes care of the BIM introduced into an existing building, it is likely that using this system will make it easier to obtain and archive managed object data.

Introducing BIM into existing buildings is a very time-consuming process. The continuity of implementation of BIM is influenced mainly by the readiness and timeliness of the documents, staffing of key and trained persons, and last but not least, by information technology equipment. In most cases, the documents are not up-to-date, they are incomplete or even missing completely. In such cases, the documentation must be updated or even created.

Another factor affecting the length of the process is the occupancy of key people. Anyone involved in implementing BIM into an existing building must be able to operate one of the CAD systems that supports 3D and BIM drawing, followed by a CAFM (Computer Aided Facility Management) system that is compatible with the CAD system and can be interconnected. Interconnection BIM and CAFM systems can convert graphical and alphanumeric data.

Building information model is just a database of information, including data from the initial design, through construction, building management and eventual changes to completed buildings (reconstruction) to demolition, including the ecological disposal of the building and restoration of the space. It covers therefore the whole life cycle of the building. All participants in the building process enter information into this database. For this database to be fully functional, all participants from the entire building cycle should upload the up-to-date information. The big advantage of collaboration and
access to building information is the confidence that data is not lost and access to the current version is maintained. Therefore, information that is important to other participants in the building process is shared [7].

Steps to Implement BIM for Existing Buildings:

1. Evaluation of the current state of passport data and drawing documentation.
   The existing drawing documentation is evaluated. The timeliness of the data is determined and further action is determined accordingly.

2. Defining relevant passport data for FM / BIM.
   It is necessary to set the goals that facility management / BIM should fulfill. According to these goals, the exact structure and detail of the data is then determined.

3. Passportization of the building
   Focusing and documenting the actual state of all real estate, ie all buildings, outdoor areas, etc., in a predetermined range of data and structures. A well-arranged database of the current state of the building will be created. The database provides all the information on the building and technical condition, from individual building structures to internal installations to utility lines. It is one of the possibilities of property registration, which allows to monitor not only the house as a whole, but also its individual parts in the form of separate housing units and non-residential premises. For example, it may reveal imperfections in areas that are not commonly used, are not visible from the outside, or are not visible at first sight.

4. Completion / acquisition of drawing documentation.
   This point is based on the current state of the drawing documentation. It is absolutely necessary to visit the building together with its complete measurement. Based on the information obtained, the necessary documentation will be created by the designer. It contains not only the necessary drawings, which clearly characterize the building, but also includes technical and accompanying reports with substantial information.

5. Digitization of 2D drawing documentation for 3D model.
   Digitization of the documentation on the 3D model is possible both from the old documentation (drawings) and from the 2D electronic format (dwg).

6. Filling the CAFM system with passport data, connecting the CAFM system with the passport data obtained. It is also necessary to fill the system with manuals, guarantees for built-in products, technical specifications, personnel agenda, overview of workplaces, etc.

7. Interconnection with drawing documentation.
   All acquired data, manuals, technical product specifications, etc. must be linked to the drawing documentation. By linking BIM and CAFM, the system can convert both graphical and alphanumeric data.

8. Setting of facility management processes in CAFM system.
   These processes include, but are not limited to, cleaning, maintenance, revision, staffing, duplicity detection, property management, and more. A necessary prerequisite for correct process management and facility management activities in the CAFM application is, in addition to the selected methodologies and process settings, the definition of specific objects for which processes are implemented (buildings, facilities, workers, departments and organizations).

9. Own management and operation.
   This is followed by controlling all necessary processes in the object using the BIM and CAFM systems.

10. Create BIM Model Position.
    You need to create a new BIM job position. The BIM model must always be up-to-date, so the administrator needs to take care of the model and keep it up to date. All data collected must remain usable throughout the construction lifecycle.

11. Continuous updating of data and processes.
    Data and processes must be continuously updated.
12. Analysis and simulation, evaluation. The final step is to decide on the other processes necessary for the construction and investment to function. Fig 3 shows complex environment of sharing and linking data within whole building lifecycle.

![Figure 3. Sharing and linking data within whole building life-cycle [8]](image)

6. Conclusions
The current practice of using paper records for all documentation of buildings is being gradually replaced by digital models with constantly evolving technology. These models allow for faster and cheaper management of all properties. Therefore, the process of digitization of already-built buildings has also become part of modern trends that go beyond maintenance and property management. This digitization is greatly aided by the current rapid development of laser scanning and the development of SW, which allows point clouds to convert, at least in part, to 3D models, BIM models. This process, of course, goes beyond the digitization of the entire area, where both the buildings themselves, the surrounding area, the terrain, other infrastructure, etc. will be advantageously linked to data. This paper outlines the beginning of this approach that has just begun.
Acknowledgments

The research described in this paper has been financed by TAČR - program ÉTA - project TL02000559 Safe and secure cities for pedestrians and senior citizens, (Bezpečná města pro chodce a seniory).

References

[1] Pivec D 2014 Modern methods of 3D model creation based on laser scanning [presentation on conference Revit in practice, Prague, 2014
[2] bimtech.cz 2019 available at www.bimtech.cz/bim [online] cit 15.5.2019
[3] ODBOR71100 2017 Concept of BIM implementation in the Czech Republic. Ministry of Industry and Trade, September 2017. Available from: https://www.mpo.cz/assets/ez/stavebnictvi-a-surowiny/bim/2017/10/ Concept-introduction-methods-BIM-v-CR.pdf.
[4] Bartuska L, Hanzl J and Lizbetinova L 2016 Possibilities of Using the Data for Planning the Cycling Infrastructure. World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium (WMCAUS), Prague, CZECH REPUBLIC, Procedia Engineering Volume: 161 Pages: 282-289
[5] cept.cz 2019 available at http://www.cept.cz/cinnosti/laserove-skenovani/ [online], cit. 15.5.2019
[6] CAD.cz 2019 CAFM Systems - IT Facility Management Support [online] cit 3.5. 2019 Available from: https://www.cad.cz/pdmplm/7-2007/1311-cafm-systemy-it-podpora-facility-managementu.html
[7] SVJ: Passportization in Practice [online] cit 4.5. 2019 Available at: https://www.svjaktualne.cz/33/pasportizace-v-praxi
[8] BIM for Existing Buildings [online] cit 3.5. 2019 Available from: https://www.tzb-info.cz/bim/18480-zavadeni-bim-u-jiz-existujicich-staveb