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# Point clouds in BIM

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# Point clouds in BIM

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**Abstract.** The representation of physical buildings in Building Information Models (BIM) has been a subject of research since four decades in the fields of Construction Informatics and GeoInformatics. The early digital representations of buildings mainly appeared as 3D drawings constructed by CAD software, and the 3D representation of the buildings was only geometric, while semantics and topology were out of modelling focus. On the other hand, less detailed building representations, with often focus on 'outside' representations were also found in form of 2D /2,5D GeoInformation models. Point clouds from 3D laser scanning data give a full and exact representation of the building geometry. The article presents different aspects and the benefits of using point clouds in BIM in the different stages of a lifecycle of a building.

## 1. Introduction

Application of the technology of laser scanning (Figure 2, 3 and 4) is popular in geodetic and GIS environments for many years now. However, recent advances in hardware technology and development of BIM help to give a home to a new level of use of the point cloud data by laser scanning in the construction industry. Scanning for the purpose of construction applies most often to existing objects (eBIM or existing BIM), but appear and applications associated with new construction and design. The scanning technology is becoming an essential step and for the completion of the integrated BIM cycle plays an important role in the process. Throughout these document readers will begin to see and understand the many different ways that point clouds can be used to optimize the building construction and operation process, while also reducing project risk, cost, and time to complete.

## 2. Definition for BIM & Point cloud

### *2.1. BIM-BAM-BOOM*

Since the start of 2000s, detailed models containing geometric, topology and semantic information have begun to emerge with the advent of Building Information Models. Isikdag & Underwood [1] defined Building Information Modelling as “the information management process throughout the lifecycle of a building (from conception to demolition) which mainly focuses on enabling and facilitating the integrated way of project flow and delivery, by the collaborative use of semantically rich 3D digital building models in all stages of the project and building lifecycle”. From this same perspective a Building Information Model(s), i.e. BIMs can be defined as “the (set of) semantically rich shared 3D digital building model(s) that form(s) the backbone of the Building Information Modelling process”. These models are capable of containing geometric/semantic information regarding the building indoors and outdoors, in a very high level of detail (i.e. models can be regarded as Levels of Detail models (LOD)), where a model in some cases contain the geometry/semantics of nut & bolt or a picture frame in the house. The complexity of the BIMs (in terms of object relations) is very high and furthermore as the population of the entity instances (i.e. the data) of the model increases, it becomes costly to store and perform advanced queries on the models [2].

Building Information Modelling (BIM) is an intelligent 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure.

The content of the three definitions for BIM used in foreign practice concepts defined in the following way [3]:

**Building Information Modelling**: this is the PROCESS of creating and exchanging data about the building during its design, construction, use, maintenance and destruction in the full life cycle of the building. BIM allows participants in these processes can access the same information through interaction of different technological platforms.

**Building Information Model**: is a DIGITAL DESCRIPTION of the physical and functional characteristics of the facility (building), which serves as a shared data source, and information about it. It formed a reliable basis for decision-making at the time of its existence, from creation through destruction.

**Building Information Management**: represents the ORGANIZATION and control of business processes using information from a digital model for the implementation of the exchange of information throughout the lifecycle of the object. Benefits include – centralized and displayed information preliminary study of possibilities, stability of decisions, efficient design, integration of majors and installations, complete construction and technical documentation, and more.

MacLeamy [4] develops the definition to BIM-BAM-BOOM. It all begins with **BIM**- the architect uses 3-D modelling to investigate options and test building performance early on in order to optimize the building’s design. The design is then handed off to the contractor who streamlines the building process with **BAM** (Building Assembly Modelling), which allows for a significant decrease in construction costs. Once complete, BAM is turned over the owner and becomes **BOOM** (Building Owner Operation Model or Building Operation and Optimization Model). This allows the owner to manage the building over time and ensure optimized building performance throughout its entire life cycle. This concept corresponds to the division of the lifecycle of a building in three stages -design, construction, operation [5].

### *2.2. Point clouds from Laser scanning*

To understand how point clouds can be applied to the integrated BIM we must first take a moment to understand what point clouds is and what basic functions it intends to serve. Current laser scanning technology has the ability to send out thousands of beams per second, resulting in a "point cloud" of data defined with X, Y, Z coordinates. Scanners can also identify the intensity value of the reflecting surface for a more intuitive display of point cloud information. Resulting point clouds can include millions, even billions, of data that reflect the physical environment being scanned.

**Figure 1.** Point cloud from laser scanning (left) and 3D model (right) [6]

Point clouds resulting from scan data are immensely powerful for analysis on their own; however this paper assumes that the point clouds will be converted to object-based BIM models. Converting scan data into BIM models is traditionally a three step process: First, multiple scans are captured from different scanning stations. Second, data from multiple scanning stations is stitched together in what is commonly known as the post processing or registration stage. Next, CAD or BIM software can be used to author object models while referencing the point cloud, [7]. Some registration software, such as Trimble RealWorks, has the capability to create content from within the point cloud by running algorithms across the data points and recognizing surfaces from it.

## 3. Point clouds throughout the life cycle of a building

This chapter discusses the benefits in using point clouds in the different stages of a lifecycle of a building. Many companies producing laser scanners already issued instructions on how point clouds can be applied in BIM-BAM-BOOM process in construction of a building. For example, 3D information is often used in design validation and creation. Further, element information can be used to extract 4DBIM (BIM+time) and 5DBIM (4DBIM+cost information). Last but certainly not least, objects can be further populated with 6DBIM (5DBIM+facility management) [8]. Examples of each use case will be outlined further in this paper.

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*3.1 3D Modelling*

The combination of the project of the building or facility with real terrain and surroundings from laser scanning serves for creation of realistic 3D models of the designed object, illustrating the investment intentions.

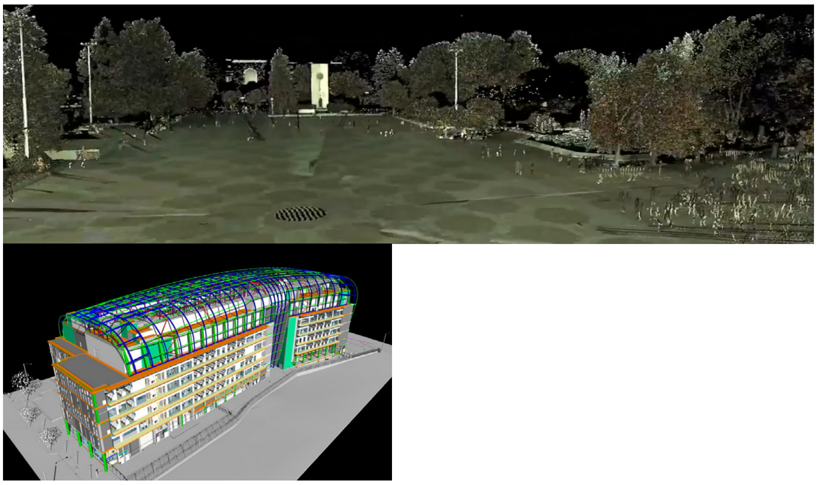

**Figure 2.** Building design on a real terrain [9]

Object creation from point cloud can occur in the registration software or in external modelling applications. When extracting building models from raw data, it is important to decide what the most appropriate representation for them is. One might say that the best object representation from a dense point cloud would be a triangulated surface. This is typically used for free-form objects, where the original measured point cloud is triangulated, smoothed and simplified. But an object-wise representation is more appropriate than a huge triangulated surface in the context of modelling manmade objects such as buildings. It is desirable to model buildings in such a way that different levels of detail (LOD) can be derived automatically.

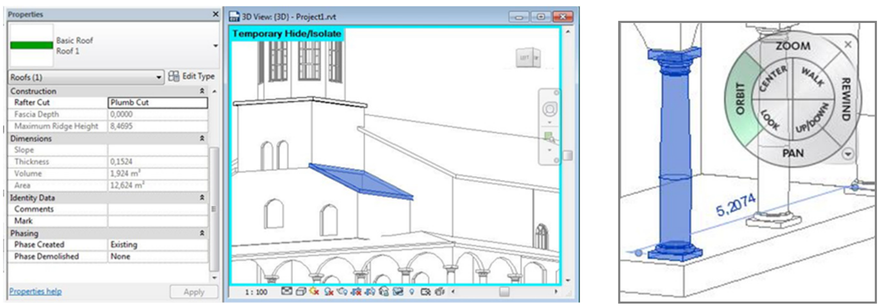


**Figure 3.** Construction elements derived from a point cloud [9]

The choice of which tool to use for modelling should depend upon the desired scope outcome. For detailed scopes, such as complex structures, specific authoring applications like Tekla, Revit, and ArchiCAD are often used. Many projects will see that structures are modelled first; existing to remain architectural features modelled second, and mechanical systems follow. In the case of renovation work, modellers will be well advised to include some kind of "existing to remain" delineation so that those model elements can be viewed separately throughout the BIM use cycle.

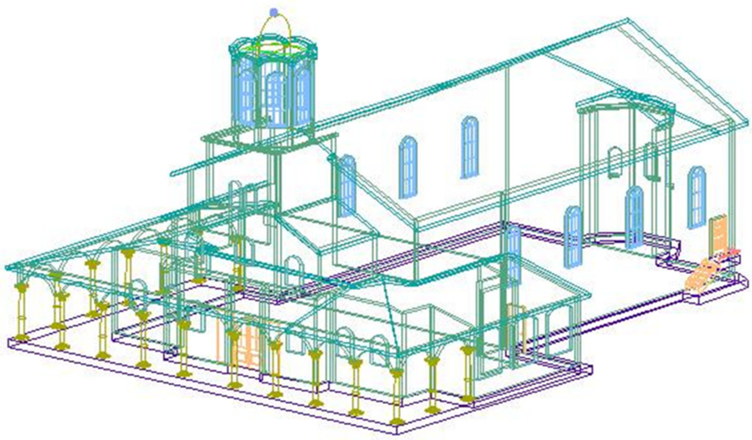

**Figure 4.** 3D model of a building [9]

*3.2 4DBIM Scheduling*

Having an accurate 3D representation of elements from scanned data allows for further use of the data when considering the 4D time aspect associated with each construction element. The combination of scanning and scheduling has already demonstrated significant benefit in specific cases of phased renovations of occupied spaces, including renovations of healthcare and manufacturing facilities.

*3.3 5DBIM Quantity and Cost*

Scanning of work before construction has also proven to be a value-add as the quantifiable information coming from 3D elements allows for more detailed cost planning, or 5DBIM as it is called. Point clouds produce 3D models and allows for the accurate delineation of cost assemblies associated with new and existing work. Contractors have also found a way to be more precise when applying cost buffers to renovation work after scanning. All contractors recognize that there are many unknowns when doing renovation work and so put a buffer on the project cost to account for the unknown. Scanning and modelling the work before execution allows for the cost buffers to be tied to the actual quantity of work which is existing and/or new, and so may have a less dramatic impact on the overall estimate.

*3.4 6DBIM Facilities Model*

A clear benefit to point cloud can be identified when considering the final deliverables that will go to the owner at the end of a project. Owners are responsible for operating the facility throughout its lifecycle and so are very interested in having as much detail as possible about the as-built condition of the building. Laser scanning can be applied at various stages of work commencement to measure the final position of work installed. Final element position can then be cross-checked with the BIM to ensure that the handover model truly reflects the installed position.

## 4. Conclusions

Point clouds from scanning technology can be used to optimize the construction process while at the same time reduce the risk of the project, the cost and the time of its completion, respectively. The goal is an understanding of the practical application of point clouds, as for object-oriented modelling and integration in BIM.

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