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Lidar to HBIM for Analysis of Historical Buildings

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ABSTRACT

The design, documentation and construction processes in Architecture, Engineering and Construction industries (AEC) have been undergoing major changes in recent years with Building Information Modeling (BIM). The use of BIM together with 3D laser scanning (LIDAR) technologies has brought great innovations by going beyond traditional methods in studies carried out in historical environments. With the developed of used technologies together with Heritage Building Information Modeling (HBIM), efforts documentation and rehabilitation of historical buildings have rapidly increased in the last ten years, especially in European countries. This article provides a framework for the implementation of LIDAR to HBIM related to heritage buildings in Turkey. An approach is carried out a process that is a workflow from document historic structures with 3D laser scanning and subsequently generation of a HBIM model. The process of producing an different detailed of HBIM models for provide the documentation and restoration needs of historical buildings from point clouds and processed point clouds for using different platforms was carried out as a case study.

1. INTRODUCTION

Along with technological developments, the using of tools such as 3D terrestrial laser scanning and photogrammetry, which are used for documentation, in construction processes has facilitated the applications and design processes. These tools, which acquire precious data with high accuracy, providing access to the detailed geometrical features of the structures, provide advantages over the repetitive steps of traditional methods in many ways such as time, total working time and quality (Rocha et al., 2020). 3D laser scanning (LIDAR) is a measurement technique that is suitable for documentation on complex and high-dimensional objects with various scales (Wang and Cho, 2015). Laser scanners, based on LiDAR technology, sends high-intensity laser beams to scanned objects and then calculates the coordinates of each point, which are the laser hits. High speed 3D point cloud models can be easily obtained with these technologies. Thus, it creates a high-density point cloud model of the scanned object (Marzouk et al., 2016; Yakar et al., 2010). Point cloud data represents the captured geometry of the entire building. Laser scanners capture and record information such as texture, surface color, as well as geometry of building. Laser scanner technology determines different types of principles and functions, and levels of accuracy and precision for different environments (Chiabrando et al., 2016). It can measure and recognize inaccessible areas. It can properly connect between indoor and outdoor. (Mol et al., 2020). The integration of laser scanning into the BIM workflow has brought innovation to all architecture and construction services, including existing building interventions (Quattrini et al., 2015). With the two platforms coming together, it provides facilities for obtaining important parameters in documentation, management process, error detection, intervention and repair options. After making intervention decisions on a historical building, many stakeholders are involved in that process. Thanks to the management process, monitoring, control of different disciplines and decisions on a single platform can be achieved by the effective use of BIM and LIDAR systems. Integration of the two systems would be very helpful for making intervention decisions as well as minimizing their errors. But this integration requires a challenging and qualitative works. Because it requires a disciplined fieldwork, qualified data combination, processing and then a comprehensive modeling process (Piderit et al., 2019; Alptekin et al., 2019). The study focuses on the combination of LIDAR-BIM, which includes these processes. As a case study, the process of digitally making HBIM models of a historical house is explained.

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2. METHOD

The combined use of LIDAR and BIM systems follows a reverse process in terms of construction techniques, unlike new buildings in historical buildings (Bruno and Roncella, 2018). Process; It consists of 4 different stages with LIDAR data. Point cloud processing, HBIM model and drawings obtained from the model; each stage is realized depending on the previous purpose (Figure 1). Before scanning, firstly, with observation-based examinations, all information about the architectural features of the building is obtained. In addition to observational studies, the details of the building are recorded by photographing (Figure 2).

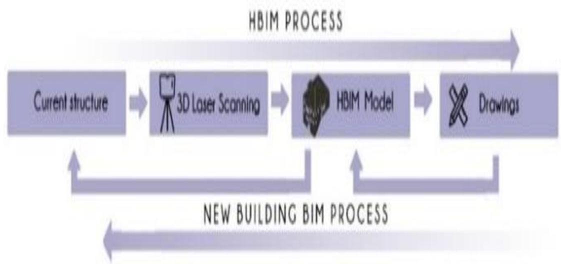

Figure 1. Working Process

Figure 2. 3D Laser scanner of historical house

2.1. Terrestrial Laser Scanner for case study

Horizontal and vertical measurements of the building were taken with Faro Laser Scanner, which can measure without reflector. Although the measurement consists of certain stages, primarily the determination of the places to position the Laser Scanner around the structure to be measured, that is, the polygon points are determined. These polygon points are connected to the first polygon point (P1) where the measurement will be made and the other polygon points. The numerical equivalents of the x, y, z values of the connected polygon points in the coordinate system are recorded by laser scanner. Thanks to the these polygon points all scanner positon were aligned. This method increased the quality of the alignment and error values were reduced.

2.2. HBIM (Heritage Building Information Modeling)

Building Information Modeling (BIM) is an integrated collaborative methodology for the design, manufacture, display and management of structures (Eastman, 2008). Nowadays, it is mainly used in new constructions and designs (Ma et al., 2016). Unlike current practices, Working with historical building much more difficult compere with modern structures thanks to the uniqueness of historical buildings, their non-standardity, the anomalies in the spatial features, the limitations in materials (Green and Dixon, 2016; Ulvi & Yakar, 2014; Alptekin et al., 2019). Historical Building Information Modeling (HBIM) is a system that all data could be storage in that platform and could be manage this data for analysis and management of historical buildings. HBIM could contain different data received from related engineering works. Thanks to the HBIM, decision related to historical building can be make base on overlapped knowledge. HBIM platform also allow user to manage point cloud data and to modeling of historical building using with it. Using of laser scanning data, which contains a large amount of knowledge far beyond three-dimensional representations, due to the differences and difficulties of buildings in terms of historical, cultural, physical and construction techniques. (Murphy et al., 2009; Gigliarelli et al., 2017). It could be said that high accuracy 3d documentation should be necessary for cultural heritage studies because historical building studies have some constraints and difficulties related to data collection and also geometries of historical buildings should represent existing shapes in project and decision making process (Tapponi et al., 2015; Yakar & Yılmaz, 2008). The combination of HBIM and Lidar could be provide complex knowledge to effective method for conservation of historical building. It could be said that knowledge base decisions could reduce historical building risk factor related to construction and conservation practice (Malinverni et al., 2019; Yılmaz et al., 2008) (Figure 3).

2.2. Case Study

Ermenek district of Karaman province in Turkey was chosen as study field where Ayfer Sönmez Historical House is located as a case studuy. Ermenek is located within the geographical structure of Southern Anatolia, surrounded by Antalya in the west, Konya in the north, Mersin in the east, and the Mediterranean Sea in the south (Figure 4). There are many architectural heritage buildings built in the first quarter of the 20th century in the historical town. Historical buildings in the region are preserved and used in this town and also surrounding settlements. In general in this region; It is observed that the houses are two-storey and made of stone and wooden materials. This historical building has dominat character and view in Ermenek urban townscape. Becasue of the house features and character conservation projects were prepared for prolong life of historical buildings and confortably using this building and update historcal building's phisical condition to current standarts especiallay related to it's energy performance (Figure 6-7).

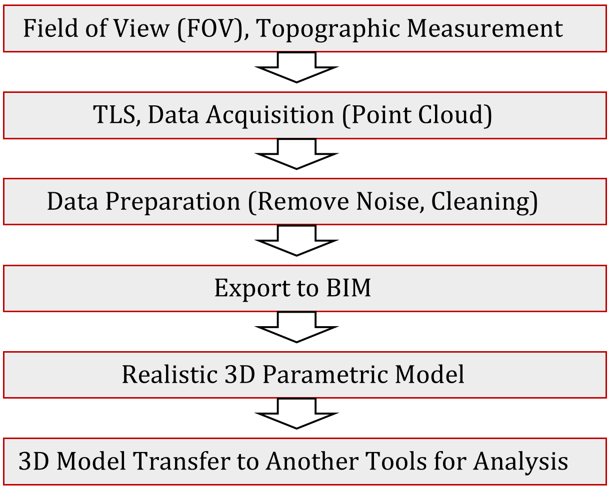

Figure 3. Workflow of point cloud to HIM steps


Figure 4. Ermenek location


(a)


(b)

Figure 5. (a)- Case Study Traditional House
Figure 6. (b)Case Study Traditional House

3. DATA AQUSITION, POST PROCESSING and HBIM

Data acquired with Terrestrial Laser Scanner (TLS) (Faro S120 Laser Scanner) were transferred and aligned with Scene 5.0 software. All alignment, flittering, cleaning works carried out in Scene software. Autodesk Recap software also provide some opportunities related to post processing works. Sequential operations such as data processing, database formation, point cloud editing, file format editing were carried out in these software. After editing the scan data, the point cluster is exported to Revit software in RCP file extension (Figure 7-8).

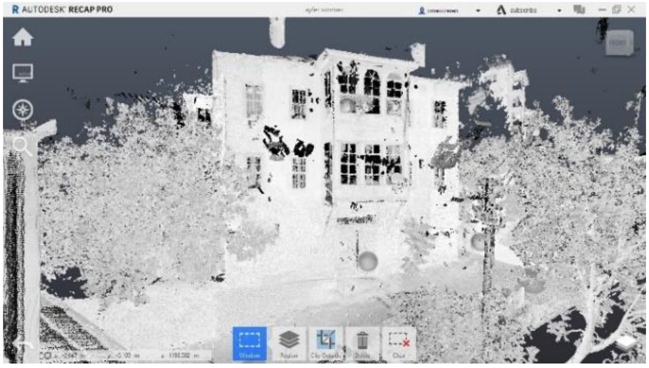

Figure 7. ReCap Pro point cloud post-processing

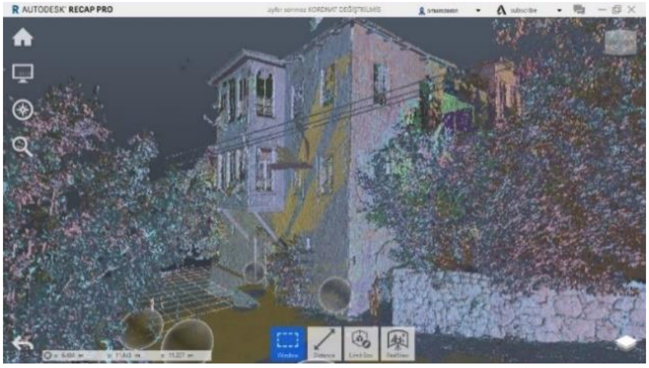

Figure 8. ReCap Pro point cloud post-processing

Before starting the modeling, some steps need to be done. The first is to get the coordinate of a point in the point cloud and to determine the coordinates of that point (preferably the ground) in the working interface in Revit. After the point set is transferred, it is moved to the determined point coordinates without changing its original coordinates. In this way, some problems that may arise in point cloud coordinates in Revit are solved beforehand. At the same time, this process ensures that when placing the point cloud, the building's ground level is automatically placed at level 0 in Revit. After that, the point cloud within the project is fixed. These operations prevent any change in position in case the point cloud is revised again. After the point cloud location is fixed, the model can be started to be created over the point cloud with Revit tools (Figure 9-10).

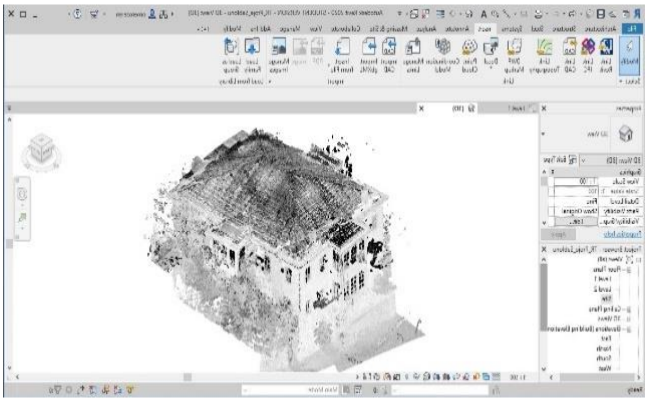
Figure 9. General view of point loud in Revit

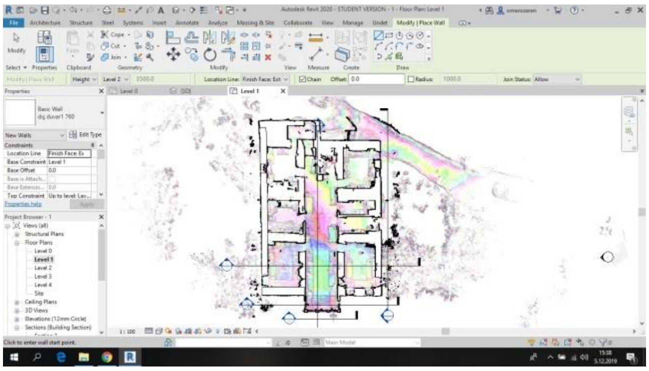

Figure 10. General plan section of point cloud data

One of the detail to be considered while creating a model is the wall types according to different thicknesses and geometric properties. It would be easy to classify and access different type of walls, if they are modelled according to their properties. HBIM platform provides detailed model according to aims of works. The model's level of detail (LOD) determines the quality of the resulting project. Therefore, attention should be paid to details while working. Photographs were taken during the fieldwork for support the model and special objects are produced. In this way, a more advanced model could be obtained (Figure 11-12).

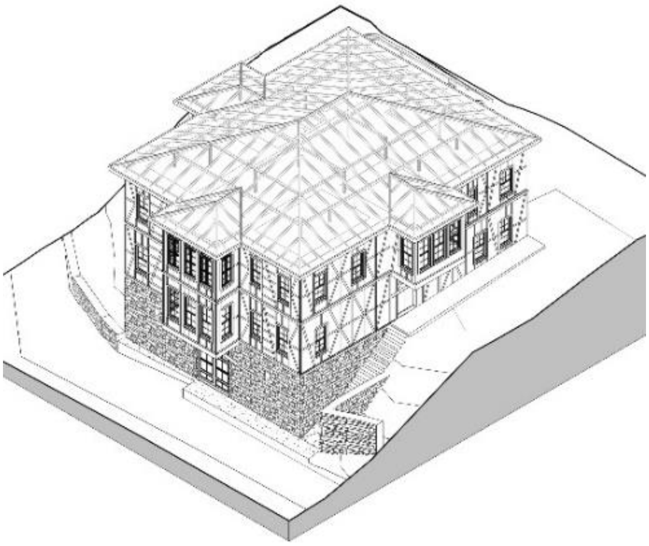

Figure 11. HBIM modeling

Figure 12. HBIM modeling LOD 350

Figure 13. Structural model in BIM Platform

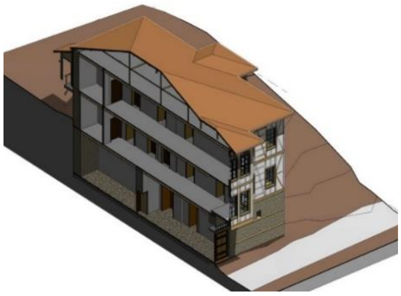

Figure 14. HBIM model section with LOD 350 detail

The final model could be used in different analyzes and simulations. The most important of these are related to the energy efficiency of the building. Using with these models, the amount of energy required and consumed by buildings can be calculated. Structural analysis can be made using these models with some plugin in HBIM platform. Different engineers can import these models into their own software. HBIM-based model can be used for analyzes such as disturbance analysis, mapping, etc. The main data source of all these analyzes is high-accuracy laser scanning data (Figure 13-14).

4. RESULTS

The use of LIDAR systems makes valuable contributions to architectural, construction, conservation, renovation decisions and processes. LIDAR and HBIM platforms could be operated and used in direct integration with modern documentation techniques. With this cooperation, qualified, fast and more accurate intervention decisions could be made. At the same time, using these two platforms together provides documentation of buildings with reduced errors. With the conveniences HBIM platform some works could be easly done such as high accuracy data collection, management of this data, detailed 3d models. Most of this works couldnot be done with tradational techniques. When using HBIM software, user ability is very important for quality model production. Use of laser scanning and HBIM model generation; data management requires architectural expertise as well as software skills to manage a point cloud. When LIDAR and HBIM are used efficiently in the field of cultural heritage, they make an important contribution to the production of the most appropriate solution in the design and using of cultural heritage.

Point Cloud data and HBIM platform create high-accuracy models for different analysis. Other engineers are provided to analyze with detailed data. Analyzes made with these data are easily used in many innovative computations for designer and restorer.

Author contributions

Ömer ÖZEREN**:** Case Study Survey, Software, Data curation, Writing-Original,
Mustafa KORUMAZ**:** Conceptualization, Methodology, Writing-Reviewing and Editing, Field Survey

Conflicts of interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics

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