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Stone material damage detection in restoration using terrestrial laser scanning (LiDAR): The case study of Karacabey Government Mansion in Bursa, Türkiye

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Abstract

Combining observational examination and terrestrial laser scanning (TLS) techniques is a highly effective method for documenting the architectural features of cultural heritage structures. These techniques have been increasingly used in recent years to create detailed and accurate plans, elevations, dimensions, and details of the structure. The purpose of this presented paper is to utilize the data obtained from observational examination and terrestrial laser scanning to produce survey drawings and reports of the historic government mansion located in the Karacabey district of Bursa, Türkiye. The study aims to reveal information about the current state of the structure and its historical evolution over time. Through the study, the final condition of the structure, as it has evolved from the past to the present, has been determined, and floor plans and reports have been prepared. Consequently, the floor plan architectural drawings of the structure have been projected as analytical surveys, providing information about its current state for future restoration efforts.

Introduction

Terrestrial laser scanning (TLS) relies on the emission and collection of laser beams around the structure using a laser scanner. The scanner sends thousands of laser points to the structure and measures the reflection time of the points to obtain distance information [1-3]. This process allows the creation of a 3D point cloud of the structure. Observational laser scanning enables the precise documentation of the external facade, roof, windows, and other details of the structure [4-7]. Terrestrial laser scanning is performed from a ground vehicle or a fixed point, typically covering larger areas and surrounding structures. It operates similarly to observational laser scanning, generating a 3D point cloud. This method is used to document the surrounding area and the overall appearance of the structure [8-12].

The combination of observational and terrestrial laser scanning techniques allows for the detailed documentation of both the interior and exterior spaces of structures. These methods can also be used to detect deformations, damages, or other changes in addition to architectural features [13-15].

In this context, the aim of the study is to utilize the data obtained from terrestrial laser scanning to generate survey drawings and reports of the historic government mansion located in the Karacabey district of Bursa, Turkey, providing information about its current state. As a result of the study, the final condition of the structure, as it has evolved from the past to the present, has been determined through drawings and reports.

Material and Method

The methodology adopted for the creation of analytical surveys of the identified structure involved literature research, observational examination, and terrestrial laser scanning. The gathered information was evaluated using descriptive and systematic analysis methods.

In the initial phase of the research, a situational analysis was conducted to gather general information about the historical structure to be studied. This included an archival search and the presentation of data obtained from the Bursa Karacabey Municipality archives. Additionally, an observational analysis of the structure was carried out to document material issues.

The combination of these methods allowed for a comprehensive understanding of the architectural features, conditions, and material problems of the structure. The data collected served as the basis for the subsequent steps of the study, such as the creation of survey drawings and reports.

The systematic steps followed for documenting material deteriorations of the structure using methods derived from terrestrial laser scanning are presented in this section after the assessment of the current condition of the building.

Before proceeding with the scanning process in the field, it is necessary to plan the scanning operation. During the planning stage, the locations and number of stations for scanning need to be determined.

The locations of the scanning stations should be determined adequately to cover the entire building and all its details. In this study, for the scanning of the exterior of the Bursa Karacabey Government Mansion, 11 station locations were designated. In the study, the first scanning station was selected as the instrument-centered coordinate system, which served as the project coordinate system. The point cloud data obtained from all other stations were transformed into this coordinate system. After the data cleaning process, a 3D point cloud encompassing the entire structure was generated. In this stage, terrestrial laser scanning was employed for documenting the Bursa Karacabey Government Mansion. The structure was scanned using a terrestrial laser scanning device (Faro Focus Laser Scanner), and point cloud data were obtained from the scanning process.

In this section, the detailed steps followed for generating orthophotos using point cloud data are provided. The point cloud data obtained from the laser scanning process was processed using software called PointCab Origins 4.0 to obtain the 3D images of the structure (Figure 1). In the next stage, using the PointCab Origins 4.0 software, cross-sections were extracted from the 3D images of the structure at desired locations, resulting in the production of orthophotos depicting the building (Figure 2).

In the next step, the AutoCAD software was used to create architectural drawings. Before the drawing process, the orthophoto images generated in PointCab Origins 4.0 software were transferred to the AutoCAD environment. The orthophoto images were imported into AutoCAD as TIF (Tagged Image File) format, which is a common data format for AutoCAD software. Using the scaled orthophoto images, the AutoCAD program was utilized to obtain the building's elevation drawings.

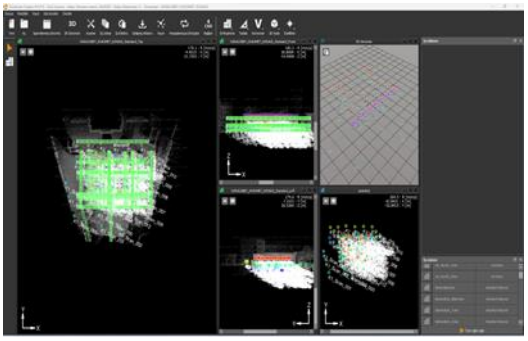
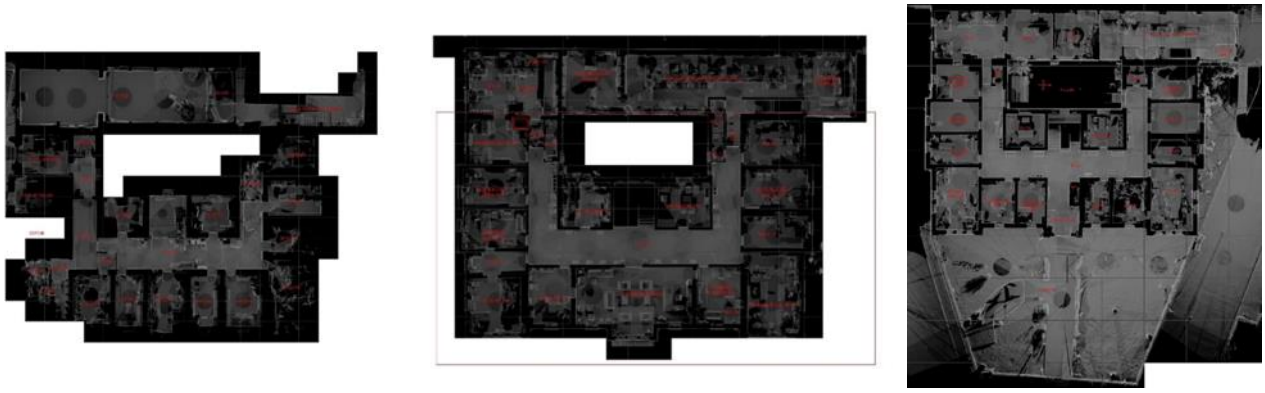


Figure 1. An example scene from obtaining scaled orthophotos of the building using the PointCab Origins 4.0 software



(a) (b) (c)

Figure 2. Obtaining scaled orthophotos of the building's floor plans using the PointCab Origins 4.0 software: a) Basement floor plan orthophoto, b) Ground floor plan orthophoto, c) First floor plan orthophoto

Results

After evaluating the macro and micro visual observations conducted in the previous section, along with the current condition analysis of the building or monument, and the comparative analysis of the elevation drawings obtained from laser scanning-derived orthophotos, the following findings have been reached:

Architectural features of the basement floor

The structure was originally built in a "U" plan type. However, due to the later addition of the Population Directorate, it can be described as a square-planned structure with a courtyard. In the current condition, the basement floor exhibits spaces belonging to the southern structure group (Population Directorate Archive B24, Room B25, Storage B26) (Figure 3).

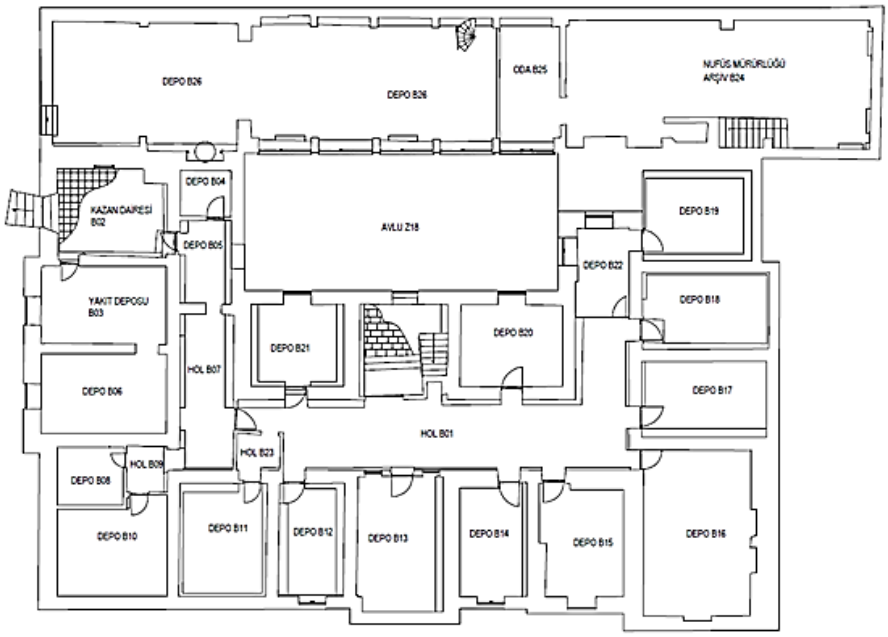


Figure 3. Basement floor plan analytical survey drawing

Architectural features of the ground floor

The southern section of the ground floor is dedicated to a group of spaces, including rooms Z20, Z21, Z22, Z23, Z24, and Z27. These areas belong to the population directorate. The rooms of the population directorate are arranged in an east-west direction, with interconnected passages between them. The connection between the population directorate and the main building is established through two door openings on the north wall of room Z24, leading to room Z02 (Personnel Affairs) and the Z01 hall.

As seen in the photograph, the spaces in this area of the building are arranged around the Z01 Hall. The floor of the hall is covered with ceramic tiles, while the walls and ceiling are plastered. To the east of the hall, rooms Z02, Z03, Z04, and Z05 are located, while rooms Z13, Z12, Z11, and Z10 are situated to the west. On the north side of the hall, rooms Z05, Z06, Z07, Z26, Z08, Z09 can be found, while rooms Z14 and Z15 are positioned on the south side. the north side of the z01 hall houses various units, including application units z05, interview room z06, application and identification unit z07, windbreak, z26, room z08, room z09, and room z10. the floor, walls, and ceiling of the hall are adorned with ceramic tiles and plaster.

Moving westward from the Z01 Hall, one can find district governor's archive- Z13, prayer room- z12, and room-Z11. The floor, walls, and ceiling of this area of the hall are also finished with ceramic tiles and plaster. On the south wall of the hall, there is a tea room with rooms Z15 and Z14. Additionally, there are reinforced concrete stairs in the central axis of the hall, providing access to the upper and lower floors (Figure 4).

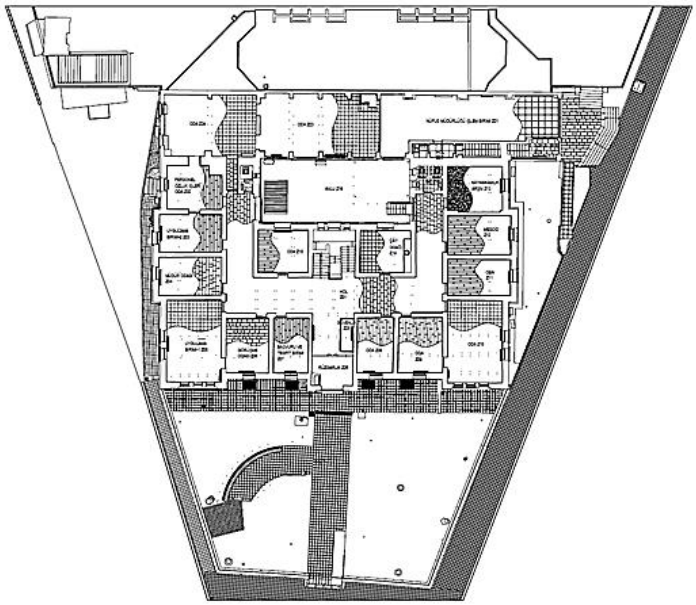


Figure 4. Ground floor analytical survey drawing

Architectural features of the first floor

The first floor plan of the building is almost symmetrical to the ground floor plan. On the first floor, there are rooms belonging to the southern section of the building, including room -126, photocopy room -124, archive room- 125, population registry archive- 123, population registry transaction counters -122, and population registry director's office- 121. These rooms, like on the ground and basement floors, belong to the population registry department. The rooms belonging to the Population Registry Department are arranged in an east-west direction, and the transitions between spaces are facilitated through connecting rooms.

Room 126 and photocopy room 124 have openings on their northern walls, providing access to the main building (accounting office -102 and storage room- 116). The connection between the ground floor and the first floor is established through concrete stairs, with the creation of the central space, room -120, towards the south. The rooms belonging to the Population Registry Department are arranged from east to west in the floor plan. No significant deterioration is observed in these rooms. The walls are plastered, the ceilings are suspended ceilings or plastered, and the floors are either ceramic or parquet.

The main space of the building follows the 'U' scheme and consists of rooms placed around the courtyard and room-101. On the south wall of the central space, there are room -115, the furnishing room, and room 114. on the south wall of hol -120, there are room -107 (secretary's office), room -108 (governor's office), and room -109 (governor's resting room) (Figure 5).

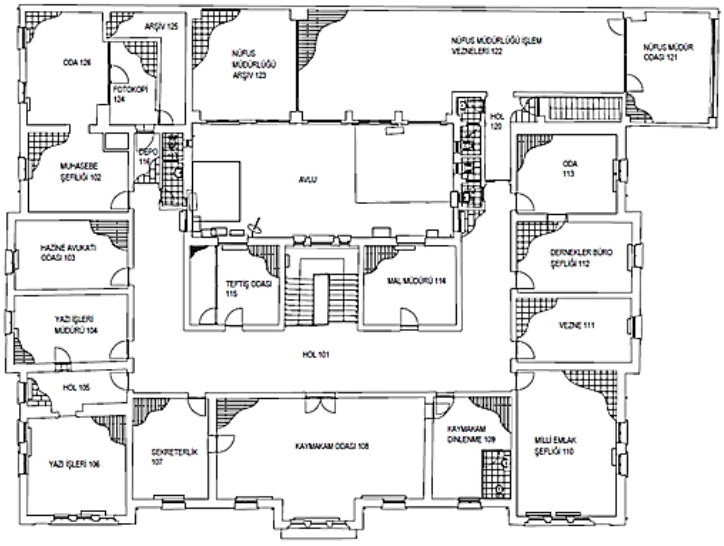


Figure 5. First floor plan analytical survey drawing

Conclusion

The study focuses on the documentation of material deterioration in historical buildings by combining data obtained through terrestrial laser scanning with on-site observations. It aims to analyze the current state and architectural features of the historical structure based on research conducted with terrestrial laser scanning techniques. The evaluation involves integrating the data obtained from laser scanning with other collected data to document material deterioration in the building. The study is significant in its systematic approach of showcasing the methods for creating orthophotos as a basis for documentation by converting the data obtained from laser scanning into visual representations. It emphasizes the importance of documenting the architectural features and current condition of historical buildings.

Based on the findings, the historical Karacabey Government Mansion exhibits various types of material deterioration, including surface pollution, incorrect repairs resulting from human activities, and the detachment of plaster due to faulty restoration work. The observed damages in the structure can be attributed to user-related deterioration and the adverse effects of environmental conditions.

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