DIGITAL DOCUMENTATION INTEGRATED IN BIM FOR BUILDING REUSE AND SUSTAINABLE RETROFIT

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Abstract. Architectural survey is an evolving field in architecture that has been affected during the past decades by the technological advancements in the field of 3D data acquisition. Data acquired from laser scanning and photogrammetry, for the purposes of documentation can be integrated in the BIM data base of the project and contribute as the first stage in the sustainable process of building reuse and retrofit and for an appropriate design intervention for a building under preservation. This paper presents the case study of the documentation and design intervention of a building under preservation in Ramat Gan, Israel. All phases of the design process were integrated into a comprehensive BIM data base: the digital documentation of the building, through laser scanning and photogrammetry, the architectural geometry, the structural information, the HVAC and electrical planning. This case-study demonstrates how the compilation of the various phases in a BIM database facilitated a smooth workflow in a complicated project under preservation, allowed for an immediate coordination between the various consultants and resulted in a non-invasive design intervention.

Keywords. Laser scanning; BIM; digital survey; retrofit; preservation.

1. The site and its history

Shenkar College of Design and Engineering is located in the city of Ramat Gan, bordering Tel Aviv, in Israel. The campus is composed of several buildings, some older and some newer, within the dense urban fabric in the area. The department of plastics is accommodated within the old building from the 1920’s. The department includes a large open space area that has
various types of machines for processing plastic compounds, as well as rooms that serve as classrooms and offices. The building was in bad shape and either needed to be replaced or in need of retrofit.

Shenkar College organized an architectural competition to propose a solution for the building that contains the department of Plastics. The winning proposal was from architectural office Geotectura that by looking at the existing fabric and its heritage, suggested a retrofit, rather than replacing the old structure with a new building. Research into the Ramat Gan City Archive¹ revealed that the site was part of Goldberg’s orange orchard that was established during the 1920’s. The original grove was the result of a philanthropic action by Yitzchak Leib Goldberg (1860-1935). It was the main income source for the people in this area long before it became a city, a legacy that was forgotten since. The old building in the middle of the site was actually the first modern packing structure in the country, built in 1928. The wooden roof structure, exposed from the inside, together with the thin silicate bricks in the walls are giving the building a unique appearance that should be preserved for aesthetic reasons, as well as for its historical value.

To fully understand the meaning of an existing building, one needs to look back and trace its origins and its history. The historical context of an existing building, its presence in time and space, its unique existence at the place where it happens to be², gives the building its unique character and its meaning. Its unique existence determined the history to which it was subject throughout the time of its existence.³

A conscious decision was made that the history should be the main initiator of all the design intervention. The past would be reflected in every corner, even when it was combined with a new design. On one of the interior walls, the design team put a printed image that was taken from the very same spot almost 100 years ago, as a reminder of the legacy that this place contains. The legacy represents pioneering and modern methods that are also part of Shenkar’s approach to nowadays: the college is always seeking to combine academia and professional practice with cutting edge technology, together with creative and sustainable thinking. The forgotten orchard will be reintroduced to the site thanks to the new building plan next to the preserved packing building. The new building is composed by two circular shapes that maximize the exterior area for a new orange grove and will eliminate the need for separating fences between the public area and the campus site.

The existing building condition was quite neglected. A roof addition to the main structure several decades ago was built using unhealthy and dangerous material of asbestos. This was needed to be replaced immediately but without changing the historical layout of the building. Further improvements such as accessibility demands and a new program were introduced to the site.
with the notion that all the design process should be made with the building information modeling approach that can superimpose the existing historical data with the needed modern and sustainable intervention.

2. Preservation and digital documentation (laser scanning and photogrammetry)

The first step to preservation, conservation and re-use of a building that has a historical architectural value is to create a comprehensive survey of its existing condition, as well as a reference of its historical record. Digital methods in documenting cultural heritage sites are the latest endeavor both in the field of architecture and survey. Two main methodologies for digitally documenting the building were used in this project: laser scanning and photogrammetry. Each methodology has its limitations and advantages. This digital survey is comprised of both methodologies, so that the survey outcome can gain from the advantages of both ways of work.

The general geometrical survey was implemented with a long-range laser scanner. The equipment used on-site was a C-10 Leica Scan that has the capacity to scan up to 300m radius. The interiors of the main double height space were documented from 5 scan-stations, which then were registered into one point cloud that gives information about the three-dimensional geometry of the space, as well as color information from pictures taken by the scanner during the scan. This point cloud (Figure 1) was incorporated into the Building Information Database, where it served as a basis for the “as-built” architectural drawings. In addition to its value for the two-dimensional drawings, it served as a three-dimensional envelope for the new design intervention. Particularly, in the case of the main double height space of the building, the digital survey managed to provide for accurate information of the geometry of wooden roof structure, and help create a good conservation strategy regarding these special architectural elements (Figure 2).
As is common practice nowadays in survey documentations, this campaign also included photographing the building. Such pictures served a pictorial record of the existing state of the building and also some of them were used for photogrammetry. Photogrammetry is the field of reading measurements from photographic imagery. The main parameter during the image acquisition is that the view in each photograph has an approximate 30% overlap with the next photograph. This way of image acquisition makes it possible to “stitch” the images together with the help of photogrammetry software. The output of photogrammetry can be a map, measurements or a three-dimensional mesh model of a building or a building element.4
For the photographic documentation of this building, a GoPro digital camera was mounted on a Phantom II drone and took pictures from above. The view of the camera was transmitted to a screen on the ground, where the drone operator can control and plan the series of photos that are shot. The camera was sometimes aimed vertically downwards, while at times took pictures from above but in an angle. Since our site is in a dense urban setting, the pictorial record taken from air, allowed us for viewpoints that gave us information on the condition of the roof and which could not be acquired in any other way. The method of shooting pictures of the building in different angles is consistent with the close-range photogrammetry method. However, the fact that the pictures were taken from the air allowed for a greater distance between camera and object and therefore could be used to create three-dimensional meshes of the building, which from this distance was perceived as an object.

These overlapping pictures were handled in photogrammetry software, which performed photogrammetric processing of the digital images in order to generate three-dimensional spatial data. This means that the photographs taken on the site were connected together by this automated processing system and produced three-dimensional textured meshes of the buildings or areas of the site.

Each tool (namely laser scanning and photogrammetry) has its own strengths and weakness and can contribute to a specific aspect of the documentation. The outcome of the laser scan is a point cloud that gives a raw database of three-dimensional geometrical points, which is highly accurate. In addition, it gives some photographic information of the site that can be used to color the point cloud and give us a realistic preview of the existing geometry. Laser scanning has advanced the quality of architectural documentation and allows for creating comprehensive three-dimensional databases of information. It also makes the data acquisition process very fast and efficient, compared with conventional survey methods.

High quality imagery for texture mapping purposes is best collected through high resolution digital cameras. There are various software and applications that allow for capturing geometry with a series of photographic imagery and through cloud computing or algorithms within the software, the photographic material can produce three-dimensional textured meshes. While the geometrical information of such meshes is not as accurate as the geometry of a point cloud that was created by laser scanning, the textures of the meshes are photorealistic and high resolution. In the case of this project, the three dimensional mesh produced was not accurate, since some of the views of the building were completely inaccessible and therefore there was a lot of information missing in the photogrammetric processing.
3. BIM Building information modelling: an integrated database

Using phases and external links for each discipline within the design file allowed us to arrange the architectural data in the 4th dimension as well as by capturing the time phase of each intervention. Working with many consultants, whose design can collide with each other’s, is becoming more challenging when we are adding the additional layer of the survey of the historic building that needs to be protected. Inserting all the various layers of information within a comprehensive BIM data base, helped the design team to detect collisions right from the start and to take better design decisions that take into consideration the complexity of all aspects.

3.1. SPATIAL SURVEY IN A BIM ENVIRONMENT

The revelation of the historical importance led to the strategy of documenting the building and designing respectfully according to it from an early stage. The spatial layout of the existing building could not have been documented with conventional survey techniques. The existing survey of the building in the city’s archive had several inconsistencies. Surveying the building with laser scanning made it possible to correct such inconsistencies in an early stage of the design process. Critical building elements that were high above ground were measured accurately through the spatial scanning and the interior envelope of the main space was well defined.

The registered point cloud set that was obtained from the laser scan was inserted into the Revit BIM model and served as a reference to building’s existing structure, walls and beams in the most accurate way. The desire to respect the existing interior envelope of the main space, led to a design intervention that was offset of all interior surfaces. One of the results was a floating gallery and a structure for a new roof without touching or damaging the original and fragile silicate walls (Figure 3). The implementation of 3D scanning gives great confidence to each design decision that need to be taken along the way. The point cloud helped further by showing the distribution and heights of the existing workshop machinery inside the building, so to avoid collisions of large machines with the proposed gallery (Figure 4).
3.2. STRUCTURAL INTERVENTION IN A BIM ENVIRONMENT

In the east wing, where the asbestos roof needed to be replaced, the design team took into consideration the fragile condition of the historical silicate walls. It was decided that the new roof would be supported by a thin steel structure that would be placed within the historical walls like a hand within a glove. This was one of the results that came out from the prior step of the survey and the structural analysis and “as-built” condition.

After taking apart the problematic roof in the east wing the light steel system was built parallel to the original walls. The use of a light steel system has several advantages: The building process is very clean and accurate and it was needed in an historical site. The material usage was done with no waste and with digital fabrication of the trusses (from the software to the extrusion manufacturer machines with no paperwork in-between). In addition, the duration of the entire building process took less than a week and this was important in order to avoid the chance of rain coming inside the old building that was without a roof temporarily. This type of structure is earthquakes re-
sistant and the roof is floating above the walls, unlike the previous situation, where the asbestos roof was leaning on the fragile thin silicate walls.

3.3. MATERIALS QUALITY AND QUANTITY IN A BIM ENVIRONMENT

In contradiction to the asbestos roof, the new roof tiles are ecological tiles. The Onduline system was chosen for several reasons as well: The bituminous roofing tiles are composed of recycled fibers and natural pigments for coloration and do not contain any asbestos. It is manufactured with 50% post-consumer recycled cellulose material. These tiles are extremely lightweight (4kg/m²) and therefore appropriate for the thin steel structure that is supporting them. They also provide a water proofing solution, combined with thermal comfort and acoustic performance during extreme heat or rain.

Each element in the BIM design file got the material specification that was part of the bidding accuracy and helped to emphasize in the BID the need to use ecological materials such as the recycled tiles or gypsum boards, the thin steel structure and the insulation materials. The new floor tiles have the old stylish look of painted aged wood tiles but they are made out of porcelain in order to keep the strength, durability, heat and moisture resistance and still keep the warmth and personality of a natural timber. The lighting fixtures in the main lobby are from the recyclable by-products of the very same plastic workshop that one of the industrial designers (Artist Yaron Elyasi) that is working at the college was asked to produce for the project with a free-moulding technique.

3.4. NATURAL LIGHT IN A BIM ENVIRONMENT

The fact that we were using 3D data right from the first day helped to obtain the climatic analysis for the site and to get natural and artificial light simulations that influenced the detailed design at a later stage. For natural lighting solutions in the few internal rooms in the east wing, where no windows were available, the design suggested three solar tubes units with the diameter of 45 cm each. The sun pipes are allowing natural light to enter, while blocking heat and UV radiation. This will save the need to use artificial light inside those rooms during most days of the year but also improve the quality of life and health for the students inside the building. The light simulations enabled the designer to identify the indoor daylight conditions in the problematic rooms and to suggest the optimal solution.

It was important to incorporate natural lighting solutions in the spaces lacking windows, because of the many well know advantages of the use of natural light within buildings, such as studies that have shown that people
work better under natural light environment, statistics that show that electric lighting during daytime hours is minimized by as much as 75% and therefore it is cost effective. In addition, reducing energy usage can reduce the CO₂ emissions.

3.5. MEP AND MORE IN A BIM ENVIRONMENT

Each space within the preserved building got a room tag within the BIM database that contained all the information of the mechanical calculations, as well as an accurate equipment schedule for bid. The mechanical consultant made several alternatives for the HVAC systems. All alternatives were included in the Revit platform and allowed the design team to detect collisions and to get in the bid accurate estimations that helped the client to decide on the preferred solution after considering the price and the quality all together.

Other performative aspects, such as acoustic simulations and artificial light simulations were made as part of the design process and were taken into consideration. The BIM process helped the team to perform in a very tidy schedule on a very delicate historical site without compromising the design qualities. The new building is designed as well with BIM tools and will be subjected to the local Israeli green code. It preserves the aesthetic values of the historical site by using the same materials and allowing clear view and close relations to the historical packing building.

4. Conclusions

While using BIM databases and processes starts becoming an established practice for new buildings, one encounters few case-studies where BIM is used for design interventions for existing buildings and where the digital survey becomes an integral part of the BIM database. The design process of architecture in the last couple of decades started to change: Rather than the architect on the top of the pyramid, managing the various consultants and their information, nowadays the architectural project is a team work, where data is constantly cross referenced and exchanged between the different players in the design process. In this way, the various aspects of the project can influence one another, and this multi-disciplinary approach can define a more holistic and appropriate design intervention.

Incorporating the digital survey into the BIM database, gave a solid foundation to the decision making for the design intervention of this building. The digital survey within the database anchored the design decision to the authenticity of the character of the building and contributed to the respect of all team members of its history and architectural elements. Further, the integrated BIM database allowed for better spatial coordination management and geometric clash detection, as well as for an efficient and multi-
disciplinary collaboration from the schematics to bid and to construction of the project.

**Endnotes**

1. Krinizi Museum and Archive
3. Ibid.
4. There are two main methods of collecting pictures for photogrammetry, which differ on the camera location in relationship to the object of interest: Aerial photogrammetry and close-range photogrammetry. For more information on aerial photogrammetry, see J. Campbell, R. H. Wynne, Introduction to Remote Sensing (New York: The Guilford Press, 2011).
5. The photogrammetry software that was used in this project was Photoscan from Agisoft.
7. The point cloud was exported from Cyclone in *.pcg format, to be able to be inserted in Revit.
8. Israeli green building code 5281.

**References**