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dal Progetto di Architettura al Design Industriale

Research Innovation and Internationalisation

National and international experiences between identity and inclusivity

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Survey and Representation Research, from Architectural to Industrial Design

The Series aims at providing a deep investigation of the topics related to Survey and Representation also with reference to the themes of Project (architectural, urban, landscape and restoration) and Industrial Design (product, communication, interior) by connecting methods, tools and processes to the contents of the Scientific-Disciplinary Area of the Drawing (ICAR 17).
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Cover: Three-dimensional view of the photogrammetric model used in surveys, displaying control points where the model was compared with the laser scanner point cloud (Image by Stefano Bertocci and Matteo Bigongiari).

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Digital Survey for the Restoration Project, Al-Raabiya Mosque in Mosul

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1. Introduction

This paper presents a comprehensive account of the digital architectural survey and documentation project conducted on the Al-Raabiya Mosque in Mosul, Iraq, initiated in June 2021(Fig. 1). The documentation of this historic monument is geared towards its reconstruction and restoration, with the primary objective of reinstating a social focal point for Mosul's historic center. The survey operations were, therefore, designed to amass morphological, quantitative, and qualitative knowledge of the structures. This data was crucial for scientifically supporting the creation of a restoration plan for this religious complex. In 2017, the mosque suffered significant damage (Fig. 2), much like the rest of the city's historic center, during the war against Daesh. Following the war, Mosul has emerged as a colossal restoration project, with international organizations working diligently to restore its main civil and religious landmarks and rehabilitate the residences that were severely impacted by the conflict.

The University of Florence's Department of Architecture played a pivotal role in this project, offering scientific support throughout its various phases. Their involvement was most pronounced during the initial survey and architectural data compilation phases. Additionally, they provided valuable insights into operational decisions, supporting the expertise of restorers and structural designers.

After the war in Mosul, extensive damage was inflicted upon the urban fabric of the city. The conflict resulted in widespread destruction, including the collapse of buildings, infrastructure damage, and the displacement of residents. Cultural and historical

Figure 1: Representative image of a perspective section obtained from the colored point cloud of Al-Raabiya Mosque.

landmarks were heavily impacted, leaving scars on the city's rich heritage. The rehabilitation efforts post-war aimed to restore the city's essential services, rebuild residences, and revive its cultural and architectural treasures, such as mosques, churches, and historic structures, to help Mosul recover and regain its identity.

The restoration and revitalization of the Al-Raabiya Mosque in Mosul have the potential to serve as a powerful catalyst for the rejuvenation of the city's historic core. This ambitious initiative not only aims to restore a significant religious and cultural symbol but also offers a multitude of far-reaching benefits for the local community. First and foremost, the restoration of the mosque signifies the resurgence of Mosul's rich cultural and historical heritage. Once restored to its former glory, the mosque becomes an enduring symbol of resilience and hope for the city's residents, fostering a renewed sense of identity and pride among the community. Beyond its cultural and symbolic significance, this architectural project generates a substantial number of employment opportunities for the people of Mosul. Skilled labor is in high demand for the meticulous restoration work, encompassing a range of trades, including masons, carpenters, electricians, and various artisans. This infusion of job prospects not only enhances the livelihoods of the local workforce but also contributes significantly to economic stability and growth in the region. Moreover, a beautifully restored mosque has the potential to function as a compelling tourist attraction, drawing visitors from far and wide to the heart of Mosul's historic center. This influx of tourists can stimulate the local economy further, providing a much-needed boost to businesses in the area, such as restaurants, cafes, and shops.

Figure 2: Comparative views displaying the volumetric state of the blocks where the mosque is located before (left) and after (right) the bombings.

The restoration project also has a community-centric dimension. It has the potential to actively involve and engage the local community, fostering a sense of ownership and participation. Community engagement activities, including cultural events, workshops, and educational programs, can be organized around the mosque. These initiatives not only bring people together but also strengthen social bonds within the community. Furthermore, the rehabilitation of the mosque can serve as a catalyst for broader urban regeneration efforts. As the historic center of Mosul undergoes restoration, it may inspire private investment in neighboring properties, leading to the revitalization of the entire area. This ripple effect can breathe new life into the urban landscape, creating a vibrant and thriving city center.

The restoration journey of the Al-Raabiya Mosque in Mosul stands as a testament to the power of collaboration and knowledge exchange (Fig. 3). At its core, this monumental endeavor has thrived on partnerships with various stakeholders, both local and international, underscoring the shared commitment to safeguarding the cultural legacy of this historic site. These collaborations have been pivotal in shaping the restoration process, ensuring that it transcends mere architectural revival and encompasses a holistic revival of a community's identity. Local universities have played an integral role in this restoration project. Collaborations with academic institutions have fostered an enriching exchange of knowledge, with students and scholars actively engaging in the preservation efforts. This partnership not only invigorates the restoration process with fresh perspectives but also empowers the younger generation to become stewards of their cultural heritage, strengthening the ties between the mosque and the community it serves. The invaluable guidance and expertise offered by architectural and archaeological authorities, including local supervisory bodies, have been instrumental in steering the restoration journey. Collaborative dialogues with these entities have ensured that the restoration adheres to rigor-

Figure 3: View of the mosque area taken from the rooftops of the madrasa before the start of architectural survey activities.

ous preservation standards and respects historical accuracy. Their unwavering commitment to safeguarding Mosul's architectural treasures has illuminated the path toward comprehensive heritage conservation. On the global stage, the Al-Raabiya Mosque restoration project has garnered the support and recognition of esteemed international organizations such as UNESCO and UNDP. These organizations, known for their dedication to preserving cultural and historical landmarks, have lent their expertise and resources to the project, further bolstering its impact. Their involvement extends beyond the mosque itself, encompassing the broader revitalization of historic residential areas in Mosul, cementing the city's resurgence as a testament to resilience and heritage preservation.

2. Survey Methodology

The comprehensive survey of the Al-Raabiya Mosque in Mosul utilized a multifaceted approach, integrating advanced technologies such as laser scanning and 3D photogrammetry techniques. This hybrid approach was meticulously chosen to capture the intricate details of the mosque's architecture, ensuring accuracy and completeness in the collected data.

2.1. Laser Scanning

Laser scanning, a cutting-edge technology, played a pivotal role in this survey. It involved the use of a highly specialized instrument, the Faro Focus S350, known

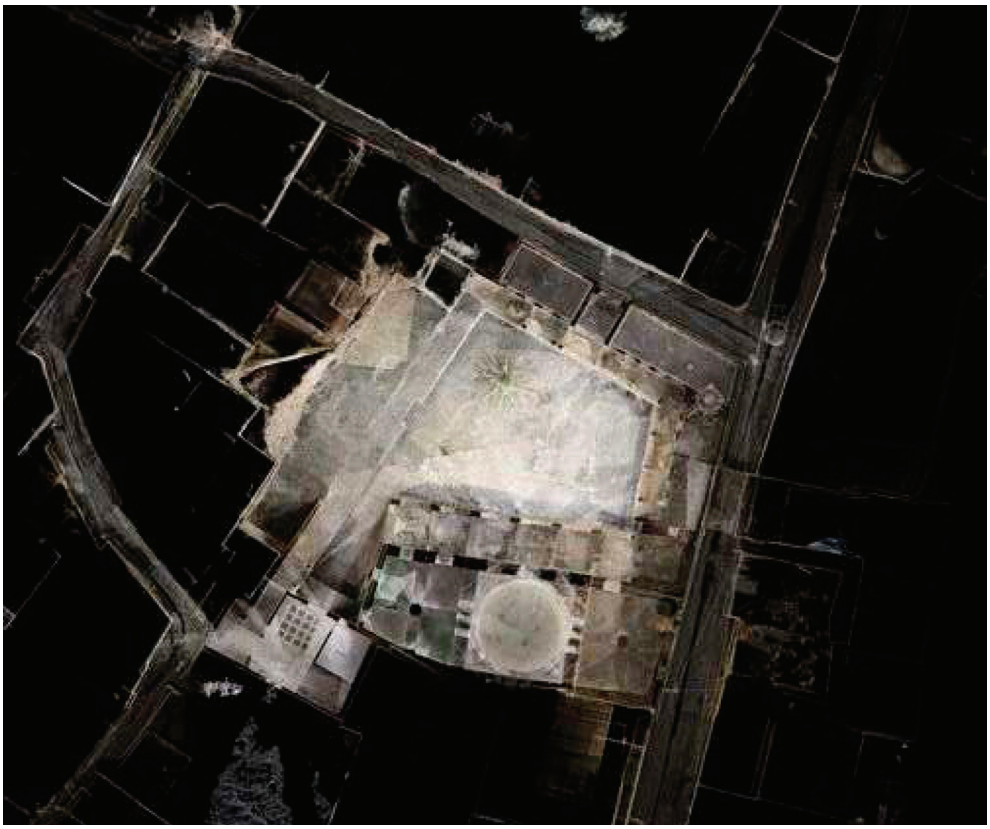

Figure 4: Orthoimage from the point cloud depicting the extent of the laser scanner survey of the religious complex.

for its precision and efficiency. This instrument emitted laser beams, which were directed at the mosque's surfaces, creating a dense point cloud representation of the entire structure.

The key advantages of laser scanning were twofold: accuracy and speed. The Faro Focus S350's ability to rapidly acquire measurements with millimetric precision was paramount. As it swept its laser beams across the mosque's architectural features, it meticulously recorded the position and depth of each point on the surfaces. This data, when merged, formed an incredibly detailed CAD representation of the mosque, down to the finest nuances of its design.

Furthermore, the registration process, which ensured the alignment of 145 individual scans, was rigorously conducted (Fig. 4). These scans had significant overlaps, and meticulous cloud-to-cloud alignment techniques were applied. By simulating

the creation of topographic polygons, errors were minimized, guaranteeing an error margin of less than 1.5 centimeters. This level of accuracy was deemed critical for the subsequent stages of the project, including architectural drawing creation and structural analysis.

2.2. 3D Photogrammetry

In conjunction with laser scanning, 3D photogrammetry was employed to provide a complementary perspective on the mosque's architectural features. Photogrammetry involves capturing multiple images of an object from different angles and using software to reconstruct a 3D model based on the visual information contained within these images. For this project, both ground-based and aerial photogrammetry techniques were employed. A Sony A7R II camera, equipped with a high-resolution 42.4MP CMOS sensor, was used for ground-based photography, allowing for detailed close-range capture of the mosque's surfaces. Additionally, drone-mounted cameras, particularly a DJI Phantom 3 drone, were employed to capture aerial images, providing a unique vantage point for reconstructing challenging areas, such as the mosque's elevated sections and vertical walls.

However, it's important to note that photogrammetry posed unique challenges, particularly due to the varying lighting conditions between the mosque's interior and

Figure 5: Three-dimensional view of the photogrammetric model used in surveys, displaying control points where the model was compared with the laser scanner point cloud.

exterior spaces. Careful planning was essential to mitigate these challenges. Each photograph had to be meticulously examined for factors like focus, white balance, and exposure to ensure the quality and reliability of the data. The resulting photogrammetric point cloud, which was created by reconstructing the mosque's surfaces from thousands of images, was then scaled and aligned with the laser scanning point cloud. This meticulous calibration ensured that the two datasets were seamlessly integrated, producing a comprehensive and highly accurate representation of the mosque's architecture (Fig. 5).

This dual approach, combining the precision of laser scanning with the visual richness of photogrammetry, allowed for a thorough and comprehensive understanding of the Al-Raabiya Mosque's structure, ensuring that no detail was overlooked during the subsequent phases of the project.

3. Data Processing and Analysis

Following the survey campaigns, data underwent a post-production phase. A comprehensive database was compiled, incorporating laser scanner, camera, and drone-acquired material.

This cataloging streamlined the process of remote verification, interrogation, and the creation of 2D/3D outputs (Figg. 6-8). These outputs would serve as the foun-

Figure 6: Graphic representation of the site's planimetry from drone's orthoimage.

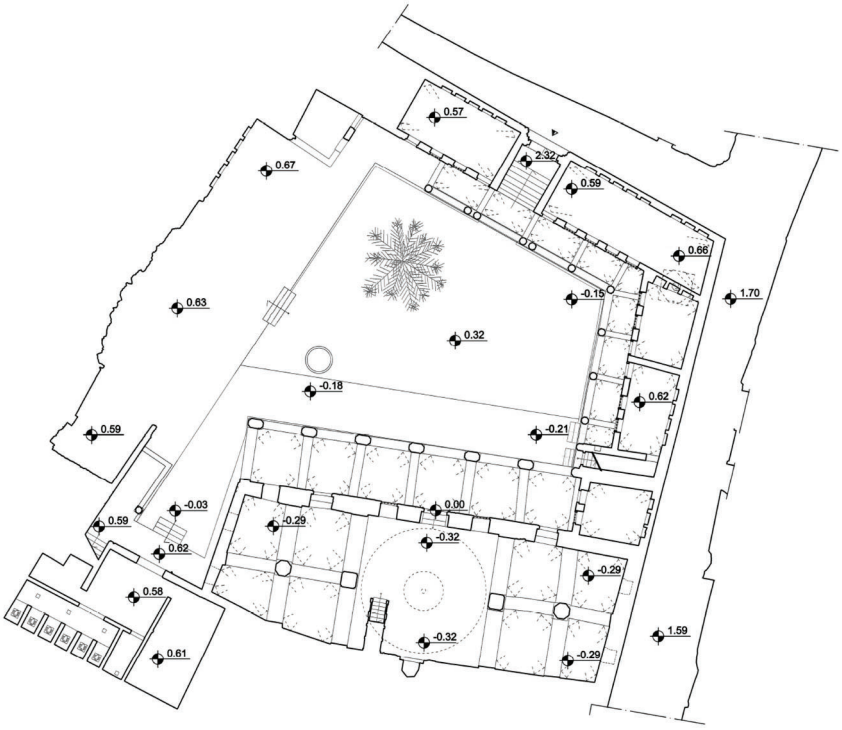

Figure 7: Ground floor drawing.

dation for the study, comparison, and analysis of the case study. In the context of our study on the restoration and revitalization of the Al-Raabiya Mosque in Mosul, a thorough diagnostic process was undertaken to inform the restoration efforts and ensure the structural integrity of this historic monument. This diagnostic process comprised several critical analyses conducted on-site. Firstly, an in-depth surface condition assessment was meticulously carried out, involving a comprehensive evaluation of the masonry and an identification of areas displaying deterioration and damage incurred during war-related events. These findings served as the foundational basis for determining the necessary restoration interventions. Subsequently, structural analyses were conducted to map the extent of damage across various elements of the mosque's structure.

This meticulous mapping process documented the precise location and severity of lesions, cracks, and structural weaknesses, providing valuable insights into the scope of structural rehabilitation required. Furthermore, due to concerns arising from post-bombing events, structural analyses were also dedicated to rigorously

verify the vertical alignment of the architectural surfaces.

This assessment addressed potential distortions and deviations that may have arisen due to the impact of bombings, ensuring structural stability and safety. Collectively, these diagnostic endeavors constituted a comprehensive framework, guiding the selection of appropriate interventions and assuring the faithful restoration of the Al-Raabiya Mosque's architectural and structural integrity.

4. Conclusions

The three-dimensional survey of the Al-Raabiya Mosque has yielded an extensive collection of data regarding the building's morphology and the condition of its masonry walls, both superficially and structurally. This data is invaluable for shaping a redevelopment and restoration project for the area. Leveraging this survey data, the team, led by Archimedia Trust, meticulously evaluated interventions and their implications in terms of volume and cost.

During the meticulous restoration of the Al-Raabiya Mosque, the construction site emerged as a vital crucible of discovery, shedding light on the rich history and structural intricacies of this architectural gem. Several significant revelations came to the fore, profoundly impacting our understanding of the mosque's past and present.

One of the most remarkable discoveries during the restoration process was the unearthing of subterranean structures beneath the mosque's floor. These concealed structures hint at the presence of earlier architectural elements, offering a tantalizing glimpse into the mosque's historical evolution. This revelation has ignited scholarly intrigue and further underscores the site's significance as an archaeological treasure trove.

The restoration project also provided a unique opportunity to delve into the interstitial spaces between the two domes of the mosque. These hitherto uncharted areas have opened up new avenues for structural analysis and research. The intricate network of supports and arches between the domes reveals fascinating insights into the mosque's construction techniques and the engineering prowess of its builders.

Another compelling challenge that surfaced during the restoration process was the presence of a subterranean water fault beneath the foundations of the mosque's portico. This unforeseen issue necessitated innovative engineering solutions to mitigate potential damage and ensure the mosque's long-term stability. The effective resolution of this problem exemplifies the synergy of historical preservation and modern engineering techniques.

While the restoration of the Al-Raabiya Mosque is well underway, it remains a dynamic journey toward the preservation of its rich heritage. The project's ongoing efforts are dedicated to returning the external dome to its pristine original state, a meticulous endeavor that involves painstaking attention to detail.

At the heart of the restoration project lies the meticulous rejuvenation of the external dome, a once-iconic architectural marvel that adorned Mosul's skyline. This monumental task involves a multi-faceted approach. Firstly, a careful analysis of his-

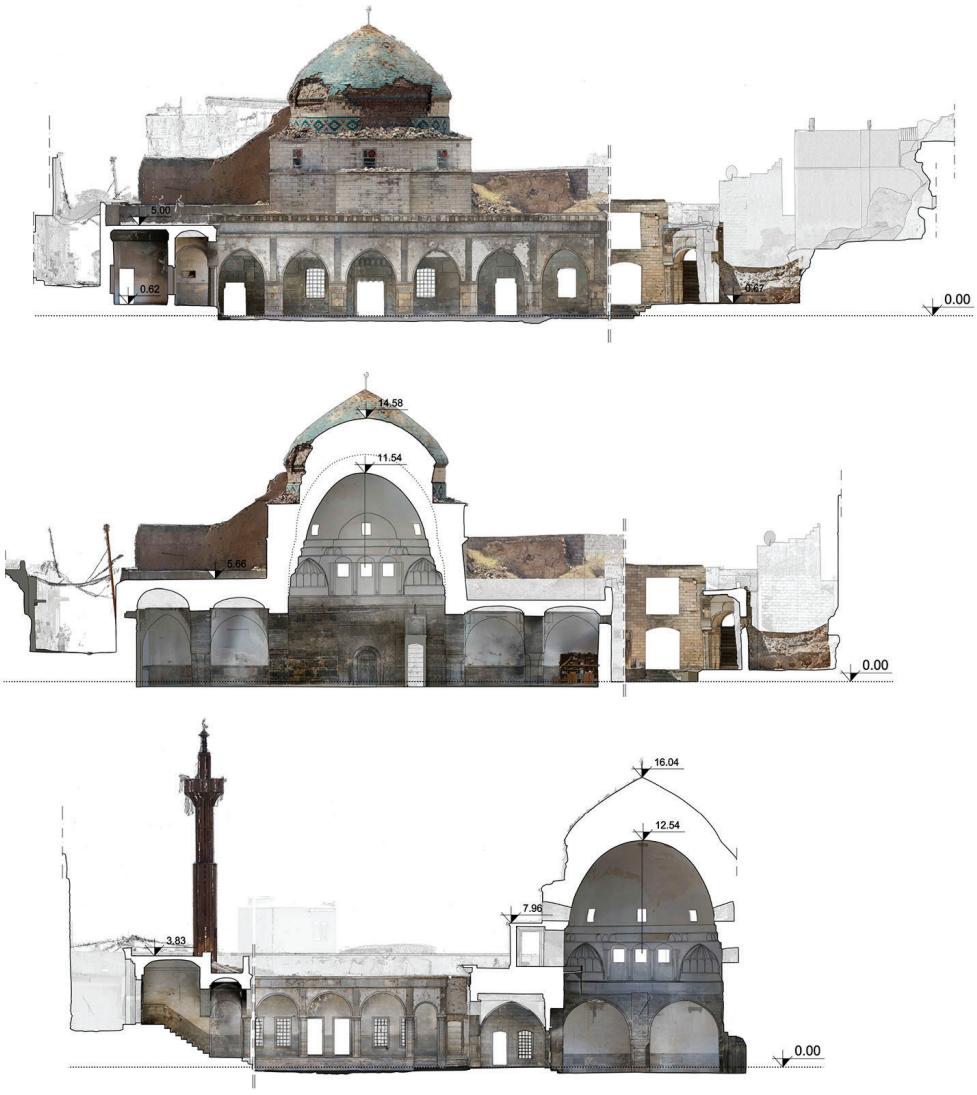

Figure 8: Elavations and sections drawing, showing the architectural state of conservation of the building.

torical records and architectural documentation has been employed to ensure that the dome's restoration aligns with its original design. Expert craftsmen, skilled in traditional techniques, are meticulously repairing and replacing damaged elements, paying homage to the craftsmanship of the past. Furthermore, state-of-the-art materials and conservation practices are being employed to ensure the longevity of this restoration, allowing the dome to once again grace the cityscape as a testament to its enduring cultural significance. The restoration project extends its meticulous care to every surface of the mosque that has been marred by time and conflict. A team of conservators and artisans is painstakingly cleaning and repairing damaged surfaces, from intricately carved stone facades to delicate interior decorative elements. This process is a delicate dance between modern conservation science and time-honored techniques, with each surface receiving individualized attention to ensure the faithful restoration of its original beauty. Integral to the overall ambiance of the site are the areas surrounding the mosque's structures. These spaces, though often overlooked, are of paramount importance to the holistic restoration of the mosque's heritage. Landscape architects and preservation experts are working collaboratively to rejuvenate these areas, aiming to create a harmonious synergy between the restored architectural elements and their surroundings. This entails meticulous planning to ensure that the revitalized areas are not only aesthetically pleasing but also conducive to enhancing the visitor experience, making the Al-Raabiya Mosque an inviting destination for all.

Acknowledgments

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