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DESIGN INFLUENCES

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Working Paper Series

MODERN SUSTAINABLE RESTORATION AND REHABILITATION OF HISTORIC BUILDINGS: INSIGHTS FROM EGYPT

Ayman Khalil, Sandra Zaffarese, Mohamed W. Fareed

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MODERN SUSTAINABLE REHABILITATION OF HISTORIC BUILDINGS AND SURROUNDING COMMUNITIES: DRAWING LESSONS FROM EGYPT'S RICH HERITAGE AND FORWARD-LOOKING PRACTICES

♦ ♦ ♦

The dynamism in traditions is essential for current societies - developing through advances in science and technology - to preserve their heritage, identity, and culture. Adapting to continuously arising challenges is no longer a luxury but also a great economic added value that cannot be replaced once buildings get demolished or neglected.

Preservation of historical buildings as well as their valued heritage - tangible and intangible - has become more difficult due to many factors such as overpopulation, urbanization, climate change, financial crises, and many other environmental issues.
The severity of the aforementioned challenges induces uncertainty in the traditional restoration methods of historical public buildings which formerly served different functions. It is not surprising that many classical theories in traditional renovation have been facing new challenges for decades.

The scope of this paper is to examine three of our completed projects: The main post office building in Cairo, Egypt (Circa 1886), the rehabilitation of an old historical palace in Aswan, Egypt (Circa 1912), and the historical El-Shalal train station also in Aswan (Circa 1905).

These three projects were executed through a modern four-pronged methodology; these being:
a) Following the latest international restoration standards and embracing the heritage of these architecturally significant buildings, their elegant proportions, and intricate decorative details, rehabilitating them to ensure the aesthetic is preserved.
b) Employing elements of social architecture to renew the customer and employee experience by introducing new elements of design while preserving the historical soul and character of the buildings.
c) Integrating green and sustainable building specifications to commit to the future through the use of solar energy, waste reduction, and use of locally sourced materials.
d) Developing the urban communities around the buildings by supporting local artisans and materials, and investing in their practical education; to preserve their knowledge and techniques as a cornerstone of the success of these projects and future iterations of renovation.

This four-pronged approach sets the blueprint for future urban renewal endeavors and sheds some light on the potential challenges and conflicts such projects may entail in the future. These challenges are split into two intertwined aspects: the technical and the human. Technical challenges include adapting the buildings to new electromechanical services and digitization, the structural restoration of these buildings, preserving the natural environmental elements such as lighting and ventilation in the buildings, and procuring the necessary local materials, as old sources are exhausted and recycling entails rigid permissions. On the other hand, the human challenges include the clash between innovative and conservative schools of thought, working within the constraints of bureaucracy, the erosion of cultural identity as people look favorably upon everything flashy, and the capitalist incentive for short-term gain which reduces the timeframe for the project.

Finally, the paper concludes with a discussion of the results of these unique renovation projects which stand toe-to-toe with contemporary architectural standards and the creation of a new exemplary landmark with added value that serves the community for generations to come.

1. INTRODUCTION

Preservation of historical buildings as well as their valued heritage - tangible and intangible - has become more difficult due to factors such as overpopulation, urbanization, climate change, financial crises, and many other environmental issues.

The severity of the aforementioned challenges induces uncertainty in the traditional restoration methods of historical public buildings which formerly served different functions. It is not surprising that many classical theories in traditional renovation have been facing new challenges for decades.

The 3 buildings studied in this paper are all of great historical importance, representing unique architectural and cultural treasures in Egypt. Each of these structures - the main post office building in Cairo (Circa 1886), the old historical palace in Aswan (Circa 1912), and the historical El-Shalal train station, also in Aswan (Circa 1905) - has its own story to tell and is deeply intertwined with the history of the communities they serve.

Historical buildings like these are not mere structures; they are living embodiments of the past, narrators of the evolution of society, and cornerstones of cultural identity. These buildings connect the present with the past and are invaluable resources for understanding the heritage of a nation. Preserving them is not just an architectural endeavor but also a cultural and societal responsibility.

Over the years, so many other historical buildings have faced neglect, decay, and numerous threats. Whilst traditional and classical theories of restoration have been effective in preserving such landmarks, but lacked longevity due to their allotted new-use, the ever-evolving challenges of our time have necessitated a more dynamic and holistic approach. This paper seeks to explore and highlight the successful transformation of these historic landmarks in Egypt using a modern, sustainable, and community-centric methodology.

The four-pronged methodology employed in these projects sets the stage for future urban renewal challenges emphasizing the need to not only preserve the physical structure but also breathe new life into them while maintaining their historical essence. This approach focuses on maintaining aesthetic value, revitalizing social architecture, integrating sustainable building practices, and nurturing local communities.

In the following sections, we will delve into the specific challenges faced during the rehabilitation of these buildings, both from a technical and human perspective. We will discuss the innovative solutions employed to adapt these structures to modern needs, all while preserving their historical significance.

The objective of these projects is not simply to restore old buildings, but to create enduring landmarks with added value, enriching the lives of the local communities and serving as a testament to the harmonious coexistence of history, culture, and modernity. This paper, therefore, seeks to provide valuable insights into the sustainable rehabilitation of historic buildings and their surrounding communities, drawing lessons from Egypt's rich heritage and forward-looking practices.

2. RELATED WORK

2.1. Linking Between Community Participation in Adaptive Reuse and Sustainable Development

Community participation in adaptive reuse is intrinsically linked to the pursuit of sustainable development. Sustainable development, as highlighted in Agenda 2.1, is underpinned by the active involvement of communities, particularly disadvantaged groups, in shaping policies, alternative design choices, investment decisions, management, and oversight of development initiatives within their localities. International charters underscore the pivotal role that local communities play in the execution of urban revitalization and regional sustainable development strategies [1]. For instance, the Washington Charter, also known as the Charter for the Conservation of Historic Towns and Urban Areas 1987, explicitly underscores the importance of resident participation in the success of conservation programs, recognizing that the conservation of historic urban areas primarily concerns their residents. Additionally, the Burra Charter emphasizes that heritage conservation is unsustainable without active community involvement [2].

The integration of communities in urban conservation serves two main purposes, as highlighted by [3]. First, it aids in the resolution of conflicts stemming from legal, social, and economic factors, wherein the public may hold differing perspectives. Second, it aids in delineating the significance and cultural meaning of heritage structures, often in situations where disparities exist between expert opinions and community viewpoints.

In the context of adaptive reuse, [4] examines the community-initiated adaptive reuse of historic buildings in the inner city of Shanghai, shedding light on how such ventures can contribute to sustainable development. Their findings underscore the value of community participation in repurposing historic structures to meet the evolving needs of society, ultimately fostering sustainable urban development.

2.2. Between Adaptive Reuse and Sustainability

Adaptive reuse is a concept that involves unlocking additional functionality and extending the life of functionally outdated buildings. Essentially, it can be seen as a form of architectural recycling. While often associated with historic preservation, it goes beyond mere restoration. Rehabilitation, within the context of adaptive reuse, refers to the process of making a property suitable for compatible new use through repairs, alterations, and additions, all while preserving the aspects that convey its historical, cultural, or architectural significance. The key distinction here is that instead of striving to maintain a building's existing use through upgrades or returning it to a specific historical period, adaptive reuse focuses on finding new and relevant purposes for these structures. Furthermore, the success of adaptive reuse isn't contingent on a building's architectural grandeur but relies on respecting its history and structure while introducing innovative uses. Economic and social benefits are associated with adaptive reuse. In cases where a building is in good structural condition and easily adaptable to its new purpose, economic advantages come into play. These include potential cost savings in construction, reduced expenses in land acquisition, and shorter construction timelines based on the extent of the work required. Adaptive reuse also aligns with energy conservation, addressing economic concerns about resource utilization.

On a social level, adaptive reuse holds advantages, such as reconnecting with the past and breathing life into neighborhoods. Rather than attempting to resolve urban issues by demolishing structures, reusing buildings contributes to creating a 'sense of place' in the community. The physical revitalization resulting from reuse positively impacts the surrounding neighborhood and often triggers improvements in nearby structures [5].

As Jane Jacobs [6] asserted, cities require old buildings, not necessarily pristine or museum-worthy structures but a mix of ordinary, low-value, and even dilapidated old buildings. These buildings are essential for the vibrancy of urban areas.

In terms of terminology, Holyoake and Watt [7] differentiate between reuse, which can encompass distinctive and often costly transformations, and adaptation, which involves rehabilitation, renovation, or restoration without necessarily changing the building's intended use [8]. Restoration aims to return a building to its original condition, while renovation modifies it to meet contemporary standards and codes. Although renovation extends a building's useful life, it doesn't entail a change in its purpose. Therefore, it is plausible to argue that adaptation represents a strategy for prolonging the sustainability of buildings by combining improvements and repurposing [9].

3.1. Attaba Post Office in Cairo

The Attaba Post Office, situated on Abd El Khalik Tharwat Street in Cairo, Egypt, represents a historical landmark dating back to its construction during the reign of Khedive Ismail in 1865. It occupies a central role in the geography of Downtown Cairo and plays a pivotal part in the Egyptian economy and social life. Recognizing the cultural and historical importance of this district, Architect Ayman Khalil embarked on a long-term commitment to restore and conserve the architectural heritage of this area of Cairo.

It was of the utmost importance that the project be underpinned by a strong emphasis on sustainability, with the restoration process serving as a vehicle to achieve this goal. A central challenge encompassed the adaptive reintegration of antiquated elements while seamlessly accommodating contemporary technological requirements.

Of particular significance was the focus on enhancing the main post office in Cairo, a space encompassing 1220 square meters. The primary architectural philosophy for this project revolved around reverting to the building's original design, which harked back to the early 20th century. A comprehensive study of the building's elements was conducted to seamlessly integrate them with its historical context and authenticity while removing foreign elements that had been introduced over time. To restore the building's architectural and historical integrity, several foreign elements were eliminated, including partitions, certain concrete works, marble cladding, oil-based paints, and suspended ceilings. The restoration aimed to bring back the post office's historical character.The architectural concept for the project involved not only removing foreign elements but also reevaluating the functionality of the building. This included enhancing the work environment, improving energy efficiency, and ensuring compliance with recognized standards. The project embraced technological advancements and digitalization while maintaining the building's historical integrity. Various elements were utilized in the renovation, such as local stone flooring that resembled the original stone used in the building, adorned with copper strips to emphasize its historical character. Existing iron columns were preserved to highlight the architectural and structural elements, and additional ironwork was introduced for both aesthetic purposes and to create functional spaces for employees. The entrances were also reconfigured to create a more efficient flow for both employees and the public while considering capacity.

Fig. 1: The building during the late phases of the project. (Source: Authors, 2022).

The project followed the following Sustainable Restoration Strategy:

I. Matching Historical Integrity with Contemporary Demands:

The restoration and conservation of this culturally invaluable structure harmoniously amalgamated timeless aesthetics with intricate decorative elements to cater to the contemporary needs of its users. Preserving the integrity of a prominent historic edifice while fulfilling the demands of the 21st century necessitated a holistic vision that struck a balance between delivering an exceptional customer experience and safeguarding tangible cultural heritage.

II. Transformation of Architectural and other trades of engineering

The restoration included the reactivation of new two secondary entrances designed to regulate visitor flow and enhance seating arrangements. The booth space allocation, which was initially conceived without the consideration of computers and the increasing number of visitors, was revisited, increasing from 11 to 26 booths.

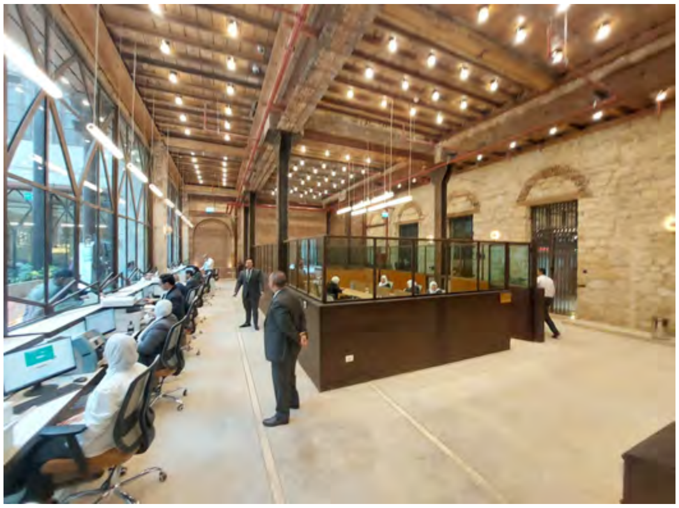

Fig. 2: The building in its early days of operation. (Source: Authors, 2022).

Stone walls

Making a complete restoration and treatment of stone walls while raising the efficiency of each stone by adding natural materials to close off the joints and removing layers of cement materials from the bricks. as per classical local restoration codes.

Woodwork

The restoration of the wooden elements was made in the ceilings with the addition of structural reinforcement, and the implementation of reinforcements to hide all mechanical and electrical works and show a beautiful shape with the introduction of fire and moisture-resistant materials.

Flooring

All the flooring areas were replaced to fix underground water problems and to do all the required investigations and also to allow the installation of the huge amount of electromechanical services that a public modern service office requires that had to be coordinated concerning the original structure to pass underneath.

Local stone was provided from a nearby local quarry where the same types of stone were used to build the building, and structural slats were added where required.

Iron Work

After removing a huge amount of irrelevant elements such as concrete walls, beams, marble cladding, and suspended ceiling and gypsum board partitions from the original iron and stone columns in the building to emphasize the existing architectural and structural elements, and also adding iron elements, suit the same character exists in the building, were painted with anti-rust- and fire-resistant paint protection to become environmentally friendly.

Landscaping

One of the confirmed elements of the general trend of sustainability and green buildings is the use of different types of plants (low maintenance) to create a natural environment for workers and the public and spread the idea of beauty with development.

The Clock

Museum officials were consulted to reinstall the original clock in the building, restore it, and restart it through the museum administration, and it was installed in the place designated for it and brought back to life via modern technology.

Harmony and compatibility in the elements used in the office and the use of craft, handmade, and local industries to emphasize the use of Egyptian labor with local materials to suit the historical character and create a functional and natural environmentally friendly environment that contributes to creating spaces, movement paths and vision for all elements of the office through glass elements, which also keep pace with all means of technological development. The use of modern digitization and the general trend of green buildings.

Fig. 3: The building Main courtyard after innovation. (Source: Authors, 2022).

III. Enhanced Customer Experience:

The Counter

Manufactured from iron to suit the general character of the building, the iron elements in the building give more space for the employee, which gives freedom of movement. Traffic distribution was reviewed, capacity increased, and operating efficiency increased by increasing the number of windows to 32, as well as 3 windows for major customers and 1 window for people with special needs.

Bathrooms

Total renovation and provision of an increased number of bathroom facilities (as per local codes). The inclusion of a sensor-controlled water and drainage system thus ensures a more efficient use of water. In keeping with the general character of the project a conscious continuation of the use of natural granite and the addition of exposed stonework.

An additional designated space was designed for Ablution.

People with special needs

To the State's interest in people of determination and special needs, and taking into account the use of elements to facilitate their dealings with the office, dedicated toilets, ramps, and counter windows with dimensions and levels suitable for access were added.

IV. Sustainable Design Elements:

The architectural components of the restoration involved the sourcing of stonework from the local Mokattam quarries for interior elements. Wooden false ceilings were integrated to accommodate MEP (mechanical, electrical, and plumbing) installations and contemporary technologies. Stone arches and arches were refurbished, steel frames were introduced, and greenery, benches, additional counters, handicap counters, and modern rod lighting units were incorporated into the design.

Lighting and ventilation

Elements were developed to increase natural lighting and ventilation, such as the coverage of the courtyard with a new skylight taking into account the introduction of the element of industrial ventilation (air conditioning and ceiling fans), where a suitable environment can be created for building workers, with emphasis on the element of sustainability and energy saving, using also lighting units of energy-saving hand-saving industries.

Original stones employed in the initial construction were reutilized, underscoring the project's commitment to preserving historical authenticity.

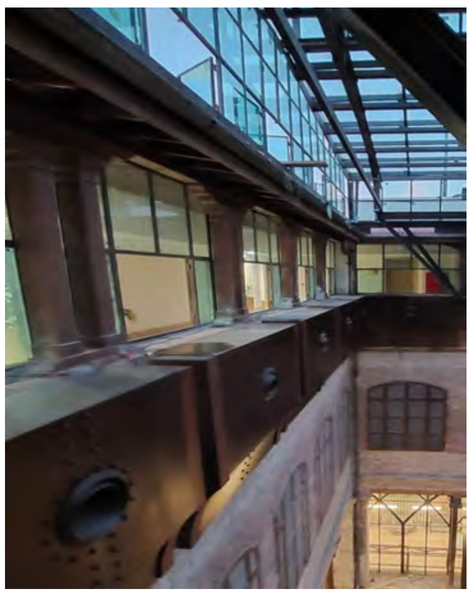

Fig. 4: The building after renovation. (Source: Authors, 2022).

V. Investment in Local Skills:

We endeavored to utilize a local workforce, particularly concentrating on reviving old traditional methods and thus the rejuvenation of factory production.

Training professional restorers, artisans, and engineers by classical restoration regulations.

Fig. 5: The building roof. (Source: Authors, 2022).

The renovation project focused on harmony, integration, and the use of local craftsmanship and materials to emphasize the building's historical character while creating a functional, environmentally friendly workspace. This involved the creation of open spaces and pathways, the incorporation of glass elements for visibility, keeping up with technological advancements, and a strong emphasis on environmental sustainability.

Fig. 6: The building in its early days of operation. (Source: Authors, 2022).

Fig. 7: The building in its early days of operation. (Source: Authors, 2022).

Fig. 8: The building courtyard after renovation. (Source: Authors, 2022).

4. OLD POST OFFICE OF ASWAN

Aswan, a city in southern Egypt, possesses a distinctive historical and architectural character unlike any other. It bears witness to a rich narrative spanning millennia, featuring nationally significant archaeological sites and monuments. This city, with its dynamic energy and enduring cultural importance, recently unveiled the restored Aswan branch of Egypt Post. This endeavor signifies Egypt Post's enduring commitment to safeguarding Aswan's invaluable architectural heritage.

Situated in the historic Corniche district, Egypt Post's Aswan branch has undergone a restoration and rehabilitation process guided by an innovative vision that respects tradition while embracing the future. Aswan is renowned for its global stone products and a culture of building and renovation expertise, attributes reflected in the restoration project. This effort is deeply rooted in the city's rich heritage and considers the environmental implications of our actions for future generations.

The Aswan branch, initially built in the early 20th century, is intimately intertwined with the collective memory of the city. Originally designed as a private residence on the Nile's banks, it underwent various transformations over the years, including serving as a schoolroom. Egypt Post has been a long-standing occupant, providing a vital community hub for the residents of Aswan.

Restoration and Conservation:

In the restoration and conservation of this culturally valuable building, characterized by elegant proportions and intricate decorative elements, the past has been vividly revived to better serve the community. Today, the structure serves as a hub for essential postal and banking services and stands as a flagship for sustainable green development through the following strategy:

I. Balancing Historical Integrity and Contemporary Demands:

Maintaining the integrity of this historically prominent building while adapting to 21st-century requirements necessitated a holistic approach. Contemporary aesthetics and cutting-edge solar technology harmoniously meld with traditional craftsmanship, offering a valuable asset to the city and serving as a model for positive urban renewal.

II. Architectural and Interior Transformations:

The restoration began by removing modern additions that compromised the building's original structure and layout, revealing exposed brick and stonework that showcased centuries-old craftsmanship. The project aimed to retain and restore original fittings whenever possible to preserve the building's character.

III. Enhanced Customer Experience:

The architectural harmony and symmetry of the post office were preserved, allowing concealed features to be reopened, thus restoring the original architect's intent for light and air circulation. On the ground floor, the layout was optimized to improve customer service, featuring restored covered arcades, an open lobby, and fifteen service desks with lowered countertops to facilitate employee-customer interaction. Accessibility for all was ensured through ramps and wheelchair-height counters.

IV. Renewal of Outdoor Spaces:

The external courtyard was transformed into a tranquil waiting garden, complete with shaded pergolas and ample seating. This garden oasis not only enhances the customer experience but also contributes to urban greening and the overall aesthetics of the surrounding streets.

V. Environmental Commitment:

In addition to heritage preservation, a strong commitment to green energy and sustainability is evident. The Aswan branch is set to receive EDGE certification, representing environmentally conscious development. The building operates on renewable energy from discreet rooftop solar panels, supplemented by original architectural features that provide natural ventilation and insulation. Energy-efficient climate control systems and LED lighting further reduce environmental impact.

VI. Sustainable Design Elements:

Sustainability extends to decorative details, with recycled glass lighting and the use of environmentally friendly materials in restoration and finishing. Local materials were prioritized to celebrate Egyptian craftsmanship and minimize the environmental impact of long-distance transportation.

VII. Investment in Local Skills:

Supporting and investing in local artisans, including stonemasons, carpenters, ironworkers, glassworkers, and marble cutters, was crucial to the project's success. Collaborating with these craftsmen showcased the region's talent and ensured that traditional skills and modern design elements were seamlessly integrated into the project.

Fig. 10: The building before and after restoration. (Source: Authors, 2021).

Fig. 11: The building before and after restoration. (Source: Authors, 2021).

Fig. 12: The building before and after restoration. (Source: Authors, 2021).

Fig. 13: Solar panels on the building's roof. (Source: Authors, 2021).

In conclusion, the Aswan Post Office restoration project exemplifies a harmonious blend of historical preservation and modern sustainability, contributing to the preservation of architectural heritage while embracing contemporary environmental and design standards.

5. EL SHALLAL POST OFFICE IN ASWAN

The town of El Shallal, located southeast of Aswan, has a rich and historically significant past as a pivotal trade center connecting Egypt and Sudan for millennia. This importance was facilitated by two key elements: the Nile River and the railway system. These intertwined aspects, which facilitated the transportation of goods like henna, cotton, and hibiscus, converged at the El Shallal railway station, marking a critical hub for exchange and cultural interaction.

In the present day, the river has receded, and the trains have ceased operating, but the historic railway station still stands as one of Egypt's oldest of its kind, dating back to the early 20th century, predating the High Dam and Aswan Dam. Egypt Post has been operating from this iconic building for many years, symbolizing the local community's commitment to maintaining its tradition of connectivity and global outreach.

In pursuit of a long-term vision to honor and preserve Egypt's national heritage, Egypt Post and the Ministry of Communication have completed the restoration and revitalization of this architectural treasure in El Shallal. Simultaneously, this endeavor demonstrates their dedication to safeguarding the future through sustainable green development and investment in renewable energy, meeting international standards.

Fig. 14: Local materials were extracted from nearby quarries. (Source: Authors, 2021).

I. The Transformation of the Post Office

The existing structure of the post office and its surroundings presented an opportunity to create a modern and inviting facility for Egypt Post services while honoring its historical significance. Engineering solutions were implemented to minimize environmental and architectural impact while meeting contemporary requirements.

The building's exterior showcases remarkable stonework, with a cleaning program revealing a spectrum of Aswan colors ranging from cream to honey to deep pink. Local carpenters worked in a traditional style to restore the original appearance of the station's external apertures.

The interior had undergone various changes over time, necessitating restoration to align with the early 20th-century exterior. Replacing the suspended ceiling with a design that harmonized with the historical context allowed for the introduction of electromechanical services and necessary access points for maintenance. Traditional wooden bulkheads running the length of the branch were creatively renewed, and vintage patterns inspired the design of overhead vents, which were refined with a contemporary touch. The internal plasterwork was thoughtfully repaired, and a neutral color complements the overall scheme, creating a modern canvas for Egypt Post's branding.

The use of local red Aswan hardstone for the flooring pays homage to the region's premium natural product, usually used for decorative purposes or exported abroad. The project's emphasis on sourcing local materials reduced the environmental impact of long-distance transportation and showcased the expertise of local artisans, who adapted traditional craftsmanship to meet contemporary design needs. For example, the choice of rich green basalt for the service desk countertop, historically found in Pharaonic statuary, exemplifies this approach. Additionally, recycled glass light fixtures, handmade by Egyptian glassworkers, further demonstrate the fusion of traditional skills with environmentally conscious design choices.

II. A Commitment to Excellence and Sustainability

A commitment to both preserving cultural heritage and embracing sustainable development is evident in the El Shallal branch project. It aligns with EDGE (Excellence in Design for Greater Efficiencies) certification, which places rigorous emphasis on eco-friendly systems and green building practices, both in terms of technological integration and material selection.

The project successfully retained nearly century-old building elements, such as external masonry walls and the layering of timber, organic materials, and stone in the roof, integrating these historical elements with green technology for environmentally conscious development. Solar panels on the roof have augmented the building's natural insulation against high desert temperatures, providing clean, renewable energy to power the El Shallal branch, ensuring energy efficiency and reducing reliance on fossil fuels.

This approach not only reduced the carbon footprint but also resulted in aesthetic harmony. The original wooden shading structure around the building was repaired and revived, helping reduce the building's temperature and creating visual harmony with the stonework and the surrounding landscape.

III. A Vision for the Future

The El Shallal branch has been redesigned to offer modern postal and banking services to the local community, with an elegantly appointed environment that subtly references its history as a railway station. The elongated wood and glass interface in the main hall preserves the building's integrity and accommodates the increased number of Egypt Post employees, reducing customer wait times. The introduction of contemporary facilities, including bathrooms featuring Aswan stone tiles, reflects the region's stonemasonry heritage.

Externally, the branch now features serene and attractive reception areas surrounded by green spaces created through gardens. These gardens incorporate arid-adapted plants, highlighting the project's sustainability ethos. The Egypt Post railway branch now stands as a symbol of responsible heritage management, boutique customer service, and wholly sustainable contemporary design, embodying a commitment to the preservation of Egyptian architectural history while addressing future challenges.

Fig. 15: The building during the early 1900s. (Source: courtesy of AK architects).

Fig. 16: The building during restoration. (Source: Authors, 2021).

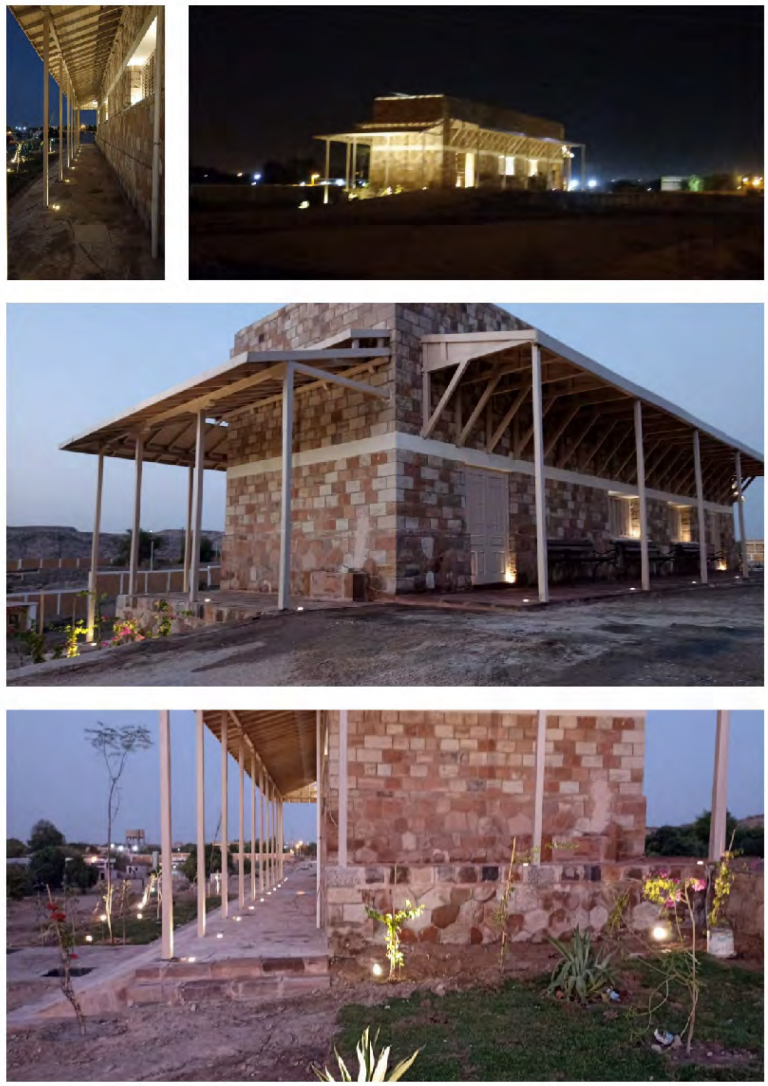

Fig. 17: The building after restoration. (Source: Authors, 2021).

Fig. 18: Solar panels were used on the building's roof. (Source: Authors, 2021).

6. DISCUSSIONS

The three case studies of historical building rehabilitation in Egypt offer valuable insights into contemporary sustainable approaches for the preservation of architectural heritage while accommodating modern needs. These case studies provide a foundation for several pertinent discussion points and lessons in the field of historical building restoration and urban renewal. Notably, they shed light on the delicate equilibrium required to balance tradition and modernity in historical contexts. The successful incorporation of sustainable and green building practices, such as solar energy utilization, natural ventilation, and the utilization of locally sourced materials, underscores the significance of environmentally conscious restoration in the preservation of historical architecture. The pivotal role of community engagement, including support for local artisans and their education, emerges as a fundamental aspect in enhancing the success of restoration projects and the preservation of traditional craftsmanship.

Furthermore, these case studies emphasize the historical and cultural importance of the buildings, prompting discussions about the methods employed in identifying and prioritizing structures with such significance for restoration. As historical buildings are repurposed to meet modern requirements, the question of how to adapt them while conserving their architectural and historical attributes becomes increasingly relevant. The case studies also underscore the existence of multifaceted challenges, including bureaucratic obstacles, conflicting viewpoints, and profit-oriented motives. These challenges stimulate dialogue regarding strategies to surmount them.

Investing in the training and education of local artisans emerges as a pivotal factor in the successful execution of these restoration projects. This engenders discussions concerning the vital role of education and skill development in the preservation of traditional craftsmanship. The persistent tension between preserving cultural identity and incorporating contemporary design elements is a recurrent theme, eliciting debates on the methods restoration projects employ to reconcile modernization with the conservation of cultural identity. A long-term vision for preservation and sustainability is a defining characteristic of these projects, emphasizing the importance of foresight in the context of historical buildings and the communities they serve.

The studied projects have presented several challenges and demonstrated a strong commitment to sustainability while embracing local artisans. One of the prominent features of these projects is the emphasis on handmade craftsmanship, particularly in areas like carpentry, marblework, and stonemasonry. This approach not only preserves traditional artisanal skills but also adds a unique, authentic character to the renovated spaces. Moreover, these projects have aimed to achieve a green building certificate (EDGE), with sustainability principles integrated into the design from the conceptual stage. This commitment to environmental considerations signifies a significant step towards a more sustainable future for these structures[10].

However, it's essential to recognize the substantial challenges these projects faced due to their private nature and the need for rapid completion. The urgency was driven by the client's desire to open the sites quickly to minimize financial losses, highlighting the delicate balance between economic considerations and sustainable redevelopment efforts.

Additionally, one noteworthy achievement in the projects is the transformation of the user Attaba Post Office, which involved extensive electromechanical coordination, substantial structural restoration, and intricate site logistics. This multifaceted approach showcases the comprehensive nature of adaptive reuse projects, reflecting the dedication to preserving historical structures while making them functional and sustainable for the modern era.

While the case studies are geographically specific to Egypt, the principles and strategies employed within them offer universal lessons and inspiration for analogous restoration projects worldwide. The economic value of restoration, as alluded to in the paper, merits discussion concerning the economic benefits of historical preservation and its impact on local economies. Moreover, these projects contribute to heritage tourism by safeguarding historical sites, which invites discourse on the role of heritage tourism in advancing cultural preservation and local economies.

7. CONCLUSIONS

The sustainable rehabilitation of historic buildings and their surrounding communities, as exemplified by our projects in Egypt, presents a compelling model for the preservation of heritage in an ever-evolving world. As our societies progress through the advancements of science and technology, it is imperative to adapt and embrace the dynamism in traditions. This adaptation not only safeguards our heritage, identity, and culture but also brings significant economic value. The challenges we face today, including overpopulation, urbanization, climate change, and financial crises, demand innovative solutions that go beyond traditional restoration methods.

The four-pronged methodology we employed in the restoration of the main post office building in Cairo, the historical palace in Aswan, and the El-Shalal train station is a blueprint for future urban renewal endeavors. By following international restoration standards, rejuvenating social architecture, integrating sustainability, and investing in local communities, we have demonstrated that it is possible to breathe new life into historical landmarks while preserving their historical significance.

Yet, it is crucial to acknowledge the technical and human challenges that such projects may entail. Adapting old structures to modern needs, navigating bureaucratic constraints, and preserving cultural identity are complex tasks. However, the results of these renovation projects, which align with contemporary architectural standards, are more than just restored buildings; they are enduring landmarks that serve as beacons of the harmonious coexistence of history, culture, and modernity. These projects offer valuable lessons and inspire hope for the preservation and revitalization of historical treasures, ensuring they continue to enrich the lives of communities for generations to come.

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MAINTAINING CULTURAL HERITAGE THROUGH ADAPTIVE REUSE: THE CASE OF AL-MUGHESLA IN AL-MADINAH AL-MUNAWARAH

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MAINTAINING CULTURAL HERITAGE THROUGH ADAPTIVE REUSE: THE CASE OF AL-MUGHESLA IN AL-MADINAH AL-MUNAWARAH COMMUNITIES

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This study focuses on one of the remaining historical buildings in al-Madinah al-Munawarah – the Prophet city – in Saudi Arabia; it is known as Qalʻat al-Mughesla (al-Mughesla Fort), which was built about 107 years ago outside the ancient city walls. Fifty years later, the function of Qalʻat al-Mughesla was changed, and it was used as a residence by one of the local families. Nowadays, the building is distinguished by its location, the center of al-Mughesla neighborhood, as well as its type. The neighborhood is located nine kilometers away from the mosque (Masjid) of Prophet Mohammed (al-Masjid al-Nabawi). It has a rich historical background as it was inhabited by the maternal uncles of the Prophet (peace be upon him). This historical dimension will be explored, starting from the building's main function to the proposals to make more use of the space. More importantly, the study analyses the building's layout and construction, including its materials and its main functions. It highlights the evolving chronology of the usage of the building, aiming to understand the historical layers that lead to the potential for new uses. Furthermore, this investigation exemplifies several significant lessons for the current generation, such as maintaining the site's architectural heritage; and valuing and appreciating its local culture. The study does not only aim to examine the repurposing of an existing structure for new uses or economic purposes; its objective is also to provide a new way of observing the local neighborhood and bringing it to sustainability through the adaptive reuse of the remaining buildings. Primarily, this research examines the reinvention of historical buildings and the preservation of the original architecture to maintain their unique heritage.

1. INTRODUCTION

Located 400 kilometers from the holy city of Makkah, al-Madinah al-Munawara is the second holy city for Muslims; it is in the Hijaz region, along the Red Sea coast, in the western part of the Kingdom of Saudi Arabia. The city is bounded on the east by an extensive lava field, which increases soil fertility in the area (Fig. 1–2). On the other three sides, the city is enclosed by arid hills; of which the most well-known is Uhud mountain[1]. Amazingly, Anas ibn Malik relates that the Messenger of Allah (may Allah bless him and grant him peace), saw Uhud and said, "This is a mountain which loves us, and we love it. O Allah! Ibrahim made Makka Haram, and I will make what is between the two tracts of black stones (in Madina) a Haram."[2]. He used the precise scientific term "بَيْنَ لاَبَتَيْهَا" which means volcanic lapilli and used the term ḥarrāt in another hadith. In a recent study of Madinah, it is claimed that al-Madinah is located between two ḥarrāt[3] (lava fields), or two lapilli, called the Eastern Ḥarra and the Western Ḥarra. The Eastern Ḥarra stretch extends about 300 kilometers north of Jeddah, while the Western Ḥarra is small in size and does not exceed the limits of Medina. Geological and geophysical studies have shown that Ḥarrat Rahaṭ (حرّة رهط) which is on the eastern side, includes geothermal reservoirs at a depth of up to 3 kilometers (Fig. 2–3). These geothermal reservoirs can be used as a pure and environmentally friendly source of electricity generation, refrigeration, and heating[4]. The Saudi Geological Survey[5] (SGS) argues that most of the Kingdom's ḥarrāt are a result of volcanic activity that occurs just once in a certain period in a particular place, and then, the eruptions cease and do not recur.

Ḥarrat Rahaṭ erupted in Madinah in 654 AH (1256 AD) and formed several scoria volcanoes, accompanied by a basaltic lava flow within 12 kilometers of the city. Most of the volcanic ḥarrāt were formed during the first phase of volcanism, which coincided with the rifting of the Red Sea in western Saudi. The recent volcanic ḥarrāt that were formed during the second phase of volcanism in the area, extending from the north of Makkah to the south of Madinah. This area hosts historical volcanoes that were formed in the last 6,000 years and were concentrated in the northern part of Ḥarrat Rahaṭ (Fig. 3). This volcanic ḥarra is mostly composed of sequences of basaltic lava flows, compacted on top of one another, forming the distinctive shape of the ḥarra[6]. This geological fact identifies the building materials in the area, which will be reflected in the analysis of the case study.

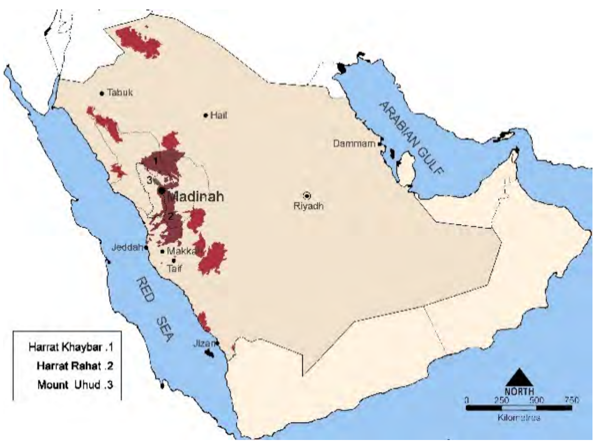


Figure 1: Al-Madinah's location between the two biggest lava fields in Saudi Arabia (Ḥarrat Rahaṭ and Ḥarrat Khaybar.

Figure 2: A satellite image of al-Madinah with the basaltic flows in the black areas and Uhud Mountain. https://eoimages.gsfc.nasa.gov/images/imagerecords/144000/144471/medina_tm5_1984174_lrg.jpg

Figure 3: Ḥarrat Rahaṭ near al-Madinah al-Munawarah. Historical Volcanism (sgs.org.sa)[7]

Figure 4: Al-Mughesla neighborhood's current location with al-Masjid al-Nabawi and other features.

Al-Madinah as a region has two of the biggest ḥarrāt in Saudi Arabia: Ḥarrat Khaybar and Ḥarrat Rahaṭ (Fig. 1). The most famous geographical features in the ḥarra zone include Ḥarrat Rahat, Ḥarrat Wāqim (Eastern Ḥarra), Ḥarrat al-Wabara (Western Ḥarra), Ḥarrat Shoran (south of Medina), and Ḥarrat Khyber. Whereas Uhud mountain is one of the famous mountains, Wadi Khaybar and Wadi Aqeeq are among the most well-known valleys in the region. Accordingly, this is where al-Madinah al-Munawarah is located: the first nucleus of Islamic civilization "مدنية". This city is characterized by a geographical and topographic location of high strategic importance in the Arabian Peninsula, with a diverse nature environmentally, historically, and culturally[8]. Geographically, al-Madinah is surrounded by lava fields and highlands (mountains and hills) and contains some green valleys. It is located in the hot desert range (very cold, and dry in summer and winter), and it has low rainfall[9]. Historically, the city of al-Madinah existed for over 1,500 years before the Hijra (622 CE), and it was known at that time by the name "Yathrib". In 622 CE (1st Hijra), Prophet Mohamed immigrated from Makkah to "Yathrib", where he established the first Islamic state. The Prophet changed the name of the city to "Taibah" and then to "al-Madinah" which means "the city". Al-Madinah was the first capital city for Muslims; it includes al-Masjid al-Nabawi and most of his heritage. Al-Madinah has a high religious status, and it contains important historical Islamic sites such as the house of Prophet Muhammad (peace be upon him), his masjid with the holy pulpit, and the Rawda. The Rawda is a rectangular area that is located between the house and the pulpit and is believed to be part of paradise on earth (Ministry of Hajj and Umrah). Farther away from al-Masjid al-Nabawi, there are many historical sites including small masjids and tombs of the Prophet's companions. Al-Mughesla is one of the old sites since it was inhabited by Banu Dinār who are the maternal uncles of the Prophet (peace be upon him). In addition to this significant historical background, al-Mughesla the neighborhood is home to seventy historical sites that vary in type and date of construction[10]. The chosen historical building is one of the iconic remaining sites. Al-Mughesla is not a memorial, it is a layer of history and part of the Islamic period of the Prophet city. Thus, what is al-Mughesla as a historical building, and why consider options for adaptive reuse now?

Historic buildings are generally legally protected from demolition, whereas adaptive reuse provides redundant buildings with a new purpose and function; while maintaining parts of their original features. Although adaptive reuse retains buildings' heritage and pays homage to their history, it serves as a reminder of a city or town's culture and past[11]. Jackie Craven claims that adaptive reuse is a way to save a neglected building and benefit the environment by conserving natural resources and minimizing the need for new materials. Although the cost of rehabilitation and restoration is more than demolition and building something new, adaptive reuse has become more than a preservation movement. It has become a way to save memories and a way to save the planet[12]. In this regard, Alice Chen argues that adaptive reuse is beneficial to the building and the city in general. Saving history collectively on a city scale is beneficial in terms of preserving intangible values, especially from an ideological and cultural perspective[13]. She adds that historic buildings are unique to a specific time frame in the life of a city; these buildings' architectural features served a purpose that only occurred at that time. The redevelopment process ought to respect the uniqueness of history and operate in harmony as cities evolve. She concludes that "Adaptive reuse is more than preserving a past but creating a future for the past, adding layers to show the city's process of evolvement. The architectural redesign is a delicate art of balance, between creating a future and not overwhelming the past, between celebrating the history and leaving room for breathing"[14]. Overall, adaptive reuse is the practice of repurposing an existing structure for new uses other than the original. This practice is best understood as a way to reinvent historic buildings and preserve their original architecture. Adaptive reuse can also reduce costs and improve environmental sustainability, maintaining the historic preservation of buildings that would not be built today. More importantly, it is essential to undertake an adaptive reuse project which will be supported by the community[15]. Apart from the benefits of reuse concerning sustainability and economic issues or maintaining income, the point of adaptive reuse and community support is vital.

2. AL-MUGHESLA NEIGHBORHOOD

Al-Mughesla neighborhood is currently located 900 meters southwest of al-Masjid al-Nabawi. Although it is now located in the central area, previously it was outside the city walls and far from full protection. The gate of Quba' which used to be on the outer gate of the old Madinah illustrates the location of al-Mughesla, which is outside al-Madinah al-Munawarah (Fig. 4). The enlargement of the Prophet Masjid area means that the current location of al-Mughesla is in the center of the city. It is bordered to the east by Jādat Quba' (جادة قباء) and to the north and northwest by the al-ᶜAnbaria (العنبرية) area and the Hijaz railway station, and to the south Ḥarrat al-Wabara (حرة الوبرة) (Fig. 5). The area was well-known for its farms and each farm had a name, some bearing the named of the owners. One of the farms was called al-Maghsala which was the name of the neighborhood for many years[16]. The neighborhood has also a significant historical background because it was inhabited by Banu Dinār from Banu al-Najjār, the maternal uncles of the Prophet (peace be upon him). It is known as the "Bani Dinār neighborhood", named after one of the clans of the Bani Najjār tribe with high honor and high standing among the tribes of al-Khazraj (Ibn Kathīr 710 AH)[17]. However, it is claimed that they first settled at Dār Abi alJaham which is to the west of al-Masjid al-Nabawi, then they moved to al-Maghsala or alGhasaleen area, which is currently known as al-Mughesla[18]. The earliest historical scholars also identified where Banu Dinār had settled exactly to the Prophet Masjid (Al Samahudi 911 AH)[19].

3. QAL^C^AT AL-MUGHESLA

3.1. Analysis of the Site

In an aerial image of the site taken in 1965 where the building is located, it appears that other architectural elements have been removed (Fig. 6). Previously, the building was among several other facilities:

1. A well is located outside the building on the southwest side, facing the building's water entrance at 20m approximately.
2. The external waterway is a stream that connects the well and the water entry hole in the building's wall.
3. A fence surrounds the building and its annexes, which is irregular in shape, and there is a reminder of this wall in the actual part.
4. A Patio is located to the west of the building and the western door opens onto it.
5. A pond is located directly northwest of the building and collects water from the sewer.
6. The outer door: The aerial photograph shows a gap on the eastern side of the wall overlooking the road, which suggests that this space is the outer door.
7. Remnants of a wall: in the northeastern part, the rest of a wall appears, which may be the corridor between the outer door and the building.
8. A garden is located to the north of the building and is fed by a pond.

Al-Mughesla is located entirely outside the city walls and far from the full protection area provided by the barracks and the tower, which makes the building – if it was a military one – an easy target for those who might want to attack it. The building is located approximately 80m from the military barracks; one of the largest militaries at that time was heavily armed and had many soldiers. There is a military tower 50 meters away, on the outer city wall for protection. Therefore, there is no justification for having a building with the same function nearby[20]. Currently, the Hijaz railway station, a well-visited tourist attraction, is opposite the al-Mughesla building, and Jādat Quba' is on the eastern side of the site (Fig. 5).

Figure 5: Qalᶜat al-Mughesla current location in relation to al-Masjid al-Nabawi. Edited map from: https://www.google.com/maps/@24.4628691,39.6081906,940m/data=!3m1!1e3

Figure 6: The old ariel image of the building's site (MDA 2020).

3.2. The Building's Background

The building was inhabited by Bait Al-Daqaq, one of the Madinah families, in the 1970s. During this period, there were some changes in the building which are visible as recent additions. It is represented in mosaic tiles, cement bricks, cement floors, cement plaster, and colored paint for interior walls, iron doors, blocking the water flow, additional walls on the roof, and some other changes[21]. As with the neighborhood of al-Mughesla and the historical studies and arguments regarding its exact location and who settled there, the building's ownership history is trapped in the same debates. Currently, Qalᶜat al-Mughesla, is located in the south between both the city Principality and the city Municipality, approximately 100m from both buildings (Fig. 5). It is a square-shaped building with an approximately area of 225 square meters (Fig. 6,7,10). There is no information on the date of construction or who built it or what its exact function was. However, its age can be estimated through some architectural elements and some aspects that give useful indications in this regard. The presence of shooting holes in the roof wall of the building (Fig. 11), indicates that the building may date back to periods of political turmoil and insecurity before the Saudi dynasty. Consequently, the building is more than 99 years old at least. Based upon the discovery of the waterway, pottery pieces (remains of jars) were found inside them, which date back to the Ottoman era. Though their presence in al-Madinah ended in 1334 AH (م1915), this gives an indication that the building exceeds the age of its construction 107 years ago; for example, there are shooting slots with guns and the presence of a small store on the ground floor next to the watercourse. This store was a warehouse for ammunition, whereas the water in the stream worked to moisten and cool the place so that the temperature of the stored ammunition did not rise to the point of detonation. This type of military feature is similar to the Ottoman military fortress in Madinah[22]. All these signs may suggest the possibility of a defensive function, leading to the hypothesis that this building was established for a military or security purpose, which could be the reason for calling it "Qalᶜat al-Mughesla".

Some scholars claim that the building may be classified as a private house, and the small holes are for protection and security rather than for military use. This idea may justify the location of these openings in the southeastern corner only, which means that the protection was intended to be from one side that overlooks the road passing next to it. The door in the wall and the southern openings facing the well indicate security concerns. Other indications may support this claim based on the fact that the building is located near the military base and has a small area to accommodate many soldiers[23]. Although the building is not similar to most of the old city houses of Madinah, there are some architectural features indicating that it might be a private house (Fig. 9). Some of the layouts of the spaces including the location of the storeroom in relation to the other chambers are similar, besides the waterway system. The mechanism of this system involves opening a channel of a well inside the house to reach a small basin where water is collected for easy intake and use; another function is to reduce the heat of the place and to cool the air. Interestingly, a unique architectural element is present above the main entrance: the carving of a quadrilateral or five-petaled flower (Fig. 8). This element is found in most urban houses. Some scholars rely on these facts as indications that this house was built as a private house and not as a military building and that the shooting holes were for security[24].

Figure 7: The northern façade and the main entrance (the authors)

Figure 8: The entrance flower's detail.

Figure 9: The interior of the room on the right of the building.

Figure 10: The side entrance in the western façade.

Figure 11a: The roof walls with openings for gun shooting.

Figure 11b: Details of the slots.

3.3. The Building's Layout

The ground floor (Fig. 12) consists of the main door located on the northern side, which is accessed by a side staircase from two sides, and opens onto a hallway (vestibule/locally *Dehleez*). There are rooms on both sides; however, facing the main entrance there is a door leading to two side halls. Following the western hall, a vestibule that ends with the other door of the building, opens out on the western side, ending with two rooms. The eastern hall opens to the kitchen, which contains an arched stove with an upper stone chimney that opens onto the roof of the building. However, in the middle of the building, there is an inner courtyard that ventilates the house through an upper opening in each wall. This opening resembles a shaft (called locally *Jila*) found in old houses in Madinah (see Fig 12, 14a). But it is here locked and does not open onto any of the internal elements, as there is only one door to enter this yard. It is noted that the ground floor has two levels because there is a small store next to the western door (Fig. 13). In addition, the ceiling level of this floor reaches the upper floor, which has only one room. There are also some other architectural elements, such as the apse (*hanya*) and the toilet/bathroom, which are characterized by the presence of remnants of the sewage system. Specifically, there are pottery tubes connected (to each other) and buried in the bathroom wall, and still, have functioning sewage. The water stream was detected on the ground floor, which links the building from south to north. It is built with basalt stone lined with a layer of lime and begins with an opening for water to enter through the southern corner wall. It ends with the water exit hole in the northwest corner wall[25].

The first floor (annex) consists of one room to the right of the one that is ascendant to the stairs with a small store in one of the room's walls which is adjacent to the stairs (Fig. 13). Facing this room is a bathroom on the other side of the building. The roof of the building consists of two parts: the first section is surrounded by a low wall, 50 cm high; and the other is surrounded by a wall that is about 180 cm high. This section ends with the staircase and the shaft opening, with two walls separating both sections (Fig. 14a, b). On the edges of the roof walls, the ducts of the tubes are connected to the bathrooms, and for drainage open sanitary, with the ventilation opening connected to the stove in the kitchen, and the rainwater drainage holes. The corners of the southern and eastern walls of the roof have openings for shooting guns. There are eight openings, four on each wall[26]. The unique layout of the building may help to identify the reuse function unless the owner suggests a specific one. The neighborhood is another dimension that ought to be considered as an environmental issue relevant to a potential new function.

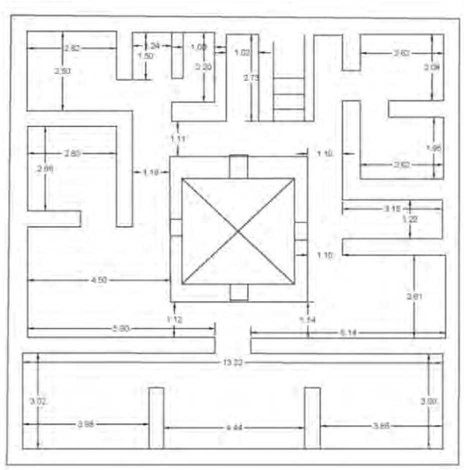
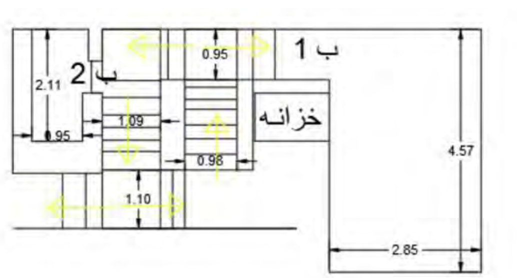


Figure 12: Plan of the ground floor.



Store (خزانة): D. 90, W. 140, H. 113 cm.

Figure 13: Plan of the first floor.

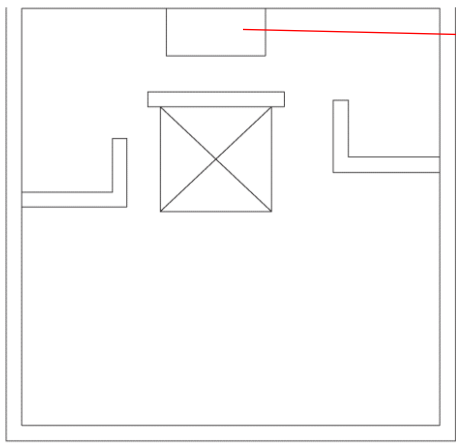


Figure 14a: Plan of the roof.

Figure 14b: Part of the roof construction and the stairs.

3.4. The Building's Materials

The materials used in the construction of the building are all local, chiefly basalt (volcanic stone). Cutting the volcanic stones was expensive, which may reflect the financial status of the original owners of the building (Fig. 14b–17). The stones were cut and prepared professionally and were put together using mud (Fig. 15, 17). Part of the roof wall and part of the windows are built with mud bricks (Fig. 16). The window arches and the roof walls were built with bricks, whereas plaster was used to paint the whole fort (Fig. 17). Tamarisk (salt cedar) is a kind of Athel tree, which is known by its strong and tall trunk, which makes it suitable to be used as beams and for the ceiling (Fig. 18). Such trees are planted around the farms of al-Madinah and in the forest area which is called al-Khilel. The palm tree is very common in al-Madinah and is famously known for it. The palm tree leaves and stems were used for the ceiling construction (Fig. 19). The leaves were interwoven like a mat and then covered by the leaf stem. Then a small layer of soft sand was added on top, forming a floor and a roof for the lower room[27].

Figure 15: Local materials used in the construction of the walls and the ceiling.

Figure 16: Mud bricks and mud in between the bricks

Figure 17: Plaster on the walls.

Figure 18: Tamarisk used to support the ceiling.

Figure 19: Palm tree leaves in the ceiling construction.

4. ADAPTIVE REUSE OF THE BUILDING

Based on Alice Chen's (2018) study's experience and research findings on the why and how of historic adaptive reuse, some issues and considerations could apply to the current case study. First, what is al-Mughesla building's historic value in terms of demonstrating its history, or an era of the city? Moreover, what is the potential value of historic buildings to the owner, developer, consumer, and residents of the district as a whole? The answers to these questions may enlighten the path to choosing the best adaptive function to serve the neighborhood most appropriately. However, the current study suggests some functions based on the historical values of the storytelling and the narrative of the buildings and their unique architectural features. Being in al-Madinah al-Munawarah as a location is a privilege in itself. The building could be a historical setting, enabling the current generation to learn, enjoy, and value this period of the history of the city of the Prophet Muhammad (peace be upon him). The story starts from here, as the Prophet City, whereas the layered historical stories embodied in the building are unique in time and place. Apposite here are the general observations of Chen, who claims that "the building may be fixed at one point, but the story carries on by future users. The dramatic expressive architecture and space make people feel important as part of a historic story"[28]. Secondly, what is to be achieved in the process of adaptive reuse, given that it is not to preserve only? It is rather to balance preservation and innovation through the adaptive function. The preservation could be achieved through the experience of the current architectural elements and the building's layout, offering an opportunity to observe, enjoy, learn, and simply bring history back to life. The re-creation process to bring the essence of the building's history back to life ought to consider its history and take the future into account. Regarding the existing building, it is important to examine its condition and consider its architectural values, including the adaptivity of the typology, interaction with the historic fashion, and the approach to contrast, or present the evolution. Simply, the objective should be to find the right fit for all previous aspects to the current industry, market conditions, and future asset trends[29].

Another study illustrates the impact of adaptive reuse on the neighborhood and notices that the final transformation of the project reflects the historical significance through preserving the bygone traditions, stories, wisdom, and local skills of the community[30]. One of the historical residential buildings (built in the 1910s) became a public art exhibition by providing a public open space within a tight urban site. The archaic building's architecture is reused for innovative art and creative industries. “Art Community” is the central concept of this project, which allows diversified and innovative reuse of the site. The study stresses that the project embraces adaptive reuse with respect to the historic architectural fabric and aims high: the objective is to undertake the best practice principles in conservation for the adaptive reuse of heritage buildings. It reinstates the nostalgic scenery and creates an avant-garde architecture that integrates the traditional urban lives and original building materials with modern technology and performances. The project becomes a creative hub that energizes new businesses and new creativity in the old district. It also consolidates the sense of place by engaging local shop owners, artists, and public prices. The findings of the study demonstrate that a more significant positive economic impact on adjacent properties can be observed from heritage conservation sites. It also illustrates how active stakeholder engagement such as discussions in focus groups can help formulate the master plan for adaptive reuse, where innovations are integrated into the welfare of the community. Overall, residents and other community members can benefit from a range of social events and the district’s sense of place has been enhanced as a result[31].

The last study highlights excellent examples of several historical buildings that are more than 90 years old in India. In these cases, the adaptive reuse aimed to benefit the environment and the economy but mainly to preserve the cultural aspects of the buildings[32]. The case studies examined buildings that were used as museums with spaces dedicated to art studios, exhibitions, and displays. Museums were regularly used to host various arts and crafts exhibitions, providing a livelihood for indigenous craftsmen. Others were transformed into boutique hotels and restaurants. Interestingly, the small colonial bungalow in Banglore became a boutique store with its vintage charm and unusual aesthetics. The Cinnamon Boutique was used as an orphanage for some time, and now its reconstruction and renovation have been undertaken with great care to form a marriage between the vintage and the modern. The restoration of the building was dealing with the foundational structural elements, the connected shell elements of the walls, and structural elements such as the roof[33]. This case study may suit the current building in Madinah or may assist in its potential adaptive reuse. Moreover, lessons could be learned from other parts of the world to enrich the neighborhood of al-Mughesla and not just the building. This involves starting from the process of suggesting ideas for the adaptive reuse of the building and the site in general through to the practical lessons of the renovation strategies. The experience could be discussed through the eyes of scholars, professionals, policymakers, and more importantly the neighborhood residents, which is the golden key to the whole process which may benefit the current study immensely.

5. CONCLUSION

This study not only adds to the knowledge of the adaptive reuse of historical buildings but also allows policymakers, planners, and architects to have a better understanding of how to assess the values of heritage preservation holistically. The results of the analysis offer new insights into discourses on the implications of preserving architectural heritage. This research provides lessons and practical evidence on the impact of adaptive reuse on the built environment and its sustainability. More importantly, it is observed that the potential of al-Mughesla is in its historical heritage, which could be a profound element to work through. The documentation of the historical layers could be a story to tell via the renovation of the interior spaces. Al-Mughesla, with its 225 square meters, could not be merely a museum, but a place to host culture and art with a focus on the building's historical documentation. The last two case studies which transform the building into a hub for culture and art including an exhibition space or a concept store might form an ideal proposal. However, the old site surrounding the building could be rediscovered and could be mimicked to bring life to this historical site. That is to bring back the old site including the garden and the pond, aiming at least to tell the story of the site with the previous features that link the building to the architectural history of this period. Being in this location surrounded by lava fields itself is a story to be told, where the building materials ought to be celebrated and acknowledged. The location which is now near the old train station (Hijaz railway station) is another factor that may work alongside the site as a tourist attraction. The major conclusion of this study focuses on the historical background of the building in all aspects: the layout, the materials, the location, and the site within al-Mughesla as a neighborhood concerning al-Masjid al-Nabawi. The privilege of the Bani Dinār settlement is another aspect that broadens the horizon of the site's significance, and the building is in the right place to embrace this story. Al-Mughesla site requires more in-depth analysis to link the Prophet's visits to the neighborhood. The building has also the potential for further study to be undertaken, historically and architecturally.

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DIGITAL FRAMEWORK OF RENOVATION OF TRADITIONAL BUILDINGS IN SAUDI ARABIA

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DIGITAL FRAMEWORK OF RENOVATION OF TRADITIONAL BUILDINGS IN SAUDI ARABIA

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Renovating traditional buildings in Saudi Arabia is crucial for preserving cultural heritage, protecting the environment, promoting tourism, developing educational and research opportunities, and benefiting communities. With the government and private organizations prioritizing the preservation of historic architecture under Saudi Vision 2030, initiatives like the housing program and Saudi Green Initiative encourage sustainable construction practices using technology. To support this, a digital framework for renovation has been devised, incorporating various digital technologies to safeguard Saudi Arabia's heritage buildings.

This paper proposes a digital architectural approach called "scan, predict, build" to renovate partially demolished traditional buildings in Saudi Arabia. The framework begins with 3D scanning techniques, particularly using LIDAR remote sensing, to create detailed 3D models and maps of architectural features and environments. LIDAR scanners employ a powerful laser and rotating mirror to scan large areas, capturing thousands of dots per second. High-capacity computers are required to handle the extensive data produced. The framework also employs machine learning algorithms to predict lost or damaged architectural elements. By training the algorithm with labelled data and extracted features, supervised learning techniques enable pattern recognition for missing or destroyed elements. Once trained and validated, the algorithm can identify which architectural elements are absent or damaged in traditional buildings. To ensure exceptional quality, the framework proposes the use of a 3D printer, specifically the robot arm technique, known for its precision and control in six axes. This technique surpasses others in flexibility and accuracy.

In conclusion, this paper presents a digital architectural framework, "scan, predict, build," for renovating partially demolished traditional Saudi Arabian buildings. Its outcomes extend beyond specific structures, contributing to cultural heritage preservation, environmental protection, tourism promotion, educational and research opportunities, and community welfare. Moreover, the rapid development of 3D scanning technology holds immense potential to revolutionize the construction industry by enhancing efficiency, safety, and quality control throughout the construction process.

1. INTRODUCTION

Saudi Arabia, a nation rich in history and cultural significance, is home to numerous traditional buildings that resonate with tales of bygone eras and ancient civilizations. These architectural marvels, a blend of unique designs and centuries-old construction techniques, serve as living testaments to the kingdom's rich cultural tapestry. However, the passage of time, coupled with urban development, has cast a shadow on these structures, leading to their decay and, in many cases, partial demolition. The urgency to renovate and preserve these historic edifices is not merely an architectural endeavor but a profound commitment to ensuring that the narratives of the past remain intact and continue to inspire future generations.

In the wake of the 21st century, the global community has witnessed an exponential growth in technology, presenting opportunities previously deemed inconceivable. The field of architecture and building renovation is no exception. Modern technological advancements hold the promise to revive these decaying structures, merging the ancient with the contemporary, while ensuring preservation of their original essence. Recognizing the potential of this synergy, the Saudi government, under the visionary Saudi Vision 2030, has underscored the importance of preserving the nation's historic architecture. This emphasis is not merely an aesthetic or cultural pursuit but is intertwined with multifaceted objectives such as environmental conservation, tourism augmentation, and fostering educational and research avenues.

The need for innovative, technology-driven renovation methodologies becomes even more pressing when one considers the dual challenge of restoring traditional Saudi Arabian buildings while ensuring their alignment with modern-day requirements and sustainability norms. It is in this context that the present paper introduces a groundbreaking digital architectural approach, termed "scan, predict, build." This method, rooted in state-of-the-art technologies, promises a comprehensive solution to the challenges of renovating partially demolished or deteriorated traditional edifices in Saudi Arabia.

This paper's foundation lies in the conviction that technology, when employed judiciously, can not only restore the physical aspects of traditional structures but can also breathe life into their cultural, historical, and societal significance. The "scan, predict, build" framework leverages the precision of 3D scanning techniques, the predictive prowess of machine learning algorithms, and the meticulousness of advanced 3D printing processes. Each step, from the initial scanning to the final construction, is intricately designed to ensure that the renovated structures resonate with their original charm while meeting contemporary standards of safety, functionality, and sustainability.

In delving deeper into this approach, we aim to illuminate how a harmonious blend of traditional architecture and modern technology can lead to outcomes that are far-reaching, influencing not just the realm of construction and renovation, but also shaping societal perceptions, fostering a sense of national pride, and catalyzing economic and educational growth. As we navigate through the intricacies of this digital architectural framework, it becomes evident that the future of traditional Saudi Arabian buildings is not one of decay and oblivion, but of revival, resilience, and enduring significance.

In historical building conservation, ethics emphasize necessary interventions and advocate for minimal effective actions. According to Feilden, explore seven degrees of intervention, based on the building's condition and future environment, include: 1) Prevention of deterioration, 2) Preservation, 3) Consolidation, 4) Restoration, 5) Rehabilitation, 6) Reproduction, and 7) Reconstruction1. These interventions may occur together in large projects. Restoration, reproduction, and reconstruction involve replacing or recreating missing or damaged elements. Virtual reproduction is commonly used in restoration tasks. Nevertheless, there are two obstacles that hinder the reproduction process: a) Stone and masonry structures are common in historical buildings and cultural heritage sites. These structures often feature intricate engravings, sometimes on complex curved surfaces 2,3, b) Drawings and other forms of documentation such as images are frequently absent or insufficient, making it nearly impossible to restore or reconstruct structures to their original state 4, c) Not only images, but also there is a lack of 3d dataset of heritage building.

The manual reproduction or reconstruction of these architectural components presents a significant challenge. Particularly, regions like China face a dwindling pool of skilled artisans possessing the necessary expertise for such endeavours. Additionally, the production of templates required to facilitate these construction activities comes with a substantial cost. Moreover, human production may introduce errors more likely than automated methods. Consequently, there is a mounting drive to promote the adoption of innovative, adaptable, and automated restoration methodologies within the field of architectural conservation. However, the progression and evolution of digital technologies offer solutions to these challenges.

The potential impact of employing this digital framework is to automate the task, thereby accelerating the preservation of cultural heritage while reducing the occurrence of errors.

The aim of this paper is to propose a framework for renovating a partially demolished traditional building in Saudi Arabia using a digital architectural approach. The framework of this approach starts with using 3D scanning techniques, a remote sensing method called LIDAR, to create 3D models and maps of architectural details and environments of a traditional building. The LIDAR scanner uses a high-powered laser that moves horizontally and a mirror that rotates around a vertical axis, covering a large area by scanning thousands of dots per second. A high-end computer capable of storing and handling large amounts of data is also necessary for laser scanning.

Next, the framework will utilize a machine learning algorithm to predict the architectural elements that have been lost or destroyed in traditional buildings. By using labelled data and extracted features, supervised learning techniques can be used to train the machine learning algorithm, identifying patterns in data that correspond to lost or destroyed architectural elements. Once the algorithm has been trained and validated, it can predict which architectural elements of traditional buildings have been lost or destroyed.

Finally, to ensure the highest quality, the elements will be constructed using a 3D printer. While there is more than one technique for 3D printing, this research uses the robot arm technique for this project. This method offers greater flexibility as the robot arm can work in six axes, allowing for greater precision and control than other techniques.

2. MUD TRADITIONAL BUILDINGS IN SAUDI ARABIA

Traditional mud architecture in Saudi Arabia boasts a deep-rooted history shaped by the region's climate, culture, and available resources. These structures represent an indispensable facet of the nation's architectural heritage, evolving across centuries to align with the unique needs of local communities. With origins spanning millennia, Saudi Arabian mud buildings stand as a tribute to the ingenuity of its inhabitants [5]. Serving various purposes, including residential, agricultural, and religious, these edifices rely on adobe as their core construction material—a blend of sun-dried bricks crafted from mud, clay, straw, and occasionally, other organic elements. Abundant and easily sourced, these materials thrive in the arid landscapes of Saudi Arabia [6].

Fig. 1: https://www.joaoleitao.com/mud-brick-villages-saudi-arabia/

In the harsh desert climate of Saudi Arabia, mud structures prove exceptionally well-suited [7]. They serve as natural insulators, effectively maintaining cooler indoor temperatures amidst scorching heat and ensuring warmth during chilly nights. Furthermore, the substantial mud walls offer valuable defence against sandstorms, enhancing their resilience in such challenging environments. Mud buildings in Saudi Arabia exhibit various architectural styles influenced by the region's diverse cultures and historical periods. These styles include Najdi mud architecture, Asir mud architecture, and traditional Hadhrami architecture, among others 5. Prominent examples of such buildings include Al-Ula Heritage Village, known as Ad-Derrah, situated in the northern region of Saudi Arabia's Al-Ula city. In Al-Ghat, the exquisite Amara Palace graces the old village of Ghat. Further south in Najd, the well-preserved ancient mud-brick village of Old Ushaiger stands proudly, a mere 200 km north of Riyadh. To the north of Riyadh, a small yet historically significant village, Uthaythiyah, quietly resides. Meanwhile, Tharmada ranks among the notable mud-brick villages in Saudi Arabia. Lastly, Ad-Diriyah Historical Village, established in the 15th century, holds historical significance as the birthplace of the first Saudi State in 1745 (See Fig. 1).

Mud construction is considered environmentally friendly as it utilizes local, renewable materials. The process of making adobe bricks involves minimal energy consumption, and the buildings themselves are biodegradable, causing minimal environmental impact [8].

Intricate decorative elements, including geometric patterns, carvings, and ornate doors and windows, are commonly found in traditional mud buildings. These embellishments not only highlight the exceptional craftsmanship but also convey the cultural identity of the communities. Mud constructions hold a significant place in Saudi Arabia's cultural heritage, serving as tangible relics of historical lifestyles and architectural prowess. They often symbolize cultural identity and enduring traditions. Despite their numerous merits, mud buildings encounter challenges such as susceptibility to heavy rainfall, erosion, and the necessity for ongoing maintenance [9].

The rise of modernization and urbanization has contributed to the waning use of traditional mud construction methods. However, there are ongoing endeavours to safeguard and rejuvenate these historic structures, aligning with Saudi Arabia's commitment to conserving its cultural heritage. Furthermore, forward-thinking architects are actively exploring the fusion of age-old mud construction techniques with contemporary design principles. This innovative approach aims to craft sustainable and inviting living spaces suitable for the demands of the 21st century.

3. RELATED WORK REVIEW OF 3D SCANNING, MACHINE LEARNING, AND 3D PRINTING

3.1. Digital Restoration Using 3D Scanning

Three-dimensional scanning is an advanced technology that operates without physical contact and avoids any destructive processes. It utilizes lasers, light, or X-rays to digitally record and replicate the precise physical dimensions and contours of objects. Through this process, a 3D scanner generates 'point clouds' of data by scanning the surface of an object. Essentially, it allows for the accurate capture and transformation of a physical object's size and shape into a digital 3D representation, which is then stored within a computer. The utilization of 3D scanning techniques for documenting and analyzing handicrafts and cultural artifacts holds significant importance within the realm of heritage object preservation and research10. The digital preservation and interpretation of cultural heritage has captured significant interest from a wide range of disciplines, encompassing computer graphics, geometric modelling, virtual reality, and the broader computer science community. This interdisciplinary involvement highlights the importance and diverse aspects of safeguarding and understanding cultural heritage in the digital era [11,12].

Gonzalez et al. 2010, introduces a method combining terrestrial laser scanner technology and digital image processing to assess damage in stony materials of historical buildings. It utilizes intensity data from three laser scanners with varied specifications and employs unsupervised classification algorithms for 2D image classification derived from 3D laser scanner data. The results demonstrate the potential of using laser scanner intensity data for identifying and characterizing pathologies in historical building materials [3].

Remondino 2011, highlights the significance of optical remote sensing sensors in landscape and heritage documentation. It discusses the ongoing advancements in 3D measurement sensors and modelling techniques, emphasizing their role in digital documentation, mapping, and conservation of cultural heritage. The paper includes examples of 3D surveys and models of heritage sites and objects [13].

Rashdi 2022, highlights the pivotal contribution of LiDAR technology in capturing intricate 3D point clouds. The paper thoroughly examines the 'Scan to BIM' methodology, providing a summary of 3D point clouds generated through LiDAR and photogrammetry while also offering a comparative analysis of LiDAR systems deployed on various platforms. Additionally, the review delves into point-cloud processing techniques and conducts a comparative assessment of open BIM standards. It concludes by addressing present limitations and proposing potential future avenues for enhancing BIM models [14].

3.2. Machine Learning Approaches on 3D Point Clouds Dataset

Machine learning approaches applied to 3D point cloud datasets involve utilizing various algorithms and methodologies from the realm of machine learning to analyse and derive meaningful insights from spatial data represented in three-dimensional space. These techniques find diverse applications across fields such as computer vision, robotics, autonomous vehicles, geospatial analysis, and more.

In the context of 3D point clouds, data is presented as a collection of points within a 3D coordinate system, typically generated through technologies like LiDAR, laser scanning, or photogrammetry. Each point encompasses essential attributes such as x, y, z coordinates, and may also include supplementary information such as colour or intensity values.

These machine learning approaches cater to a range of tasks within 3D point cloud data:

- Classification: This entails assigning categories or labels to individual points, facilitating tasks like object detection and vegetation classification.
- Segmentation: The process of grouping points that pertain to the same object or surface, enabling applications like building segmentation.

- Object Recognition: The identification and labeling of entire objects within the point cloud, for instance, recognizing vehicles or trees.
- Registration: Aligning multiple point clouds into a shared coordinate system, essential for endeavors such as constructing comprehensive 3D maps.

To address the current challenges in working with 3D point clouds, efforts are focused on efficiently managing extensive datasets, mitigating the impact of noise and outliers, handling regions with varying point densities, and addressing the resource-intensive nature of deep learning models tailored for 3D data, such as PointNet and PointNet++.

Bitelli et al. 2016, addresses the need for accurate digital surveys of historical buildings for documentation, restoration, and structural analysis in cultural heritage contexts. It presents a semi-automatic procedure to convert point clouds, obtained from laser scanning or digital photogrammetry, into filled volume models in voxel format. The approach aims to reduce operator intervention and enhance structural description, particularly demonstrated in the case study of the earthquake-affected North tower of the San Felice sul Panaro Fortress in Italy [15].

Chiabrando et al. 2016, discusses the application of 3D survey techniques and Building Information Modelling (BIM) in Cultural Heritage. It highlights the emergence of Built Heritage Information Modelling/Management (BHIMM or HBIM) for managing historic assets. The paper emphasizes the significance of 3D survey data in creating comprehensive BIM models, including radiometric attributes for conservation assessment. It explores the use of point clouds from 3D survey techniques for managing complex geometries in historical buildings, especially non-regular shapes. The paper also covers LiDAR data handling, semi-automatic segmentation, and the use of virtual and augmented reality for communication and documentation in historical heritage. The goal is to enhance HBIM platforms for various professionals in the Architecture, Engineering, and Construction (AEC) field involved in documentation and valorisation processes [16].

Grilli et al. 2017, addresses the need for meaningful attributes in 3D models and point clouds, essential for various applications. It focuses on segmentation, the process of grouping similar regions, and classification, labelling these regions. The paper reviews popular methodologies and algorithms for 3D point cloud segmentation and classification, highlighting their strengths and weaknesses. Real examples from the Cultural Heritage field are used to illustrate results, and the paper concludes by discussing open research topics [17].

Qi et al. 2017, introduces PointNet, a neural network designed to directly process point cloud data, preserving the input's permutation invariance. PointNet offers a unified architecture applicable to object classification, part segmentation, and scene semantic parsing. Despite its simplicity, PointNet demonstrates high efficiency and effectiveness, performing on par with or better than state-of-the-art methods. The paper also includes theoretical insights into the network's robustness and understanding of its learning process [18].

Grilli et al. 2019, explores the classification of heritage point clouds, focusing on architectural components like columns, facades, and windows, using various supervised learning approaches, including machine and deep learning methods. The research evaluates different accuracy metrics for each case study and classification method, aiming to enhance the automated recognition of heritage features in large datasets [19].

Grilli et al. 2020, explores machine learning for point cloud classification in cultural heritage, addressing the challenge of using a single model across diverse architectural datasets. It presents a methodology utilizing a random forest model trained on a specific dataset, focusing on identifying key features for classifying architectural elements such as walls, windows, roofs, and columns. This approach enables successful generalization to previously unseen scenarios [20].

Zhang et al. 2020, explores applying 3D Machine Learning to architectural design using GANs and spatial sequence rules. It introduces 3D architectural form style transfer at two scales (overall and detailed) through machine learning algorithms trained with two types of 2D datasets. By examining style interactions in neural networks at the 2D level, designers can manually control the desired output, creating new style 3D architectural models with a clear design approach [21].

Pierdicca et al. 2020, focuses on applying Deep Learning (DL) techniques for semantic segmentation of 3D Point Clouds in the Digital Cultural Heritage (DCH) domain. The goal is to recognize historical architectural elements in detail, expediting the modelling of historical buildings for Historical Building Information Modelling (HBIM). The proposed DL framework utilizes an enhanced Dynamic Graph Convolutional Neural Network (DGCNN), incorporating features like normal and colours. The framework is evaluated using the Arch (Architectural Cultural Heritage) Dataset, which contains 11 labelled point clouds from diverse historical structures, both indoor and outdoor, representing various architectural elements and styles. The experimental results demonstrate a high level of accuracy, showcasing the potential of DL techniques in advancing the semantic segmentation of 3D Point Clouds for the preservation and modelling of historical architectural heritage [22].

Liu et al. 2022, addresses the challenge of achieving fast and accurate 3D neural networks for edge devices with limited hardware resources. It introduces a hardware-efficient 3D primitive called Point-Voxel Convolution (PVConv) and enhances it with sparse convolution. The paper also presents 3D Neural Architecture Search (3D-NAS) to optimize 3D network architecture under resource constraints. Evaluations on benchmark datasets show state-of-the-art performance with significant speedup. The proposed method has practical applications in autonomous vehicles, improving detection range, accuracy, and latency [23].

Ning et al. 2022, introduces an automated method using PointNet++ Neural Network for semantic segmentation of point clouds in Cultural Heritage documentation. This innovative approach aims to alleviate the time-consuming manual work of experts, making a labelled dataset publicly available for further research in point cloud semantic segmentation [24].

Haznedar et al. 2023, explores the utilization of PointNet, an AI-driven deep learning technique, to segment 3D point cloud data captured from heritage buildings in Gaziantep, Turkey. PointNet displayed challenges in precisely segmenting point clouds from aged, deteriorating heritage structures. However, when trained with synthetic data, it exhibited remarkable accuracy. This study proposes an innovative workflow for point cloud segmentation in heritage buildings and underscores the promise of PointNet when coupled with restitution-based heritage data for precise classification and segmentation of heritage structures [25].

3.3. 3D Printing Technique

The implementation of this concept within the construction sector is widely regarded as an innovative and groundbreaking solution to the ongoing challenges faced by the industry26. This approach empowers the creation of components characterized by intricate geometries, all achieved without the need for molds and with minimal labor input. Simultaneously, it delivers a reduction in construction timelines and a decrease in waste generation, among an array of other advantageous outcomes.

In the last two decades, the field of robotics in construction (RiC) has arisen as an interdisciplinary domain, integrating critical technologies such as additive manufacturing, deep learning, and building information modeling (BIM). Xiao et al. 2022, study utilized a mixed quantitative-qualitative approach, reviewing 940 articles to pinpoint recent RiC accomplishments and suggest future research paths. It contributes by shedding light on contemporary trends and providing foresight into the future of RiC, ultimately aiding academia and industry in advancing robotic technologies for the construction sector [26].

To enable the successful 3D printing of a mixture, certain essential attributes must be met. These include workability, flowability, pumpability, extrudability, buildability, shape retention, open-time, interlayer adhesion, and printability. These characteristics collaborate to facilitate the printing process. Teixera et al 2023, find definitions and suggested evaluation methods for these properties. It's worth noting that while much of this information pertains to PC-based materials, all materials created for 3D printing must meet these fundamental criteria [27] (See Fig. *2*).

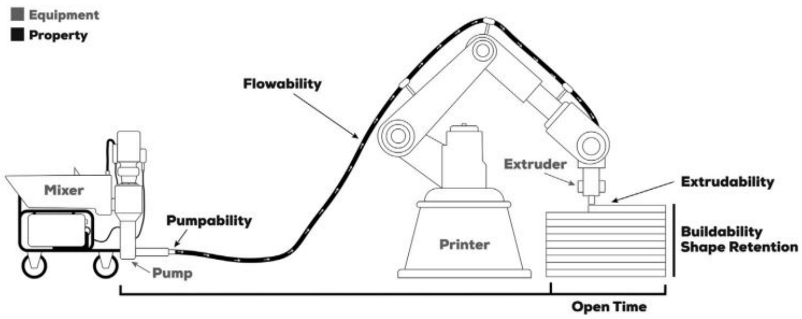

Fig. 2: Characteristics and Machinery Necessary for Material Extrusion 3D Printing.

Jesus et al. 2023, delves into the possibilities of utilizing 3D printing (3DP) for the restoration of cultural heritage structures. Typically, these structures are restored using expensive traditional methods and limited materials. The paper compiles data on common heritage building issues and materials, explores innovative construction methods like 3DP and 3D scanning, and emphasizes the importance of materials compatibility and precision in replication. It serves as a pioneering effort in applying 3DP to cultural heritage restoration, shedding light on opportunities and challenges in the integration of these technologies [28].

4. RESEARCH FRAMEWORK

The framework commences by employing advanced 3D scanning techniques, with a particular focus on harnessing the capabilities of LiDAR remote sensing technology. This cutting-edge approach enables the creation of highly detailed 3D models and comprehensive maps of architectural features and their surrounding environments. LiDAR scanners, in this context, leverage a potent combination of a high-powered laser and a precisely rotating mirror to meticulously scan expansive areas. This process is exceptionally rapid, capturing thousands of data points per second. Nevertheless, the sheer volume of data generated necessitates the utilisation of high-capacity computing systems for efficient processing and analysis.

Furthermore, the framework integrates the power of ML algorithms to predict and discern lost or damaged architectural elements within the scanned data. Through the utilisation of labelled data and feature extraction, the framework employs supervised learning techniques, facilitating the recognition of patterns associated with absent or deteriorated architectural elements. Once these algorithms are meticulously trained and rigorously validated, they exhibit a remarkable capability to identify precisely which architectural components in traditional buildings are missing or have suffered damage.

At the final stage, the framework emphasizes the use of 3D printing technology, particularly the robot arm technique, to ensure high standards of quality and precision in the production process. Advocating for 3D printing technology, it allows the creation of complex and precise objects by adding material layer by layer, known for its accuracy. The robot arm technique, involving a robotic arm with six axes (degrees of freedom), is highlighted for its exceptional control, allowing for more intricate and exact 3D printing. This method is deemed superior to other methods in terms of flexibility and accuracy, offering enhanced design freedom and precision. After creating the 3D model, the framework recommends optimization phases aimed at determining the most efficient solution in terms of time and material usage, leading to cost reduction and resource efficiency. The initial model's printability is then assessed, ensuring successful 3D printing without hitches. Once printed, the model undergoes a structural properties evaluation to ascertain its strength and durability. An environmental impact assessment, or Life Cycle Assessment (LCA), follows, pinpointing materials with the most considerable environmental impact and suggesting mitigation methods. Informed by the LCA results, material selection favors those with a lesser environmental footprint. The process culminates in reprinting the model using the optimized method and selected material, with subsequent retesting to ensure standards are met. The approach overall prioritizes precision, material efficiency, and environmental considerations, making it invaluable for specific industries and applications (see Fig. 3).

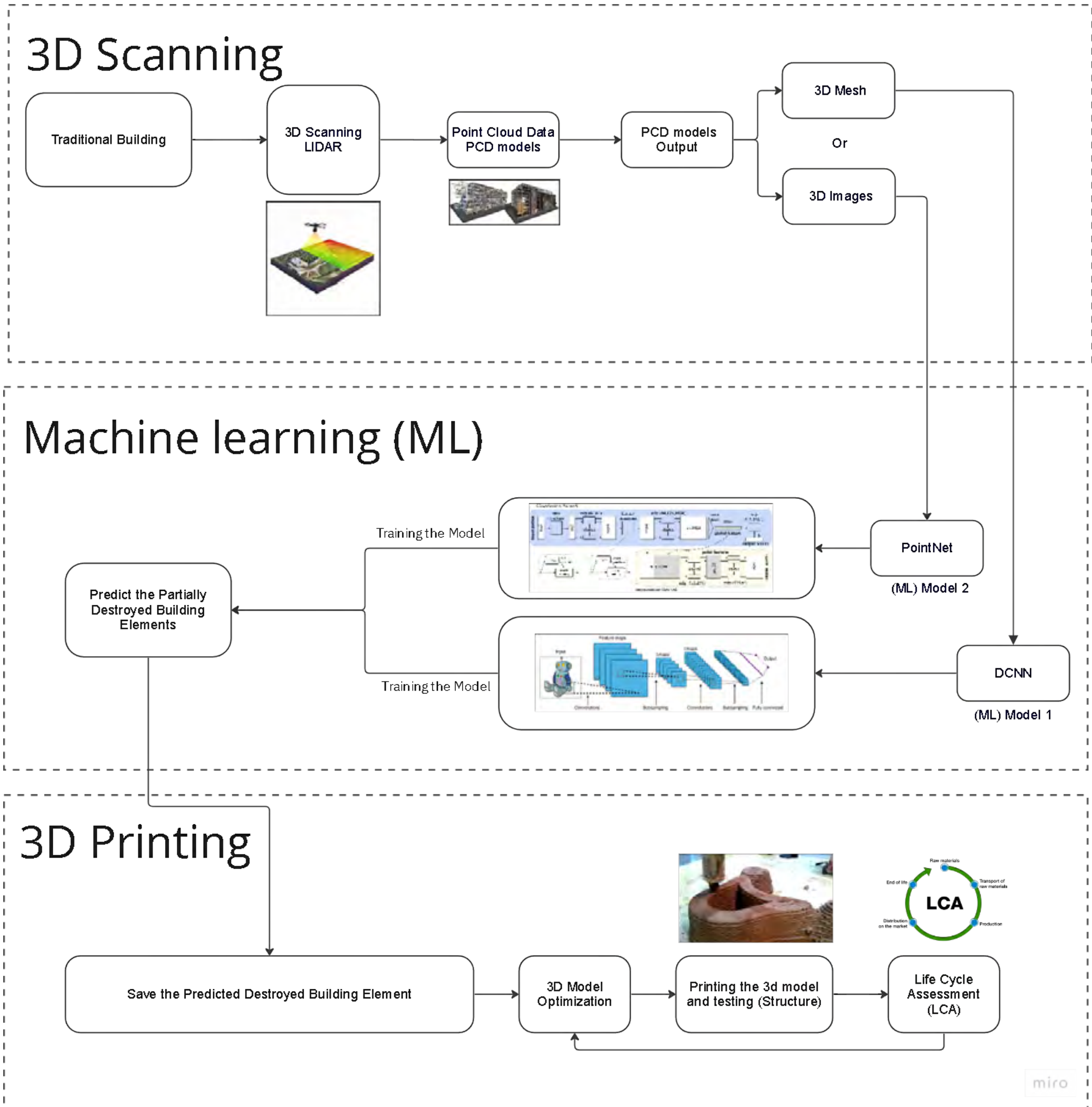

Fig. 3: Research Framework

5. DISCUSSION

The advent of the digital era has introduced transformative technologies that are steadily altering the landscapes of construction, restoration, and preservation. The integration of 3D printing, particularly when synergized with 3D scanning and machine learning, epitomizes the fusion of digital advancements with conventional architectural practices. As highlighted in the study, this consolidated approach possesses profound potential to rehabilitate, restore, and conserve structures of notable historical and cultural significance.

A standout aspect of this methodology is the precision with which 3D printing (3DP) can operate. While conventional construction methods are proven and reliable, they often encounter obstacles when trying to replicate the intricate designs characteristic of numerous heritage sites. These challenges become even more pronounced when original materials are either irreparably damaged or unavailable. In these circumstances, 3DP stands out by skillfully reproducing complex attributes that mirror the original constructs.

Yet, the essence of this technological innovation is not solely its replication capability but also its harmonization with other modern techniques. The merger of 3D scanning offers an accurate digital representation of edifices, documenting the most subtle nuances. Machine learning supplements this by pinpointing deteriorated or damaged sections, guaranteeing that restorative efforts uphold the site's historical fidelity. Together, these technologies formulate a robust and holistic model for restoration and preservation.

Another significant aspect of 3D printing is its emphasis on sustainability. In a world confronting the dual challenges of environmental concerns and swift urban expansion, the quest for green alternatives is paramount. The utilization of 3D printing in construction, emphasizing materials such as recycled plastic, bio-derived substances, and geopolymer concrete, proposes an eco-responsible trajectory. This approach not only diminishes the carbon footprint but also substantially curtails construction waste, aligning with international sustainability objectives.

Nevertheless, like all pioneering ventures, obstacles remain. The compatibility between 3D printed substances and traditional building materials is an ongoing concern. Efforts have been initiated to ensure that 3DP constituents harmonize with a site's historical essence, but continual research is pivotal. Striking the right balance between heritage and innovation is crucial to maintaining the genuine character of historical landmarks.

Furthermore, the cost aspect can't be overlooked. Despite its long-term advantages, the initial financial outlay for 3D printing can be significant. However, as this technology gains traction and becomes commonplace, it's expected that scale economies will render it more affordable, broadening its reach.

Emphasized in the discourse is the interdisciplinary essence of this domain. The fusion of knowledge from fields as varied as computer science, material engineering, architectural design, and digital innovation results in a knowledge-rich mosaic. This collaborative ethos not only bolsters the strengths inherent to each specialty but also addresses their respective challenges. Such a united front is vital to address the multifaceted hurdles that architectural conservation and restoration pose.

6. CONCLUSION

The cultural heritage of Saudi Arabia, expressed through its traditional architectural marvels, serves as a testament to the nation's rich historical tapestry. The urgency to preserve these architectural gems, especially in the face of urban development and decay, necessitates an innovative approach that harmoniously merges the old with the new, ensuring the narratives of the past remain intact for future generations. This paper has proposed a groundbreaking digital architectural framework, "scan, predict, build," which integrates cutting-edge technologies to address the unique challenges posed by renovating traditional buildings in Saudi Arabia that have experienced partial demolition or deterioration.

At the heart of this approach is the utilization of LIDAR-based 3D scanning techniques, which offer unparalleled precision in capturing architectural details. Coupled with the power of machine learning, this framework can accurately predict and recreate lost or damaged architectural elements, ensuring that the essence of the original design is retained. The inclusion of the robot arm technique for 3D printing not only ensures quality and precision but also underscores the potential for technology to streamline and elevate the renovation process.

The proposed methodology not only holds promise for the immediate task of renovating traditional Saudi Arabian buildings but also heralds a new era in the field of architectural conservation. By leveraging digital tools, we can address the longstanding challenges, such as the dwindling pool of skilled artisans and the lack of detailed documentation, which often hinder traditional renovation efforts. This approach paves the way for a more efficient, accurate, and cost-effective restoration process, which can be applied universally, transcending geographical boundaries.

In light of the Saudi Vision 2030 and the increasing global emphasis on cultural preservation, the "scan, predict, build" framework provides a timely and impactful solution. It not only reinforces the importance of preserving cultural heritage but also demonstrates the limitless possibilities that arise when tradition meets technology. As we move forward, it is our hope that this approach will inspire similar initiatives globally, ensuring that our shared architectural legacies are not only preserved but also thrive in harmony with modern innovations.

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Traditional Dwellings and Settlements

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THE IMPACT OF ARTIFICAL INTELLIGENCE (AI) ON ARCHITECTURAL DESIGN, IDENTITY, AND CULTURE MAKING IN KUWAIT AND THE GULF

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THE IMPACT OF ARTIFICAL INTELLIGENCE (AI) ON ARCHITECTURAL DESIGN, IDENTITY, AND CULTURE MAKING IN KUWAIT AND THE GULF

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Artificial intelligence or (AI) is the new up and coming technology creating a paradigm shift in virtually every sector of the tech industry and rapidly impacting many fields and industries from medicine, architecture, science, and engineering. It is defined as a wide-ranging branch of computer science concerned with building smart machines capable of performing tasks that typically require human intelligence. This study conducts vital research in this under studied topic to explore the challenges and opportunities of artificial intelligence in architectural design and further understandings into AI's role in representation in all its forms including culture, architectural experience and regeneration. It does this by employing interactive workshops to examine AI's replications of major landmarks in Kuwait City, Riyadh, and Doha. The AI generated hundreds of images that revealed fascinating evolution of architectural visualization and with it a digital bias that may suggest inaccurate representations of certain building types. Tradition and culture become dynamic in a sense, fluid, flowing, evolving with technology bridging between the past and future. The study argues that AI platforms may be used as powerful design tools that will soon transform the design of buildings and cities. Although it may provide tremendous opportunity for change in advancing architectural design and construction it is still unclear how this technology will reshape culture in the built environment.

1. INTRODUCTION

There has not been any apparent research on how AI text to image generation platforms perceive architectural culture in the Arabian Gulf. In Kuwait, architect AbdulAhad was one of the early few that applied AI to visualize renovating *AlMubarikya*, Kuwait's historic *Souq* with astonishing results[1]. The AI stripped the traditional marketplace from its vernacular elements and replaced them with contemporary minimalistic abstractions creating a new morphed translation of reality. This exploration has raised many questions. To what extent has this new vernacular been reimagined by the architect who described it or the AI who visualized a new architectural identity for the space? Will AI replace the role of an architect or will it be used as an investigative and design tool? Either way the potential consequences on the architectural profession are enormous and open the door for profound new understandings into the evolution of culture in the built environment.

In order to examine AI's potential abilities to shift boundaries of culture expression, identity in architecture workshops have been used as the primary method for this study. Participants have been tasked to select 10 landmarks and spaces throughout three cities in the Gulf (Kuwait City, Riyadh, and Doha) and command the AI to generate visuals and 3D reinterpretations based on descriptions of the buildings. Parameters of how the AI is operating and making decisions with regards to urban regeneration will be outlined and discussed. These images are then content analysed and compared to photographs of the real buildings. The findings revealed many fascinating insights and provided rich data to inform and direct future design solutions. The intention of this exploratory study is not only to see how architects may use AI as a design tool but how the outcomes influence architectural cultural identity, form, and style with significant implications for both future of design and engage in conversations of architectural heritage and preservation.

2. LITERATURE REVIEW

Origins of artificial intelligence in research date back to a paper later recognized as "AI" was McCullouch and Pitts design for Turning-complete "artificial neurons" in 1943 [2]. The term AI was coined by John McCarthy in 1955, and was defined by him as "the science and engineering of making intelligent machines" [3]. Soon afterwards in 1956 the field itself was founded at a workshop at Dartmouth College[4]. Today, artificial intelligence may be viewed as intelligence of machines or software, as opposed to the intelligence of humans or animals. It is also a field that studies intelligent machines and their development. There has been much research to program machines in order to behave and act in a clever way and try to learn like human beings do.

Throughout the 1960s some governments around the world started funding AI projects, however, it turned out more difficult than anticipated and funding stopped. In the 1980s some commercial projects with AI started but did not gain traction. In the 1990s interest in AI investment projects started again by exploiting formal mathematical methods and by finding specific solutions to specific problems[5]. At this time commercial uses for AI focused mostly in the fields of statistics, mathematics, and economics.

In 2012 deep learning a machine learning method began to dominate and was adopted throughout the field in many professions. Deep Learning uses large multi-layer (artificial) neural networks that compute with continuous (real number) representation. The idea tries to mimic the hierarchically organized neurons in human brains. It is currently the most successful ML approach, usable for all types of ML, with better generalization from small data and better scaling to big data and compute budgets[6]. Its success has seen AI funding grow over the years with increase in research, performance and speed of its systems[7]. The results of this advancement are many applications powered by AI such as Google search engines. Language translate systems such as Google translate and Microsoft translate. AI recommendation systems used in YouTube and Netflix. In addition to AI virtual assistants such as Siri by Apple and Alexa by Amazon. AI has also been used in many known facial recognition software like Apple's face ID for the IPhone and Microsoft's Deep face.

In the last few years some researchers have started to examine how different manifestations of AI will impact the discipline and profession of architecture [8] [9] [10] [11], in interior design[12], and in art[13]. In their paper, del Campo and his colleagues provide an example of how generative adversarial networks (GANs) could be used to produce architectural designs in a project called Robot Garden developed at University of Michigan[14].

Recently, in 2020 generative AI platforms have been capable of generating text, images and other media. Text to image artificial intelligence systems also have started to emerge such as Stable Diffusion, MidJourney, and DALL-E[15]. These systems called neural networks convert users' text inputs into AI-generated images. They allow designers to easily convert written descriptions of a space into realistic 3D images, giving them the ability to visualize and experiment with different design options in a matter of seconds. The images created by these bots, which are both real and imaginary, have become very popular online sparking many discussions about the future of AI technology in architecture[16]. As a result to AI's fast pace development many questions have been raised such as inadequate regulations, copyright issues, job losses, and not much transparency in the how it works.

3. METHODOLOGY

ARTIFICIAL INTELLIGENCE (AI) WORKSHOPS

For this exploratory study workshops have been used as the data collecting method. A workshop is an interactive, participatory group exercise, which in this case has been used for research purposes. According to the University College London's Public Engagement Unit it is a method that can "be used to gauge and compare opinions on a range of different aspects, criteria or qualities of a project or activity". They describe workshops as, "a means of capturing more qualitative information … probing the meanings participants give to their behavior, ascertaining reasons, motives and intentions" [17].

As the researcher the instructor's role has moved from lecturing the class to becoming a "facilitator of a conference". The teacher does not remain passive, but rather, helps "direct and mold discussions by posing strategic questions and helping students build on each other's ideas"[18]. Therefore, the workshop also becomes an essential tool for teachers to develop innovative instructional approaches and to incorporate active learning strategies as means to encourage critical thinking. The method provided an interactive way to understand different people's experiences using AI and its impact on architectural culture and identity in the Gulf.

Workshops have been conducted within the span of 3 days at the department of architecture, Kuwait University. There were 13 architecture students who participated in the study of which 12 were females and 1 male. They were directed to select 1 architectural landmark from Kuwait City, Kuwait, Riyadh, Saudi Arabia, and Doha, Qatar. Each landmark selected expressed a contemporary postmodern architecture with clear cultural references such as Islamic geometric patterns, mashrabiyas, courtyards, liwan (covered arcades) etc. Moreover, to select architectural buildings that represented the wider nation such as Mosques, houses, palaces, museums, cultural centers, governmental buildings, stadiums, and even skyscrapers. The next step was to select 10 key words that described each building's architectural elements, form, materials and color and also to include the words culture, identity, tradition, city and country and landmark name. The last four words have been added to direct the Artificial intelligence to come as close as possible to replicate the original building and most of its features.

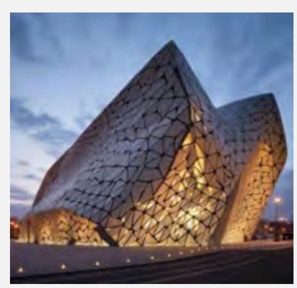
The next step asked the workshop participant's to use the AI platform know as MidJourney to produce new images of the buildings. MidJourney is a text to art or architecture image generator, an interactive 'bot.' that uses machine learning to create pictures based on text. This AI was specifically used due to its more advanced and photo realistic architectural reproductions compared to its existing counterparts.

The participants were shown how to use the program and thus instructed to write a paragraph of text describing each landmark including all the keywords, which in turn, the text prompt generated photo realistic renderings of the buildings. After that each participant picked an image that most resembled the original and directed the program to produce new enhanced variants. The images may be perfected by running the program many times. Each time participants refined the prompt description and tried different variations. This process was done until the replicated AI image was as close as possible to look like the original landmark.

The participants were then instructed to place both real image and the reconstructed AI image side by side. The researcher facilitated a larger discussion between the participant members to question the extent of how AI has influenced architecture culture and identity of each landmark. This process was repeated each day for the cities of Riyadh and Doha with a final group interview that cross analyzed the findings of each city to find patterns and consistencies between cities which in turn contributed to the emerging themes discussed below.

4. RESULTS

Kuwait City landmark photographs and AI generated image

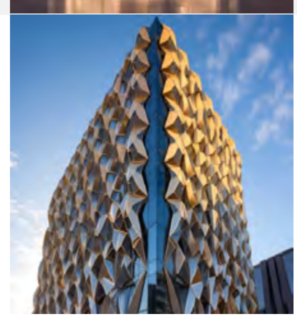
#	LOCAL ARCH. LANDMARK	KEYWORDS USED TO DIRECT (AI)	REAL PHOTOGRAPH OF THE BUILDING	ARTIFICIAL INTELLIGENCE (AI) REPLICATION
1	Kuwait Towers	Contemporary, high-rise buildings, three towers, hierarchy, sphere, repetition, mosaic, Islamic geometry, glass horizontal, sharp point, culture, identity, tradition, Kuwait City, Kuwait, Kuwait towers.		
2	National Assembly Building	Arabian tent, tensile structure, repetition, curves, solid and void, rhythm, courtyard, Islamic mashrabiyas, semi, circular shells, horizontal, culture, identity, tradition, Kuwait City, Kuwait, Kuwait National Assembly		
3	Kuwait Grand Mosque	Dome, minaret, arch, square, Arcade, Islamic pattern, repetition, high, courtyard, mashrabiya, culture, identity, tradition, Kuwait City, Kuwait, Kuwait Grand Mosque		
4	JACC-Kuwait's Opera house	Angular, sharp lines, Islamic pattern, mashrabiyas, solid and void, culture, identity, tradition, Kuwait City, Kuwait, Kuwait Opera house		

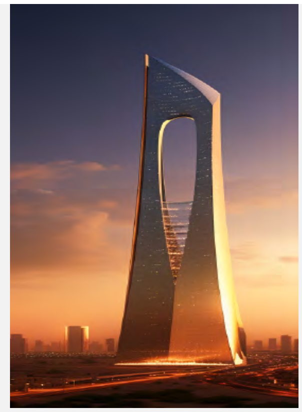
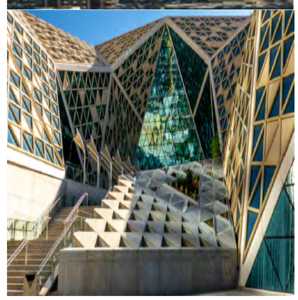
5	Fatma Mosque	Stretched dome, conical circle, Islamic pattern, green, rhythm, geometry, manara (minaret), culture, identity, tradition, Kuwait City, Kuwait, Fatma Mosque.		
6	Dahia Twin Villas	Cubic axil symmetrical, sustainable, solar panels, windcatcher, modern mashrabiya, courtyard, liwan or shaded walkway, palm trees, culture, identity, tradition, Kuwait City, Kuwait, Dahia twin villas.		
7	Tent House	Tent, pointed, repetition, arches, hierarchy, vertical lines, formed concrete, cone-like, ribbed fence, white, culture, identity, tradition, Kuwait City, Kuwait, Tent house.		
8	AlShaya Diwaniya	Islamic patterns, barrel-vault arches, courtyard, repetition, high ceiling, culture, identity, tradition, Kuwait City, Kuwait, Diwan AlShaya.		
9	AlSeif Palace	Rectilinear, clay palace, hierarchy, arches, mirzam, traditional water gutter, Islamic patterns, clock tower, dome, courtyard, mashrabiyas, liwan, arcade, culture, identity, tradition, Kuwait City, Kuwait, Seif Palace.		

10	Scientific Center	Fabric tensile tents, repetition, pattern, traditional sails, ships, boom, mashrabiya, mirzam, open, sea, culture, identity, tradition, Kuwait City, Kuwait, Kuwait scientific center.		

Table 1: Kuwait City landmark photographs and AI genterated images.

Riyadh landmark photographs and AI generated image

#	**LOCAL ARCH. LANDMARK**	**KEYWORDS USED TO DIRECT (AI)**	**REAL PHOTOGRAPH OF THE BUILDING**	**ARTIFICIAL INTELLIGENCE (AI) REPLICATION**
1	KAPSARC Mosque	Cubic form, long courtyard, glass, stone clad, concrete, Islamic patters, abstract, light, shadows, long rectilinear, modern minaret, culture, identity, tradition, Riyadh, Saudi Arabia, KAPSARC mosque.		
2	King AbdulAziz National Library	Square, shell, cladding, rhomboid textile awnings, revealing, concealing, Arabian tent, textile, triangles, opening, dissociation, semi-transparent skin, culture, identity, tradition, Riyadh, Saudi Arabia, King AbdulAziz National Library		
3	Kingdom Centre	Simple solid, curtain glass wall, parabolic arch, steel bridge, void, inverted, culture, identity, tradition, Riyadh, Saudi Arabia, Kingdom Center.		

				
4	KAFD Riyadh Conference Centre	Islamic geometric pattern, angular, sharp angles, triangular, steel, dynamic, green wall, culture, identity, tradition, Riyadh, Saudi Arabia, KAFD Riyadh conference centre.		
5	Ministry of the Interior	Inverted pyramid, shape, sharp lines, symmetrical design, central core, steel framework, strong, central dome, strong, inter-connected beams, culture, identity, tradition, Riyadh, Saudi Arabia, Ministry of Interior.		
6	Garir Villa	Contemporary villa, rectangular, concrete, wood, modern courtyard, black mashrabiya, privacy, palm trees, Islamic patterns, cantilevered, culture, identity, tradition, Riyadh, Saudi Arabia, Garir villa.		

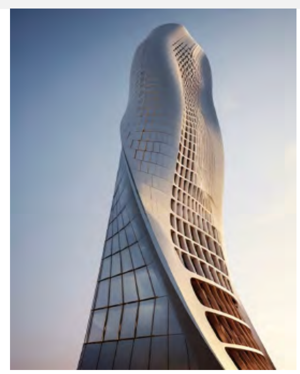
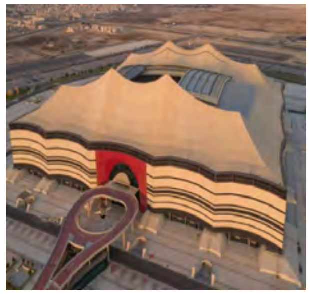
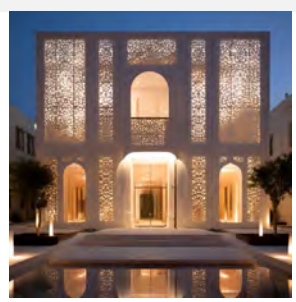
7	King Salman Palace, Riyadh	Towers, rectangular watchtower, courtyard, arcade, wood, limestone, colonnades, triangular voids, culture, identity, tradition, Riyadh, Saudi Arabia, King Salman Place, Riyadh.		
8	Al Faisaliyah Tower	Triangle, glass ball, truss system, hierarchy, pointed sharp, horizontal, organized, culture, identity, tradition, Riyadh, Saudi Arabia, AlFaisaliyah Tower.		
9	Al Muqarnas Tower	Vaulting techniques, twisting, solar performance, skin, metal panel, shimmering mosaic, culture, identity, tradition, Riyadh, Saudi Arabia, AlMuqarnas Tower.		
10	Villa Ajmakan	Modern courtyard, mashrabiyas, villa, light effect, white concrete walls, majlis, culture, identity, tradition, Riyadh, Saudi Arabia, Villa Ajmakan.		

Table 2: Riyadh landmark photographs and AI genterated images.

Doha landmark photographs and AI generated image

#	LOCAL ARCH. LANDMARK	KEYWORDS USED TO DIRECT (AI)	REAL PHOTOGRAPH OF THE BUILDING	ARTIFICIAL INTELLIGENCE (AI) REPLICATION
1	Qatar State Grand Mosque	Arches, domes, large gate, Islamic pattern, courtyard, sandstone, horizontal, mirzam, repetition, minaret, culture, identity, tradition, Doha, Qatar State Grand Mosque.		
2	Islamic Art Museum	White, cubes, geometrical shapes, artificial peninsula, volumes, courtyard, abstract, palm trees, cubes, dome, arched walls, culture, identity, tradition, Doha, Qatar, Islamic Art Museum		
3	Doha Tower	Tall, geometry, mashrabiya, Islamic patterns, cylindrical, Reflective glass, Atrium, Full-width dome, needle, Light and shadow, bird tower, culture, identity, tradition, Doha, Qatar, Doha Tower		
4	Qatar Faculty of Islamic Studies	Courtyard, geometric patterns, arches, solid/void, futuristic, curved, calligraphy, minarets, shadow and light, continuous, culture, identity, tradition, Doha, Qatar, Qatar Faculty of Islamic Studies		

5	AlBayt Stadium	Old, bayt al sha'ar (Arabian Tent), tensile structures, pointed, sadu patterns, red gate, rectangular, void, black and white stripes, symmetry, culture, identity, tradition, Doha, Qatar, AlBayt Stadium.		
6	Al Thumama Stadium	Modern mashrabiya, circle, pattern, gahfiya (head cover), geometry, Islamic, white, lighting, flat, void, culture, identity, tradition, Doha, Qatar, AlThumama Stadium.		
7	Fanar Qatar Islamic cultural center	Spiral, arches, square, mashrabiya, traditional, rectangle, cubes, culture, identity, tradition, Doha, Qatar, Fanar Qatar Islamic cultural center.		
8	Qatar University	Mashrabiya, cubes, repetition, hierarchy, cladding, patterns, liwan (covered arcade), wind catcher, culture, identity, tradition, Doha, Qatar, Qatar University.		
9	Lusail Naqsh house	White, cubic, mashrabiya, patterns, glass, minimalist, courtyard, main entrance, solid and void, light and shadow, culture, identity, tradition, Doha, Qatar, Lusail Naqsh house.		

10	Al Janoub Stadium	Sails, pearl, waves, oval, symmetry, white, void, Futuristic, curve, rhythm, culture, identity, tradition, Doha, Qatar, AlJanoub Stadium.		

Table 3: Doha landmark photographs and AI generated images.

5. DISCUSSION OF FINDINGS

The findings have resulted in fascinating insights into how AI replicated significant architectural landmarks of three major Gulf cities. AI software has managed to capture the form and essence of the buildings using specific inputted key words after a few iterations. However, the findings highlight significant divergent socio-cultural architectural manifestations, which may suggest a fundamental issue of AI's understandings and expression of culture. The following themes that emerged from the workshops are presented below all revolve around this concept.

LOCAL VS. GLOBAL INTERPRETATIONS

AI fundamental frameworks are based primarily on the vast information available in the Internet. Therefore, if major landmarks such as the Kuwait towers, Kingdom center, and Doha tower are more internationally recognized buildings and have a significant presence online they are more likely to be generated accurately then other less known regional architecture. With these reinterpretations specific instances with cultural references still remain in the buildings. Kuwait towers still had the iconic spheres, Kingdom towers it's unusual upside down arch and Doha towers it's modern mashrabiyas.

Similarly, when it comes to other important architecture such as the stadiums of Doha built for the 2022 FIFA world cup, the AI reproductions were strikingly precise. This may suggest that due to the fact that the World cup is the biggest sports event in the world and had intense media coverage online, which made it easier for the AI to generate the stadium iterations. Other notable buildings also received such connection such as Kuwait's national assembly design by architect Jorn Utzon and Riyadh's ministry of interior. The AI image has been very similar in color, vibe, and to a certain extent shape.

In contrast other buildings such as residential villas are very local, and therefore, the AI used the keywords to determine it's overall essence with some detail but sometimes failed to imitate their likeness. This was also apparent in other residential architecture types such as palaces, which the AI had more difficulty reinterpreting.

Instead of replicated a more realistic image most palaces were presented as something of the past reminiscent of ancient architectural landmarks. This is true of Kuwait's Seif Palace, which the AI saw as a gate type structure using very traditional Islamic architecture ornamentation. It seems it did not know how to represent traditional Kuwaiti palace style and found a generalized Islamic expression instead. Therefore, participant's findings in the workshops throughout all the Gulf cities reveal that the AI preformed better when generating globally recognized architecture compared to local or regional landmarks.

FUTURISTIC RENDERINGS

Another interesting pattern that emerged from the AI generated images was that 9 out of the 30 images were photo realistic architectural interpretations represented in a futuristic type setting, either by the way it has been rendered, unusual morphed forms, and even materials in some cases. It is unclear what initiated this type of image. It may be some keywords and text used that may have triggered a futuristic replication of reality. Another explanations may be based on the AI algorithm, which may have been trained in a way to relate and translate some buildings to be more attractive, eye catching and high-tech. This may suggest that architectural culture identity may have been reconfigured to a more simpler and ultra modern version. This is clearly highlighted in the before and after images of Kuwait towers landmark. The AI subtly removed traces of key features and identity markers of the original towers such as hierarchy of the spheres, materials used in the spheres, and function of the building. Instead it was replaced with a more refined sci-fi version mimicking the spherical shapes while loosing its connection to the audience with no architectural cultural significance.

DIGITAL BIAS

According to understandings into AI fundamental framework is based primarily on the vast information on the Internet. Artificial intelligence is based on a 'multi-language model'. This means the AI can be trained to learn any language from spoken languages, mathematics, to music then it seeks out patterns and decodes them. In addition, AI has been instructed to scrap billions of images from the Internet and use them to recreate new images[19]. Therefore, the Internet is a significant source of inspiration for AI, which may question its objectivity when generating images especially as it relates to culture, identity, and tradition. Machine learning applications will be biased if they learn from biased data[20]. As a result, if biased algorithms make decisions that may impact or harm people than they may cause discrimination[21] [22] [23]. In fact, some AI researchers suggest that scientific publishers may perpetuate racist AI algorithms[24], which may indicate there is some level of bias or misrepresentation of reality.

This has been apparent in some images the AI produced, which sparked interesting group interview discussions. Mosques were expressed differently by the AI, out of the 4 mosques only 1 was replicated in almost a similar image while the others digital reproductions did not look like the original. An evident issue seen from the AI images and major discussion point in the workshops was how when the words 'Islamic patterns' or 'Islamic geometry' and 'Mosque' as keywords the AI most often provided generic Mosque building types far from reality. This translation would indicate a sort of digital bias where the artificial intelligence AI uses what's available online with generalization, cultural misinterpretations, or not translating specific local cultural elements.

6. CONCLUSION

The debate over the role of AI in the architecture profession is still ongoing with many topics that are still ill defined at the moment such as copyright for AI-generated art and architecture, implications of AI on the architectural practice and the impact on culture and identity which this study intended to better understandings. It is clear from the findings that AI is a powerful architectural visualization tool, however, the data suggests that when it comes to expressing culture the MidJourney AI still needs more development. A digital bias due to limited knowledge of how to translate local traditional elements have illustrated how the AI works on generalizations especially on Mosque architecture, palaces, and even some residential types. That being said it is important to note that no one can anticipate what Midjourney can recreate. The results are somewhat predictable with a large dose of randomness. Some participants stressed that they do not always get exactly what they have written even despite several iterations but you often get "a really cool image that you were not expecting". It seems that AI itself is constantly feeding on people's feedback and changes, which in turn is the way it grows, so perhaps with more time and refining the platform algorithms will make it become a step closer to replicating a more accurate version of reality.

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