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DIGITAL RECONSTRUCTION AND REHABILITATION OF A HISTORICAL STRUCTURE-HISTORICAL BUILDINGS IN SULAYMANIYAH KRG/IRAQ AS CASE STUDY

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ABSTRACT

This paper will discuss the importance of the use of digital reconstruction and rehabilitation in historical building preservation with reference to three important heritage sites in Sulaymaniyah, Kurdistan Region of Iraq: Saray Sulaymaniyah, Hotel Farah and Peramerd House. Since traditional forms of restoration can be intensive in resources, time, and physical effort, new non-invasive ways of conserving cultural heritage can be achieved using computational technologies: 3D model, Historic Building Information Modeling (HBIM), and virtual environments. This paper explores the idea of digital reconstruction in preserving past integrity and at the same time facilitating adaptive reuse through a mix of theoretical studies and practical field research. A survey of 50 people was carried out to obtain social opinion on the preservation of the digital heritage and its significance. The findings suggest a high level of awareness of cultural significance of these buildings and the general support of application of digital techniques in the process of rehabilitation. The study indicates that virtual techniques have the possibility to facilitate cultural education, safeguard the identity of architecture, and involve the next generations in the conservation of the heritage.

KEYWORDS: Digital Reconstruction and Rehabilitation, Virtual Rehabilitation, Historical Characteristics, Cultural Merits, Building Reuse.

1. INTRODUCTION

Due to the rapid global changes associated with technology, economy, policy, society, culture, and science, dramatic cultural values have emerged replacing historical values, original buildings, and ancient architecture. In this context, it is greatly significant to take advantage of the substantial worldwide digitalization and technological changes to improve the level of awareness and knowledge among the new generations towards the historical buildings' contributions, importance, and key characteristics (Jouan et al., 2021; Barrett et al., 2020). One of the most effective approaches employed to achieve these aspects is reconstruction and rehabilitation. Notwithstanding, conventional reconstruction and rehabilitation needs high budget and physical spaces to renovate and modify old buildings to reuse again. Instead, virtual based (digital) re- construction and rehabilitation approaches have been remarkably observed in the last decades. These technological methods enable the conversion of ancient facilities, and historical buildings into modern structures, and at the same time maintain their original values and significant cultural features (Della Lucia, M., & Trunfio, M., 2018). Furthermore, virtual-based reconstruction and rehabilitation techniques do not necessarily require large physical places and architectural areas to implement renovations and modifications of historical buildings. They allow children and new generations to be familiar with valuable architecture achievements and learn beneficial measures and information of the original culture (Psomadaki et al., 2019). Mohammed-Amin, R. K., & Ali, A. F. (2020) carried out a study to investigate the critical role and major contribution of virtual-based reconstruction and rehabilitation in renovating historical buildings with maintaining their traditional characters and historical cultural values. To achieve the research goal, Mohammed-Amin, R. K., & Ali, A. F. analyzed the historical Sarai building which is in Sulaimani city related to the Iraqi Kurdistan area. They reported the significance of rehabilitation practices in transferring old buildings and obsolete facilities into useful educational buildings that can act as museums to provide original values and cultural measures for people of different ages. Further, they reviewed old and new approaches used for ancient buildings reconstruction and rehabilitation. They stated that mix renovation is used in some cases to repair, reconstruct, and rehabilitate old buildings and adding modern structures to the old building, making it historical and modern simultaneously, as indicated in (Figure 1).

Figure 1: (Left): The Glass pyramid built at the Louvre entrance. (Right): The ROM crystal expansion. (Mohammed-Amin, R. K., & Ali, A. F., 2020)

Regarding their case study, Mohammed-Amin, R. K., & Ali, A. F. revised the stages and years across which the historical Sarai building changed from ordinary building t o become a substantial icon for the Iraqi Kurdistan. Figure 2 illustrates the old Sarai buildings, and the renovated Sarai building executed in 1929 Figure 2.

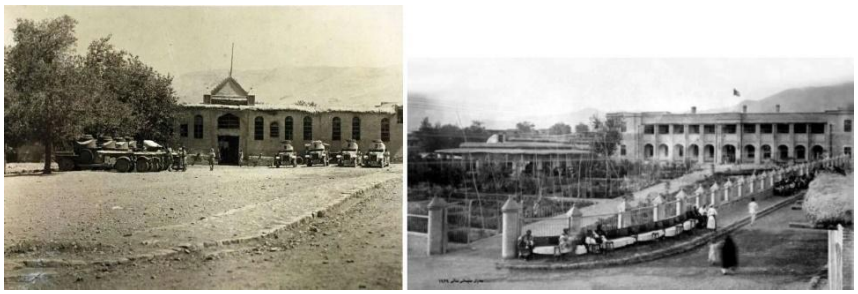


Figure 2: (Left): The original Sarai Building. (Right): The reconstructed Sarai building (1929). (Mohammed-Amin, R. K., & Ali, A. F., 2020)

To shed further light on the Sarai building renovation, Mohammed-Amin, R. K., & Ali, A. F. conducted surveys with 42 business owners and employees working around the Sarai building. In addition, they conducted two interviews, one via telephone call and the other was in-person with the Sulaimani Antiquities Directors. Through their surveys and interviews, participants affirmed that Sarai was greatly vital due to its architectural, symbolic, cultural, and historical values besides its strategic location at the heart of Iraqi Kurdistan. Also, they reported that the Iraqi government planned to convert the Sarai building into a museum. Moreover, interviews revealed that several efforts have been conducted to repair and renovate the Sarai building between 2008 and 2013. Soto-Martin et al. (2020) executed research to analyze the major role of digital-based reconstruction and contribution in rehabilitating historical buildings virtually to provide immersive and interactive experience. To achieve the study goal, Soto-Martin et al. depended on digital models that are integrated with immersive and interactive virtual reality environment. They visualized their model via Windows-Mixed Reality. They implemented their approach at the United Nations' Education, Science, and Culture Organization (UNESCO). The place that was virtually modeled was the World Heritage Site in Spain (Canary Islands). The study offered architectural models of the Saint Augustine Church in La Laguna and for its portraits. The digital imaging D Stretch tool was implemented to reconstruct architectural structures of the portraits. Aiello, D., & Bolognesi, C. (2020) published a paper through which they explored the digital reconstruction and rehabilitation implementation to recover Santa Maria delle Grazie building located in Milan, Italy.

Their aim was to utilize digital replicas to protect and enhance the historical heritage. Aiello, D., & Bolognesi, C. depended on three-dimensional (3D) modelling of several arts and historical works in Santa Maria delle Grazie. Their 3D modelling results revealed that digital reconstruction and rehabilitation was capable of recovering and reconstructing historical buildings and monuments with higher accuracy degree. Also, implementing virtual based building helped provide dynamic recovery of several archaeological sites via digital replicas. These digital replicas made 3-D modelling of numerous portraits and arts associated with Leonardo da Vinci such as Last Supper painting. Bruno et al. (2022) conducted a study to examine the critical role of digital reconstruction and rehabilitation in recovering historical building and maintaining their cultural characteristics. They relied on VERBuM products and 3D modelling of old structures and historical facilities. Their analysis findings indicated that virtual refurbishment and restoration have great potential in managing architectural and cultural heritage conservation of historical buildings. In addition, the VERBuM product was capable to offer virtual environment and 3D modelling of historical buildings to enable people to understand and recognize architectural heritage and cultural values of ancient buildings. Salah Gharib, M., and Ahmed Aboushal, E. (2020) conducted research to examine the positive impact of the use of digital reconstruction and rehabilitation on restoration of heritage towns and middle cities. They introduced Geographical Information System (GIS), in addition to the Google Maps to retrieve Qaitbay castle plaza situated in Alexandria Egypt. M. Salah Gharib, and E. Ahmed have noted that there are certain challenges associated with the digital-based heritage environments attributed to the theatricity of interaction when it comes to the deficiency of thematic interaction in terms of the lack of cultural materials and legalization of history of the renovated edifice.

Therefore, Salah Gharib, M., and Ahmed Aboushal, E. introduced digital rehabilitation feeding it with more historical data and databases to allow the enhancement of cultural content and architectural values. The outcome of their analysis impacted positive results in that the GIS and implementation of Google Maps have given a more detailed information on the Qaitbay castle plaza site effectively. It allowed interacting with the historical data which was linked to this ancient building and presenting them dynamically. Sampaio et al. (2021) conducted a study aimed at exploring the use of the virtual-based rehabilitation and reconstruction of historical buildings. They relied on Historic Building Information Modelling (HBIM) through which they made conversion, rehabilitation, and preservation of heritage values in buildings. Sampaio et al. reported that HBIM technology is greatly considerable and significant to enhance the rehabilitation and reconstruction based on digitalization techniques. Their analysis results confirmed that HBIM has dynamic capability and higher potential to model the roofs, walls, floors, finishes, and decorative details of old buildings with higher accuracy and interaction. In addition, results revealed that historical data and cultural information can be integrated into the historical building modelling to provide more details and knowledge related to the ancient buildings and make the virtual reconstruction more effective and practical. Chong et al. (2021) published a paper which aimed to investigate and evaluate the critical role of

digital rehabilitation and virtual-based reconstruction in recovering and rehabilitating historical heritage buildings. Chong et al. deepened on a comprehensive literature review through which several research publications and peer-reviewed articles were explored and reviewed (between 2007 and 2020) to shed light on virtual rehabilitation significances and major contributions. The comprehensive literature analysis reviewed 290 research articles.

The results revealed that digital rehabilitation provided functional approaches to transfer historical information and cultural details with higher degree of effectiveness, accuracy, and enriching manner. Furthermore, findings confirmed that virtual-based reconstruction provides more entertainment, and flexible learning techniques to enable people benefit from historical data and understand cultural aspects of ancient buildings. Hajirasouli et al. (2021) executed a study to explore and identify major contributions and key advantages of virtual reality and digitalization techniques implemented to rehabilitate and reconstruct historical sites and endangered heritage buildings. Hajirasouli et al. relied on a theoretical framework. They investigated a case study of the historical Kandovan village site, Iran. To fulfill their study objective, they have employed the REVIT software and AutoCAD software tools to create 2D and 3D models of the historical site and provide an opportunity to involve the real-world conditions such as the textures and materials, lighting, climatic parameters and other effects. Their model and analysis outcome proved that their rehabilitation through the application of AutoCAD and REVIT in virtual mode had effectively demonstrated an implication of important cultural nuances and historical facts of the Kandovan village site. Moreover, the software tools used in REVIT and AutoCAD had the practical ability to present the actual information of the historical data and culture related to Kandovan village site. Champion et al. (2021) published a textbook through which the definition, key characteristics, and contributions of virtual-based heritage and digital reconstruction were investigated and described. Champion et al. implemented a comprehensive literature review analysis to collect data. In addition, they supported their publication with several digital photos that describe and illustrate the critical definition and features of virtual-based rehabilitation.

Further, the textbook discussed and highlighted major limitations and key obstacles that hinder the implementation of digital reconstruction and virtual-based rehabilitation. Their analysis results, in their textbook, revealed that digital rehabilitation and virtual restoration are greatly beneficial and effective in providing detailed data on the historical aspects and cultural values of ancient buildings. They also are vital to enable people to understand several important aspects of historical sites via active digitalization techniques. Bozorgi, K., & Lischer-Katz, Z. (2020) researched to investigate the critical useful impact of digital rehabilitation implementation to restore historical buildings based on a virtual reality manner. Bozorgi, K., & Lischer-Katz, Z. depended on analyzing a case study related to Kerman desert city in Ganjali Khan Project, Iran through which an overall historical documentation and cultural details presentation were applied. The analysis results indicated that virtual reality and digitalization techniques were successful to offer active and functional presentation of overall historical database and cultural details associated with the Kerman desert city in Ganjali Khan Project, Iran. Cantatore et al. (2020) performed research to explore the substantial contribution of digital-based restoration of heritage sites and historical areas in restoring these structes and areas depending on digital techniques. Cantatore et al. explored a case study through which a historical building (cryptoporticus) in the archaeological site of Egnatia, located in Italy, was investigated.

Cantatore et al. implemented virtual tools and digitalization techniques to renovate this historical site. Their analysis results revealed that the vestural instruments and digitalization technical tools had successfully provided practical representation of historical information associated with cryptoporticus, expressing functional details of the ancient culture and historical values of this site, enabling people to understand these historical data effectively. Shi, F., Wang, H., & Li, Z. (2024) develops a virtual restoration workflow for the *Nine Eyes Watchtower* along the Great Wall. It combines data from physical evidence, historical documentation, and comparative architectural study. It is an amalgamation of survey technologies, historical research and computer modelling, to consider the architectural as well as historic value of the site. The virtual restoration is done in a systemic way, data acquisition, interpretation, modelling and restoration simulation. This is applied to retain authenticity in the restoration because restoration possibilities are visualized. Shi, F., Wang, H., & Li, Z. (2024)

Chen, X., Zhang, Y., & Luo, W. The item of focus in this paper is the lost drum towers in the Donge ethnicity of southwestern China. It is being extensively captured using a mixture of both manual and 2D photography with oblique UAV (drone) photography of internal and external zones. The

article demonstrates the possibility of digital technologies to produce descriptive records and simulations of endangered architectural structures, facilitating conservation planning and interventions **Figure 3**. **Table (1)** presents a summary of major contributions and results of the research publications addressed in the literature review.

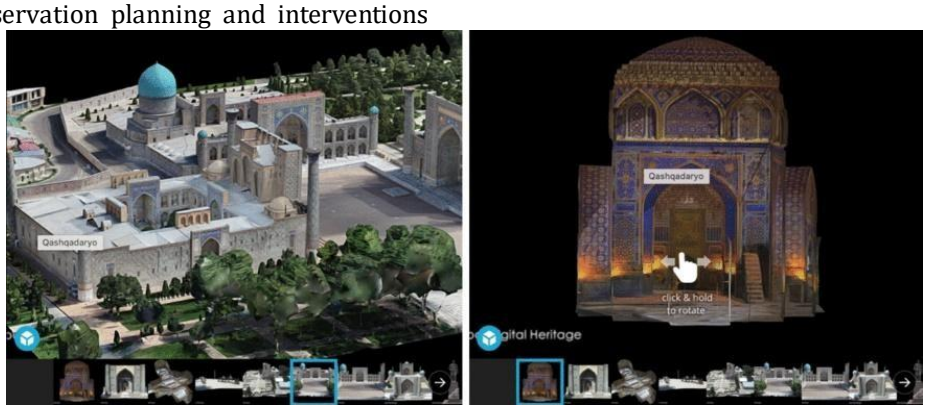


Figure 3: A 3D model of Registan Complex, b 3D model of prayer hall- "Global Digital Heritage." https://globaldigitalheritage.org/project/qashqadaryo/

Table 1: Summary of the Literature Review

No.	Authors	Year	Title	Major Contributions and Findings
1	Mohammed-Amin, R. K., & Ali, A. F.	2020	Beyond Structural Preservation: The Case of Restoring the Sarai Building as a Museum	Results indicated the significance of rehabilitation practices in transferring old buildings and obsolete facilities into useful educational buildings that can act as museums to provide original values and cultural measures for people of different ages. Further, old and new approaches used for ancient buildings' reconstruction and rehabilitation were addressed and reviewed. Results indicated that mix renovation can be used in some cases to repair, reconstruct, and rehabilitate old buildings and adding modern structures to the old building, making it historical and modern simultaneously.
2	Soto-Martin, O., Fuentes-Porto, A., & Martin-Gutierrez, J.	2020	A digital reconstruction of a historical building and virtual reintegration of mural paintings to create an interactive and immersive experience in virtual reality	The results indicated that digital-based reconstruction is effective in rehabilitating historical buildings virtually to provide immersive and interactive experience. Also, the digital models integrated with immersive and interactive virtual reality environment and Windows-Mixed Reality were capable to present historical data of the ancient site effectively. The World Heritage Site in Spain (Canary Islands) was successfully and virtually modeled. The study offered architectural models of the Saint Augustine Church in La Laguna and for its portraits. The digital imaging DStretch® tool was implemented to reconstruct architectural structures of the portraits.
3	Aiello, D., & Bolognesi, C.	2020	Reliving history: the digital reconstruction of the convent of Santa Maria delle Grazie in Milan	Their 3D modelling results revealed that digital reconstruction and rehabilitation was capable of recovering and reconstructing historical buildings and monuments with higher accuracy degree. Also, implementing virtual based building helped provide dynamic recovery of several archaeological sites via digital replicas. These digital replicas made 3-D modelling of numerous portraits and arts associated with Leonardo da Vinci such as Last Supper painting.
4	Bruno, S., Scioti, A., Pierucci, A., Di Noia, T., & Fatiguso, F.	2022	VERBUM–virtual enhanced reality for building modelling (virtual technical tour in digital twins for building conservation)	The analysis findings indicated that virtual refurbishment and restoration have great potential in managing architectural and cultural heritage conservation of historical buildings. In addition, the VERBuM product was capable to offer virtual environment and 3D modelling of historical buildings to enable people to understand and recognize architectural heritage and cultural values of ancient buildings.
5	Salah Gharib, M., & Ahmed Aboushal, E.	2020	Restoration and Development of Urban Heritage Sites (Rehabilitation of Middle cities and Heritage towns)	The analysis results revealed that GIS and Google Maps implementation has provided more detailed information on the Qaitbay castle plaza site successfully. It enabled effective interaction and dynamic presentation of historical data connected with this ancient building.
6	Sampaio, A. Z., Pinto, A. M., Gomes, A. M., & Sanchez-Lite, A.	2021	Generation of an HBIM Library regarding a Palace of the 19th Century in Lisbon	The analysis results confirmed that HBIM has dynamic capability and higher potential to model the roofs, walls, floors, finishes, and decorative details of old buildings with higher accuracy and interaction. In addition, results revealed that historical data and cultural information can be integrated into the historical building modelling to provide more details and knowledge related to the ancient buildings and make the virtual reconstruction more effective and practical.
7	Chong, H. T.,	2021	Comprehensive systematic	The comprehensive literature analysis reviewed 290 research articles. The

	Lim, C. K., Rafi, A., Tan, K. L., & Mokhtar, M.		review on virtual reality for cultural heritage practices: coherent taxonomy and motivations	results revealed that digital rehabilitation provided functional approaches to transfer historical information and cultural details with higher degree of effectiveness, accuracy, and enriching manner. Furthermore, findings confirmed that virtual-based reconstruction provides more entertainment, and flexible learning techniques to enable people to benefit from historical data and understand cultural aspects of ancient buildings.
8	Hajirasouli, A. Banihashemi, S. Kumarasuriyar, A., Talebi, S., & Tabadkani, A.	2021	Virtual reality-based digitisation for endangered heritage sites: Theoretical framework and application	The modeling and analysis results confirmed that using AutoCAD and REVIT as a virtual-based rehabilitation had successfully illustrated significant cultural details and historical information of the Kandovan village site. In addition, REVIT and AutoCAD software tools had the effective capability to provide actual details of historical information and cultural data associated with Kandovan village site.
9	Champion, E., Rahaman, H., Bekele, M., and Mcmeekin, D.	2021	Virtual Heritage: A Guide	The analysis results, in their textbook, revealed that digital rehabilitation and virtual restoration are greatly beneficial and effective in providing detailed data on the historical aspects and cultural values of ancient buildings. They also are vital to enable people to understand several important aspects of historical sites via active digitalization techniques.
10	Bozorgi, K., & Lischer-Katz, Z.	2020	Using 3D/VR for research and cultural heritage preservation: project update on the virtual Ganjali Khan Project	The analysis results indicated that virtual reality and digitalization techniques were successful to offer active and functional presentation of overall historical database and cultural details associated with the Kerman desert city in Ganjali Khan Project, Iran.
11	Cantatore, E., Lasorella, M., & Fatiguso, F.	2020	Virtual reality to support technical knowledge in cultural heritage. The case study of cryptoporticus in the archaeological site of Egnatia (Italy)	Cantatore et al. (2020) performed research to explore the substantial contribution of digital-based restoration of heritage sites and historical areas in restoring these structes and areas depending on digital techniques. Cantatore et al. explored a case study through which a historical building (cryptoporticus) in the archaeological site of Egnatia, located in Italy, was investigated. Cantatore et al. implemented virtual tools and digitalization techniques to renovate this historical site. Their analysis results revealed that the vestural instruments and digitalization technical tools had successfully provided practical representation of historical information associated with cryptoporticus, expressing functional details of the ancient culture and historical values of this site, enabling people to understand historical data effectively.
12	Shi, F., Wang, H., & Li, Z.	2024	From Data Acquisition to Digital Reconstruction: Virtual Restoration of the Great Wall's Nine Eyes Watchtower	Developed a systematic virtual restoration workflow combining data acquisition, historical interpretation, and digital modeling. Preserved authenticity and allowed visualization of restoration outcomes.
13	Chen, X., Zhang, Y., & Luo, W.	2024	Digital Construction Preservation Techniques of Endangered Heritage Architecture: A Detailed Reconstruction Process of the Dong Ethnicity Drum Tower	Digitization and preservation of endangered Dong ethnic drum towers with the use of applied UAVs, manual measurements and digital reconstruction. Enabling virtual conservation planning of high-level detail.

2. METHODOLOGY

The paper cooperates with the mixed-method approach to research the efficiency and meaning of digital reconstruction and rehabilitation in saving the historical buildings in Sulaymaniyah, in the Kurdistan Region of Iraq (KRG), and extends to three case studies in Saray Sulaymaniyah, the Peramerd House and Hotel Farah. The methodology is separated into two primary parts, theoretical framework, and the practical study consisting of field surveys and questionnaire study. The theoretical section of the present research is based on thorough literature analysis and the review of the related works, which then developed in the background section. This review dwells on the development of digital reconstruction methods, including 3D modeling, Building Information Modeling (BIM), Historic BIM (HBIM), Geographic Information Systems (GIS), and virtual reality (VR) methods, which have been adopted in the world to conserve and restore historic buildings. This theoretical research enables the study to single out significant principles and best practices in digital heritage preservation and determine how they can be applied to the environment of Sulaymaniyah. The theoretical background can be considered a guide to see how digital technologies are able to preserve cultural and architectural identity of the historical buildings facilitating adaptive reuse and interaction with the modern world.

The research process of this paper will comprise capturing the current state of the sampled buildings-Saray Sulaymaniyah, Farah Hotel and Peramerd House by using existing archival materials,

photographs, architectural layouts and field notes. Such materials are then read, and digital modeling techniques are used to visualize the possible reconstruction and rehabilitation processes. The paper focuses on the use of non-invasive digital technologies, where no physical damage will be done to the actual building during the rehabilitation process 3D digital representations and renderings are developed to demonstrate potential results of the restoration to keep the original architecture intact and add some modern functionality to reuse it as an educational and cultural facility.

2.1. Hypothesis

The historical integrity, cultural values, and architectural identity of heritage buildings can also be preserved in Sulaymaniyah by means of digital reconstruction and rehabilitation techniques (e.g., 3D modelling, Historic Building Information Modelling (HBIM), and virtual environments), which is cheaper, much more advantageous than traditional construction techniques, and more likely to enhance public awareness and engagement in preserving heritage sites.

2.2. Aims

- To test and assess electronic reconstruction methods (3D modelling, HBIM, virtual environments) on three historic buildings at Sulaymaniyah city-KRG/IRQ (Saray Sulaimani, Hotel Farah and Peramerd House) to digitally conserve the historical, architectural and cultural value of the buildings without having to physically restore them to their former state.
- To understand popular opinion and acceptance of using digital means of rehabilitating historic buildings, the impact of such practices on cultural consciousness, architectural identity, and potential for adaptive reuse.

2.3. Practical Study

To complement the theoretical analysis, a practical field study was conducted using a structured questionnaire distributed among 50 participants, who attended a formal event of (*Cultural Heritage Organization*) https://www.facebook.com/share/1JWgA1aUiK/?mibextid=wwXIfr), (located in *Cultural Factory Sulaymaniyah*, the event was to announce the projects that managed by *CHO (*the researcher is a cofounder of *CHO*) and an active participant in the *CHO* activities, the technical work was done by the researcher in cooperation with 3 teams, historical empathy, historical evolution of cities and Narrative spaces team this with a team work of volunteers. The participants included Local officials in Sulaymaniyah Governorate, local architects, planners, historians, engineers, cultural heritage professionals, university students, academics, teachers, NGO employees and residents who live or work near the historical sites. The aim of the questionnaire was to assess public awareness, perception, and opinions regarding the role of digital reconstruction and rehabilitation in preserving historical structures like (*Saray Sulaymaniyah AR, Hotel Farah AR, and Peramerd House VR*). The main questions revolved around how well the participants knew such buildings, how they regarded the significance of preserving culture and historical identity, the usefulness of digital reconstruction over traditional ones, and the perceived advantages of transforming the sites into an interactive virtual world or a museum. Table 2.

Quantitative and qualitative analysis of the data obtained in the questionnaire was done. Statistical tools were used to find out trends and attitudes in general among various demographic groups. The thematic classification of open-ended responses was also done to extract information on the cultural and emotive values attached to the historical buildings and recommendations on future projects of digital heritage. The analysis has confirmed the hypotheses of the theory and given a better imagination of the community as relating to the usage of digital technologies in heritage conservation. This presentation methodology, combined with one another, facilitates a thorough assessment of the potential of digital reconstruction and rehabilitation in Sulaymaniyah and gives viable suggestions on how digital reconstruction and rehabilitation may be used in similar historical and cultural contexts in the future.

According to the evaluated literature, several important variables were defined that impact greatly upon the success of the digital reconstruction and rehabilitation of historic buildings. This consists of the quality and accessibility of historical information that underlies any credible virtual model, the tools and software applied, which should be 3D modeling, HBIM, VR, and GIS, suitable level of detail, interactivity, and realism, and cultural and architectural value of the heritage site, which dictates the level and nature of reconstruction. Besides, community participation and awareness among the population proved to be one of the key social factors, which could positively affect the perceptions of the digital heritage projects and their sustainability in the long term. Luckily, institutional and financial support (finally) were also found to have a significant role to play since they influence scalability and translating digital rehabilitation initiatives into practice. The combination of these variables determines the efficacy, truthfulness and value of

online interventions in conserving historical sites. Figure (4) and Table (3).

Table 2: Case Studies Description (Researcher)

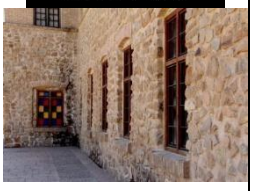
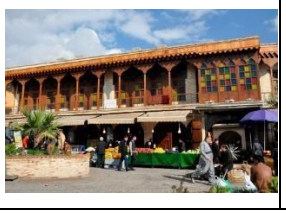
N.	Project	Description	Photos	
1	Saray Slemani	The building is in the center of Sulaymaniyah and is extremely important heritage-wise as the building was built in 1928 and refurbished in 2012. The project, which is part of a digital revitalization process, involves the use of the Talk to Sara app developed as an augmented reality (AR) application to make the history of the building come alive. Using the app, the visitors can enjoy the interesting stories showcasing the importance of certain events and prominent people in the past of the city. This is an interactive and experiential approach to storytelling which is available through mobile devices and therefore serves to validate and transmit the cultural memory of Sulaymaniyah. https://youtu.be/tYvTj_hTSHU?si=UV-PBw1FRSqDRGji	 	 
2	Peramerd House	It is a historic house in the city of Sulaymaniyah that housed one of the prominent political and social figures of the city and is the object of a research project by using virtual reality (VR). The project will help in preserving and sharing this legacy of this great personality digitally through virtual tours and storytelling. https://youtu.be/pWvblCwz0BE?si=-Q6rj5QSB02M2NRB		
3	Hotel Farah	Hotel Farah is a historical structure that has a high heritage value, it is an old building constructed in 1930 and the renovations were done in 2014. In a digitalization process, the study employs an augmented reality (AR) app that is storytelling-based. The proposed AR solution will ensure the maintenance and communication of the history of the building by using immersive digital stories.		

Figure 4: The Digital Revitalization Project (researcher)

Table 3: Questioner Form (Researcher)

No.	Category	Question	1	2	3	4	5
			0%	25%	50%	75%	100%
1	**Awareness and Interest**	Are you aware of heritage buildings in your area					
2		How interested are you in heritage buildings and their preservation					
3	**Virtual Reality Experience**	Have you ever used virtual reality (VR) technology before?					
4		If yes, how frequently do you use VR?					
5		Hava you ever heard about the VR applications?					
6	**Perception and Attitudes**	virtual reality can enhance the experience of visiting heritage buildings?					
7		**Virtual tours** / VR can be used to promote heritage buildings?					
8		**Educational program** / VR can be used to promote heritage buildings?					
9		**Interactive exhibits** / VR can be used to promote heritage buildings?					
10	**Experience and feedback**	Have you ever experienced a virtual tour of a heritage building					
11		If yes, please rate your experience.					
12		What aspects of the VR experience did you find most engaging? **Realistic visuals**					

13		What aspects of the VR experience did you find most engaging? **Interactive elements**					
14		What aspects of the VR experience did you find most engaging? **Educational content**					
15	**Preferences and Recommendations**	Would you be more likely to visit a heritage building in person after experiencing it in VR?					
16		would you suggest improvements for VR experiences of heritage buildings?					
17		Do you think VR can play a significant role in the preservation and education of cultural heritage?					
18		How likely are you to recommend a VR experience of a heritage building to others?					
19		To what extent did you feel the heritage and historical aspects of the historical aspects you visited virtually / Material – Color					
20		To what extent did you feel the heritage and historical aspects of the historical aspects you visited virtually / Spirit of place - Identity					
1–5 Likert (1=Strongly Disagree, 5=Strongly Agree)							

3- Data analysis

The data analysis evaluates how digital reconstruction and rehabilitation contribute to heritage awareness and conservation of historical buildings in Sulaymaniyah. Based on responses from 50 participants representing architects, governmental staff, public representatives, and NGOs, the findings indicate a generally strong acceptance of digital tools in heritage preservation.

Participants demonstrated high awareness of the cultural and architectural value of the selected case study buildings (Saray Sulaymaniyah, Hotel Farah, and Peramerd House). Most respondents agreed that augmented reality (AR) and virtual reality (VR) applications enhance understanding of historical narratives and architectural features. The immersive and interactive qualities of these technologies were identified as key factors in strengthening engagement and cultural appreciation.

The results also show that digital reconstruction supports non-invasive preservation by documenting architectural elements and simulating restoration scenarios without physically altering the structures. Professional participants, particularly architects and planners, expressed confidence in the accuracy and potential of 3D modeling and HBIM tools. However, moderate evaluations of governmental and financial support suggest that institutional backing remains a limiting factor in expanding digital initiatives. Importantly, many respondents indicated that experiencing heritage buildings digitally increases their motivation to visit the sites physically, demonstrating that digital methods enhance both awareness and tourism potential. Overall, the findings confirm that digital reconstruction and rehabilitation serve as effective tools for preserving architectural identity, enhancing public awareness, and supporting sustainable heritage conservation in Sulaymaniyah.

- **Demographic Characteristics:**

Demographic data analysis reveals that there was an equal representation of the stakeholder groups. The most numerous group (36%), which had the key role in the conservation, was represented by the architects and planners. One quarter of the government staff and 20% of the individuals in the NGOs and representatives of government, respectively. The sample was of a good proportion of the ages and experience in the workplace, a factor that makes the findings more reliable. The population heterogeneity can guarantee that various views of professional and community-based actors will be included in

the data, which enhances representativeness of the results. **Table 4**

Table 4. Demographic Distribution of Participants (N = 50)

Category	Sub-category	Frequency	Percentage
Professional Group	Architects / Planners	18	36%
	Governmental Staff	12	24%
	Public Representatives	10	20%
	NGO Members	10	20%
Gender	Male	32	64%
	Female	18	36%
Age Group	20–30	14	28%
	31–40	21	42%
	41–50	10	20%
	51+	5	10%
Experience	<5 Years	8	16%
	5–10 Years	17	34%
	11–20 Years	15	30%
	>20 Years	10	20%

- **Descriptive Statistics for Participation Variables:**

The results reveal strong positive trends across cognitive (awareness), attitudinal (perception), experiential (immersion), and behavioral (future intention) variables.

First, awareness (4.3) and interest in preservation (4.4) are already high, indicating a strong cultural foundation. This baseline awareness appears positively related to favorable perceptions of VR effectiveness (4.5) and its educational role (4.6). Participants who value heritage preservation are more likely to support digital tools that enhance it. Second, although prior VR experience scored moderately (3.6), knowledge of VR applications is relatively high (4.1). This suggests that acceptance of VR in heritage contexts does not depend solely on frequent prior use. Instead, perceived usefulness—particularly educational value (4.6) and interactivity (4.5)—plays a stronger role in shaping positive attitudes. Third, experiential variables (realism 4.4, interactivity 4.5, overall experience 4.3) show a direct relationship with identity perception (material authenticity 4.2; spirit of place 4.3). Higher immersion appears linked to a stronger emotional and cultural connection, indicating that well-designed digital environments can successfully communicate both tangible and intangible heritage values. Finally, behavioral intention variables demonstrate a clear outcome effect: high perception and immersion scores correspond with strong willingness to visit physically (4.4) and recommend the experience (4.5). This indicates a positive correlation between digital engagement and real-world cultural participation see **Table 5.**

Table 5. Data analysis for the variables

No.	Category	Indicator (Shortened)	Mean Score	Interpretation
1	**Awareness**	Awareness of heritage buildings	4.3	High
2	**Interest**	Interest in preservation	4.4	Very High
3	**VR Experience**	Previous VR use	3.6	Moderate
4	**VR Awareness**	Knowledge of VR applications	4.1	High
5	**Perception**	VR enhances heritage visits	4.5	Strong Agreement
6	**Promotion**	VR promotes heritage buildings	4.4	Strong Agreement
7	**Education**	VR as educational tool	4.6	Very Strong Agreement
8	**Interactivity**	Interactive elements engaging	4.5	Strong Agreement
9	**Realism**	Realistic visuals effective	4.4	Strong Agreement
10	**Experience**	Overall virtual tour rating	4.3	Positive
11	**Identity**	Material & color authenticity	4.2	High
12	**Spirit of Place**	Sense of identity & atmosphere	4.3	High
13	**Behavior**	Likely to visit physically after VR	4.4	Strong
14	**Preservation Role**	VR role in preservation & education	4.6	Very Strong
15	**Recommendation**	Recommend VR to others	4.5	Strong

4- Discussion

The findings of this study reveal a strong and coherent relationship between heritage awareness, perception of digital technologies, immersive experience, and behavioral intention. The high mean scores for awareness (4.3) and interest in preservation (4.4) indicate that participants already possess a solid cultural foundation and recognize the importance of safeguarding historic buildings. This pre-existing awareness appears to positively influence their acceptance of virtual reality (VR) as a preservation and educational tool. In other words, individuals who value heritage are more likely to support innovative methods that enhance its protection and presentation.

Although previous VR usage scored moderately (3.6), participants demonstrated high agreement regarding the effectiveness of VR in enhancing heritage visits (4.5) and its educational value (4.6). This suggests that frequent prior exposure to VR is not a prerequisite for its acceptance. Instead, perceived usefulness—particularly in terms of education, promotion, and engagement—plays a more decisive role. The strong evaluation of VR as an educational tool confirms its capacity to communicate architectural knowledge, historical narratives, and cultural meanings in an accessible and interactive manner.

The results also show a clear connection between immersive qualities and identity perception. High scores for interactive elements (4.5) and realistic visuals (4.4) correspond with strong perceptions of authenticity in material representation (4.2) and spirit of place (4.3). This relationship indicates that immersive digital environments can successfully convey both tangible and intangible heritage values. When users feel engaged and visually connected to reconstructed spaces, their emotional attachment and understanding of cultural identity increase.

Furthermore, behavioral indicators demonstrate that digital engagement positively influences real-world action. The strong likelihood of visiting heritage sites physically after experiencing them virtually (4.4) and recommending VR experiences to others (4.5) confirms that digital reconstruction enhances—not replaces—physical heritage interaction. Instead, VR acts as a motivational and promotional bridge between virtual and physical environments.

Overall, the discussion highlights a chain relationship: awareness supports acceptance of digital tools; immersive experience strengthens cultural and emotional connection; and positive perception leads to increased engagement and preservation support. These findings reinforce the role of

digital reconstruction as a complementary, sustainable strategy that enhances heritage awareness, education, and community participation while maintaining respect for the physical integrity of historic buildings.

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5- Conclusions

- The study confirms that virtual reality and digital rehabilitation methods strengthen public understanding of architectural and cultural values by providing immersive and interactive experiences that improve engagement with historic buildings.
- Among all evaluated variables, the educational role of VR received the highest agreement, demonstrating that digital tools are widely perceived as effective platforms for knowledge transfer and cultural interpretation.
- The strong relationship between interactive features, realistic visualization, and the perceived “spirit of place” indicates that well-designed digital environments can successfully communicate both tangible and intangible heritage values.
- Participants strongly supported the integration of VR into heritage strategies as a non-invasive, supportive approach that enhances documentation, interpretation, and promotion while preserving the original architectural fabric.
- The findings demonstrate that virtual experiences positively influence behavioral intentions, particularly the willingness to visit heritage sites physically and recommend them to others, thereby supporting tourism and community involvement.
- In contexts with financial or physical conservation constraints, digital reconstruction offers a cost-effective and scalable solution that supports long-term preservation, public education, and cultural sustainability.

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