REPUBLIC OF TURKEY
YILDIZ TECHNICAL UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF ART AND DESIGN
INTERACTIVE MEDIA DESIGN MA PROGRAM

MASTER'S THESIS

Reviving Lost Cultural Heritage Using Extended Reality Technology: A Case Study on The Historic Structure of Aleppo Hamidi Hospital

MUHAMMET NECİP ŞAĞAR
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SUPERVISOR
ASSOC. PROF. DR. BAHADIR UÇAN

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The study entitled “Reviving Lost Cultural Heritage Using Extended Reality Technology: A Case Study on The Historic Structure of Aleppo Hamidi Hospital” prepared by Muhammet Necip ŞAĞAR, was deemed **successful with unanimity** upon the defense examination held on **27/01/2023** and was accepted by our jury as a **master's thesis** in the Interactive Media Design Program of the Art and Design Department.

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ÖZET

GENİŞLETİLMİŞ GERÇEKLİK TEKNOLOJİSİ KULLANILARAK KAYIP KÜLTÜREL MİRASI CANLANDIRMAK: HALEP HAMIDIYE HASTANESI VAKA ÇALIŞMASI

Genişletilmiş Gerçeklik (XR) teknolojisinin kültürel bilişim ve kültür mirası çalışmalarında entegrasyonu, sürdürülebilir kültürel miras (CH) korumanın yeni imkânlarını açmıştır, ama mevcut uygulamalar çoğunlukla mevcut veya tehlike altındaki miras elemanlarını iyileştirme ve koruma üzerine odaklanmıştır, kaybolan CH sitelerinin dijital ortamda yeniden yapılandırılması ve deneyimlenmesi üzerine değil. Bu çalışma, XR teknolojisinin kaybolan CH sitelerinin sanal ortamlarda yeniden yapılandırılması ve deneyimlenmesi potansiyelini araştırmak ve CH koruma çabalarına katkıda bulunma ve kullanıcılara derinlemesine deneyimler sağlama potansiyelini anlamaya yönelikti. Sonuçlar, XR deneyimlerinin kayıp CH sitelerini yeniden yapılandırma ve deneyimleme için etkili bir yöntem olabileceğini gösterirken, aynı zamanda verimliliklerini etkileyen çeşitli faktörleri de ortaya çıkardı ve kullanıcılar için çeşitli anlamlarına ilişkin bilgi sağladı. Anahtar belirleyici faktörler, XR yeniden yapılandırmalarının doğruluğu ve gerçekliği, sanal yeniden yapılandırmanın dalış ve etkileşimsel nitelikleri ve deneyimin basit, eğlenceli ve kullanıcı merkezli tasarımıydı. Ayrıca, sitenin ve teknolojinin daha az tanıdığı kişiler için deneyimin eğitim ve yorumlama yönlerinin de dikkate alınmasının önemini vurguladı. Sınırlamalarına rağmen, bu bulgular, XR teknolojisinin kayıp CH sitelerini yeniden yapılandırma ve deneyimleme için kullanılmasının potansiyel faydaları ve sınırlamaları hakkında değerli bilgi sağlar, CH koruma çalışmalarında bu yaklaşımların dikkate alınmasının önemini vurgular, bu alandaki araştırmacılara rehberlik sağlar ve bu yaklaşımların tasarım ve geliştirilmesini iyileştirme önerileri sunar.

Anahtar Kelimeler: İnsan-bilgisayar etkileşimi, kullanıcı Deneyimi, Genişletilmiş Gerçeklik, Kültürel miras, Mimarlık

ABSTRACT

REVIVING LOST CULTURAL HERITAGE USING EXTENDED REALITY TECHNOLOGY: A CASE STUDY ON THE HISTORIC STRUCTURE OF ALEPPO HAMIDI HOSPITAL

The integration of Extended Reality (XR) technology in cultural computing and heritage studies has opened up new possibilities for sustainable cultural heritage (CH) preservation, but present practices have mainly focused on enhancing and preserving existing or endangered heritage elements rather than on digital reconstruction and experience of lost CH sites. This study aimed to explore the potential of XR technology for reconstructing and experiencing lost CH sites in virtual environments, and to understand its potential for contributing to CH preservation efforts and providing immersive experiences to users. Results indicated that XR experiences can be an effective approach for reconstructing and experiencing lost CH sites, but also revealed various factors that influence their efficiency and provide insight into its diverse implications for users. Key determinative factors included the accuracy and authenticity of XR reconstructions, the immersive and interactive qualities of the virtual reconstruction, and the design of the experience to be simple, entertaining, and user centered. The study also highlighted the importance of considering the educational and interpretive aspects of the experience for those who are less familiar with the site or the technology. Despite limitations, the findings provide valuable insight into the potential benefits and limitations of using XR technology for digital reconstruction and experience of lost CH sites, highlight the importance of considering these approaches in CH preservation efforts, and provide guidance for practitioners in this field and recommendations for improving the design and development of these approaches.

Keywords: Human-computer interaction, User experience, Extended Reality, Cultural heritage, Architecture

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Muhammet Necip ŞAĞAR
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LIST OF ABBREVIATIONS

3D	: Three-dimensional
AR	: Augmented Reality
CAD	: Computer Aided Design
CAVE	: Cave Automatic Virtual Environment
CH	: Cultural Heritage
C-VE	: Collaborative Virtual Environments
HCI	: Human-Computer Interaction
HMD	: Head-Mounted Display
ICOMOS	: International Council on Monuments and Sites
I-VR	: Immersive Virtual Reality
MR	: Mixed Reality
UNESCO	: United Nations Educational, Scientific and Cultural Organization
UNITAR	: United Nations Institute for Training and Research
WHC	: World Heritage Convention
VE	: Virtual Environment
VR	: Virtual Reality
TA	: Thematic Analysis
XR	: Extended Reality

1. INTRODUCTION

Extended Reality (XR) technology offers experiences that apply technology to narrow the gap between the real and digital worlds through the creation of immersive virtual environments which improve, modify, or alter the capabilities and features of reality, Cultural Computing literature has indicated that XR technology can be an essential contributor to heritage preservation projects. However, there are conflicting views and an overall lack of research regarding the capabilities and implications of XR practices on the applications of reviving lost cultural heritage (CH) in virtual environments (VE), where users can engage and interact in immersive and inventive cultural experiences.

The present research aims to establish an approach and evaluate applications for reviving lost CH sites in VEs using XR technology. This chapter introduces the study by first discussing the background of the study, followed by the research problem, research aims, objectives and questions, the significance and the limitations.

1.1. Background of the Study

Heritage forms the foundation of our identities and cultures, as it provides information about our past, its diversity and fruitfulness, and the development of our societies, helps us develop an awareness about ourselves, and highlights our values and priorities (The Heritage Council, n.d.), therefore, its loss endangers global stability and leads to disastrous consequences for communities, such as: the disappearance of historical and ethnographic values, diminished social cohesion, societal mental health issues, along with other numerous issues that affects our daily lives (Harvey, 2019), thus heritage preservation projects can influence and enhance almost every aspect of our lives. However, CH is consistently and repeatedly becoming exposed to a number of various man-made and natural threats. Consequently, there is a general trend toward increasing the availability and accessibility of heritage information to the general public in order to ensure the long-

term sustainability of heritage as well as to raise awareness of the importance and richness of heritage (Nofal et al., 2017).

Due to the increasing need for effective and cost-efficient solutions for preserving CH, recent developments in computer graphics and computer-aided design (CAD) have made it possible to accurately study, analyze, scan, record, preserve, visualize, represent, and reconstruct three-dimensional (3D) geometry of CH assets and objects. This widespread use of computer technology in cultural and heritage preservation projects has led to a significant expansion in the field of cultural computing, which refers to the emerging discipline that involves the use of computer technology to improve, represent, extend, and transform human creative products and processes in various fields such as arts, culture, humanities, and social sciences. Cultural computing is also considered a modern approach of cultural translation that applies scientific principles to represent the essential aspects of culture (Haydar, et al: 2011). Cultural computing and Heritage preservation projects by means of immersive technologies approaches have attracted much attention due to the recent widespread use of XR technology and the unique features it can offer. Yet, additional research in this area is needed to uncover what factors contribute to the experiences of lost CH sites in VEs, as most previous projects are based on cultural assets and endangered sites.

1.2. Research Problem

Integrating XR technology in the field of cultural computing and heritage studies introduces us to a new era of sustainable CH preservation (Hamurcu & Hamurcu, 2018). As a result, various galleries, libraries, archives, museums, and other organizations have been increasingly developing XR experiences in order to create exhibitions that are designed to improve the accessibility and preservation of CH elements (Noe, 2021). However, such experiences have frequently focused on enhancing and preserving existing or endangered heritage elements, where these experiences are inspired, influenced, and supported by the physical subjects, which also can be reached and observed in the real world. This set of research and practices demonstrates the capabilities of XR technology on specific approaches of heritage preservation schemes. Yet, it also highlights the lack of utilizing XR technology regarding lost CH - For instance, the reconstruction, archiving, and experiencing lost

CH sites in VEs, where users are also able to live cultural experiences that are no longer achievable in the actual world. As a result, the existing research is inadequate for XR practices that relate to the digital reviving schemes of lost CH sites.

1.3. The Research Aims, Objectives and Research Questions

Given the lack of research on utilizing XR technology in approaches related to lost CH, this study aims to establish an XR approach and evaluate its applications for reviving lost CH sites in VEs, where users are immersed and able to experience and interact with the provided environment, using the historic building of Aleppo Hamidi Gureba Hospital as a case study. To achieve this, the research objectives include:

OBJ 1: Observing common XR practices related to preserving heritage.

OBJ 2: Identifying characteristics that contribute to a better experience of CH sites in VEs.

OBJ 3: Exploring XR technology capabilities regarding applications of virtual reconstruction and experiencing of lost CH sites in immersive VEs.

Whereas the research questions sought to be answered within the scope of this research are:

Q 1: What implications can XR practices reflect on users' experiences and understanding of lost CH sites?

Q 2: How does the use of XR technology for reviving lost CH sites impact heritage preservation efforts?

Q 3: What are the potential benefits and challenges of adopting XR practices for reviving lost CH sites?

1.4. The Significance of the Study

This research contributes to the body of knowledge on the implications of integrating XR technology in approaches relating to the digital reviving of lost cultural heritage sites by basing it on a real case study of a lost CH site, then establishing and evaluating an XR approach and application of reconstructing and experiencing this site in VE.

It also assists in alleviating the current research gap in this field while also providing real-world benefits and framework to initiatives to reconstruct lost CH sites digitally.

1.5. The Limitations of the Study

Although the present study aims to develop an XR approach and evaluate applications regarding reviving lost CH sites in VEs, there are several limitations to this study that prevent it from being a comprehensive XR experience design process. It is critical to understand that this study is exploratory in nature, has limited time, and the methodologies used for this study are relatively limited, since it lacks financial support to carry out additional designing approaches and experiments or different in-depth testing techniques on previous related work.

1.6. Thesis Structure

Chapter one has presented the background and context of the study. The research aims, objectives and questions have been outlined and stated, and the importance of such research demonstrated. The limitations of the study have also been highlighted.

Chapter two reviews the existing literature to highlight the importance of reviving lost CH sites, and provides a comprehensive review of the case study, XR technology and its history in order to identify and classify key approaches and practices applied in the previous related work.

Chapter three presents and justifies the adopted framework and overall research approaches and addresses the limitations of methodology.

Chapter four presents an overview of the research results.

Chapter five interprets and discusses the overall outcome of the research results, including its implications, limitations, and provides recommendations for practice.

Chapter six presents the conclusion and final thoughts of the study, summarizing the main findings and their implications on the research gap, and highlighting future research opportunities.

2. LITERATURE REVIEW

This chapter reviews the literature and previous related work to establish a deep understanding of the diverse research fields, identify key elements of previous work, and develop hypotheses based on the research gap. Furthermore, the body of this chapter takes a thematic structure because the research field is interdisciplinary in nature. Accordingly, it provides a brief overview of heritage, its categorizations, and key approaches to preservation, followed by a detailed study of the selected case study site, including its condition, history, and importance. This is followed by a comprehensive study of the diverse forms of XR technology, its history, and previous practices related to heritage.

2.1. Heritage

The concept of heritage is broad and encompasses various forms of cultural and natural environments, as well as historic places and sites. It also includes the collection of past and present cultural practices and knowledge. Heritage is an integral part of modern life and forms the basis of diverse regional, national, and indigenous identities (ICOMOS, 2002), and often used to describe and contextualize the various events and experiences that occurred in the past (Waterton & Watson, 2015). Whereas UNESCO (n.d.) states that heritage is our lasting legacy from the past, which forms our present, and future, both natural and cultural resources are invaluable sources of inspiration and life.

2.1.1. World Heritage List

The concept of world heritage is exceptional as it is universal. World heritage sites are those that are considered to be the possession of all people of the world regardless of their geographical location (UNESCO, n.d.). The World Heritage List was established by UNESCO to recognize places on Earth that are of outstanding universal value, these places can be natural, Cultural, or mixed of both and they are protected for the enjoyment of future generations (UNESCO, n.d.). According to

UNESCO's statistics (n.d.) there are 1154 world heritage properties around the world, including: 879 Cultural, 218 Natural, and 39 mixed. They vary in region as follows:

Table 1. Number of World Heritage Properties by Region

Region	Cultural	Natural	Mixed	Total	%
Africa	54	39	5	146	8.49%
Arab States	80	5	3	88	7.63%
Asia and the Pacific	195	70	12	277	24.00%
Europe and North America	468	66	11	545	47.23%
Latin America and the Caribbean	100	38	8	146	12.65%
Total	897	218	39	1154	100%

Source: UNESCO, n.d.

2.1.1.1. Criteria for Selection of World Heritage Sites

According to UNESCO (2005) the sites that are considered for World Heritage List inscription must meet at least one of the selection criteria beside exhibiting exceptional universal value, these criteria are:

- To serve as a wonder of human creativity.
- To show a significant exchange of human values during a particular period of time or in areas of the world of cultural significance, based on innovations related to technology, art, and architecture.
- To be able to bear witness to a unique cultural tradition or a contemporary or extinct civilization.
- To be an exceptional example of a technological or architectural group or landscape depicting an important stage in human history.
- To be an outstanding example of a historical human settlement, land use, or sea use that is illustrative of a culture or community, especially when it becomes endangered by irreversible change.
- To be associated with a tradition, a living event, or with exceptional ideas, beliefs, and works of art and literature of global significance.
- To describe and contain unusual natural events or areas of exceptional natural beauty and aesthetic value.
- To be exceptional examples of natural phenomena that represent important events in the history and development of the earth. These include the record of life, the evolution of the landforms, and the important characteristics of these areas.
- To be exceptional examples of important biological and ecological processes that have occurred or are ongoing in the development of marine, terrestrial, plant, animal, and freshwater ecosystems.

- To ensure that in-situ conservation activities of habitats containing endangered species of scientific importance and global value are successfully implemented while ensuring the conservation of biodiversity in site.

2.1.2. List of World Heritage in Danger

The List of World Heritage in Danger is intended to alert the world community about the conditions that jeopardize the characteristics of a property that was listed on the World Heritage List, as well as to provoke corrective action, conditions that threaten the World Heritage sites include: armed conflict, natural disasters, and pollution. These threats which can negatively affect the values of the property are classified as potential or ascertained threats based on the danger level, that is a certain indicator that indicates the likelihood of a problem happening (UNESCO, n.d.).

2.1.2.1. Criteria for the Inscription of Cultural Properties on the List of World Heritage in Danger

According to UNESCO (2009) for a world CH property to be inscribed on the list of World Heritage in Danger it must face one of several conditions, such as:

Table 2. Conditions For the Inscription of a World Cultural Heritage Property on The List of World Heritage in Danger

Type of danger	Conditions
Potential Danger	A property is regarded potentially endangered when it faces threats that might have a detrimental influence on its distinctive characteristics, these threats include changes in its legal status, a lack of preservation strategy, negative impacts of regional planning initiatives, town planning, armed conflicts, or environmental factors.
Ascertained danger	A property is regarded as endangered when it is threatened by specific and proven imminent danger, such as significant degradation of its materials, structure, aesthetic elements, architectural or town-planning coherence, rural or urban space and natural environment, and loss of cultural or historical significance.

Source from UNESCO, 2009

2.1.3. Cultural Heritage

Cultural Heritage refers to a collection of various kinds of objects and sites that have cultural significance, these include structures and buildings that have cultural significance, they can also be considered for conservation measures if they have been

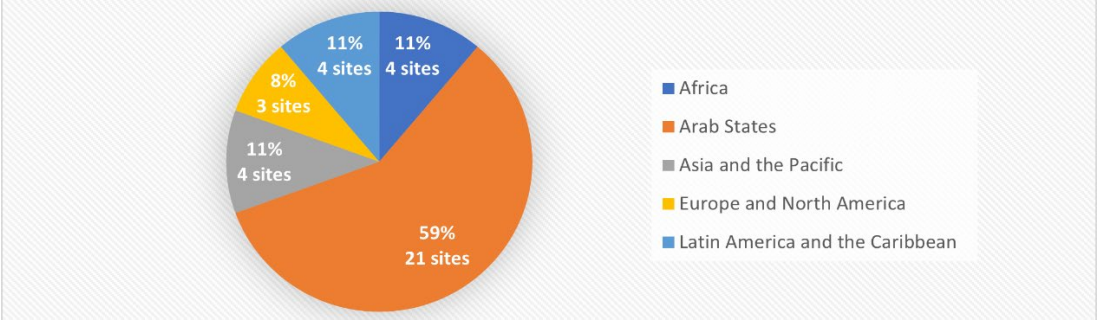
identified as old, important, and culturally significant (Brumann, 2015), according to Institute for Statistics; UNESCO (2009) definition of CH, it is divided into two:

- Tangible cultural heritage, which refers to the collection of objects and structures that are immobile, movable, or underwater.
- Intangible cultural heritage, that is embedded within cultural and natural heritage spaces, sites, and artifacts.

The relationship between the intangible and tangible CH is a symbiotic one that can be traced back to the origins of both entities, making the general concept of CH is broad and relates to the relationship between people and ideas, it is a complex relationship involving various systems of interactions, norms, and values. Accordingly, cultural sites, symbols, and traditions are all representatives of these values and norms (Bouchenaki, 2003). Thus, public interest in CH has evolved from being perceived as an asset to humanity to being of vital importance to communities and individuals and considered to be a part of their identity (Donders, 2020), inducing the political and economic activities regarding CH (Bowitz & Ibenholt, 2009). Thereby, the destruction and loss of CH does not only harms communities, but also threatens the international peace and stability (MØLLER, 2020), yet CH consistently faces a lot of threats that pose it to danger and loss, some of these include urbanization, armed conflict, and war (Groizard & Santana-Gallego, 2018). According to UNESCO (n.d.) World Heritage List Statistics, 36 sites of CH are listed as in danger and these sites diverse in region:

- Africa: 4 Sites (11%)
- Arab States: 21 Sites (59%)
- Asia and the Pacific: 4 Sites (11%)
- Europe and North America: 3 Sites (8%)
- Latin America and the Caribbean: 4 Sites (11%)

Figure 1. Cultural Heritage Sites in Danger by Region



Source: UNESCO, n.d.

2.1.3.1. Built Cultural Heritage

Every civilization with a management system, as well as a philosophy that governs it, has its own set of aims, ideals and concepts. Culture's principal function is to express these aspects by introducing concrete forms, hence architecture poses a crucial role throughout this process (Ettehad et al, 2014). Thus, built heritage is an integral part of CH although its current definitions are still subject to debate, limited and mainly based on the conventional values of historical and architectural significance (Tweed & Sutherland, 2007). Architectural heritage concerns the recognition of the significance of people and places in a society, it also involves the design of architectural landmarks that represent the image of a certain society at a certain period, these structures help people appreciate the rich cultural and political history of their communities (Lahoud, 2008). Accordingly, the obligation to take the necessary steps to ensure a proper understanding, managing, and preserving the architectural heritage of our communities is critical as much as it is to preserve the traditions and values of previous eras. Nonetheless, due to the lack of experience and proper care, many of these structures have already been lost (Embaby, 2014).

2.1.3.2. Cultural Heritage Preservation

Preservation of CH involves carefully designing and implementing strategies to maintain its significance for the benefit of current and future generations (Endong, 2018), since CH preservation is regarded as a positive and dynamic tool for growth and change, as it can help communities develop their collective memory and develop their future (ICOMOS, 2002). According to Skublewska-Paszkowska et al. (2022) CH Preservation relates to the various disciplines of research, these are:

- Documentation is related to archiving different sorts of information.
- Protection refers to the measures taken to prevent deterioration, erasure, or other losses of CH.
- Reconstruction is the practice of visualizing CH assets in order to better comprehend them.
- Restoration refers to a series of procedures, including the removal and replacement of non-original assets, infilling and reconstruction.
- Conservation is the practice of taking various measures and actions to prolong the existence of CH while supporting the dissemination of its heritage values and messages. The objective of conservation is to sustain a heritage's cultural and physical attributes so that it will retain its value while remaining intact and endure beyond our finite existence.

- Dissemination and spreading are the process of depiction and visualization of CH assets utilizing contemporary technologies in order to reach a wider audience and introduce them to cultural heritage.

Nevertheless, it is noteworthy that heritage experts have always been adverse to the reconstruction of lost CH properties as it has the potential to fabricate history and create fictional entities that never existed in that form. Additionally, The World Heritage Committee's Operational Guidelines for the Implementation of the World Heritage Convention outline that reconstruction of archaeological remains or historic buildings or districts is only permitted in exceptional circumstances, and must be based on comprehensive and precise documentation, rather than speculations and conjecture (Cameron, 2017). Accordingly the use of computer technology in CH preservation projects is rising, since cultural computing introduces additional approaches and opportunities to the field (Haydar, et al: 2011), including: digital reconstruction, repatriation, and the use of 3D technology in CH preservation projects and other approaches, which are sometimes considered to be more competent and cost-effective fieldwork methods in comparison with traditional approaches, since they are able to achieve the various objective of the diverse disciplines of CH preservation projects at once without causing unreversible modifications or damage to the proprieties (Csoba DeHass & Taitt, 2018).

2.2. Ancient City of Aleppo

Aleppo, one of the oldest continuously inhabited cities in the universe, is Syria's economical, commercial, and industrial capital of the country, it is in the north side of the country and borders Turkey; the city is known as a trade center between east and west throughout history. The location of Aleppo, its diversified social structure, and weather conditions are some of the factors that helped maintain its existence (Zin Alabadin, 2019). It is very difficult to determine how old Aleppo is as a consequence of the obliteration of its ancient remains by modern development, however archaeological studies and discoveries from multiple ancient sites in the region, such as Ebla, and Mari which have suggested that the city dates back to the 3rd century B.C (Gonnella, 2008), The citadel of Aleppo, on the other hand, has traces of prior civilizations dating back to the 10th century B.C (UNESCO, n.d.). Figure 2. Shows The ancient city of Aleppo, with the citadel at its center.

Figure 2. The Ancient City of Aleppo, With the Citadel at its Center



Source: Soltan, 1993.

Aleppo which is known for its geographical location as it located at the crossroads of various trade routes since the 2nd millennium B.C, such as the Silk Road, and halfway between the Euphrates River and the Mediterranean coast, has been ruled by various empires such as the Hittites, Assyrians, Greeks, Ayyubids, Mamelukes, and Ottomans who left their stamp on the city, the rich cultural diversity of Aleppo's inhabitants has been reflected in the city's architectural styles as many of its structures were constructed during the various periods of history, the vast remains of many ancient civilizations, such as the Hellenistic, Roman, Byzantine periods, are also featured in the surviving structures of the city's citadel. While various buildings in Aleppo represent a significant portion of the city's wealthy cultural and economic history and illustrate the social qualities of what was once one of humanity's wealthiest cities, its varied military structures are significant architectural landmarks that testify to the Arab dominance over the city during the 12th century. Therefore, due to the historical and cultural characteristics and features of the city, Aleppo met the 3rd and 4th criteria for inscription on the World Heritage List. Accordingly, Aleppo was included in the world heritage list in 1986 (UNESCO, n.d.). Being included in the list of World Heritage sites has allowed the old city of Aleppo to become a symbol of international cooperation and conservation and instead of being regarded as a local heritage site, the old city became a symbol of universal cultural heritage and its preservation the responsibility of the international community, in

1992 the old city of Aleppo became the focus of a various international rehabilitation projects (Vincent, 2004), Aleppo continued to gain international importance among time; the Islamic World Educational, Scientific and Cultural Organization (2006) declared Aleppo as Capital of Islamic Culture.

2.2.1. The Ancient City of Aleppo During the Ottoman Empire Period

Aleppo was annexed to the territory of the Ottoman Empire by Yavuz Sultan Selim Han in 1516 and lost in 1918 at the end of the First World War, during the more than 400 years of rule of the Ottoman Empire in Aleppo many artifacts were built in the city, and the works of previous civilizations were restored and renewed, allowing them to survive until today (Tekin, 2014). According to Russell (1756), the Physician of the British Factory in Aleppo in his book The Natural History of Aleppo, The Ottomans considers the city of Aleppo to be the third most important city in the empire, In terms of its luxury, size, and population, it is inferior to both Cairo and Istanbul, but it can still be considered superior to both due to its various advantages, such as its impeccable air quality, elegant private buildings, the neatness of its streets, and its significant trade share. Unlike the early years of The Ottoman Empire's rule in Aleppo, during the second half of the 16th century the functions of the city were altered, and the ottoman presence was established through creation of developments on the city's urban fabric, by building several multi-purpose building complexes in the heavily populated urban core where real estate was of great value, some of these include the Khusruwiyya, the Adiliyya (Watenpaugh, 2004). Meanwhile, as a consequence of the earthquake that occurred in Aleppo during the Ottoman Empire's rule in 1822, some parts of the city suffered natural destruction. However, thanks to the efforts of Osman Hamdi Bey and the law of 1884, the Ottoman Empire established a legal category for the protection of heritage, the prepared laws created a framework for the protection of historical artifacts and emphasized the importance of identifying areas suitable for archaeological research and preserving monuments considered as the city's heritage. Therefore, the post-earthquake rehabilitation process of Aleppo's urban heritage was carried out in a unique way during the Ottoman Tanzimat era of 1850-1914 (Durmaz, 2019). Accordingly, several additional projects highlighted the importance of the city as a pivot for the Ottoman Empire's activities in region especially after the disintegration of the Balkan provinces and the conflict with Russia, and aimed to modernize the

empire, establish a western-style army, introduce westernized medical services, and centralized time systems, some of these projects were: the establishing of Ramazaniye Military Hospital, Halep Hamidiye Gureba Hospital, Bab al-Faraj Clock Tower, and The Baghdad Train Station (Burns, 2017).

2.2.2. Ancient City of Aleppo During the War

There has been a long history of war against architecture, with the destruction of cultural assets being one of the methods used to dominate, terrorize, divide, or completely eradicate an enemy nation. The goal of this strategy is not to defeat an opposing army, but to pursue genocide or ethnic cleansing. This is a scheme that can be performed covertly and away from the front line, and it is usually carried out in rewrite history in the interests of the winner, In this context, architecture plays a crucial role: a mosque, for instance, is more than just a building; it represents to its enemies the existence of a community marked for obliteration, a library or art gallery is a collection of historical memory, serving as proof that a community's existence dates back into the past and legitimizing its continuous existence in the future. in other words, this systematic destruction of certain types of structures and the architectural traditions that occurs during conflicts is not a collateral damage or because they are on the military target path, rather they are regarded as targets and deliberately destroyed, which ensures the enforced forgetting of identities, memories, history associated with these places (Bevan, 2006). The Ancient city of Aleppo, along with its historic citadel and the historical landmarks and the monuments surrounding it which commemorate old empires, various religions, varied races, civilizations, and trade routes, as well as the city's eastern and southern neighborhoods, have all sustained massive physical damage during the war, while military operations in the city gives every indication that they have been deliberately designed to damage the city's urban and cultural past, along with its identity and cultural memory, and not just a result of them (Kurgan, 2017). Both the Syrian regime and the armed militias share the responsibility for the destruction of Syria's historic sites and the plundering of several hundreds of thousands of cultural treasures. Regarding Aleppo, the regime’s forces occupied several significant historic structures, outfitted them with heavy armaments and armored vehicles which turned them into military bases, making these sites an easy target for attacks. In response, the armed militias argued that such military occupations must come to an end during

their struggle to free the ancient city, and therefore with their intention of winning this battle, they had underground tunnels dug in several areas, filled with explosives, and then detonated. This strategy led to the destruction of the city's infrastructure, jeopardizing the reconstruction efforts of the city in the future (Ibold, 2020). Although Aleppo has been exposed to various factors pointed previously in UNESCO's reports that could threaten the heritage of the city such as lack of definition of the buffer zone, lack of conservation and/or management plans, inappropriate restoration works and urban encroachment, and housing. However, the city was first inscribed in the World Heritage in Danger list in 2013 due to war and the threat of destruction it could cause, including other potential threats (UNESCO, 2021). A study by (Qudsi, 2016) assessed that:

- 90% of the Old City's surface area was damaged during the war, while over 50% of the areas damaged were residential areas and one third of the areas damaged are commercial.
- 97% of Heritage sites, 90% of the Market area, and nearly 70% of the Old City, at a minimum 70% of all neighborhoods, are affected by the war.
- A third of the Old City was either destroyed or heavily affected by the war and the majority of the areas that have been damaged are commercial and heritage sites.
- The study also appraised the overall anticipated cost for the reconstruction of the entire Old City to be around $507,509,000 excluding the cost of infrastructural rehabilitation and the time to complete the process of restoring the damaged buildings in the Old City will take about 12 to 15 years.

In contrast to other cities in Syria during the war, the destruction of the ancient City of Aleppo was regarded as a catastrophic event that occurred not only for humanitarian reasons but also for its cultural significance (Zeido & Ibold, 2020).

2.2.3. Aleppo Hamidi Gureba Hospital (Carlton Citadel Hotel)

Aleppo was regarded as the center of attraction for many foreigners due to its special geographical location on various trade routes. accordingly, the city's foreign population grew, and residents of Aleppo felt the urge to help foreigners and the poor of the city and provide them free health services, consequently donations were raised, and a contemporary charity hospital was decided to be built. The hospital was established with the support of Sultan Abdul Hamid II; hence the hospital was named Hamidi, referring to Sultan Abdul Hamid II., and the word "Gureba" was added to the name as it means the poor and foreigners in Arabic, making the name was

"Aleppo Hamidi Gureba Hospital" (Kaadan & Hamati, 2009; Al-mallah, 2014). The decision was made to build the hospital on the site of the Ottoman era's former governor's office which was originally constructed on the remains of a medieval building known as the Dar al-Adel and was destroyed during an earthquake in Aleppo in 1822, the construction process started in 1883 and was completed in 1897 and The hospital was formally launched in 1900 after it was furnished and equipped with the essential materials (UNESCO, 2019; UNITAR, 2019). This project reflected the new priorities of Sultan Abdul Hamid II, and it was considered to be the starting point of a program aimed to introduce westernized medical services in the city, as the hospital was located in one of the most strategic locations in Aleppo (Burns, 2017). Accordingly, Doctor's rooms, male and female patient rooms, storage areas and autopsy room were among the medical services and facilities offered by the hospital, the building which consists of 32 rooms, two large residences, a morgue and two baths with eight rooms, also has an operating room, an eye examination room and two gardens with a width of 84x20 meters, it also has beautiful columns and wall railings. The structure which was the city's first modern civil hospital and possess a location in the heart of Aleppo ancient city, was built in the style of European architecture that had been popular in Istanbul and major Arab cities during the end of the Ottoman era, as some of the ancient Greek architecture characteristics can be seen in its pyramidal shape of the roof gable which is made of red bricks. However, During France's mandate in Syria, the hospital's structure was exposed to various changes, such as the removal and leveling of the pyramidal shape of the roof gable, the structure was expanded in 1924 by adding a two-story block to the general mass, similar to the original structure in terms of decorative elements and spaces, began to take the shape of the letter "U", due to the structure's unique architecture and location, it was regarded as multi-functional building and used for different purposes overtime, some of which were: University Hospital of Aleppo, Nursing School, Health Vocational School and lastly in 2010, this historical landmark with such a scientific and medical interest was put for tourism investment, following maintenance, restoration, and rehabilitation operations, it was reused as a hotel called "Carlton Citadel Hotel", see Figure 3., the structure's outward appearance was retained, but its archaeological and historical importance of its interior was not taken into account (Al-mallah, 2014). With a cost of around 11 million USD, the Carlton Hotel, with its magnificent panoramic view of the Ancient Aleppo Citadel, was put

into service with 90 rooms, 180 beds and 584 restaurant chairs, a gym, and an outdoor swimming pool (Enab Baladi, 2020).

Figure 3. Carlton Citadel Hotel



Source: latecniq, n.d.

During the war, the historic structure of Carlton Citadel Hotel was regarded as a center of interest and repeatedly deliberately targeted, after the Syrian regime forces occupied and utilized it as a military base, hence turning it into a military target for attacks. In response, the armed militias dug the underneath foundation of the structure, forming an underground tunnel, stuffed it with large amounts of explosives and detonated it, the first explosion was carried out in February 2014 and caused a partial collapse of the building, whereas the second one in May 2014 completely destroyed the structure turning it into rubble, and severely damaging other nearby historic structures (Surk, 2014). Satellite images taken following the explosions showed that the building had been utterly demolished and none of its foundations were left (see Figure 4.). The historic structure which had a prominent position at the foot of the citadel's gateway possessed a great historical and architectural significance as one of the best-preserved examples of a public building constructed during the Ottoman empire Tanzimat period and Aleppo's first modern civilian hospital, considering these characteristics the incident is classified as a serious historical and cultural loss (UNESCO & UNITAR, 2019).

Figure 4. Satellite Image of the structure's location Post Explosion



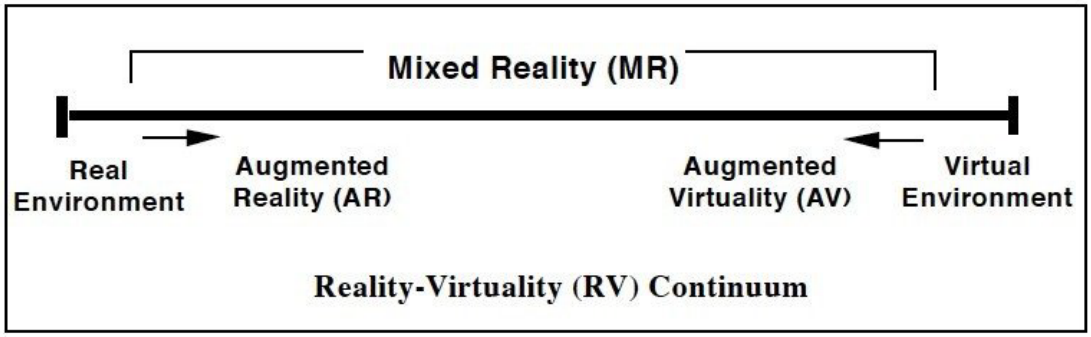
Source: Google earth, 2014.

2.3. Immersive and Extended Reality (XR) Technology

Immersive technology refers to any technology that provokes a sensation of immersion by blurring the boundaries between the physical, simulated, and virtual worlds (Lee et al., 2013), these technologies are often related to various types of reality, such as XR (Palmas & Klinker, 2020). Whereas Extended reality also referred to as Cross Reality technology is a generic phrase refers to any immersive technology that is physical-and-virtual merged or fully virtual 3D environments that combine human and computer-based input in order to produce an interactive environment (Morimoto & Ponton, 2021), these technologies include any existing technologies such as Virtual Reality (VR), Augmented Reality (AR) or Mixed reality (MR) and any new technologies that may be created in the future that alter reality (Interaction Design Foundation, n.d.). Unlike traditional 3D representations or photorealism, XR technology is more than just a visual representation of space; immersive interfaces with well-designed, impactful, and meaningful information experiences based upon visual and interaction design, that enhances our daily experience with geographic and physical spaces, changes our perception of space (Çöltekin et al., 2020), and bridges the divide between physical and digital world, individuals, experiences, and information, and provides the users with new ways to interact through immersive environments and experiences (Alnagrat et al., 2022). therefore, XR technology is also regarded as the new form of Human-Computer Interaction (HCI), as it transfers real-time users' interactions and inputs to the host computer and feeding them back into the generated VEs (Tan, 2022), these Virtual Environments can be described as computer-generated environments which provide the users with the ability to enter and interact with worlds that does not exist or inaccessible, thereby every VE must have some degree of immersion, whereas Immersive Virtual Environments (I-VE) refers to a developing subset of VE's distinguished by its high degree of immersion, that encompass a wide range of computer-based simulations from fully VEs to real environments enhanced with digital data (Stachoň et al., 2020). Moreover, the various types of VEs can also be network supported which are referred to as Collaborative Virtual Environments (C-VE), allowing massive numbers of users to exist and interact with each other and the surrounding environment in real-time as avatars (Han et al., 2022). However, according to Milgram & Kishino (1994), proposed concept the "Virtuality

Continuum" (see Figure 5.), which establishes and defines the concepts of AR, VR and MR, and argues that every XR experience has also a relation to the real world by existing somewhere on the Virtuality Continuum, where VR is presented as one end of the continuum, the real environment where we live as the other end, while MR with its suggested subsets including AR, ranges in between both endpoints.

Figure 5. Virtuality Continuum



Source: Milgram, & Kishino, 1994.

Nonetheless, three main linked principles shape any XR technology and allow us to distinguish between the various types of it (Matthews et al., 2021; Mütterlein, 2018), these are:

- Immersion: which refers to a phenomenon that an individual goes through when they lose their awareness of their physical self partly or completely as a consequence of being surrounded in an absorbing total environment, which usually is artificial. This type of experience can cause them to disengage from their awareness of the time and physical world (Handa et al, 2012).
- Presence: refers to the sensation of existing in an environment other than just our immediate physical environment (Agrewal et al., 2020).
- Interactivity: is the level of user participation in modifying a mediated environment's form and content in real-time (Steuer, 1992).

2.3.1. Virtual Reality (VR)

VR is a computer-generated interactive three-dimensional VE represented by models and simulations, that enhances the users' immersion by allowing them to explore and interact with the environment and its virtual objects in a spatial way (DoD Modeling and Simulation (M&S) Glossary, n.d.; Bevilacqua et al., 2019). However, in this environment, users' perceptions of the real world vary according to their level of immersion (Tacgin & Dalgarno, 2021), therefore, VR experiences are divided into 3 categories depending on the user's level of immersion when engaging with the VE and the types of interfaces or components used in the system, these are: non-

immersive, semi-immersive, and completely immersive (Bamodu & Ye, 2013; Bevilacqua et al., 2019).

2.3.1.1. Non-immersive VR

Non-immersive VR experiences allows users to experience a 3D interactive VE through a standard computer, without the use of extra hardware to enhance the immersive experience such as Head-mounted display (HMD), while traditional equipment such as keyboards and mice, are used to interact with the environment (Suh & Prophet, 2018; Freina & Ott, 2015). Modeling and CAD programs (Bamodu & Ye, 2013), and games such as Minecraft (Suh & Prophet, 2018) are considered to be examples of non-immersive VR systems.

2.3.1.2. Semi-immersive VR

Semi-immersive VR experiences provide the user a partial VE to interact with, (Lorusso et al., 2021) this is achieved either by Computer Automatic Virtual Environments (CAVE), in which the VE is produced using system consists of three projection screens forming a VR booth (cave), where the user is able to move around freely while exploring the VE by stereo glasses. However, sensors such as motion tracking systems adjust the projection of the images onto the screens according to the user's changing position. or by combining a VE with a physical model, where the user experience the VE through a HMD or multiple screens while controlling the simulated experience using physical models as input devices, throughout this process user's movements are reproduced and represented in the VE using virtual identities or avatars, which are models generated by an image capture system or by a digital representations (Barrett et al, 2010; Fernández-Vázquez et al., 2022), one example of these systems would be driving simulators, where users explore the VE through HMD while controlling the experience using steering wheel as input device (Barrett et al., 2010). So, in order for semi-immersive VR systems to provide a more immersive experience these systems integrate high performance software with additional equipment such as stereo glasses, large projectors, HMD, enhanced field of view, haptic input, or other various accessories (Lorusso et al., 2021; Barrett et al., 2010; Fernández-Vázquez et al., 2022; Boas, 2012). Education, research, and training are the major areas where semi-immersive VR is commonly employed (Lorusso et al., 2021).

2.3.1.3. Immersive VR (I-VR)

I-VR experiences provides the highest degree of immersion (Boas, 2012; Bamodu & Ye, 2013), by completely placing the users in a 3D computer-generated realistic or believable interactive VE through VR headsets while supporting the experience with a lifelike sensory-motor interaction, allowing them to engage with the VE using their own body (Fusco & Tieri, 2022). In other words, these experiences are designed to completely immerse the users in a VE, providing the sense of being physically located in a non-physical world, where they may engage in various sensory and cognitive activities while interacting with it (Martínez et al., 2021), and blocking them from interacting with the physical environment since they are fully immersed in the VE (Parveau & Adda, 2020). So, in order to ensure a high level of immersion, I-VR systems are typically multi-modal in nature, enabling interactive 360° scenes with aural stimulation through the VR headset (Hamilton et al., 2021), that are supported with head tracking systems, which increases interactivity, allowing users to freely move and explore through the VE in addition to interact with 3D objects if haptic devices are used in conjunction with the system. Therefore, through I-VR systems, users gained the ability to create and experience highly immersive VEs that are equivalent to their real-world counterparts, in addition to develop situations and scenarios that are too expensive, risky, or impractical to create in the real world (Jelić et al., 2016). As I-VR systems also provide a high level of presence, leading users to suspend any notion that the experience is artificial (Markowitz et al., 2018), causing them to act in a natural behavior in the VE, and respond realistically to virtual stimuli, triggering physiological and psychological responses as if the subject were physically present in a real location (Fusco & Tieri, 2022). Due to the unique features and effective experiences I-VR systems offers, it has been employed in a range of fields, including Education, Medicine (Stepan et al., 2017), Entertainment and Gaming (Oh & Lee, 2021), Tourism (Beck et al., 2019), Architecture (Jelić et al., 2016) Heritage Conservation (Alboul et al., 2019) and much more.

2.3.2. Mixed Reality (MR)

MR technology, also known as hybrid reality, blends the real and virtual environments, generating an enhanced VE, where the user along with real and virtual elements co-exist and interact with one another in real-time (Sidhu, 2020). In other

words, MR has distinct characteristics and features such as spatiality, immersion (Yepes-Serna et al., 20121), and mapping the real and virtual environments, establishing interactions between them (Hoenig et al., 2015), these characteristics enable users to stay immersed in the real world while exploring and interacting with the VE (Mathew & Pillai, 2020). However, as MR is an emerging, ever evolving and not widely used technology (Sürmeli & Şağar, 2021), experts have difficulties establishing a universally agreed definition. Yet, MR experiences are described in various terms such as: strong AR, the combination of AR and VR, or AR with full immersion, meanwhile some experts believe that in the upcoming years we will not be able to differentiate between AR and MR due to the increasing number of devices and the capability of them to provide various types of immersive experiences (Speicher et al., 2019), whereas Virtuality Continuum concept, argues that MR experiences encompasses many forms of environments that range between the real world and VR, such as AR environments (Milgram, et al:1994). Regardless, in order to experience MR, additional equipment is required such as: Microsoft's MR headset HoloLens (Pillai & Mathew, 2019).

2.3.3. Augmented Reality (AR)

AR experiences, overlay the real world with digital content such as texts, videos, 3D models, audios, haptics, etc. in the shape of virtual objects, forming an enhanced environment and providing seamless integration of computer interface with the physical environment, thus enabling users to access information that's not typically physical in the real world (Evangelista et al., 2020). This means, AR does not replace reality; rather, supplements it. and aims to provide users with a view of the real-world objects and the virtual data coexisting in the same VE (Azuma, 1997). Accordingly, AR experiences provide a limited level of immersion in comparison to other XR technologies, users are able to view and observe with contextual data that is not related to the real environment. Moreover, in terms of interactivity, QR codes or image recognition algorithms or Tags trigger the AR into generating a VE, yet the produced actions are generally passive, meaning the data will be presented without users having interactions to execute (Parveau & Adda, 2020). As AR is established by inserting virtual data into real world scenes using a video camera in real time (Ludwig & Reimann, 2005) smartphones became the most popular platform for achieve AR experiences (Chen et al., 2019), since they grant users the ability to

access AR experiences wherever they are and whenever they want at a low cost in comparison with other equipment (Craig, 2013). However, a variety of other equipment such as AR glasses, HMDs or tablets can also be used in achieving AR experiences (Sünger & Çankaya, 2019). Thanks to its easy accessibility, AR became widespread and present in a lot of fields, such as: medicine, education, training (Munzer et al., 2019), marketing (Vilkina & Klimovets, 2019), heritage studies (Luna et al., 2019).

2.3.4. Brief History of XR Technology

This section aims to provide a comprehensive overview of XR history by dividing it into two categories: Art History and Technical History.

2.3.4.1. Art History

The origins of immersivity and XR concept could be traced back to the 14th century, when the engineer Giovanni Fontana developed the principles of the CAVE system, by projecting images using lighting techniques on room walls formed of folded transparent papers, thus establishing an immersive environment of moving images (Codognet, 2003). Over the next few hundred years, more engineers and artists started contributing to the development of the XR concept; some practices could be seen later in the 18th centuries when painters worked on establishing immersive environment experiences by painting 360-degree panoramic murals. Moreover, throughout this process science fiction also played a vital role in the development of the XR concept. For instance, the short science fiction story "Pygmalion's Spectacles" described a pair of glasses created by future technology that provides an immersive environment experience for the user. Accordingly, it is fair to say that humanity has been long interested in simulating an illusion for the users that they are somewhere else than the one they are actually in, altering their perception of reality (Sürmeli & Şağar, 2021).

2.3.4.2. Technical History

Regarding technical history, the earliest practices of the modern era at developing the structure of XR technology goes back to the 1950's, when cinematographer Morton Heilig created "Sensorama", which is a huge machine that provided an immersive theater experience via wide-angle stereoscopic 3D visuals along with various

elements such as stereo audio, vibrations, wind, and smells that are activated at various times throughout the experience (Matuk, 2016). Nevertheless, despite the technological advancements that Sensorama created in the field of XR, it lacked portability therefore interactivity, which represents the element required to create a sense of presence. However, in 1965 Ivan Sutherland introduced the "The Ultimate Display" to the world, this portable device is widely regarded as the first HMD to use computer technology in order to establish a XR experience. Consequently, this combination of portability and XR led to the creation of the HMD based XR technology concept, which eventually became the norm for creating XR systems over the ensuing decades (Johnathan et al., 2017; Xing et al., 2021). During the following years a lot of research was conducted in the field of XR technology. Yet, the next big advancement in the development of XR technology was made in 1984, when "The Virtual Environment Workstation" was developed by NASA Ames Research Center, this HMD system provided potent computer graphics and introduced new HCI form to the XR technology through tracking the user's finger gestures and head movement beside a variety of other interactive features. Eventually, "The Virtual Environment Workstation" was considered a low-cost device with minimal equipment and space requirements in contrast to previous XR devices (Fisher et al., 1987), since then numerous research studies have been conducted on XR technology's potential in various fields such as transportation, medicine, and energy. Consequently, this increasing interest in XR along with the advancements of smartphones and computer visuals, led to the development of new XR equipment that was more cost-effective than previous devices while providing a high level of performance, including: the Oculus Rift, which was unveiled in 2013 and regarded as the first commercial VR headset. However, this was followed by the entry and contribution of major companies such as Google, Microsoft, Samsung, and Apple to the field by introducing their own XR solutions (Arnaldi et al., 2018). Lately, the prevalence of COVID-19 epidemic affects every aspect of people's lives, raising the necessity for immersive technology such as XR. As a result, the practices of XR technology in many fields have dramatically increased, changing people's perceptions about its acceptability (World Economic Forum, 2022), and shifting their activities online, hence bringing forth applications like the metaverse (Damar, 2021). Accordingly, the XR technology started to spread out and became accessible to the public between 2010 and 2020. (Xing et al., 2021).

2.3.5. Metaverse

Considered as the future of the Internet and communication and the successor to the mobile internet (Meta, 2022), the Metaverse refers to a perpetual collaborative decentralized online 3D virtual universe composed of various C-VEs and spaces (Lee et al., 2021). utilizing various advanced technologies such as Artificial Intelligence, Blockchain, etc., the Metaverse made it possible to create interactive and virtual replica of the real world in terms of its inhabitants, places, and objects, and enable users to explore and interact with it as avatars in immersive VEs through XR technology (Pimentel et al., 2022). the metaverse, has its own economic, social, and political structures, hence users are able to fulfill their social needs and extend their offline lives online through accessing services and information related to their offline activities and engaging in a variety of social, commercial, and leisure activities along with other users across the world in real-time (Oh et al., 2022).

2.3.6. XR Technology in Cultural Heritage Preservation

The use of applications of diverse 3D technologies such as XR technology can help advance the preservation of CH procedures, as they provide the access to CH properties that are challenging to reach in the real world (Paszkowska et al., 2022), supporting excavation and restoration efforts beside enabling non-destructive work on them since they are frequently extremely delicate and occasionally invisible to the naked eye (Gaugne et al., 2022), and improve cognitive and interpretative processes for a better understanding, preserving and sharing of the properties' values, geometry and appearance through the generated digital substitute, 3D documentations and virtual restorations (Beraldin et al., 2005; Beraldin et al., 2005). Furthermore, User-centered XR solutions can help improve users' CH experiences by increasing their engagement with the heritage (Doukianou et al., 2020) and adding a human compassion aspect to experience (Okanovic et al., 2022), these solutions include: the integration of digital storytelling and serious games with heritage, which can be presented in web-based or mobile applications, or in the form of complex applications that combines physical and digital interactions. However, these solutions are usually designed simple and intuitive as they aim to target all audiences and raise users' engagement by allowing them to explore ancient contexts which inspire participation, encourage them to experience heritage more and contribute to its

preservation (Doukianou et al., 2020: Okanovic et al., 2022). Additionally, In high immersion XR experiences, the source memory system might temporarily blur between reality and VEs, resulting in comprehending these experiences as real-world occurrences (Rubo et al., 2021) in addition to enhancing people reminiscence and experiences which influences their future choices and behaviors (Bonnail et al., 2022), making XR applications an effective approach to offer cultural experiences, benefit a wider variety of people including disabled people (Silva & Teixeira, 2020), and educate, communicate, and share with the public, the historical and cultural values of heritage that are occasionally underrepresented, understudied, difficult to reconstruct or completely restore (Nguyena et al., 2022). However, it is noteworthy that these experiences have potential risks for instance memory manipulation since it is easy to manipulate its features, which cognitive psychology literature has demonstrated that exposure to manipulated pictures may corrupt perceptions and result in the formation of false memories (Bonnail et al., 2022). Moreover, diverse CH preservation projects have been carried out by various universities and research centers, organizations, etc. using XR technology (Ferdani et al., 2021), such as:

- Guildford Castle VR

The application of Guildford Castle VR allows users to virtually explore one of England's first castles, 900 years old Guildford Castle, along with the town of Guildfor as it was back then in a fully I-VR journey to the 14th century. Additionally, it provides users with the ability to explore the castle as it stands today. (Figure 6.). Moreover, the experience is supported with digital storytelling and audio-visual information presentations, the application also provides users the ability to experience the sights and sounds of the era, with extensively researched historical reconstructions, medieval soundscape and dynamic day-night lighting (Steam, 2022).

Figure 6. Screenshot of Guildford Castle VR Experience



Source: Steam, 2022.

- CyArk

CyArk provides the ability to explore historical sites all around the world through I-VR to all audiences regardless of their location online. The provided VEs embody 3D models or 3D-scanned recordings of the sites with information and facts about it, (see Figure 7.). Additionally, these experiences can also be reached through various mediums and platforms such as place-based web, mobile, HMDs, etc. (CyArk, n.d.).

Figure 7. Screenshot of CyArk's Madrasa al-Jaqmaqiya Experience

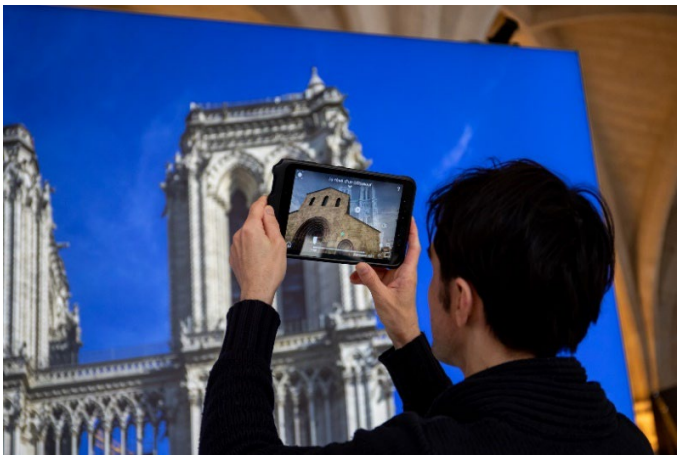


Source: CyArk, n.d.

- Notre-Dame de Paris: The Augmented Exhibition

This AR experience immerses the users in the history and restoration of the cathedral, which was destroyed in the 2019 fire, through touchscreen tablets, (see Figure 8.). the experience also allows users to explore 3D models and photos of the cathedral while learning about it from the interactive information provided about the cathedral's construction and splendid history, the experience is designed to appeal to visitors of all ages and includes a virtual scavenger hunt for kids where they can search for objects hidden within the AR screens (National Building Museum, 2022).

Figure 8. Notre-Dame de Paris: The Augmented Exhibition Experience



Source: National Building Museum, 2022

- A Journey into the World of Osman Hamdi Bey: Virtual Reality Experience

Through this VR experience, users can get a glimpse into the world of the Turkish painter, archaeologist and museologist Osman Hamdi Bey, explore his working environment, observe his artworks and belongings, and step inside his painting "The Tortoise Trainer", where they can look the artist in the eye and experience the architecture of that era, as the VE features an imaginary space constructed in accordance with era civilian architecture and study on the artist's waterside mansion in Kuruçeşme, as well as objects designed considering numerous available visual documentation and testimony, (see Figure 9.) (Pera Museum, n.d.).

Figure 9. Screenshot of A Journey into the World of Osman Hamdi Bey: VR Experience



Source: National Building Museum, 2022

- Mixed Reality Museum in Kyoto

This MR experience allows viewers to be guided around Kennin-ji, the oldest Zen temple in Japan by a hologram Buddhist monk, while visiting and interacting with the ancient artwork (see Figure 10.). The experience features a dynamic, holographic narrative in which the process of learning becomes experiential and interactive, enhancing visitors' experience in the ancient temple.

Figure 10. Mixed Reality Museum in Kyoto



Source: Hansen, 2018

2.4. Summary of Key Findings

In conclusion, this literature review has demonstrated the possibility for XR technology to be utilized in approaches related to reviving lost CH sites. Through the examination of common XR practices for preserving heritage, identifying characteristics that contribute to a better experience of CH sites in VEs, and exploring the capabilities of XR technology for virtual reconstruction, it was found that XR technology has the potential to greatly impact users' experiences and understanding of CH sites. Additionally, the use of XR technology for reconstructing and experiencing lost CH sites has the possibility to significantly impact CH preservation efforts. However, it has been noted that there are potential benefits and challenges of adopting XR practices for these purposes. Overall, this research aims to address the current gap in the literature on utilizing XR technology for reviving lost CH sites digitally, and the proposed case study of the historic building of Aleppo Hamidi Gureba Hospital holds the potential to provide valuable insights and practical applications for this field.

3. METHODOLOGY

This chapter provides a general overview of the philosophical background behind the process of developing research methodologies needed to complete the experimentation of the current study and addresses the design framework for developing an experience of lost CH using XR technology. Additionally, it discusses the data collection strategy, including the selection of research sampling and data analysis approaches, as well as the present limitations of these practices and methods.

3.1. Research Philosophy

Scientific research philosophy is the foundation of research, which guides the selection of a research approach, formulation of the topic, data collection and analysis (Žukauskas et al., 2018). Therefore, adopting the relevant research philosophy is the highest-level design decision as it influences the research approaches. Furthermore, As the study's purpose has been to develop, explore and evaluate the hypothesis based on people's perceptions and experiences, the interpretivism approach fitted the research aims and objectives. Since Interpretivism emphasizes the importance of lived experience in acquiring knowledge (McBride et al., 2022), and tends to use qualitative data to develop a theory or hypothesis.

3.2. Research Type

Modern research is usually associated with two main logical system: Deductive and Inductive reasoning: deductive reasoning works from the broad to the specific and considered the ideal approach for testing theories that are founded on rules, laws, etc., whereas inductive reasoning works from the specific to broader theories and concepts and considered ideal approach for developing empirical hypotheses which can be explored and resulting in generic theories. Despite their differences, social research frequently involves both inductive and deductive reasoning processes at some point throughout the project (Trochim, 2023). Furthermore, logical systems are

generally adopted in various research and data analysis approaches including qualitative and quantitative approaches.

Quantitative research approach aims to understand relationships between variables (Creswell, 2012) and concerned with quantities and measurements (Biggam, 2011), whereas Qualitative research focuses on the meaning, observations and experiences, which may not be subject to quantitative analysis, seeks to provide a comprehensive understanding of phenomena based on the perception of those who experiencing it, and enables finding quality responses throughout the research by the in-depth exploration of the study (Alharahsheh & Pius, 2020).

Due to the multidisciplinary, exploratory nature of current research which aims to explore the capabilities of XR technology regarding reviving lost CH sites In VEs, a mixed qualitative-quantitative research approach was the most appropriate choice as it allows the use of both inductive and deductive reasoning. This approach allowed the observation of previous work in order to develop new hypotheses and test it, in addition to further ensuring the neutrality of the research results.

3.3. Research Strategy

The research goal has been to establish an XR application for reconstructing and experiencing lost CH sites in VEs and evaluate whether such an approach is effective or not. Accordingly, this experience has been developed taking into consideration characteristics that contributed to the experience of similar previous practices that has been highlighted in the literature review chapter. Thus, a method of case study-based experimental strategy has been seen as the ideal approach to this study. Furthermore, it should be noted that the case study in the context of this research refers to the subject on which the experiment is reflected on. Since case studies are defined as an in-depth exploration of a bounded system (which is separated via time, place, or physical boundaries), such as practice, process, etc. based on extensive data collection. Thus, research based on case studies allows researchers to better concentrate on particular efforts, ambitions, or pursuits, and gain a comprehensive understanding of the case through various data forms such as pictures, videos, and e-mails, etc. (Creswell, 2012), which results in revealing multiple aspects of the subject. Meanwhile, qualitative experiments expose individuals to thoughtfully rendered mediated environments and situations and test and compare their responses

and reactions to various kinds of content formats in a contextual, reflective way that reveals the processing of meaning construction in creative manners (Robinson & Mendelson, 2012). In other words, qualitative experiments are an alternative approach to understand experiences, explore characteristics in an exploratory manner using an open but controlled research environment, and aim to uncover and explain experiences that participants might not be able to directly articulate, highlight similarities and differences across various study conditions. Thus, contributes to the discovery of reliable and genuine ideas, and provides an authentic interpretation that reflects the experience of participants (Steils, 2021).

3.4. Time Horizon and Sampling Strategy

All primary data was collected at one time using a cross-sectional time horizon due to time constraints.

Regarding sampling, a non-probability sampling strategy was adopted as it allows for easy access, intended variation, and is time and cost-effective. Therefore, and due to the broad research population, sampling methods including purposive sampling and convenience sampling were used. Accordingly, the selected 10 samples were over the age of 18, yet varied in many aspects including gender, age, and profession. Moreover, it is important to point out that samples included 4 professionals in heritage, architecture, and design, who assessed and provided supplementary feedback on the experience, improving the credibility of the results, in addition to samples who had previously visited the site of the case study before and after it was destroyed, and samples who had never known the site.

The research was approved by the Yildiz Technical University Research Ethics Committee before the researcher contacted or involved any potential participants (Appendix 1.), then all participants were informed about the nature of the experiment, provided preliminary information about the environment and experience, and a consent form was then signed (Appendix 2. And 3.).

3.5. Data Collection Methods

3.5.1. Designing the Experiment

The historical structure of Aleppo Hamidiye Gureba Hospital was chosen as the research case study due to the international cultural value it once represented, in addition to the relatively ease of access to samples, and data relating to the structure including photos, videotapes, and its architectural plans. Accordingly, using Google Earth software, satellite images were obtained and analyzed in order to gain a better knowledge of the structure and the changes it experienced through time (Figure 11.).

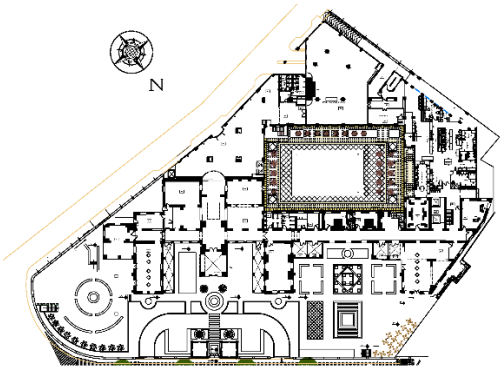
Figure 11. Satellite Images of the Structure Pre-explosion



Source: Google earth, 2013.

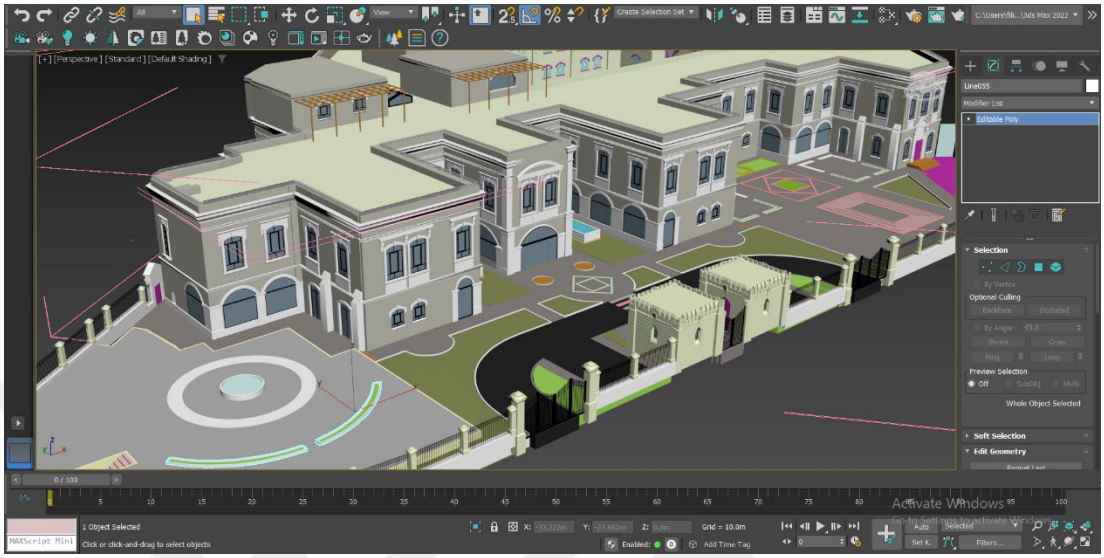
However, despite the abundance of available material such as pictures and video related to the structure's architecture, it wasn't sufficient to produce a highly accurate model of the building with all its architectural characteristics. Therefore, the structure's latest official architectural plans which were drawn by Aleppo governorate were acquired, which then were observed and modified using AutoCAD software, in order to be importable to 3D modeling software (Figure 12.).

Figure 12. Example of the Revised Architectural Plan of the Structure



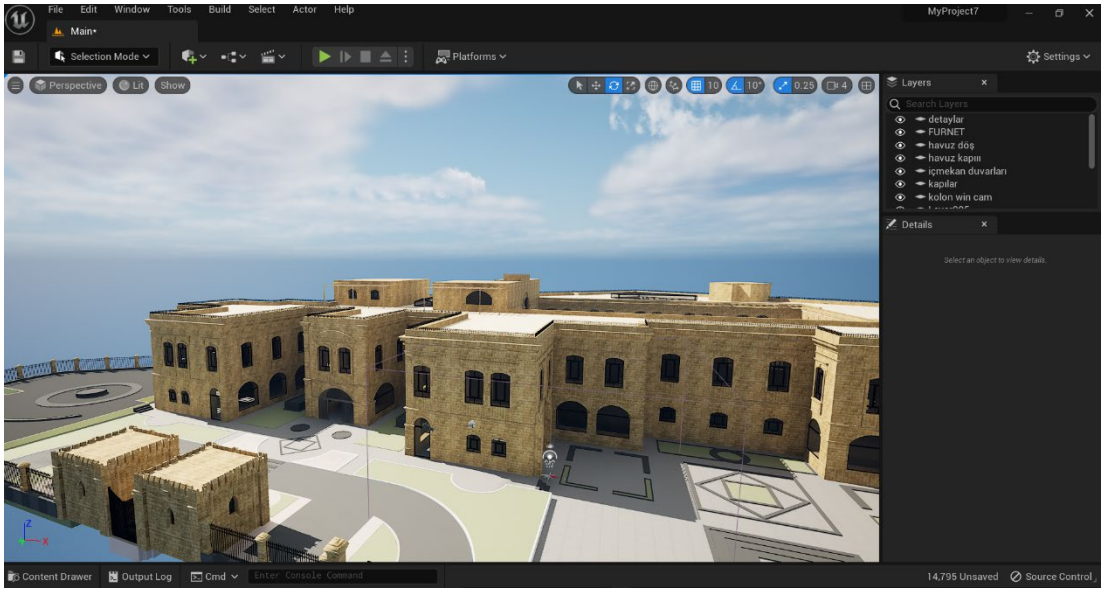
Thereafter, a fairly accurate and detailed 3D model based on the structure's latest architectural plans, images, videos, and descriptions, was generated using 3ds Max software (Figure 13.).

Figure 13. The 3D Model Design in Progress



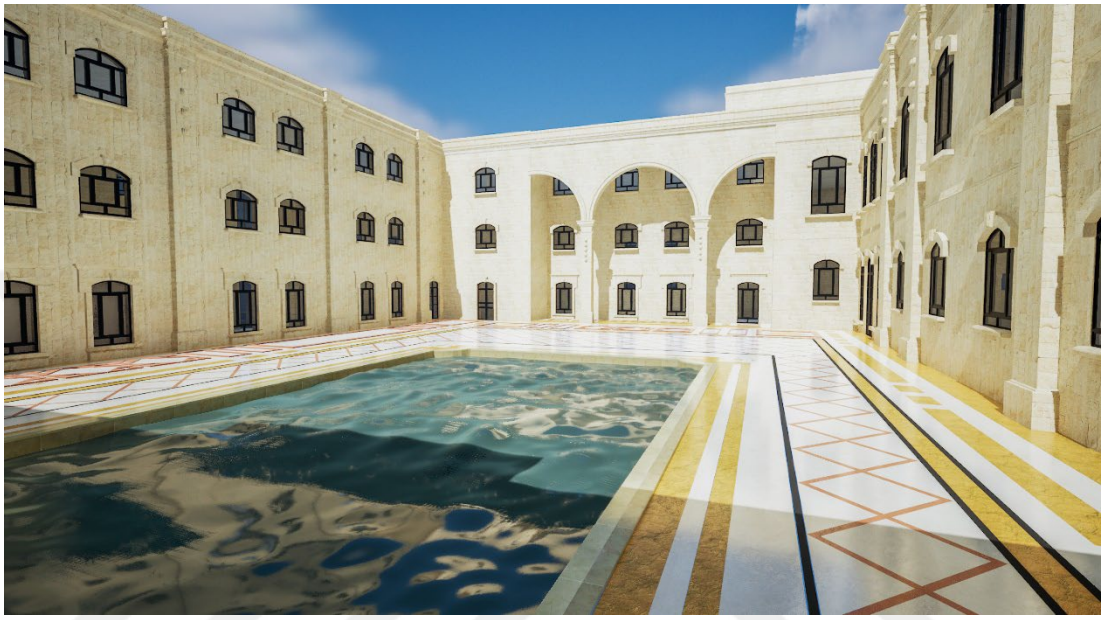
Moreover, although the model was designed to be compatible with the various types of XR, I-VR was seen as the most effective approach for reviving lost CH due to its ability to provide the highest degree of immersion in comparison with other forms of XR by offering a completely new VE for sites that cannot be accessed for enhancing. Accordingly, it was imported into Unreal Engine software (see Figure 14) where final touches were added, resulting in a VE that can be experienced through I-VR.

Figure 14. Enhancing the Environment with the Final Adjustments



Nevertheless, it is important to note that as the model was designed based on the structure's latest architectural plans, it portrays it as the Carlton Citadel Hotel, and offers the experience of the structure’s landscape, architecture, environment, and essential parts of its interior including the corridors and the swimming pool which represents the space of the middle garden (see Figure 15 and Appendix 7.).

Figure 15. Screenshot of the Designed Experience



3.5.2. The Experiment and Interviews

In order to develop an in-depth understanding and evaluate the effectiveness of experiencing lost CH in immersive VE using XR technology on participant's experiences, The experiment was conducted in the form of a semi-controlled quasi-experiment, with a one-group pretest-posttest design. Moreover, to guarantee the participant's immersion in the experiment, and un-influenced experiences and opinions, settings were done individually, at different times, and took place in a quiet room with enough extra space to move around freely during the experiment if needed. Firstly, participants were interviewed the first time (pre-test questionnaire) to gather demographic data of participants, determine if they have prior experience with XR technology, and assess their knowledge about the site (see Appendix 4.), this interview took around 5 minutes to be conducted, then provided with foundational information about the site, VR experience and how to navigate within the environment, HTC Vive Cosmos VR headset was placed and adjusted according to the participant's comfort, and they were handed the controllers. Every participant

took approximately 15 minutes to explore the VE; during this period, the researcher observed the participant's exploration of the provided VE via the host computer and didn't intervene unless participants needed or asked for help or guidance. Thereafter, the participants were given a 5-minute break, then interviewed the second time (post-test interviews). It is noteworthy to point out that due to the exploratory nature of the experiment, the interviews were semi-structured, with predetermined closed and open-ended questions which aims to understand their experience, evaluate its implications on them, and analyze the effectiveness of the experience in terms of reconstructing lost CH (see Appendix 5.), yet some questions were modified or added as required, and lasted roughly 10 minutes, during which note-taking was employed to document and record the data in an effort to make the participants feel at ease, rather than using methods such as audio recordings which may have been less comfortable for them. (Muswazi & Nhamo, 2013).

3.6. Data Analysis Methods

Thematic Analysis (TA) method with a reflexive approach was adopted, as TA is a simple and theoretically flexible interpretive technique of qualitative data analysis that helps identify and analyze important concepts and patterns of meaning in a database such as interview transcripts (Braun & Clarke, 2012), making it particularly useful when attempting to understand a participant’s experiences, perspectives, and opinions. Meanwhile, the reflexive approach to TA highlights the researcher's active involvement in the creation of knowledge, since this approach involves the interpretation of data by the researcher, taking into account the database, the researcher's analytical skills and resources, and the theoretical assumptions of the analysis. In other words, the reflexive TA approach is characterized by the researcher's personal interpretation of the data. (Byrne, 2022).

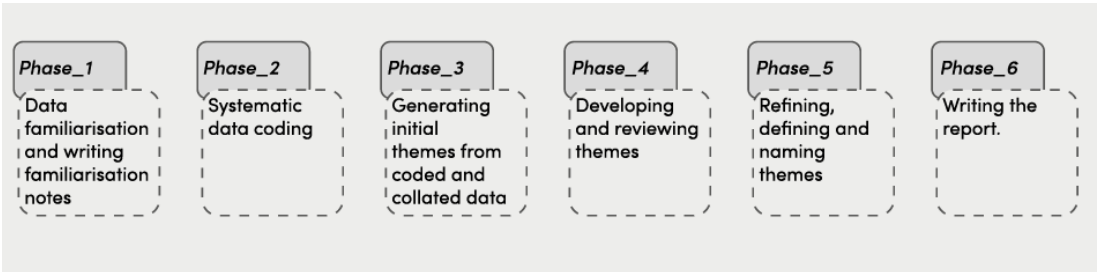
Moreover, to analyze the data, the systematic data coding approach was used to identify themes by breaking the data down into smaller units and assigning codes to these units based on their content. A codebook was used to ensure consistency and reliability of the coding process. The emerged themes, along with some of the codes assigned to them based on the collected data, and samples of the raw data are as follows:

Table 3. Emerged Themes and Codes during Data Analysis Using the Systematic Coding Method

Theme	Code	Raw data (example quote)
Virtual immersion	"Fully immersed"	"I felt like I was really there"
	"Somewhat immersed"	"It was interesting, but I didn't feel physically there"
	"Lonely"	"I felt a part of the environment, yet lonely"
	"Control"	"I wanted more control over the elements of the environment, just like the real world"
User experience	"Smooth"	"It was easy to use, and I didn't have any problems"
	"Clunky"	"It was a little hard to navigate, but not too bad"
	"appealing"	"The experience is very exciting, and entertaining"
Educational value	"engaging"	"I learned a lot and I was really interested"
	"informative"	"I learned some new things, but it wasn't particularly engaging"
Cultural authenticity	"Realistic"	"I was surprised, it looked exactly like the real place"
	"Enhanced"	"It was an improved version of the building, as the colors were more vivid"
	"Inaccurate"	"There were a few details that weren't as I remember it"
Benefits of digital reconstruction	"Reach"	"It provided me with an experience that I wouldn’t be able to go through in real life"
	"Conservation"	"This experience can contribute to the efforts of conservation heritage sites"

Regarding the Overall Research Flow, the six-phase process for conduction reflexive TA (see Figure 16.) proposed by Braun and Clarke (2020) was adopted.

Figure 16. Reflexive Thematic Data Analysis Process



Source: Braun & Clarke, 2020

Accordingly, after reading and re-reading the collected data, an Excel table was prepared with the codes, themes were highlighted, reorganized, and defined in the context of the study. Lastly, within the generated themes, several subthemes were identified. Throughout the whole process the report has been produced based on the analysis. Moreover, it should be stated that due to the flexibility of the reflexive TA method, secondary data collected in the literature was also used to support the coding process. This helped to provide additional context and depth to the analysis and allowed for a more comprehensive understanding of the participants' experiences and perspectives on reviving lost CH using XR technology.

3.7. Methodological Limitations

Qualitative research is often criticized for producing biased results. However, by using a case study-based experimental research approach and supporting it with collected quantitative data, this study added a positivist perspective and contributed to the accuracy of the results.

There were some limitations to the methodology, including lack of time, which led to all data being collected at once. However, this was mitigated by using a purposive sampling method, which allowed for reaching diverse samples including specialists who further contributed to evaluating the experience. In addition, budget and equipment constraints, along with a lack of time, prevented further experiments using other XR forms. To address this, the generated 3D model was designed to be modifiable and compatible across various XR platforms for future research.

Despite these challenges, the unique methodology used in this study provided a deep understanding of the design framework of such practices and approaches, as well as people's perceptions and reactions to such experiences. It also helped to answer the research questions presented in this study.

4. RESULTS

This chapter presents the findings of the study, which used reflexive TA to examine the effectiveness and implications of a digital reconstruction of a lost CH site in a VE on participants' experiences and on the CH preservation efforts. The data for this study included interview transcripts and field notes collected during the experiment process.

The TA allowed for a detailed examination of the data and consideration of the potential impact of subjectivity on the research process and findings. Through this process, we identified several themes, and within each theme, several subthemes emerged, providing more detailed insights into the topic, and helped to identify specific traits and characteristics for improvement in such approaches.

4.1. Pre-test Questionnaire

Table 4. Demographic Characteristics and Prior Knowledge of Participants

	Participant	**Number**	**Percentage**
Gender	Male	4	40
	Female	6	60
	Nonbinary	-	-
Age	18-24	4	40
	25-34	3	30
	35-44	1	10
	45-54	1	10
	55-64	1	10
Education	Bachelor’s degree	5	50
	Master’s degree	2	20
	PhD	2	20
	Other	1	10
Expert in related fields (e.g., Heritage, Architecture and Design)	Yes	4	40
	No	6	60
Prior experience with XR technology	Yes	3	30
	No	7	70
Prior knowledge about the site	Yes	3	30
	No	7	70

4.2. Post-test Interviews

4.2.1. Virtual Immersion

Virtual immersion refers to the degree to which participants felt immersed in the virtual reconstruction of lost CH using XR technology and was identified through codes related to the immersive and interactive experience of digital reconstruction, and the characteristics and features that influences the level of immersion.

Table 5. Virtual Immersion Subthemes

Theme	Subtheme
Virtual immersion	Immersive experience
	Interactivity
	Presence

Evidence from the data supporting this theme included participants' descriptions of the degree of immersive and interactivity the provided, as well as the potential for such practices to deliver a more effective alternative experience for visitors than physical exhibitions and provided in-depth understanding of the characteristics that can improve the experience, including presence, realism, control, and interactivity. Nevertheless, all participants reported feeling immersed to a high degree. For example, participant-1 stated: "The immersion provided by the environment is really impressive. It feels like I was really walking there.", participant-9 stated: "I felt as a part of the environment yet being alone in it reduced this feeling, overall it felt real to be there like any place in real-world", and participant-4 expressed: "It was surprising to go through such an experience, the objects felt so real which inspired my desire to experience more in the environment.". Moreover, participant-8 added "I felt I'm in the real world. but I wanted more control over the environment's elements.", and participant-10 explained: "The experience felt good generally speaking. But I still believe that experiencing CH sites in real life feels more touching despite all the advantages these approaches have.".

4.2.2. User Experience

User experience refers to the participants' perceptions of the ease of use and overall enjoyment of the virtual reconstruction of lost CH using XR technology and was identified through codes related to participants' overall experience of the VE using XR, including any challenges or difficulties they encountered.

Table 6. User Experience Subthemes

Theme	Subtheme
User experience	User engagement
	User satisfaction

Evidence from the data supporting this theme included participants' descriptions of their experiences in the immersive environment, their satisfaction as users regarding the experience, and features that can enhance the visitor experience and increase user engagement. Moreover, every participant reported that the experience was easy in general. However, some participants highlighted the need for additional entertainment components within the experience. For instance, participant-1 reported: "I have never tried VR before. However, it was straightforward and very enjoyable.", while participant-6 stated: "This kind of approach enhances the visitor experience by providing a more immersive and interactive experience. It also increases user satisfaction and engagement with the cultural heritage being represented.", while participant-9 explained: "The navigation was easy enough, which allowed me to enjoy the experience without stressing about the control.". Additionally, participant-5 mentioned that "Adding an adventurous factor such as gaming to the experience may increase user engagement with the environment, thus improving the level of immersion." And Participant-7 added: "This was a fantastic experience! Though, I wish the experience was supported with audio commentary that recounts the tale and history of each section of the site while moving around it."

4.2.3. Cultural Authenticity

Cultural authenticity refers to the participants' perceptions of the accuracy and realism of the virtual reconstruction of lost CH using XR technology and was identified through codes related to the accuracy and authenticity of the XR reconstruction in relation to the physical site, and the potential risks of using XR technology to revive lost CH.

Table 7. Cultural Authenticity Subthemes

Theme	Subtheme
Cultural authenticity	Accurate and respectful representation
	Ethical considerations of digital reconstruction

Evidence from the data supporting this theme included participants' discussions of the architecture of the building, its representation of history, along with the

importance of accurately representing historical structures and cultures within such practices, as well as the potential for digital reviving of CH to perpetuate inaccurate narratives and information. Regardless, the majority of participants affirmed the experience featured a fairly accurate model and represented the building's history and values. For example, participant-6 stated: "Although there are minor details that could be added to the produced model, it is overall a pretty accurate representation of the building. However, it is important to ensure that the representation of historical structures and cultures in digital reviving projects is accurate and respectful. This helps to preserve the authenticity and integrity of the CH being represented.", participant-1 expressed: "As someone who worked in this building for years, I can say that it is just how I remember it.", meanwhile, participant-5 add: "It is a fascinating place, the building echoes the sense of the Tanzimat era with its unique form.", whereas participant-10 added: "The building was amazing to see and explore, but still I'm hesitant to fully embrace such practices because it have the potential to manipulate cultural authenticity, and ultimately harm our understanding and appreciation of culture."

4.2.4. Educational Value

Educational value refers to the participants' evaluations of the usefulness and effectiveness of reviving lost CH using XR technology as a learning tool and was identified through codes related to the perceived educational value of the XR reconstructions.

Table 8. Educational Value Subthemes

Theme	Subtheme
Educational value	Interactive learning
	Access to information

Evidence from the data supporting this theme included participants' descriptions of the interactive learning opportunities and access to information provided by digital reviving, as well as the potential for digital reconstruction to be used as a teaching tool. Furthermore, participants emphasized that the environment is enough for reflecting the architectural characteristics of the site. Yet, they stressed the necessity of alternate teaching approaches such as voice notes, descriptions, and text. For example, participant-5 stated: "Digital reviving provides an interactive learning experience that is not possible with traditional exhibits. It also allows visitors to

access a wealth of information about the CH being represented. Therefore, this should only be practiced in accurately presented settings.", and participant-6 noted "The environment provided a wealthy amount of information regarding the site through visuals. However, I think adding a voice over or guidance can further provide an educational aspect to the experience.". Moreover, Participant-2 expressed: "I wish there were descriptions about the site on the walls, like the one in the real-world heritage sites!", and Participant-10 added: "Integrating entertainment educational tools such as serious games will definitely increase the educational value of the experience especially for younger users.".

4.2.5. Benefits of Digital Reconstruction Through XR Technology

The benefits of digital reviving refer to the opportunities that such practices can offer to the CH preservation efforts, as well as its potentials in visualizing lost CH sites and its values and was identified through codes related to the potential of XR technology to preserve and share CH in a way that is accessible to a wider audience.

Table 9. Benefits of Digital Reconstruction Through XR Technology Subthemes

Themes	Subthemes
The benefits of digital reconstruction	Accessibility
	Preservation
	Affordability
	Sustainability

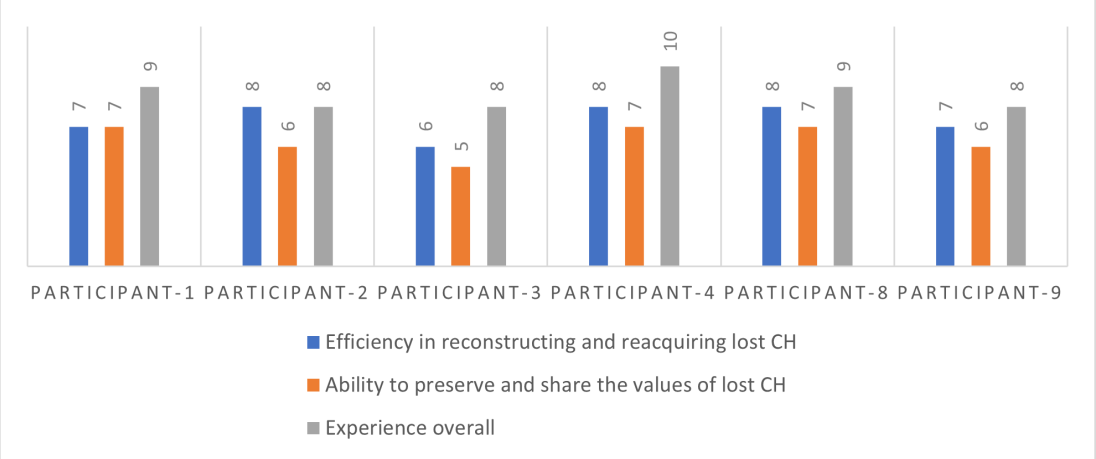
Evidence from the data supporting this theme included participants' descriptions of the potential of digital reconstruction to provide a more immersive and interactive experience for visitors, as well as the ability to preserve and share CH in a way that is not possible with physical structures. Furthermore, all participants exhibited believing in this approach for providing the access to lost CH sites, preserving heritage for the following generations in a safe, cost-efficient, and sustainable manner, while supporting real-world lost CH sites reconstruction efforts. For example, participant-7 stated: "Digital reconstruction allows us to create a virtual experience that is much more interactive and immersive than a physical exhibit. It allows visitors to explore the structure in a way that is not possible with a physical model.", while participant-6 explained: "Such practices pose a huge responsibility on us to share the world our heritage and communicate it with the locals, since it highlights the values of our culture and community.", participant-2 stressed: "I believe such applications can make lost heritage accessible globally and contribute in

inheriting it to upcoming generations", and participant-5 added: "I think experiences like these can improve real-world restoration projects because they enhance our understanding of the sites, their environments, measurements, materials, etc. and allow us to conduct work and research on its elements that are inaccessible or exceptionally fragile.", whereas participant-6: "I believe that including and integrating recent advances in technology such as metaverse and AI with this type of practices can provide an alternative and sustainable solution for archiving and accessing heritage and culture, as well as enabling practically everyone, regardless of their peculiarities or physical location to engage in low-cost or free unique cultural experiences that include extra entertainment and educational resources that would not be available otherwise.".

4.2.6. Ratings of the Approach

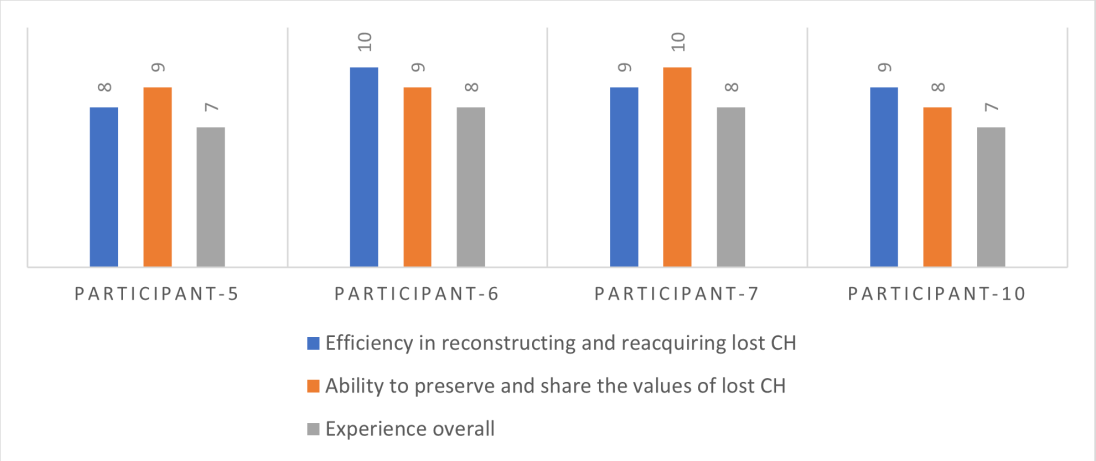
Participants were asked to rate this approach on a scale of 1 to 10 based on its efficiency in reconstructing and reacquiring lost CH, its ability to preserve and communicate lost CH values, and the overall experience (Figure 17.). Nevertheless, since participants 5, 6, 7, and 10 are experts in related fields such as heritage, architecture, and design, their ratings are presented separately (Figure 18.).

Figure 17. Evaluation of the Approach: Participants' Ratings



According to the ratings, non-expert participants gave an average rating of 7.3 out of 10 for the approach's efficiency in reconstructing and reacquiring lost cultural heritage, an average rating of 6.3 out of 10 for its ability to preserve and communicate lost cultural heritage values, and an average rating of 8.66 out of 10 for the overall experience.

Figure 18. Evaluation of the Approach: Experts' Ratings



According to the ratings, expert participants in related fields gave an average rating of 9 out of 10 for the approach's efficiency in reconstructing and reacquiring lost cultural heritage, an average rating of 9 out of 10 for its ability to preserve and communicate lost cultural heritage values, and an average rating of 7.5 out of 10 for the overall experience.

5. DISCUSSION

The integration of XR technology in cultural computing and heritage studies has opened up new possibilities for sustainable CH preservation, but present practices have mainly focused on enhancing and preserving existing or endangered heritage elements rather than on digital reconstruction and experience of lost CH sites. The aim of this study was to explore the capabilities of XR technology for reviving lost CH sites in VEs, and to understand its potential in contributing to CH preservation efforts and providing immersive experiences to users.

The results of the analysis indicate that XR experiences can be an effective approach for digital reviving of lost CH sites, but also reveal various factors that influence their efficiency and provide insight into its diverse implications for users. This chapter aims to provide a reflection on the research findings by interpreting and analyzing the results and evaluating their implications for theory and practice in the light of existing literature, and to address and discuss the limitations of the research. Additionally, the main findings are presented in three main sections that encompass the themes identified in the results, allowing for a focused and comprehensive examination of each research question.

5.1. Effectiveness of XR Technology for Reconstructing and Experiencing Lost Cultural Heritage Sites

This section discusses the findings on the themes of 'virtual immersion' and 'user experience,' as the data from the literature and research reveals that these relate and influence the overall effectiveness of the XR technology in creating an immersive and enjoyable experience for users that influences users' experiences and understanding of lost CH sites.

5.1.1. Virtual Immersion

Data collected from all participants shows that the experience was relatively immersive. It is clear that participants perceived the VE as a real-world experience

where they felt present in it. This suggests that the immersive and interactive qualities of the virtual reconstruction were successful in presenting the site realistically and immersing the users and helping them feel like they were truly experiencing the lost CH site, and aligns with the findings of Rubo et al (2020) and Bonnail et al (2022) which suggest that highly immersive XR experiences can blur the line between reality and VEs, allowing these experiences to be perceived as real-world experiences and influencing people's memories and experiences, which in turn can shape their future choices and behaviors. Although the results suggest that the immersion of the experience is high, they also indicate that the immersion could be further enhanced by presenting it in C-VE, which may reduce feelings of loneliness and increase presence, in addition to allowing users to interact with objects in the VE, this demonstrates a correlation between immersion, presence, and interactivity and supports the findings of (Matthews, et al:2021: Mütterlein, 2018) that immersion, presence, and interactivity are 3 main connected principles that shape and influence any XR experience.

5.1.2. User Experience

Gathered data from all participants indicates that the VE was easy to use and navigate around and overall enjoyable, which could appeal to a wider audience and visitor demographic. However, it also shows that this theme was one of the most commented subjects. It is clear that there is room for improvement in terms of user engagement and satisfaction by adding entertainment and adventurous components, for instance games and interactive storytelling. Thus, the present findings corroborate those of Doukianou et al (2020) and Okanovic et al (2022) in demonstrating that these experiences should be designed simple and easy to target all kinds of audiences and integrating user centered XR solutions that adds a human compassion aspect to the experience can increase user satisfaction and engagement, thereby improving the overall user experience in these approaches. These results highlight the need to consider user experience during the design and development process of XR technology for CH preservation, to ensure that the technology is enjoyable and engaging for all users.

5.1.3. Key Takeaways and Implications for Future Research

Overall, the findings from this study suggest that XR technology can be an effective tool for reviving lost cultural heritage sites, as it allows for immersive and interactive virtual experiences that can be perceived as real-world experiences by users. This is also demonstrated by the interest shown by all participants regardless of their diverse demographic characteristics and prior knowledge of the site and technology in the experience, high levels of virtual immersion, and overall enjoyment reported by participants. Moreover, these findings are supported by the ratings given by participants, with an average rating of 8.2 out of 10 for the overall experience.

The results also highlight the importance of considering factors such as virtual immersion and user experience when designing XR experiences related to lost CH sites, as these can significantly influence the effectiveness of the technology on the overall experience. These findings have several implications for the literature and research on XR practices and their impact on users' experiences and understanding of lost CH sites. Firstly, the results support the idea that XR technology can be a valuable tool for experiencing lost CH sites. Secondly, the findings indicate that the design of XR experiences for lost CH should consider the principles of immersion, presence, and interactivity to create effective and engaging experiences for users. Finally, the results suggest that user experience is an important factor in the success of XR technology for reviving lost cultural heritage sites and highlight the need to consider the user's perspective when designing these experiences. Overall, this study contributes to the understanding of the potential of XR technology for reviving lost cultural heritage sites and highlights the importance of considering user experience and immersion in the designing process of these experiences. Nevertheless, further research is needed to explore the long-term impacts of such approaches on the users' memories and perceptions, and to investigate its implications on other types of users, for instance users with disabilities.

5.2. Implications of XR Technology on Cultural Heritage Preservation Efforts

This section discusses the findings on the themes of "cultural authenticity" and "educational value" as the data from the research results and literature reveals that these connected factors relate to the potential of XR technology to contribute to CH preservation efforts and to accurately represent CH elements. This will help to

provide a deeper understanding of the impacts of XR technology on CH preservation efforts.

5.2.1. Cultural Authenticity

The collected data implies that the experience presented the site accurately and respectfully and featured a detailed representation of the building's architecture and history. However, the data also shows that this was the main theme that raised concerns regarding the potential risks of adopting such approaches for lost CH sites, since the potential for manipulation of cultural authenticity, modifying history and harming our understanding and appreciation of culture and heritage. These findings concur with previous findings of Bonnail et al (2022) that suggest such experiences can be (intentionally or not) inaccurate which results in false memory manipulation. In other words, these findings corroborate the theory of (Nguyena, et al:2022) that XR technology can be an effective tool for preserving, representing, and communicating the values of lost CH sites, provided that the representation is accurate and authentic, and the potential ethical considerations are taken into account.

5.2.2. Educational Value

The collected data shows that the experience allowed the access to valuable essential information regarding the site, its history, architecture, and environment, validating that XR experiences have the potential of presenting an interactive and immersive preservation and educational tool. Thereby, the findings agree with the claims of Beraldin, et al: (2005) that XR experiences have the ability to improve cognitive and interpretative processes for a better preserving, understanding and sharing of the properties' values, geometry and appearance. Regardless, the data also highlights the lack of additional educational aspects within the experience that can attract younger audiences to engage with the experience, further improve it as an educational tool, and enhance the overall educational value of such approaches, such as serious games, virtual guidance, and audio commentary. Most importantly, the data highlights the importance of cultural authenticity by revealing the crucial connection between the educational value, accurate representation of the site and the efficiency of XR technology in contributing to CH preservation efforts. Therefore, the presented data suggest that in order to present such experiences as a valuable educational tool it has

to present the subjects very accurately and consider the integration of additional interactive educational aspects.

5.2.3. Key Takeaways and Implications for Future Research

The findings from this study suggest that XR technology can be an effective interactive preservation and educational tool that contributes to the accurate representation of lost CH elements and provides easy access to its values and information in a way that cannot be achieved in real life. These findings are supported by the ratings given by participants, with an average rating of 7.4 out of 10 for the ability of the experience to preserve and communicate lost CH values.

As such, these findings have several implications for future research in this field and highlight key considerations for presenting such experiences as educational and preservation tools. For instance, it is important to prioritize the accuracy and authenticity of XR reconstructions in order to avoid perpetuating false narratives and information, which can be achieved through in-depth research and consultation with heritage experts on the site being represented. The integration of interactive and educational elements, such as serious games and audio commentary, can also enhance the educational value of XR experiences and make them more attractive to younger audiences, and be an effective way to engage the next generation in learning about and preserving CH. Overall, these findings suggest that careful consideration of cultural authenticity and the incorporation of educational elements can make XR technology a valuable interactive preservation tool for lost CH. Nevertheless, Future research is needed to explore the long-term impacts of these approaches on visitors'/users' perspectives and appreciation of lost CH values.

5.3. Benefits of Digital Reconstruction Through XR Technology Approaches

This section discusses the findings on the theme of "benefits of digital reconstruction through XR technology" as the data from the research results indicates that this theme examines and summarizes the potential benefits of adopting such approaches.

5.3.1. Benefits of Digital Reconstruction Through XR Technology

The data collected supports the idea that reviving CH using XR technology can offer several benefits in terms of accessibility, preservation, affordability, and

sustainability. Moreover, the results also agree with the assertions made by Beraldin (2005) that the use of XR technology allows for the long-term, sustainable preservation of cultural heritage sites in a digital format, which can be accessed by practically everyone regardless of their characteristics or location. It also offers affordable cultural experiences that feature entertainment and educational aspects that attract a wider audience while raising awareness and support for the preservation of physical CH sites. Furthermore, the results agree with the claims of Gaugne (2022) that the highly immersive and interactive experiences XR offers, supports the work and research on the CH sites and their elements without exposing them to any probable damage.

However, the data also highlights the additional potential benefits of these approaches in context of recent advances in technology such as the Metaverse.

5.3.2. Key Takeaways and Implications for Future Research

The findings of this study suggest that the adoption of XR technology in this field offers a wide range of benefits to all disciplines of CH preservation efforts, particularly those related to lost CH. These benefits enhance the overall efficiency of practices aimed at reviving lost CH in some form. These findings are supported by the ratings given by participants, with an average rating of 8 out of 10 for its efficiency in reconstructing and reacquiring the lost CH site.

Overall, the findings of this study provide valuable insight into the potential benefits using XR technology for digital reconstruction of lost CH sites and highlight the importance of considering these approaches in current CH preservation efforts. Nevertheless, Further research is needed to examine the potential for these approaches to be integrated with other technologies such as artificial intelligence or the metaverse in order to enhance the user experience and create more realistic virtual reconstructions while improving current benefits.

5.4. Highlights and Recommendations for Practice

The findings of this study suggest that XR technology is an effective tool for reviving lost CH sites, but also highlights the importance of considering several factors in order to enhance the overall effectiveness and user experience of these approaches.

One key determinative factor is the accuracy and authenticity of XR reconstructions. It is crucial to prioritize the accuracy and authenticity of these experiences in order to avoid perpetuating false narratives and information. This can be achieved through in-depth research and consultation with experts on the cultural heritage site being represented.

Another important factor is the importance of immersion, presence, and interactivity in shaping the user experience. The findings suggest that presenting XR experiences in a C-VE and allowing for more interactivity can enhance the immersive qualities of the experience and increase presence, leading to a more realistic and enjoyable experience for users. Additionally, designing XR experiences to be simple, entertaining, and user-centered, and incorporating interactive and educational elements such as serious games and audio commentary, can improve user satisfaction and engagement and make the experiences more attractive to a wider audience.

It is worth noting that participants with prior knowledge of the site and experience with XR technology tended to rate the efficiency and ability to preserve and communicate CH values higher, while those without prior knowledge or experience tended to rate the overall experience higher. This suggests that while the virtual reconstruction is successful in presenting the site accurately and immersing users, there may be an opportunity to further improve the educational and interpretive aspects of the experience for those who are less familiar with the site or the technology.

5.5. Limitations of the Research

The following limitations should be taken into account when considering the implications of this study's findings. Firstly, the time duration was relatively short. Thus, long-term implications on samples' memories and experiences could not be examined. Additionally, the reach to a wider sample was limited. So, the study was conducted with a specific group of participants who may not be representative of the whole population. Finally, the study was conducted using I-VR. Accordingly, the results may not be generalizable to other types of XR experiences.

Additionally, this study employed note taking as a method for data recording and documentation to ensure the comfort of the participants. However, it should be noted

that using alternative methods such as audio or visual recordings could potentially provide additional insights. These methods could allow for re-examination of the data in its entirety, as well as the ability to observe users' movements during the experience, which could enhance our understanding of the user experience.

Despite these limitations, the findings of this study provide valuable insight into the potential benefits and limitations of using XR technology for reviving lost CH sites and highlight the importance of considering these approaches in CH preservation efforts.

6. CONCLUSION

This chapter concludes the study by summarizing the key findings of the study in relation to the research aims and questions, discussing their significance and value. Additionally, it suggests areas for future research that may build upon and extend the insights gained from this study.

The current research aimed to create an XR experience of a real lost cultural heritage site, in order to evaluate its implications on users and its efficiency in reviving lost CH.

The focus of this research was on the following questions:

- What implications can XR practices reflect on users' experiences and understanding of lost CH sites?
- How does the use of XR technology for reviving lost CH sites impact heritage preservation efforts?
- What are the potential benefits and challenges of adopting XR practices for reviving lost CH sites?

Based on a reflexive TA of the collected quantitative and qualitative data from 10 participants, it can be concluded that XR technology can provide highly immersive and interactive virtual reconstructions of lost CH sites in VEs that can be perceived as real-world experiences, influencing users' understanding and perception of lost CH and supporting real-world preservation efforts. However, this is only possible if the representation is accurate, authentic, and realistic, since the data indicates that inaccurate representations pose a risk, as they can manipulate cultural authenticity, modify history, or harm our understanding and appreciation of culture and heritage. In addition, the findings also highlight the importance of considering the user experience and integrating user-centered solutions and technological advancements that may enhance engagement and satisfaction to take advantage of all the benefits these experiences offer.

However, further research with larger sample sizes and different participant groups is needed to extend the findings of this study. Additionally, future research should

focus on examining the long-term effects on users' memories and the potential benefits and challenges of integrating advanced technologies such as the Metaverse and artificial intelligence. It would also be valuable to explore the use of XR technology to enhance the educational and interpretive aspects of CH experiences, including considerations of historical accuracy and cultural sensitivity, as well as examining the long-term impacts on users' understanding and appreciation of CH. Finally, I-VR may offer the most appropriate medium for reviving lost CH sites. Yet, further research is needed to explore the potentials and limitations of using other forms of XR technology in projects related to reviving lost CH.

Overall, this research has demonstrated the effectiveness of XR technology for reviving lost CH sites and has provided valuable insights and recommendations for improving the design and development of these approaches, and for future research. These findings have the potential to contribute to the body of knowledge on the use of XR technology for CH preservation and provide guidance for practitioners in this field.

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APPENDIX

Appendix 1. Research Ethics Report

YILDIZ TEKNİK ÜNİVERSİTESİ
Sosyal ve Beşeri Bilimler Araştırmaları Etik Kurulu

Toplantı Tarihi: 27.12.2022 **Toplantı No: 2022.12**

SOSYAL VE BEŞERİ BİLİMLER ARAŞTIRMALARI ETİK KURULU TOPLANTI KARARI

Yürütücülüğünü Üniversitemiz Sosyal Bilimler Enstitüsü öğretim üyelerinden Doç. Dr. Bahadır Uçan danışmanlığında lisansüstü öğrencisi MUHAMMET NECİP ŞAĞAR tarafından yapılacak olan "Digital Reconstruction Of Lost Cultural Heritage Using Extended Reality Technology A Case Study On The Historic Structure Of National Hamidi Hospital" adlı çalışma ve bu çalışmada kullanılacak veri toplama araçları ve yöntemlerine ilişkin bilgilerde etiğe aykırı herhangi bir bulguya rastlanmamıştır.

Etik Kurul Üyeleri

Prof. Dr. Murat DÜNDUREN
Başkan

Prof. Dr. Ali ERYILMAZ
Üye

Prof. Dr. Gülhayat GÖLBAŞI ŞİMŞEK
Üye

Doç. Dr. Mehmet Emin KAHRAMAN
Üye

Doç. Dr. Senay OĞUZTİMUR
Üye

Doç. Dr. Yasin ŞEHİTOĞLU
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Rapor Doğrulama Adresi: "etik.yildiz.edu.tr/dogrula" Rapor No: 20221201811 Doğrulama Kodu: 6767a

Appendix 2. Participants Voluntary Consent and Informed Consent Form

Ek-2. Deneklerin Gönüllülüğü ve Aydınlatılmış Onam Formu

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DENEKLERİN GÖNÜLLÜLÜĞÜ
VE
AYDINLATILMIŞ ONAM FORMU

"Digital Reconstruction of Lost Cultural Heritage Using Extended Reality Technology: A Case Study on The Historic Structure of National Hamidi Hospital" araştırmasında, 18 yaşından büyük yetişkin ve bu deneye katılmaya engel herhangi bir sağlık sorunu bulunmayan gönülluler katılacaktır. Muhammet Necip ŞAĞAR tarafından yürütülecek araştırmada, HTC Vive Cosmos sanal gerçeklik gözlüğü ve dizüstü bilgisayar kullanılarak kayıp miras alanı Halep Hamidiye Hastanesi sanal ortamda deneyi yapılacaktır. Deney esnasında, kayıp kültürel miras alanlarının sanal ortamlarda yeniden inşası ve deneyimlenmesi için bir XR yaklaşımı ve uygulaması oluşturmayı ve değerlendirmeyi amaçlamaktadır. Böyle bir deneyim sorunları/zorlukları elde edilen veriler ve mülakatlarla tespit edilip, kültürel miras alanlarının sanal ortamlarda daha iyi deneyimlenmesine katkıda bulunan özelliklerin belirlenmesini daha sonra bu özellikleri sonraki deneyimlerde kullanmaya yönelik çıkarımlar yapılacaktır. Deney esnasinda görüntü kaydi yapılabilir ve deney sonrası yayin, rapor vb. dökümanlarda kullanilabilir. katılımcıların kişilik hakları ve özel bilgileri korunacak, paylaşılmayacaktır. test ve mülakat calısmaları toplamda 35 dakikayı geçmeyecek ve belirlenecek gün ve saatte tek seferde yapılacaktır. mülakat yanıtları gönüllülerin kimlikleriyle ilişkilendirilmeyecek "katılımcı-1, katılımcı-2" seklinde isimlendirilecektir. katılımcılardan test esnasında sanal ortamı, görevleri başarıyla tamamlama ve yaşadığı deneyimi mülakat sorularıyla aktarması gibi bilgiler istenecektir. Deney asaması ve deney sonrası elde edilen bilgiler katılımcılarının özel hayatini etkilemeyecektir. Katılımcı deney esnasında istediği zaman deneyi sonlandırıp çalısmadan ayrılabilecektir. Bilgilendirilmiş Olur Formu ile katılımcılardan yazılı izin alınacaktır.

Dr. Öğr. Üyesi Bahadır UĞAN

Muhammet Necip Şağar

Doküman No: FR-1628; Revizyon Tarihi: 01.10.2021; Revizyon No: 03

Appendix 3. Informed Consent Agreement Form

Ek-4. Bilgilendirilmiş Olur Formu

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BİLGİLENDİRİLMİŞ OLUR FORMU

1. Aşağıda imzası olan ben " Digital Reconstruction of Lost Cultural Heritage Using Extended Reality Technology: A Case Study on The Historic Structure of National Hamidi Hospital" başlıklı çalışmaya katılmayı kabul ediyorum.
2. Bu çalışmayı yürüten Muhammet Necip ŞAĞAR çalışmanın yapısı, amacı ve muhtemel süresi, hakkında ayrıntılı sözlü ve yazılı bilgi verdi.
3. Araştırmacı Muhammet Necip ŞAĞAR'a çalışmasıyla ilgili her soruyu sorma fırsatını buldum. Cevapları ve bana verilen bilgiyi anladım.
4. Araştırmacı Muhammet Necip ŞAĞAR'a bilgilerin ayrıntılarını açıklamama ve benimle ilgili sırları koruması şartıyla benimle bu çalışmayı yapmasına izin veriyorum.
5. Çalışma boyunca tüm kurallara uyacağıma, araştırmacı Muhammet Necip ŞAĞAR ile tam bir uyum içinde çalışacağıma ve konuyla ilgili herhangi bir sorun çıktığında hemen onu arayacağımı kabul ediyorum.
6. Bu çalışma sonuçlarının kullanılmasını kısıtlamayacağımı ve yayın, rapor ve benzeri bilimsel dokümanlarda kullanabileceğini kabul ediyorum.
7. Bu çalışmadan istediğim zaman çıkabileceğimi anladım.

OKUDUM VE ONAYLADIM.

Katılımcının Adı ve Soyadı, Adresi: Tarih, İmza:

Araştırmacının Adı ve Soyadı, Adresi: Tarih, İmza:

Muhammet Necip ŞAĞAR

Esenler/İstanbul

Danışm. Bahadır UĞAN

Doküman No: FR-1628; Revizyon Tarihi: 01.10.2021; Revizyon No: 03

Appendix 4. Pre-test Questionnaire

Pre-test Questionnaire

Participant name: .....
Date: .....

		Answer
Gender	Male	
	Female	
	Nonbinary (other)	
Age	18-24	
	25-34	
	35-44	
	45-54	
	55-64	
Education	Bachelor's degree	
	Master's degree	
	PhD	
	Other	
Are you an expert in related fields (e.g., Heritage, Architecture and Design)	Yes	
	No	
Do you have any prior experience with XR technology	Yes	
	No	
Do you have any prior knowledge about the site	Yes	
	No	

Research Signature

Participant Signature

Doküman No: FR-1628; Revizyon Tarihi: 01.10.2021; Revizyon No: 03

Appendix 5. Post-test interview Questions

Post-test Interview Question Examples

Q_1: Can you explain how your experience went in a few sentences?

Q_2: What difficulties did you encounter while experiencing the environment?

Q_3: Can you describe how the environment felt in general, was it realistic or artificial?

Q_4: Did you feel like you were a part of the environment?

Q_5: How would you describe your feelings during the experience?

Q _6: Were there any shortcomings in the environment?

Q _7: What features would you like to be added to the experience?

Q_8: How did the building provided in the environment felt, and would you like to explore and experience it more?

Q_9: If you were able to explore the building in real life, do you think would you be able to get to know and navigate its surroundings based on the experience you have had?

Q_10: Do you think such practices are efficient in communicating lost cultural heritage values?

Q_11: How much would you rate the experience based on its efficiency in reconstructing and reacquiring lost CH out of 10?

Q_12: How much would you rate the experience based on its ability to preserve and communicate lost CH values out of 10?

Q_13: How much would you rate the overall experience out of 10?

Note: The interviews are semi-structured, so questions can be modified, and additional questions can be added as required.

Doküman No: FR-1628; Revizyon Tarihi: 01.10.2021; Revizyon No: 03

Appendix 6. Originality Report

Alıntı raporu_Muhammet Necip Şağar

ORIGINALITY REPORT

5%	4%	3%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	docomomojournal.com Internet Source	<1%
2	Submitted to University College London Student Paper	<1%
3	Ramiro Barberena, Augusto Tessone. "Chapter 811 Isotopic Studies of Foragers' Diet: Environmental Archaeological Approaches", Springer Science and Business Media LLC, 2020 Publication	<1%
4	gradcoach.com Internet Source	<1%
5	en.m.wikipedia.org Internet Source	<1%
6	whc.unesco.org Internet Source	<1%
7	pdffox.com Internet Source	<1%
8	www.dailysabah.com Internet Source	

Appendix 7. Additional Photos of the Designed Experience

