UNIVERSITAT POLITÈCNICA DE VALÈNCIA

School of Architecture

FEASIBILITY OF DEVELOPING EXTENDED REALITY APPLICATIONS FOR THE INTERPRETATION OF THE NABATAEAN ARCH OF PETRA (JORDAN)

Master's Thesis

Master's Degree in Preservation of Architectural Heritage

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ABSTRACT

The Archaeological Park of Petra is one of the most visited UNESCO World Heritage Site, but it also suffers problems caused by an expanding mass tourism dynamic. The site management plans have always attempted to address the Park's challenges in terms of sustainability, and this project proposes a strategy to facilitate the initiation of this complex process starting by reformulating the initiative promoted by the Petra Development Tourism Region Authority to reconstruct the Nabataean Arch of the ancient city.

To achieve the goal of preserving the authenticity of the site and digitizing the cultural offering of the Park, the evaluation of the benefits associated with the adoption of an augmented reality application for the dissemination of the digital reconstruction of the Nabataean Arch was chosen. The methodology employed included an initial documentary and field analysis aimed at identifying the main challenges faced by the Authority, subsequently, the complexity related to the physical reconstruction of the monument were analysed according to UNESCO and UN directives. The next phase involved evaluating the best available digital technology for reading the Arch without a physical reconstruction. Finally, the benefits of the proposal were evaluated and demonstrated in terms of sustainability, starting from the digital interpretation program of the Nabataean Arch and expanding the initiative to the majority of the Park's monuments that are no longer visible.

KEYWORS:

Petra; tourism; user experience; augmented reality; digital heritage.

RESUMEN

El Parque Arqueológico de Petra es uno de los Sitios Patrimonio Mundial de la UNESCO más visitados en el mundo, pero sufre problemas causados por una dinámica de turismo de masas en expansión. Los planes de gestión del sitio siempre han intentado abordar los desafíos del Parque en términos de sostenibilidad y, este trabajo propone una estrategia para facilitar este proceso complejo, empezando con la reformulación de la iniciativa promovida por la Petra Development Tourism Region Authority para reconstruir el Arco Nabateo de la antigua ciudad.

Para lograr el objetivo de preservar la autenticidad del sitio y digitalizar la oferta cultural del Parque, se hizo la evaluación de los beneficios asociados con la adopción de una aplicación de realidad aumentada para la difusión de la reconstrucción digital del Arco Nabateo. La metodología empleada incluyó un análisis inicial documental y de campo destinado a identificar los principales desafíos enfrentados por la Autoridad, posteriormente, se analizaron las complejidades relacionadas con la reconstrucción física del monumento teniendo en cuenta las directivas de la UNESCO y de la ONU. La siguiente fase implicó evaluar la mejor tecnología digital disponible para volver a leer el Arco sin su reconstrucción física. Finalmente, los beneficios de la propuesta fueron evaluados y demostrados en términos de sostenibilidad, considerando el programa de interpretación digital del Arco Nabateo y expandiendo la iniciativa a la mayoría de los monumentos del Parque que ya no son visibles.

RESUMEN
(Valenciá)

El Parc Arqueològic de Petra és un dels Llocs Patrimoni Mundial de la UNESCO més visitats en el món, però patix problemes causats per una dinàmica de turisme de masses en expansió. Els plans de gestió del lloc sempre han intentat abordar els desafiaments del Parc en termes de sostenibilitat i, este treball proposa una estratègia per a facilitar este procés complex, començant amb la reformulació de la iniciativa promoguda per la Petra Development Tourism Region Authority per a reconstruir l'Arc Nabateo de l'antiga ciutat.

Per a aconseguir l'objectiu de preservar l'autenticitat del lloc i digitalitzar l'oferta cultural del Parc, es va fer l'avaluació dels beneficis associats amb l'adopció d'una aplicació de realitat augmentada per a la difusió de la reconstrucció digital de l'Arc Nabateo. La metodologia emprada va incloure una anàlisi inicial documental i de camp destinat a identificar els principals desafiaments enfrontats per l'Autoritat, posteriorment, es van analitzar les complexitats relacionades amb la reconstrucció física del monument tenint en compte les directives de la UNESCO i de l'ONU. La següent fase va implicar avaluar la millor tecnologia digital disponible per a tornar a llegir l'Arc sense la seua reconstrucció física. Finalment, els beneficis de la proposta van ser avaluats i demostrats en termes de sostenibilitat, considerant el programa d'interpretació digital de l'Arc Nabateo i expandint la iniciativa a la majoria dels monuments del Parc que ja no són visibles.

ملخّص

تعد محمية البتراء الأثرية واحدة من أكثر مواقع التراث العالمي لليونسكو زيارة، ولكنها تعاني أيضًا من مشاكل ناجمة عن ديناميكيةَ السياحة الجماعية المتزايدة. لقد حاولت خطط إدارة الموقع دائمًا معالجة تحديات المحمية من حيث الاستدامة، ويقترح هذا المشروع استراتيجية لتسهيل بدء هذه العملية المعقدة بدءًا من إعادة صياغة المبادرة التي تروج لها سلطة اقليم البترا التنموي السياحي في البترا لإعادة بناء قوس النصرالنبطي في مدخل السيق في المدينة القديمة.

ولتحقيق هدف الحفاظ على أصالة الموقع ورقمنة العرض الثقافي للمحمية الأثرية، تم اختيار تقييم الفوائد المرتبطة باعتماد تطبيق الواقع المعزز لنشر إعادة البناء الرقمي للقوس النبطي. تضمنت المنهجية المستخدمة تحليلاً وثائقيًا وميدانيًا أوليًا يهدف إلى تحديد التحديات الرئيسية التي تواجهها لها سلطة اقليم البترا التنموي السياحي، وبعد ذلك، تم تحليل التعقيدات المتعلقة بإعادة البناء للنصب التذكاري وفقًا لتوجيهات اليونسكو. تضمنت المرحلة التالية تقييم أفضل التقنيات الرقمية المتاحة لدراسة القوس دون إعادة البناء المادي. وأخيراً، تم تقييم فوائد المقترح وإظهاره من حيث الاستدامة، بدءاً من برنامج التفسير الرقمي للقوس النبطي وتوسيع المبادرة لتشمل غالبية آثار المحمية الأثرية التي لم تعد ظاهره.

1. INTRODUCTION

This Master's Thesis is part of several research projects, mainly the "Analysis and development of the integration of HBIM in GIS for the creation of a protocol for cultural heritage tourism planning" (ref. PID2020 - 119088RB - I00), funded by the Ministry of Science and Innovation, Government of Spain and the FPU grant (ref. FPU21/06469) funded by the Ministry of Universities, Government of Spain. Additionally, the author of this work was awarded a grant from the UPV (Universitat Politècnica de València) Development Cooperation Programme 2023.

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1.1 OBJECT OF THE STUDY: THE PETRA ARCHAEOLOGICAL PARK

All the countries of the Middle East boast sites of natural, historical, archaeological, architectural, and artistic significance; among them, Jordan has several sites internationally recognised by UNESCO, including the Petra Archaeological Park (PAP), that was listed as a UNESCO World Heritage Site since 1985 (PDTRA, 2022). In Jordan, there are more than ten thousand archaeological sites (Bala'awi et al., 2022), but the PAP stands out worldwide thanks to some exceptional universal values that have been identified by UNESCO for the inclusion of the ancient city in the World Heritage List (PDTRA, 2022). The criteria are the first, the third, and the fourth:

I. *to represent a masterpiece of human creative genius;*

III. *to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;*

IV. *to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history.*

Petra, located in the Ma'an Governorate, is situated halfway between the Dead Sea and the Red Sea **(fig. 01)** and it is a city of Nabataean origin, with several thousand monumental facades carved into the rocks of region's mountains. In addition to Nabataean era monuments, the Archaeological Park also features structures modified or built by successive civilizations and dwellings carved into caves.

The Nabataeans, who founded the city, were a nomadic people of Arab origin that settled in the Petra Region between the 7th century BC and the 2nd century AD (Burgen, 2000). The Nabataean people chose Petra as the capital of their kingdom because it was located along one of the main trade routes connecting the ancient Asian empires, Egypt and the Mediterranean basin. The topographical conditions of the area provided security to the settlement and passing caravans, fostering over the centuries the economic, demographic, and cultural growth of the city. In fact, the Site is naturally fortified by high mountains and inaccessible gorges. The Nabataean contact with major ancient

civilizations they engaged in trade with or were dominated by, led Petra to its monumental uniqueness.

The rock formations and architecture of the monuments make Petra's landscape a captivating masterpiece, making it one of the most visited archaeological sites globally and the most visited in Jordan. The Archaeological Park of Petra is also one of the most extensive sites in the world; it covers an area of about 264 km^2 (PDTRA, 2022), ranging between 900 and 1,500 meters above sea level (Bala'awi et al., 2022). However, the attraction of the Park is exposing the site to a degradation phenomenon, reinforced by the impact of climate change, which, by increasing the frequency and intensity of natural events, risks compromising the integrity of the Petra natural and archaeological heritage.

The entrances to the Park are marked by the town of Wadi Musa, which also hosts the Park's Visitor Center and most of the tourist facilities in the area, and Uum Sayhoun, one of the little villages of Wadi Musa now mainly inhabited by the Bedouin community, but originally built to house the Budool tribe, that once dwelled in the cave houses of the Archaeological Park. These two inhabited centers, characterized by significant differences in the presence of services (proportioned to the population of each urban area), are physically disconnected and culturally and socially distinct. Wadi Musa, crossed by the homonymous stream, features an urban center primarily geared towards tourism, although various facilities are also located outside of it. Uum Sayhoun, on the other hand, traversed by the Back Road leading to the secondary entrance/exit, is predominantly residential.

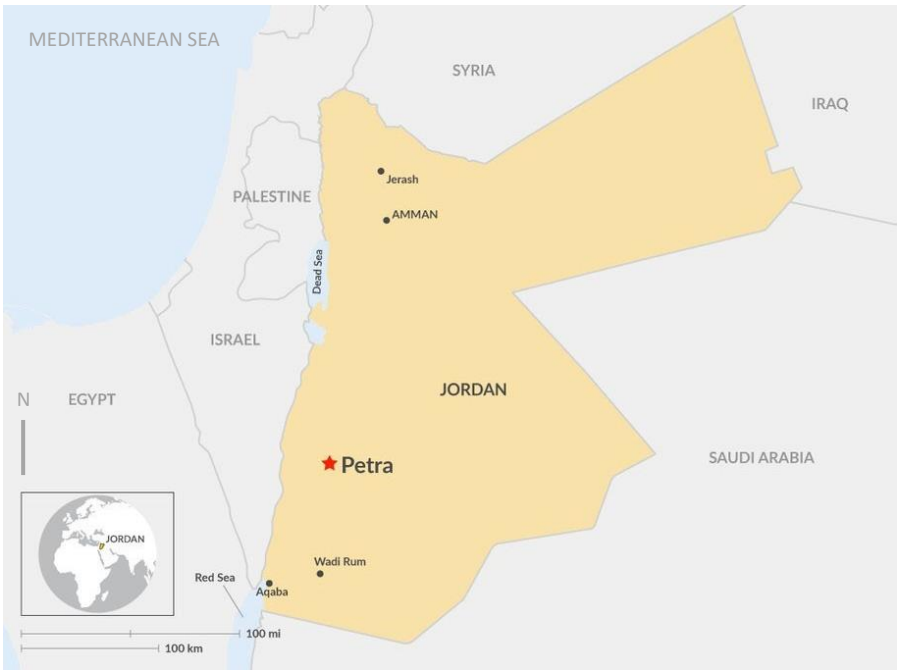


Fig. 01. Jordan map with Petra position (kimkim.com)

1.2 JUSTIFICATION OF THE WORK

Within the framework of the International Cooperation experience gained in Petra (UPV Cooperation Grants 2022/23), it was possible to understand the complexity behind managing a UNESCO archaeological site of international significance, pivotal to the Jordanian economy. From the beginning of the permanence in Wadi Musa, in the Archaeological Park and in the surrounding inhabited centres, a series of problems have been identified.

Consulting the literature and site management plans revealed that some of these issues have persisted for decades, making them structural and challenging to resolve. The most intense challenges encountered during the cooperation experience, not entirely controllable by the Park's management authority, were in the alteration of the environmental balance of the area and deficit in the maintenance of some monuments, poor maintenance of urban settlements, low permanence in Wadi Musa and Uum Sayhoun city centres and low visitor comfort into the Park and inhabited areas.

The first action taken within the cooperation project, and reiterated for the discussion of this work, was the study and direct analysis of the challenges affecting the Park, the local community, and the adjacent urban settlements. This allowed an understanding of the existing relationship connecting the development of the tourism sector with the dynamics of the local environmental and social degradation. In parallel, as cooperants, we have been called to cooperate to the reconstruction of the Nabataean Arch at the entrance to the Petra's Siq **(fig. 02)**; a monument almost entirely lost in the 19th century due to an earthquake. The evaluation of the opportunities deriving from this project promoted by the PDTRA (Petra Development and Tourism Region Authority), led to the formulation of a proposal which, if adopted, could better contribute to the solution of part of the critical issues founded in the Archaeological Park and its surroundings.

To meet the needs of the PDTRA, a document containing recommendations for the reconstruction of the Arch was written considering international guidelines for the conservation of UNESCO World Heritage Sites. However, in light of the identified challenges that the Authority should address, at first to improve the visit performance of the Park, this work proposes considering an alternative solution to the physical reconstruction of the Nabataean Arch. The proposal involves adopting a sustainable and technologically advanced strategy, specifically reconstructing the Arch solely in digital form, which will be made accessible through the development of an augmented reality application. The structure of the cooperation effort in which we have been called to participate,

leading to the formulation of this work, has been graphically summarized in the following diagram **(fig. 03)**.

Fig. 02. The remains of the Nabataean Arch of Petra. Authors: J. Lendering, M. Prins (2022)

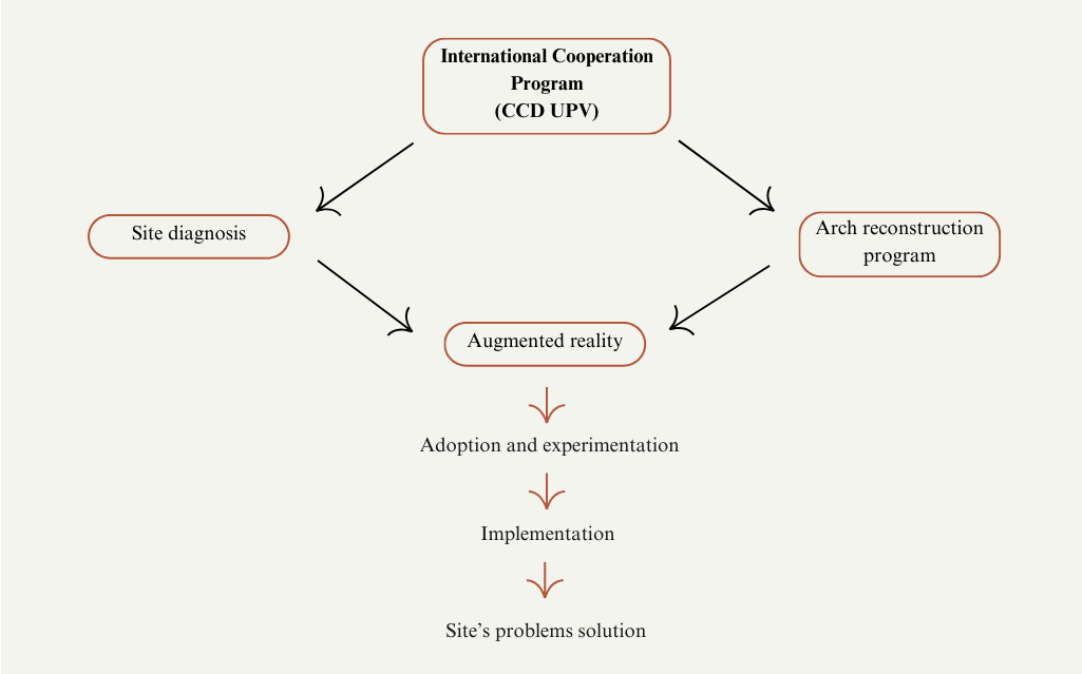


Fig. 03. Diagram of the cooperation experience

The interactions with visitors, furthermore, revealed difficulties in reading and interpreting the original architecture of the major ruins located in the Park, specifically, the most challenging archaeologies to interpret are those that are not-funerary and not-carved into the rock. The developing of an appropriate augmented reality application can solve the actual interpretation problem of the majority of ruins, making also easier the understanding of the architectural role of every disappeared monument.

The proposed strategy is briefly contextualized through diagrams related to all identified challenges and possible solutions **(fig. 04/a and 04/b)**; the digital reconstruction of the Nabataean Arch encourages, at first, greater investments to solve the urgent problems that actually affect the Park, the local community and visitor experience.

The challenges encountered in the field, the urgency in resolving them, and the alternative proposed to the physical reconstruction of the Nabataean Arch align with the Archaeological Site's development programs and the efforts of the PDTRA. In fact, on the *Strategic Plan for Wadi Musa and surrounding areas* produced by ATC Consultant GmbH in association with Design Workshop and JPC s.r.l. (2011), at the chapter *Overall Vision for the Petra Region* said that the wish of the plan is to:

> *"Change from a mere Attraction to a World-Class Tourism Destination based on its unique, well-preserved and authentic cultural and natural heritage, outstanding service quality and high environmental standards."*

And that:

> *"The mission of the Petra Development and Tourism Region Authority (PDTRA) will be to act responsibly in every possible way to protect the archaeological treasures of the area and to foster and maintain development in a sustainable way. The PDTRA will act in the best interest of the people of the region and will strive for social equality and equal opportunities for all citizens of the region alike. The PDTRA will ensure to actively engage each of the six communities in the future development processes of the region."*

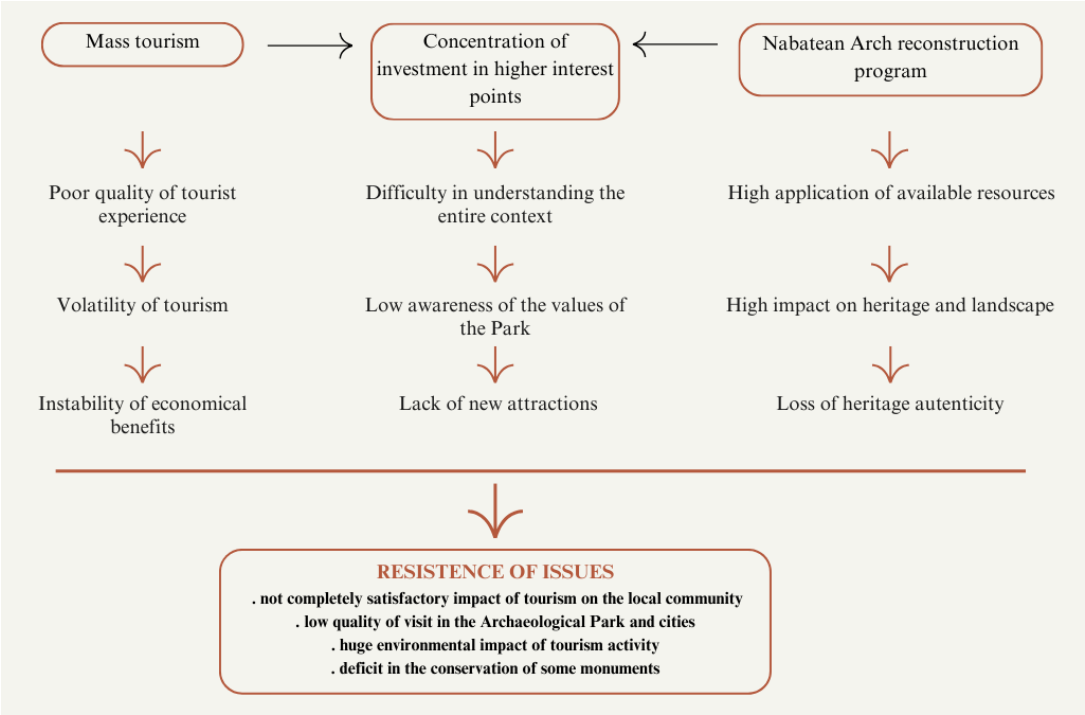


Fig. 04/a. Map of problems

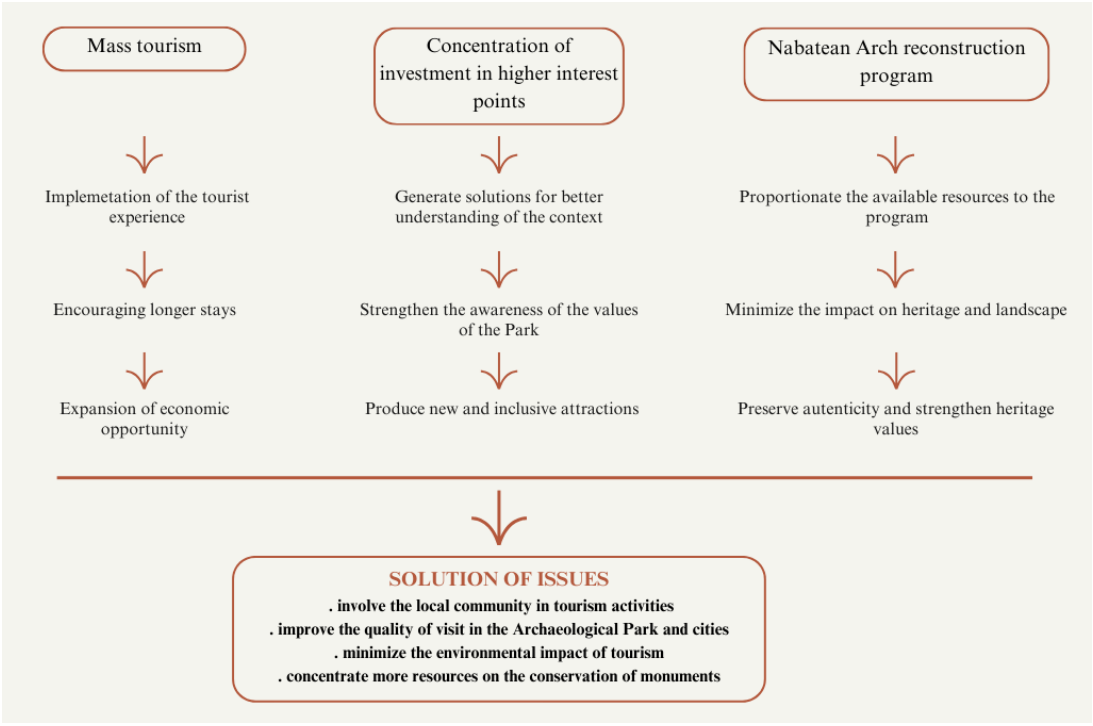


Fig. 04/b. Map of solutions

1.3 OBJECTIVES OF THE WORK

In light of the above, considering the challenges connected to the Archaeological Park, an alternative proposal has been put forward to reformulate the Region Authority's intention to physically reconstruct the Nabataean Arch. With the help of technology, it is possible to produce a digital reconstruction of the ancient monument, making it accessible to the visitors through an augmented reality application. At the same time, the adoption of the application preserves the site from new invasive works and can allocate more resources to addressing the urgent issues related to Park management, surrounding areas, and meeting the needs of the local community and tourists.

The **general objectives** of this work are:

- to formulate an alternative for the Nabataean Arch's physically reconstruction that preserve the Archaeological Site from invasive works;
- to technologize the Archaeological Park and enhance the experiential possibilities for tourists.

The **specific objectives** are:

- to assess the advantages of a digital reconstruction of the Arch;
- to identify the best available technology for the multimedia visualization of the reconstructed Arch;
- to conduct an evaluation of the benefits provided by the implementation of the proposal.

2. METHODOLOGY

The research carried out and the drafting of this work is analytical in nature; it is characterized by a mixed process that involves scientific literature review, documental consultation, data collection and direct observations.

Initially, a diagnosis of the critical issues concerning Petra, Wadi Musa, and Uum Sayhoun was conducted from an environmental, heritage, social and touristic perspective with direct observations and bibliographical and statistical resources. Subsequently, the proposed collaboration to the reconstruction program for the Nabataean Arch was analysed, identifying its advantages and disadvantages in relation to the issues encountered in field analysis phase. In light of the diagnostic process, an alternative proposal to the physical reconstruction of the Arch was formulated, considering technologies that make it possible (augmented reality and virtual reality). To conclude and assess the relevance and implementation of the proposed solution, a choose of the most adequate technology and a benefits analysis was conducted, considering the principles of sustainability.

The research phases justifying the proposal were as follows **(fig. 05)**:

1. identification of the critical issues of the World Heritage Site of Petra and its surrounding urban areas in relation to tourism sector;

2. analysis of the edited documentation about the Petra Nabataean Arch and of the international documents that regulate reconstructions in heritage sites;

3. analysis of the alternatives to the physical reconstruction with the help of technology;

4. proposal of an alternative solution considering the challenges affecting the Park, local community and tourism experience;

5. evaluation of the benefits resulting from the strategy adoption.

The themes addressed in this work have primarily been analysed through direct observation of the effects of tourism dynamics on the social, ecological, and economic balances that characterize the area. Direct interaction and informal interviews with the local community, some Park management staff members and visitors have helped outline the problems that are lowering the quality of visits to Petra, in the surrounding inhabited centers and that are weakening the environmental and social balance of Wadi Musa and Uum Sayhoun settlements. In support of the analysis, statistical data regarding tourist access to the Park (furnished by PDTRA) have been examined, allowing for contextualization of the critical issues related to the massive visitation at the Archaeological Site.

The problems that have afflicted the Park for decades have been examined and dissected in various publications, especially scientific articles, and have been well delineated in most of the Site management plans. Consulting some volumes dealing with the improvement of the tourist experience and, concurrently, with the revision of management strategies in heritage sites, facilitated the identification of the causes of the problems, as well as the improvement proposals formulated in the following chapters. The sources featuring the information to synthesize the problems encountered have been indicated in the arguments of each chapter of this work. Scientific articles and publications reporting on the suffering state of tourist destinations due to tourism dynamics focus on the sense of cultural disorientation and economic inequality affecting local communities; almost all these publications compare these issues with other tourist destinations, validating a cause-effect system that is almost common to all highly frequented tourist destinations.

Documentation regarding the Nabataean Arch has been largely explored by cooperating UPV colleague Yang Wang and has been examined through publications available at the PDTRA headquarters and through material traceable on the web and currently unpublished in books or articles.

The analysis of technologies that would make possible the public dissemination of the digital reconstruction of the Nabataean Arch has been addressed by reading some of the many articles explaining features and examples of extended reality application for the interpretation of archaeological heritage. Regarding the available technologies, a summary analysis of virtual and augmented reality has been prepared in order to understand the advantages and disadvantages of adopting each one based on the characteristics of the Archaeological Site under study.

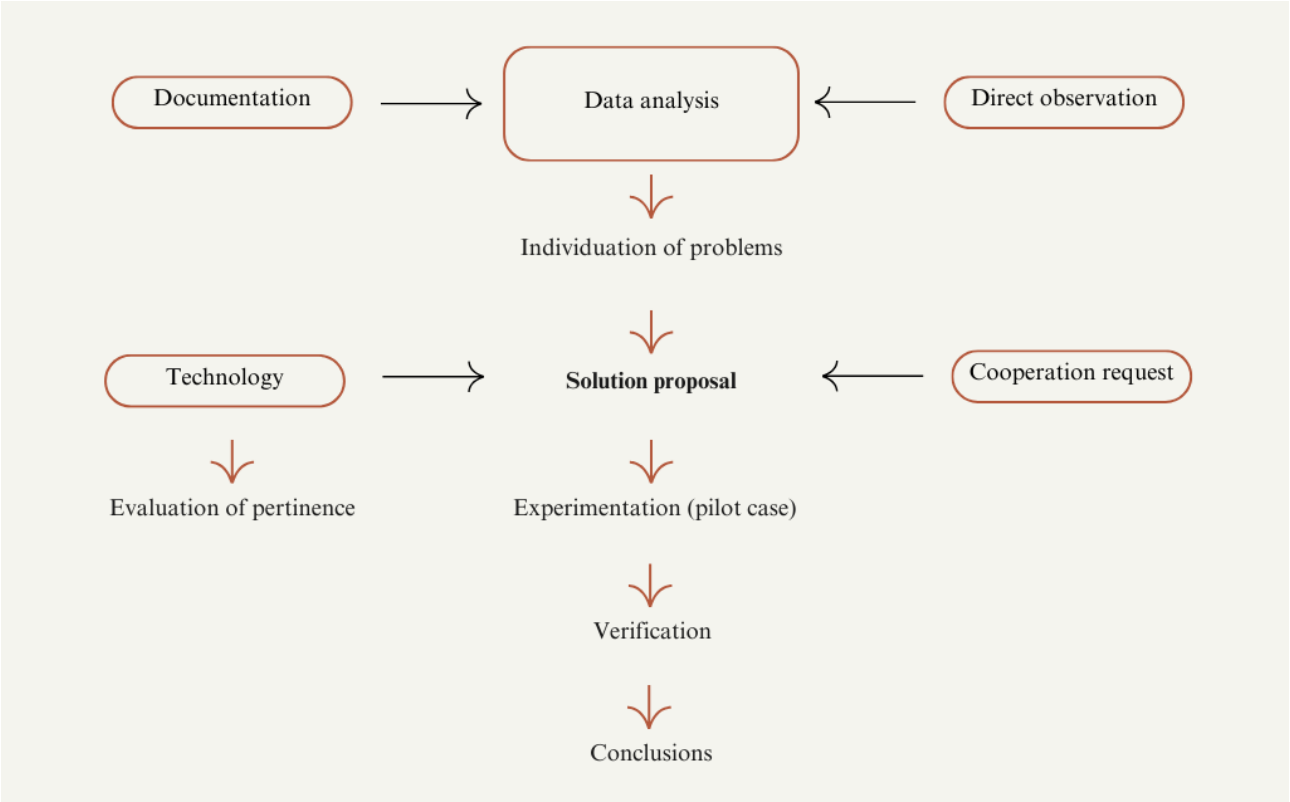


Fig. 05. Diagram of the adopted methodology

3. RESULTS

3.1 ANALYSIS OF THE CRITICAL ASPECTS OF THE WORLD HERITAGE SITE OF PETRA AND ITS SOURRONDINGS

The first action carried out within the context of the International Cooperation project was the analysis of the critical issues affecting the Archaeological Park of Petra and the surrounding urban areas. These included the negative impact of mass tourism on the environment and on the local community, the precarious state of conservation of some monuments and management problems related to the massive flow of tourists who visit the Park daily.

Such analysis identifies numerous criticalities and provide as many possibilities of action to counteract their causes and effects. The knowledge framework of the challenges that the management office of the Site is in part called upon to address outlines the urgency of some of them and indicates that the main management efforts should aim to contain environmental criticalities, improve living conditions of the local community, address monument conservation issues and improve the visit performance.

3.1.1 Impact of tourism on the local community

During the stay in Petra, Wadi Musa, and Uum Sayhoun **(fig. 06)**, and as part of the completion of the UPV International Cooperation program, a general analysis based mainly on direct observations was conducted on the impact of tourism sector on the local community.

At first, it's essential to note that in Jordan, before the Covid-19 pandemic, so in periods of greater stability for movements than actually, tourism contributes to 19.4% of the Gross Domestic Product (GDP), involves almost 8.8% of national investments, and employs about 20% of the country's workforce (Alrwajfah et al., 2019). Petra is the most attractive site nationally and one of the most internationally visited and, furthermore, it attracts workers from all Jordan, neighbouring countries and from villages near Wadi Musa. This flux of human resources depends on the source of income brought on the site. Female employment, although minimal nationally, has significantly

improved in Petra over the years, primarily due to the strengthening of tourist activities related to the Park, but it remains considerably deficient compared to male employment (Alrwajfah et al., 2019).

This investigation has identified some critical issues affecting the interaction between tourism sector and residents of Wadi Musa and Uum Sayhoun, requiring timely solutions to prevent rapid loss of identity and a general decline in the quality of tourist experience.

Through direct observation, informal interviews, and a brief documentary study, it is apparent that residents with higher economic power locally benefit directly from the tourist market; they have greater ease in starting new economic activities or investing in existing ones. On the other hand, less affluent classes benefit only marginally from tourism economy. They often complain about the high cost of living in urban areas, which has increased with the explosion of mass tourism; however, they still always identify tourism as an opportunity for social and economic redemption (Alhasanat, 2011).

In the case of Petra, partially thanks to the State's programs to minimize Covid-19 effects such as the Jordan Jannah Program, the annual tourist flow has gradually led to an increase in the offering of tourist services, especially near the Visitor Center. While this has favoured the establishment of new economic activities, it has also conditioned the implementation of infrastructure works in a particularly restricted and mono-functional area of the city. The tourist neighbourhood, the nearest to the Visitor Center, **(fig. 07)** is generating a phenomenon of centralization and internationalization, allowing only superficial and non-authentic contact between tourists and the local community. The greater economic benefits of tourist flows are concentrated solely in this area, characterized by a certain anonymity. The maintenance of post-pandemic growth in tourist flows is crucial to ensure continuity in the operation of local businesses and the consequent maintenance or increase in employment for residents.

Due to direct contact with the substantial annual tourist flow and the economic opportunities generated by it, younger members of the local community have adopted Western habits for several decades, causing a division with their cultural identity and triggering the progressive loss of traditional customs.

Social cohesion in Wadi Musa and Uum Sayhoun strengthens tourist reception in their respective centers, but a significant cultural, social, and economic contrast between the populations of the two centers leads visitors to prefer places where "westernization" prevails.

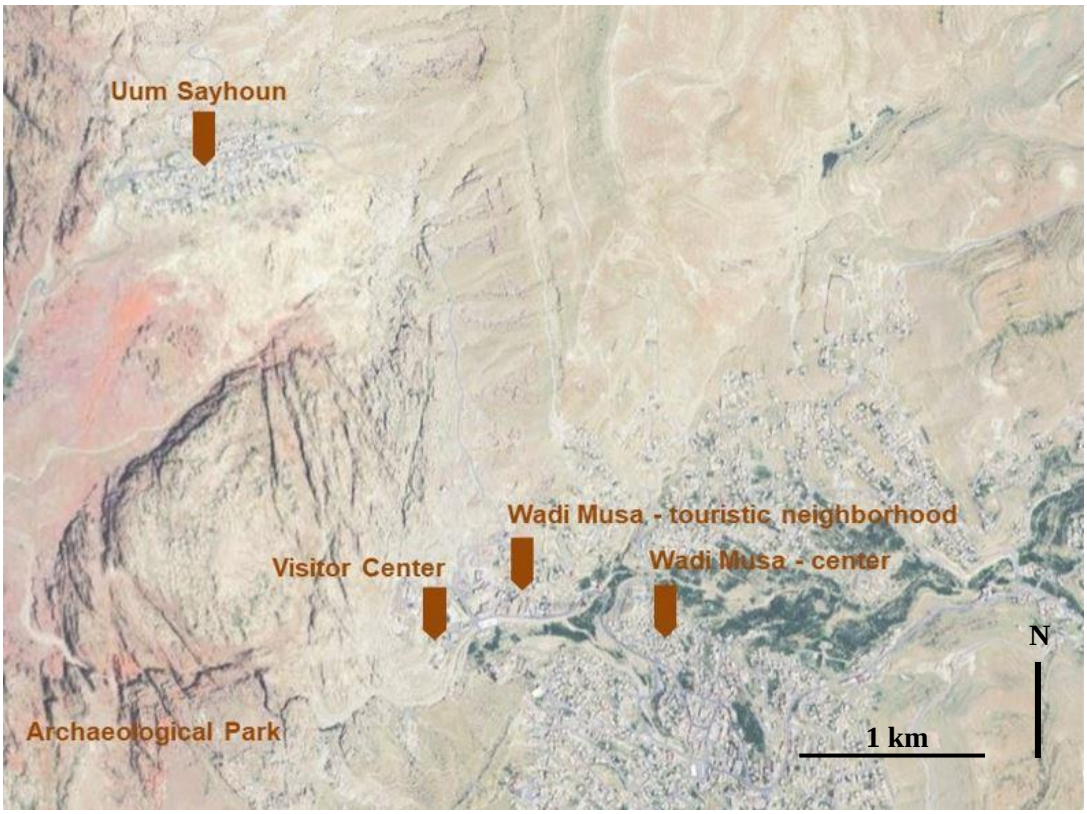


Fig. 06. Wadi Musa and its surroundings. Aerial image from Google Earth (2023)

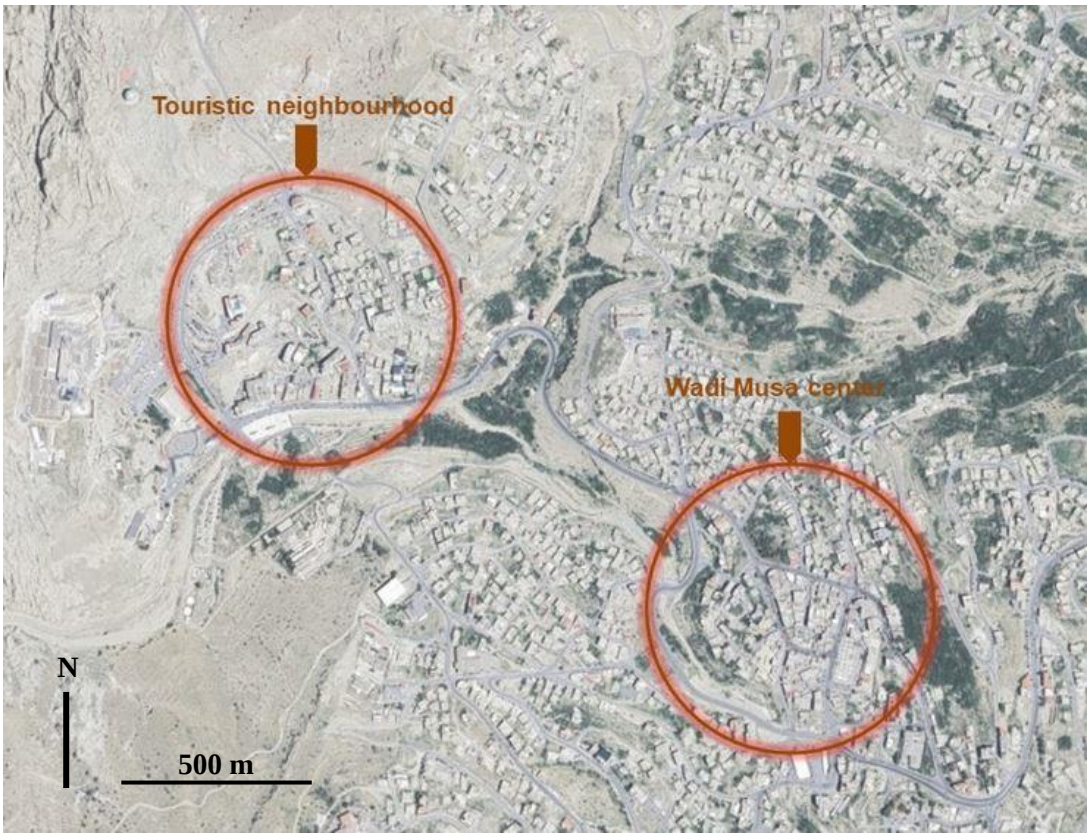


Fig. 07. Wadi Musa center and the touristic neighbourhood. Aerial image from Google Earth (2023)

3.1.2 Quality of visit in the Archaeological Park and Cities

Deficit and lack of comfort in the Archaeological Park

The quality of the visit to Petra's Archaeological Park is negatively affected by the massive flow of daily tourists, currently managed in a way that can be improved. At the moment, only a small portion of visitors stay in Wadi Musa or Uum Sayhoun for more than a single day, revealing a tourism dynamic that does not allow for interactions with the urban community and experiencing the cultural and environmental significance of the Park. The short time spent in the city and, in most cases, inside the hotel facilities, does not allow for the expansion of profit margins for the entire local community and does not give sufficient time to sensitize visitors on the place values and fragility. As reflection, the Archaeological Park results subject to daily over-tourism.

According to the data provided by the PDTRA **(table 01)**, Park access has been steadily increasing, with exponential growth resuming after the limitations imposed by the Covid-19 pandemic. The congestion issues in the Park, currently unsustainable, risk worsening further following current growth trends. There's a need to shift the tourist model from quantity to quality, improving the visitor experience into the Park.

Monthly access to Petra 2018-2023						
Month	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
January	40,460	56,559	75,248	3,517	20,574	82,990
Frebruary	49,268	72,915	81,364	5,597	30,287	97,398
March	86,426	116,132	31,009	4,656	72,021	143,962
April	116,180	138,110	0	3,242	61,913	146,687
May	70,216	87,622	0	10,225	98,036	139,685
June	44,680	68,025	288	15,658	62,882	87,380
July	42,094	58,449	17,387	20,819	69,709	72,706
August	57,975	66,437	32,269	31,165	66,910	80,140
Sptember	53,115	93,665	16,600	37,680	82,234	116,935
October	96,414	137,967	11,765	47,767	125,193	121,420
November	101,806	152,576	1,801	60,690	131,531	54,349
December	70,318	92,530	4,029	40,773	84,112	30,485
TOTAL	**828,952**	**1,140,987**	**271,760**	**281,789**	**905,402**	**1,174,137**

Table 01. Monthly access to Petra. Done by the author from PDTRA statistics

The first critical issue is encountered upon arrival at the Visitor Centre, which is not a starting point except for organized groups benefiting from an introduction by their guides. Most of the informative signage in the centre is in poor condition, making it unreadable **(fig. 08)**.

In addition to these deficient conditions, there is an absence of an interpretive exhibit in the Visitor Center spaces **(fig. 09 and 10)**. Since the museum collection has been moved to the new Archaeological Museum **(fig. 11)**, the Visitor Center appears empty, despite having ample equipped and sequential spaces. However, employees in the Visitor Centre, at the information office, can provide visitors with all information about the Park and visits, compensating the partial lack of an information system in the exposition.

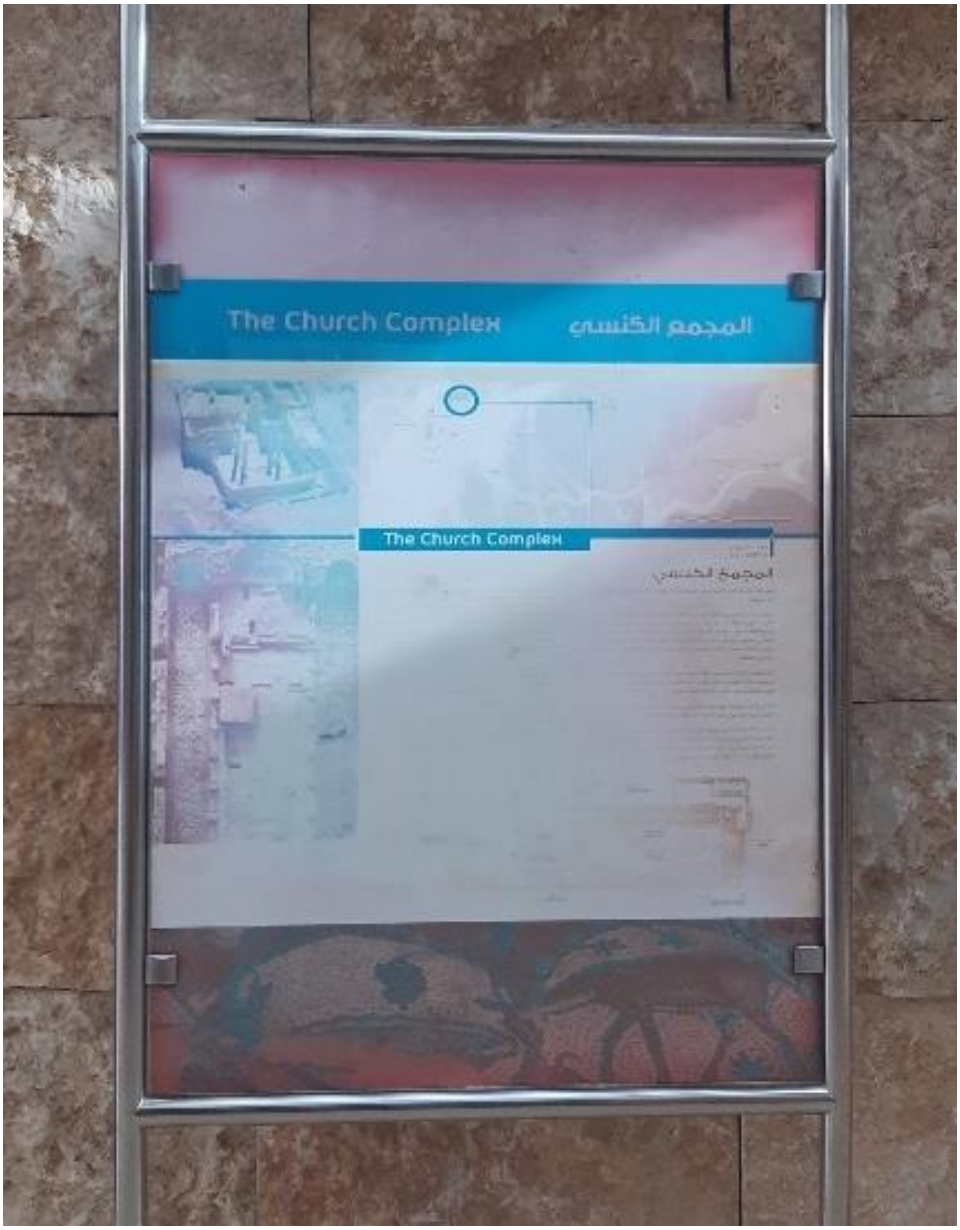


Fig. 08. Informative signage unreadable. Author: G. Cantore (2023)

Fig. 09. Empty Visitor Center spaces. Author: G. Cantore (2023)

Fig. 10. Empty Visitor Center spaces. Author: G. Cantore (2023)

Fig. 11. The new Archaeological Museum (universes.art)

The initial challenges in the Main Trail of the Park **(fig. 12)**, the only one considered for this analysis, arise near the Djin Blocks, the first visible monuments in the Park **(fig. 13)**. Here, organized groups with up to about 30 people, mostly without earpieces, whose use is optional, interfere with each other during their first stops.

The continuation of the entrance route, connecting to the Siq, is long and, especially on hotter days, becomes difficult to traverse due to the absence of shading pavilions. These earlier mentioned deficiencies quickly divert tourist's attention from their guides explanations, significantly reducing the information absorbed by visitors.

However, the condition of disturbance and inattention significantly intensifies inside the Siq, where groups often stop for explanations, interfering with other incoming or outgoing groups and creating noisy bottlenecks and congestion **(fig. 14)**. Additionally, there is interference caused by the passage of authorized electric vehicles transporting people from the Visitor Center to Al Khasneh (The Treasury) **(fig. 15)**. This detract attention from guides, monuments, landscapes, and the path which is, in some cases, rugged due to the presence of cobblestones.

The lack of visit comfort reaches its peak on the esplanade facing Al Khasneh **(fig. 16)**. This area experiences an excessive concentration of people (visitor saturation) and pack animals used, for a fee, to take photos with tourists or transport them to other areas of the Archaeological Park. In this place of high tourist interest, there is a general feeling of insecurity due to the movement of animals, electric vehicles and presence of stray animals. Many tourists spend only a few minutes at the most

attractive place in the Park, the esplanade of Al Khasneh, and then continue their visit with calm towards other ruins. In this location, there is a refreshment point that, nevertheless, suffers from the negative impact of the confusion; noise, dust, bad small, stray animals (dogs and cats), and violent attitudes used to drive away its make tourists nervous and mostly disappointed with the setting.

The Main Trail is long, making the visit strenuous, and there are few resting areas along the visit. This trail was studied by Halasa and Viñals (2010), noting already in that year most tourists reach the Theatre **(fig. 17)** from which they return back. A small portion of visitors continues to the Quasr al-Bint **(fig. 18)** and only a few of them use the second entrance/exit near the Winged Lions Temple **(fig. 19)**. From the Quasr al-Bint, some tourists continue to Al Deir (The Monastry) **(fig. 20)**, one of the most impressive monuments in the Park. Among these visitors, a good portion reaches Al Deir on pack animals, which not only disturb hikers due to their substantial passage but also damage the path and are subjected to constant mistreatment to exploit their work resistance.

For independent tourists, the visit is quite challenging due to the Park's vastness. Understanding the monuments is difficult, there is poor signage for main and secondary paths, and there are no informative signs. The few existing signs are hard to read due to inconvenient placement or are in poor condition and directly affixed to the stones that make up the ruins **(fig. 21)**. A little-visited and undervalued element in the visitor circuit is the Archaeological Museum of the city, which houses a significant collection of artifacts within a building of great architectural quality.

A serious problem is the difficult accessibility for people with impaired motor and sensory abilities. To solve this problem, mainly due to the topography of the site and the classification of the Main Trial as medium difficulty, the PDTRA provided electric vehicles to guarantee the visit to people with special needs.

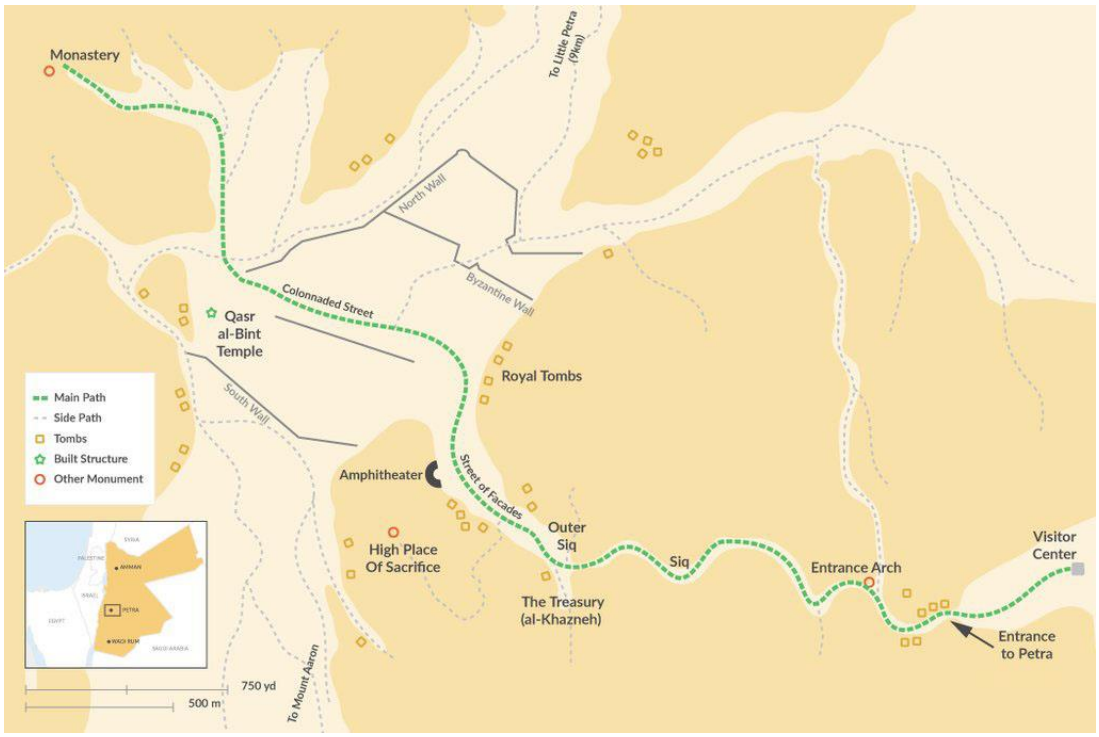


Fig. 12. The Main Trail (kimkim.com)

Fig. 13. Main Trail, the Djin Blocks. Author: Cristina C. (2020)

Fig. 14. Congestion along the Siq. Author: R. Reddy (2023)

Fig. 15. Electric vehicle path between Visitor Center and Al Khasneh. Aerial image from Google Earth (2023)

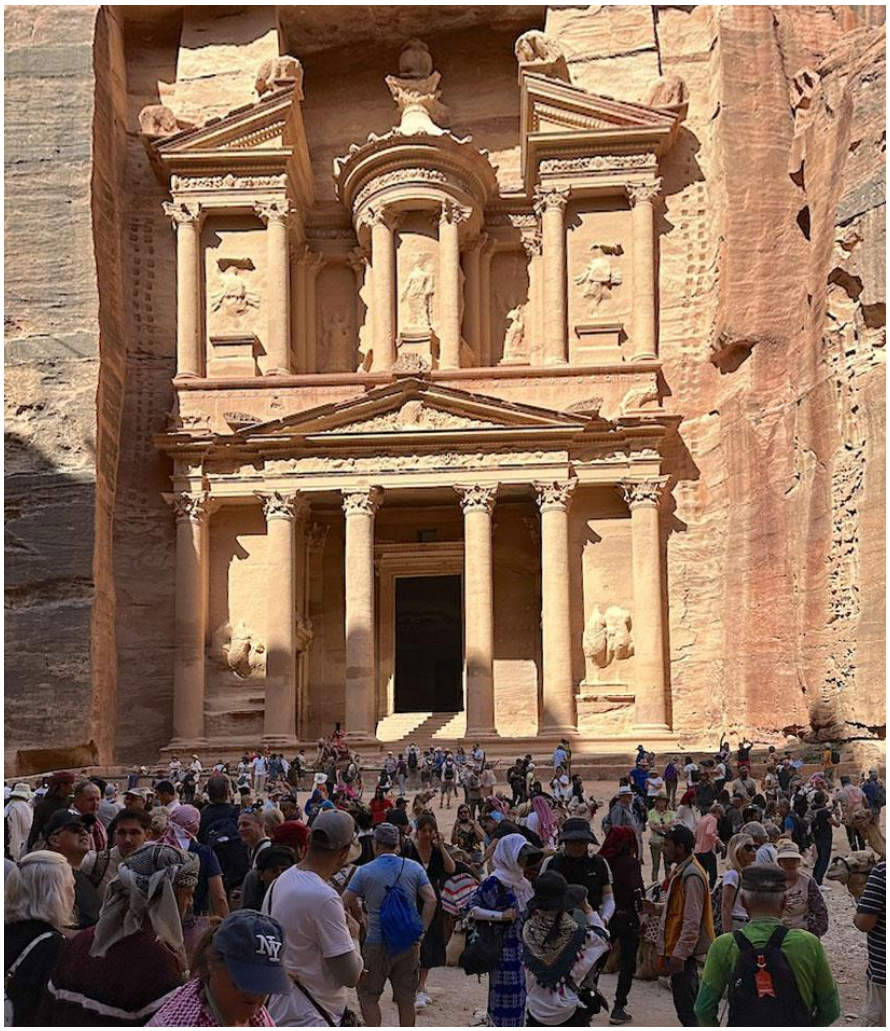


Fig. 16. Visitors saturation at Al.Khasneh (The Treasure) esplanade. Author: R. Reddy (2023)

Fig. 17. The Theatre. Author: G. Cantore, Y. Wang (2023)

Fig. 18. Quasr al-Bint. Author: G. Cantore, Y. Wang (2023)

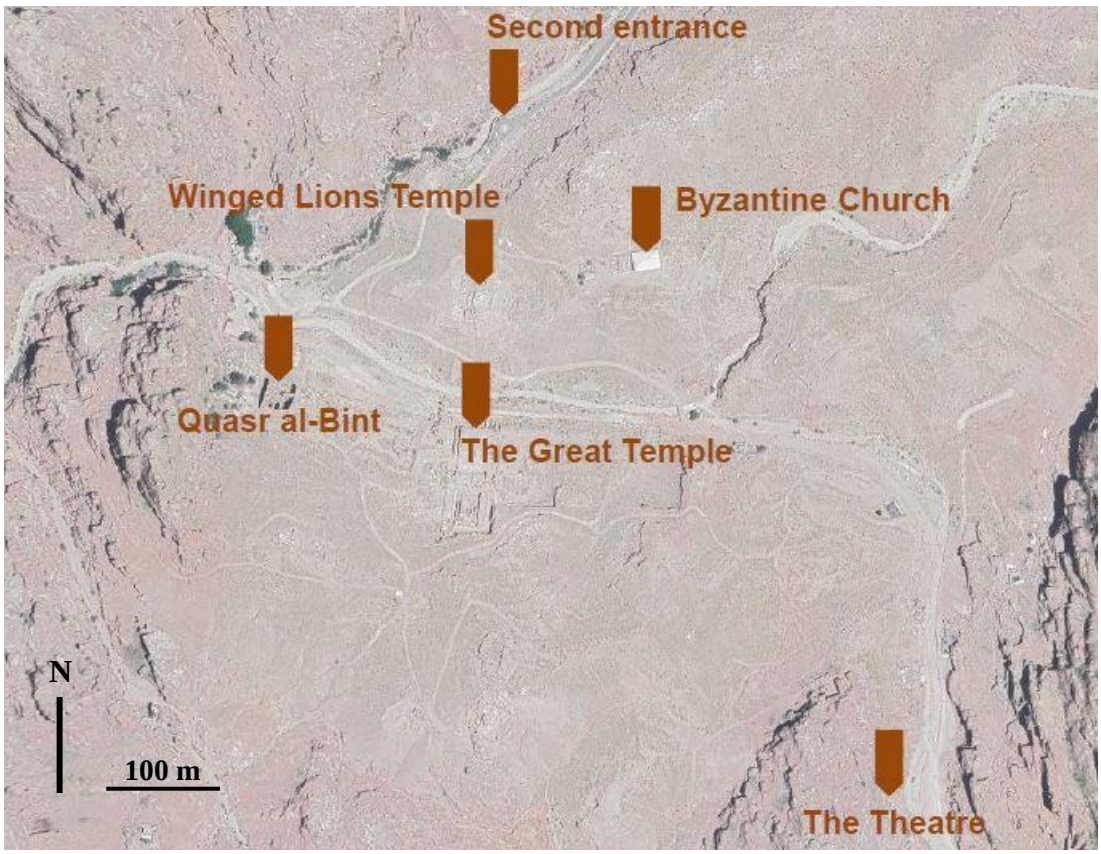


Fig. 19. Position of Second Entrance. Aerial image from Google Earth (2023)

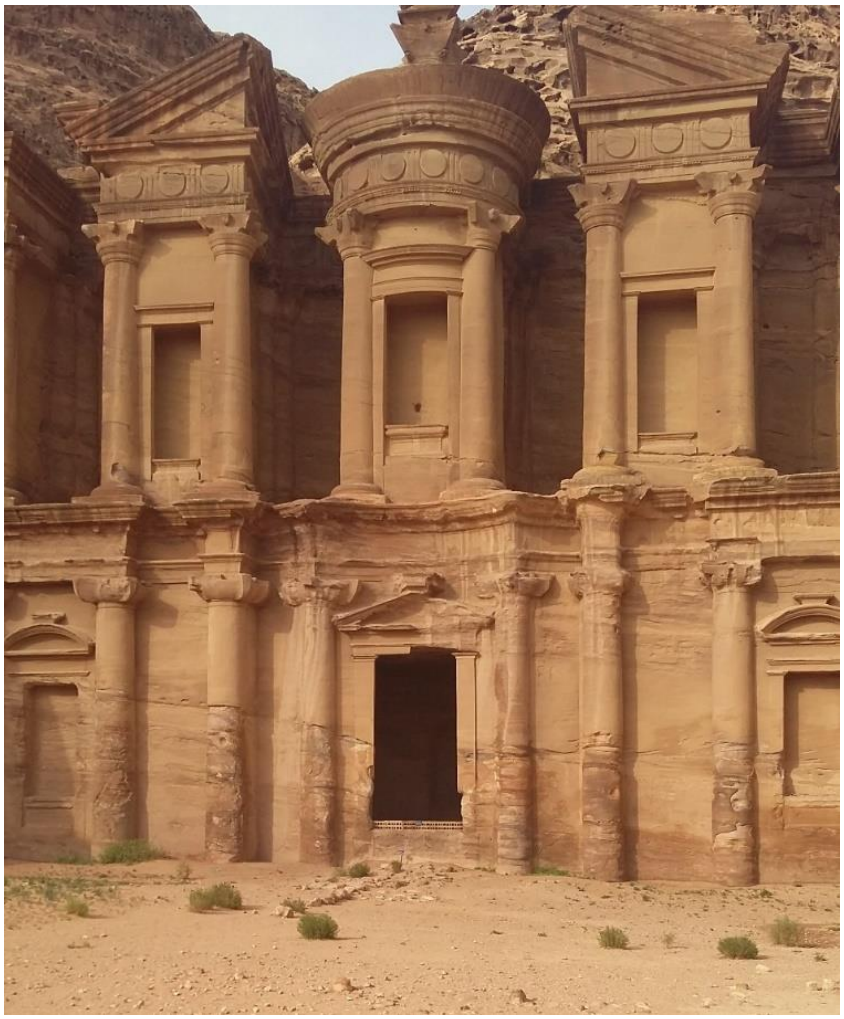


Fig. 20. Al Deir (the Monastery). Author: G. Cantore (2018)

Fig. 21. Inconvenient placement of signage (Siq). Author: G. Cantore (2023)

Wadi Musa, built on the banks of the homonymous stream, is the largest urban settlement of Petra Region (Ma'an Governorate); furthermore, is its biggest administrative center (Cesaro et al., 2011). The city is closed to the entrance of the Archaeological Park and it constitutes its main gate. Wadi Musa is the city with the best infrastructure of the region and it is constituted by tourist accommodations, facilities and transport lines that nets the city to other touristic Jordanian sites in northern and southern regions (Cesaro et al., 2011). The local community counts a lot of members of the Al-Layathneh tribe, that dominates politic and commerce of the Region; this clan controls the touristic services and activities scene and its members got a high level of school education (Cesaro et al., 2011).

Tourists in Wadi Musa mainly concentrate in the tourist district next to the Visitor Center, the most equipped for welcoming, the most well-kept, but also the one with the most expensive services, making it less accessible to the local community. Almost all hotel facilities offer a complete service inside or in partnership with surrounding restaurants and cafes. This has led to the internationalization of the neighbourhood, which does not allow experiential contact with the local community and results in strong centralization.

To experience the local culture and customs, it is necessary to access the city center (downtown, **fig. 22**), which, however, is reached by only a small number of tourists by taxi or, rarely, on foot, through Tourism Street. This street is a fast-flowing road with a large sidewalk entirely exposed to the sun and lacking shading structures that connects the Visitor Center to the city center.

Tourists, in Wadi Musa, experience a sense of bewilderment due to the density and liveliness of commercial activities in the center and in the presence of intense and frequent traffic jams. The absence of a city map indicating economically interesting tourist activities also does not encourage or help in enjoying the place, giving a good tool for orientation and identifying commercial districts and accessible businesses.

The city streets are in a hygienic condition that could be improved. It is impactful and particularly disturbing due to the widespread presence of abandoned garbage that is often thrown into the few urban channellings.

Fig. 22. Wadi Musa (downtown). Author: G. Cantore (2023)

The marginality of Uum Sayhoun

Uum Sayhoun **(fig. 23)** was built in the 1980s to relocate the originally Budool community, following the will of the Ministries of Tourism and Antiquities, and of Agriculture, which arose after its inclusion of Petra in the UNESCO list (PDTRA, 2019). The tribe displaced to the new village mainly consisted of members who, over time, also engaged in selling ancient objects found in the Park, as well as souvenirs, drinks, and snacks. The society of Uum Sayhoun is predominantly dependent on tourism, as it sustains itself through the use of pack animals and the management of stalls in the Park (PDTRA, 2019).

Despite the Bedouin community, with its cultural characteristics and testimonial value, being a cultural attraction for tourists, there are no incentives to enter the Uum Sayhoun village where they

reside. The small settlement is distant and disconnected from Wadi Musa, lacking tourist appeal services.

Uum Sayhoun was recently built strategically, near the second entrance/exit of the Park. The village is crossed by a road connecting the Park's secondary entrance/exit to Wadi Musa and witnesses the massive daily transit of tourist buses travelling between the Park and Wadi Musa. However, the buses do not stop in the village but head towards Wadi Musa, increasing the Bedouin community's frustration and dissatisfaction, increasingly isolated from the city, recognizing its economic and centralizing power.

The Bedouin community, directly in contact with tourists inside the Park, offers the opportunity for shared experiences, especially culinary ones, with their families in Uum Sayhoun. It should be noted, however, that most of these experiences are not legally recognized.

The insistent attitude of most Bedouins with tourists inside the Park and the poor maintenance of Uum Sayhoun, distant from the city and with few and essential services, lead to a total absence of tourists in the village. Despite this, some families have attempted to open accommodation facilities that are more economically accessible than those in Wadi Musa, but they remain unused.

The Bedouin community is crucial to providing tourists with a complete experience of Arab customs, traditions and society partially formed by the descendants of nomadic peoples of the desert. They are also direct witnesses to life in the Archaeological Site before its preservation policies moved them away and the cave houses, they used to dwell in.

Fig. 23. Uum Sayhoun. Author: G. Cantore (2023)

3.1.3 Environmental impact of tourism activity

In 2017, after Petra Park was annexed to the National Protected Areas Network, PDTRA and the United Nations Development Program (UNDP) planned a series of strategies to achieve some of the Sustainable Development Goals promoted by the UN (Alrwajfah et al., 2019). To make Petra Park a nature reserve in line with other internationally significant ones, efforts are being made to reduce the impact of tourism on the site.

The profit brought by the tourism sector is slowly disrupting the local environmental balance. In recent years, there has been a rapid urban expansion, leading to the construction of hotel complexes. The new constructions, whether prefabricated or made of cast-in-place concrete, increase air emissions and deplete local resources.

The city of Wadi Musa is undergoing continuous urban transformation, decreasing the permeability of already arid soils, contaminating the few surface waters, and generating disorder with many active construction sites that often-become dumping grounds for debris and waste (PDTRA, 2019). The urban landscape, although typical of a contemporary city grown without planning rules, is losing its fragile local identity in favour of a Westernized image brought by construction models atypical for the geographical area.

A serious problem negatively impacting the Archaeological Site's image and environmental health is the abandonment of waste in the Park and inhabited areas **(fig. 24 and 25)** as well as the creation of new infrastructures, with the consequent change on the use of land and landscape image. Within the Park, areas with the most garbage are near the resting points of the Bedouin community or where they have abandoned their economic activities and along some secondary trails. This degradation situation is likely due to the insufficient number of garbage containers, cleaning staff for such an extensive archaeological area and a lack of effective control by law enforcement.

Fig. 24. Plastic pollution into the Wadi Musa stream (Wadi Musa city center). Author: G. Cantore (2023)

Fig. 25. Plastic pollution into the Wadi Musa city center. Author: G. Cantore (2023)

3.1.4 State of conservation of monuments

The Archaeological Site of Petra, as mentioned above, is characterized by considerable vastness; the ancient city covers an area of 264 km^2 and features thousands of monuments with unique architectural characteristics globally (PDTRA, 2022). The archaeological heritage of Petra is not solely concentrated along the Main Trail, but also extends along secondary paths. Over time, the city has hosted various civilizations that changed its image by constructing and modifying existing architecture according to their cultural identification needs.

Observations of the ruins during site surveys have revealed that the state of conservation is not uniform. This is primarily due to the dating of the last restoration works carried out on them and to the visibility of the monuments; the most significant conservation efforts have been made over time on the monuments with the highest tourist appeal, ensuring safe access. The best-preserved monuments are those directly related to the Main Trail, making them the most visited. Among them are El Kazneh, the Theatre, the Urn Tomb, the Great Temple, the Quasr al-Bint, the Byzantine Church, and Al Deir.

Given the extensive nature of the Archaeological Park and the numerous ruins, restoration works over time have been diverse, carried out by different intervention groups, showing differences in the criteria used. A survey of the conservation status of all monuments in the Archaeological Park is necessary to establish common criteria for future conservation efforts.

Most of Petra's monuments are in a state of improvable conservation and, besides those distributed along the Main Trail, others are underappreciated, if not forgotten, with difficult physical and informational access.

To scientifically describe the conservation status of Petra's monuments, a diagnosis of all ruins is necessary. Therefore, for the purpose of this work, the condition of the ruins is discussed solely in relation to the risks they face. These risk factors have been extracted from existing literature on about monument conservation (Farajat, 2011; Halasa et al., 2011; Halasa, 2016), through considerations based on direct observation, and from the book Risk Management at Heritage Sites: A Case study of Petra World Heritage Site (Paolini et al., 2012).

Some facades are at risk of serious damage due to the erosion of the rocky surfaces in which they are carved. This damage is primarily caused by weathering elements such as the runoff of rainwater from torrential rains and floods, as well as capillary infiltration; this risk manifests especially during the short periods of rainfall and flash flood in the arid region, leading to significant and recent floods (Bala’awi et al., 2022).

Most ruins, between one UNESCO survey and another, show signs of erosion and since 1995, the World Monument Found has listed Petra among the 100 Most Endangered Sites globally.

Another cause of site damage is attributable to tectonic movements. Petra lies in a great rift valley east of Wadi Araba, south of the Dead Sea. This is a seismically active zone with three faults: the Al Matahan fault, running NE-SW; the Wadi Arab fault, running N-S; and the Abu Ullayqa fault, running like the first but with an eastward flexure (Jaser and Barjous, 1992). A UNESCO report from 1992 reveals that approximately every 100 years, a potentially destructive earthquake occurs in Petra. Therefore, it is essential to secure the city's monuments to ensure their interpretative continuity. Losses due to earthquakes in Petra have been diverse, including the Nabataean Arch at the entrance to the Siq, which the Region Authority intend to reconstruct and is the subject of study in this work.

Another erosion element is the seasonal temperature fluctuations and wind, especially during sandstorms that accelerate the abrasion of rock materials and the crystallization processes of the salts composing local rocks; all those factors leading to favourable conditions for the proliferation of invasive plants (Bala'awi et al., 2022).

Human-related deterioration factors are connected to the massive and continuous presence of visitors at the Site, leading to surface deterioration of rocks, pavements and monuments in the absence of intrusion barriers. Another significant anthropogenic alteration is due to urban expansion near the site, as in the case of Uum Sayhoun, damaging the aesthetic surroundings of the Park. Increased urban traffic due to urbanization and tourist flows generates higher emissions of polluting chemical agents, altering the surface composition of Petra's rocks and monuments over time.

Commercial activities within the Park, mostly illegal and managed by members of the Bedouin community, in some cases constitute a serious threat to the monuments. Near the most interesting archaeological sites, temporary structures have been installed for selling souvenirs. Sometimes, these facilities damage the ruins and contaminate less visible parts, acting as storage or accumulation points for garbage. Immediate remediation is required in such cases (critical locations include the top of Sacrifice, some tombs near the Royal ones, inside the Urn Tomb, and on the top of the Great Temple. It is essential to note that some commercial activities, especially those far from the Main Trail, are crucial for providing refreshment and guidance to visitors travelling along secondary paths. These locations also serve as points of contact with the Bedouin community, encouraging visitors to enjoy an encounter with their culture in strong connection with nature and the Park's ruins.

3.1.5 Consideration of critical issues in the major management plans of the Site

Since 1968 (the year in which the first Site management plan was drafted by the US National Park Service), various directional, management, and operational plans have been implemented at the Archaeological Site and at its surrounding area (Halasa, 2016). These plans impose the overcoming of international challenges, including the verification of conservation standards disclosed in the State of Conservation Reports submitted to UNESCO.

The critical issues identified during the stay in Petra, Wadi Musa, and Uum Sayhoun also emerge in some of these historical management plans of the Park, which have been selected and reported below for content concordance. In all plans, problems are reported that have persisted to the present day and have proven difficult to solve.

The 1968 US National Parks Service Masterplan

This document, the first drafted for the management of Petra's heritage, lays the foundations for the site to become a National Park. It includes archaeological, geological, and local socio-economic diagnoses. The Plan identified the initial problems of environmental conservation, preservation of monumental heritage and emergencies related to the growing tourist infrastructure around the Site.

The 1994 UNESCO Management Plan

This Plan, following Petra's inscription on the UNESCO list in 1985, recommends the formation of an independent authority to manage the Park. The authority is named Petra Development Tourism Region Authority (PDTRA) and it was created to planning and managing tourism growth in Petra Region and promoting its cultural heritage. The 1994 Plan identified conservation issues within the archaeological site, its management, discomfort in the local community due to tourist impact, economic interest degradation, negative impacts of pack animals in the site, concerns about flooding in the Siq and uncontrolled urban expansion tied to tourism-related speculative interests.

The 2000 National Parks Service Operating Plan

Drafted again by the US National Parks Service, this Plan noted deficits due to limited Park staff, significant monument deterioration, the ignition of social conflicts in the local community, and low visitor satisfaction in the context of the tourism experience.

The 2012 Conservation Plan and 2014 Conservation Action Plan

The 2012 Plan, drafted by local consultants CulTech, was adapted by incorporating the Conservation Action Plan as part of the USAID Jordan Tourism Development Project III. Similar to a management plan, it identified ongoing issues, such as uncontrolled exploitation of animals in the Park, potentially risking tourists' safety, uncontrolled issuance of concessions for construction and economic activities inside and outside the Park, monuments and quarries used as deposits, noise from power generators, strong and unqualified visual impact of some services, poor management of cleaning services, and problems with the supply and distribution of energy and resources (water).

The 2019 Petra World Heritage Site Integrated Management Plan

Taking into consideration all the problems that, over the years, have been attempted to be addressed through the updating of the management plans for the Archaeological Park and its surrounding areas, the recent Petra World Heritage Site Integrated Management Plan (2019), coordinated by Giorgia Cesaro (UNESCO Amman office) and Aylin Orbasli, an independent consultant, considering that Petra is *"a fragile site where the eco-system, monuments, geological formation, biodiversity, and local community are interlinked and dependent"* has set the following objectives:

1. *protect the Petra World Heritage Site and its Outstanding Universal Value in accordance with international good practice and guidance;*
2. *enhance the experience of visitors engaging with Petra and its surrounding areas.*
3. *continue to realise the potential of the site to serve the tourism, economic and social development of the Petra Region and its communities;*
4. *encourage wider appreciation and understanding of the site, its uniqueness and fragility by its local communities, visitors to the site, nationally and internationally;*
5. *introduce measures and management practices that reduce the adverse impacts of site operations and associated visitor functions on the cultural and natural environment.*

"The Integrated Management Plan has been developed within the context of the 2030 Agenda for Sustainable Development, and specifically integrates concerns for environmental sustainability, resource management, and local economic and social development."

3.1.6 Reflections about the acquired data

The main problems emerging from the analysis reveal emergencies that have persisted for decades, as recorded in almost all management plans submitted for the Archaeological Site. The well-being conditions of the local community, environmental conservation, and the preservation of ruins, as well as the quality of the visitor experience at the Park and neighbouring urban centers, are negatively affected by the massive daily tourist flows.

The local community, experiencing a loss of identity values and worsening social inequalities, requires greater inclusion in new cultural activities related to the Park, which needs qualification and experiential implementation. It is also necessary to initiate a concrete plan for social reconnection among the inhabitants of Wadi Musa and Uum Sayhoun in the context of the tourism offer related to the Park.

The Archaeological Site suffers from a serious overcrowding problem due to the massive daily presence of tourists, Bedouins, and pack animals. This condition exponentially diminishes the quality of visit, which remains deficient even considering the low quality of the information system and refreshment points within the Park. It is therefore of fundamental importance to activate a strategy that extends the stay on-site by leveraging new cultural attractions that better satisfy visitor's expectations and allow for an innovative understanding of the historical and cultural value of the place. Among these strategies, it should be implemented a series of initiatives aimed at a better understanding of the architectural consistency that once characterized Petra and which today is difficult to interpret. Strategies implemented in this direction help decongest the most popular points of the Park, elevating the entire Main Trail to the rank of the most visited ruins within it.

Extending tourist's stay on-site is essential to ensure greater economic benefits for all the local community, more economic availability for risk prevention and for the restoration and conservation of the environment and monuments. A longer stay allows for effective environmental awareness campaigns and greater opportunities of contact between tourists and local community, appreciating more the cultural characteristics of the residents and having more time to visit the Park in all its extension.

The activation of the strategies identified previously to address the problems affecting Petra and its surrounding areas, especially from an environmental and social perspective, would gradually bring the Park closer to top-tier international sustainability standards. The implementation of strategies to improve the visitor performance of the Park and the conditions that characterize its context should be promoted and clearly indicated in all new management plans for the Site and in its

integrations. The necessary focus is on revising the public use of the heritage asset for the benefit of tourist community and the management and conservation conditions of the area.

4. DISCUSSION AND PROPOSALS

4.1 THE NABATAEAN ARCH OF PETRA AND ITS RECONSTRUCTION PROGRAM

During the Cooperation period, the PDTRA has requested participation in the development of a project for the reconstruction of the Nabataean Arch at the entrance to the Siq of the ancient city. This initiative, whose implementation is actually of primary interest to the Region Authority, has been examined from the outset to assess its feasibility in accordance with UNESCO and UN guidelines. The analysis of existing documentation on the Arch, international restoration charts, UN recommendations, and the criticalities of the Park subsequently led to the formulation of an alternative hypothesis to the physical reconstruction of the monument, one that better meets the needs for improving the current conditions of the Site.

4.1.1 Preliminary notes

The Nabataean Arch at the entrance to the Siq of Petra **(fig. 26, 27, 28 and 29)** is believed to have been built by the Nabataean but was destroyed by an earthquake in 1895 (Abudanah et al., 2023). In the past, no studies have been conducted on this monument, and only a few travellers, from Burckhardt in 1812 to Martineau in 1857, have depicted and described it during their stays in Petra. From their descriptions, the hypothesis arises that the Arch likely had a dual function: triumphal, hence symbolic, and as an aqueduct (Abudanah et al., 2023). However, the symbolic function of being an entrance to the Siq seems to be more plausible. If research were to confirm that the Arch also served as an aqueduct, it would provide further evidence of the well-known Nabataean technological ability to manage water resources in an area prone to desertification; ability that makes Petra an artificial oasis.

The Petra Development & Tourism Region Authority (PDTRA) is planning to restore and rebuild the Arch with the intention of achieving the following goal transmitted by Dr. Bilal Khrisat:

- Restore the remaining parts of the Arch, mitigating the risk of losing the remnants of one of the monuments in the Archaeological Park, and rebuild the missing parts to ensure continuity in understanding an element partially lost from the city's architectural heritage.

It is important that the reconstruction goal should be partially revised, including:

- The desire to preserve the historical significance and construction technique of the monument, making the urban role it played in the Petra settlement readable again and facilitating the public's understanding of the symbolic meaning of a partially vanished monumental element.

The Arch reconstruction project requires a high-level and sufficiently rigorous preliminary analysis that does not cast doubt on the physical reproduction of the monument. The investigation must allow for the most coherent interpretation regarding the function of the monument, enabling its accurate and exhaustive narration. However, based on the current information available on the Arch (descriptions, paintings, and a photo), the reconstruction would only allow the interpretation of the technical/formal aspects of the vanished monument. The project must also be accompanied by a comprehensive analysis of the environmental and historical context, namely a Natural and Archaeological Park, and the social and cultural context, namely the Bedouin community and the inhabitants of Wadi Musa, primarily of Arab culture.

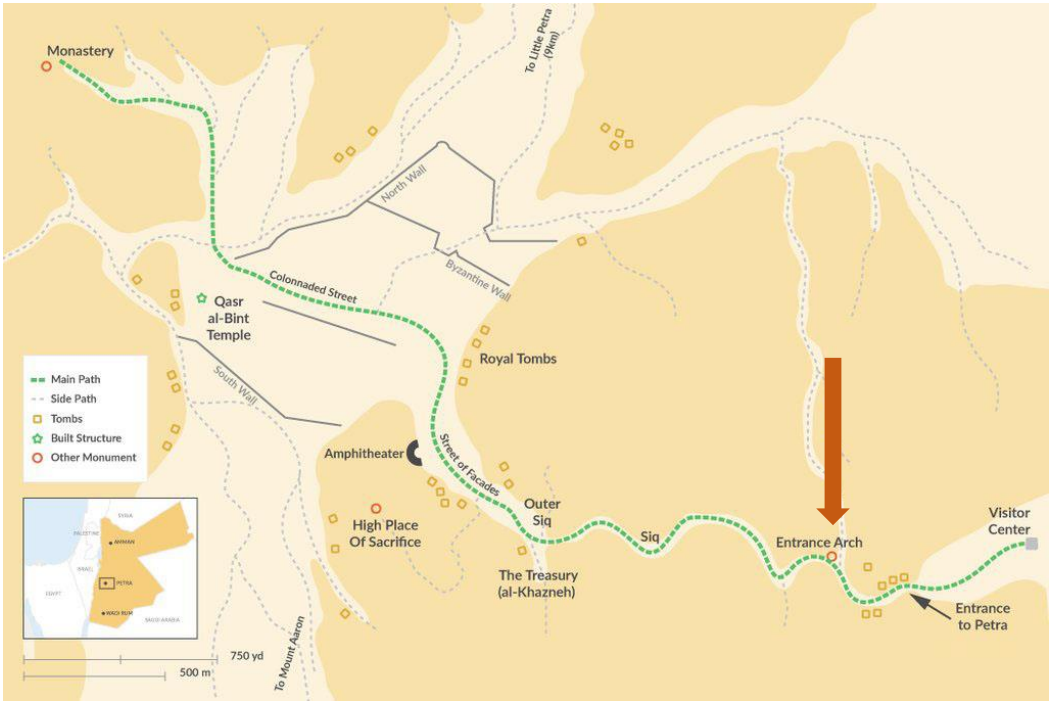


Fig. 26. The Nabataean Arch position along the Main Trial (kimkim.com)

Fig. 27. The remains of the Nabataean Arch. Author: Y. Wang (2023)

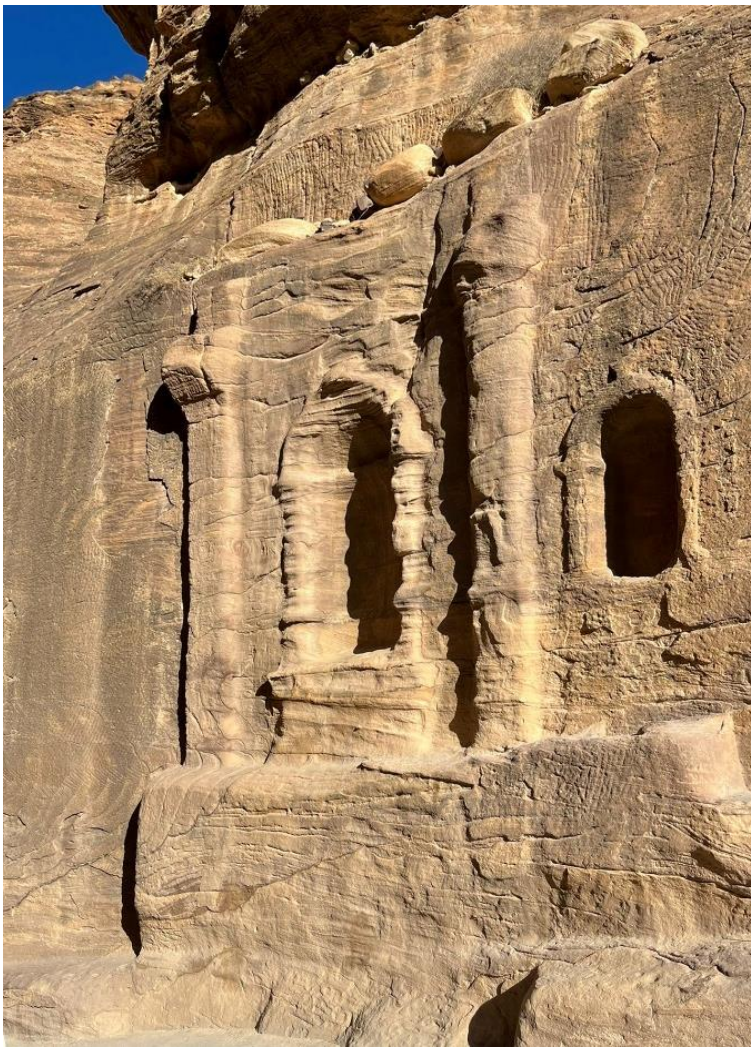


Fig. 28. The right side of the Nabataean Arch. Author: Y. Wang (2023)

Fig. 29. The left side of the Nabataean Arch. Author: Y. Wang (2023)

4.1.2 Descriptions and graphic materials about the Arch

Below is the literally and graphic description of the Arch; the descriptions were performed by various travellers, in order to lay the foundation to develop the analysis on the origins and appearance of the Nabataean Arch at the entrance to the Siq. The graphic material, instead, was done by landscape artist and is characterized by the aesthetic interpretation of every author. These descriptions have been compiled by the UPV cooperant colleague Yang Wang (2023) taken from the volume *Petra, In the Accounts of Western Travelers* written by Fawzi Abudanah and Saad Twaissi (2023).

The journey of Burckhardt in 1812

> "*About fifty paces below the entrance of the sky a bridge of one arch thrown over the top of the chasm is still entire; immediately below it, on both sides, are large niches worked in the rock, with elegant sculptures, destined probably for the reception of statues. Some remains of antiquities might perhaps be found on the top of the rocks near the bridge.*"

The journey of Laborde in 1828

> "*A grand triumphal arch, erected over the ravine after the fashion of the ancients, who usually constructed similar arches at the entrance to their cities, boldly spans the two lofty walls of rock on each side. The novel arrangement of this arch induced me at first to suppose that it served as a bridge from one side of the ravine to the other or as a conduit for the waters to an aqueduct which was formed along the face of the rocks. I ascended to it by a steep and rugged path with great difficulty; but I found nothing to justify the idea that the arch had been intended for any other purpose than as an ornament to the capital*."

The journey of Kinnear in 1839

> "*About two-thirds of the way between the entrance opposite the khasne and the further extremity of El Syk, the rocks are connected at top by a bridge of a single arch. Even at that height there appear to be some remains of building; and it seems more probable that this bridge formed a regular communication between the opposite sides of the ravine, than that it was placed there merely for ornament. Below it, on each side, there is a niche for each side; but the bridge itself is without ornament, or anything to give it the character of a triumphal arch; and, indeed, situation seems to be rather ill chosen for such a structure*."

The journey of Olin in 1840

"*I was disappointed in the ancient Triumphal Arch which spans towards its eastern termination. It is certainly a highly picturesque and even noble object, but, like other things in Petra, has been vastly overdone in the descriptions of travellers. Instead of being two or three hundred feet height, as commonly represented, it certainly does not exceed eighty feet in height; on the north side of the syk, and a little east of the arch, I discovered some ancient steps cut in the rock, firmly and fearlessly planted upon this granulated sandstone, and I soon found myself upon the summit, looking down upon the bridge upon which I had gazed from below with so much interest. This venerable arch, which is broken away on the eastern side. Seems to have been constructed solely for ornament, as there never could have been either road or aqueduct in this place. Its two ends rest upon foundation cut in the face of the rock. A few rods west of the arch are marks of the chisel, employed in facing the rock and in forming immense niches, which appear adapted to no conceivable purpose. This is one large quadrangle sixteen paces square, cut out of the rock, which rises to a great height above*."

The journey of Millard in 1842

"*About half a mile distant, we came to a triumphal arch, thrown across its top. The ravine is about twenty-five feet wide at the place, and the bed of the stream. The sides of the rock, directly under the arch, are polished smooth. The arch is constructed of thirty-four layers of stone. Some have supposed that this arch was in reality a bridge to cross from one cliff to another*."

The journey of Castlereagh in 1842

"*At last, we reached the arch which spans the ravine, perhaps this was neither a bridge nor an ornamental arch, but an aqueduct.*"

The journey of Martineau in 1847

"*After exploring above a mile and a half of this winding defile, we came to a narrow part where an arch springs from side to side at a great height; an arch whose purpose is unknown, as it appears impossible to ascend to it. It is too narrow to have been a bridge and too steep to have been an aqueduct. Beneath the arch, on the either side, is an empty niche, and pilasters much defaced; and on the eastern side in a second, small niche.*"

The graphic material describing the Nabataean Arch at the entrance to the Siq of Petra, consisting of some landscape drawings and a photo **(fig. 30)**, is particularly useful for a better formal interpretation of the Arch. In each image, the monument exhibits characteristics that distinguish it from others, with a notable change in the masonry texture above it, specifically at the simple attic, which has experienced progressive losses, especially on the extreme right. Probably, all the depicted differences, including the radius and centre of curvature of the Arch, are mostly due to the interpretative filter of each artist. However, the real geometric and formal characteristics of the Arch are well observable in the only known photo taken by Francis Frith in 1839 (available from: https://world4.eu/arch-ravine/, accessed on 01/10/2023 **fig. 31**). In this reasonably defined image, the almost perfect semi circularity of the arch, the number of voussoirs composing its structure on the outer side, and the compositional simplicity of the attic, with gaps and bareness, are verifiable.

To formulate a sufficiently mature reconstruction of the Arch with fewer margins for interpretation, in addition to the geometric survey of the remains, it is advisable to conduct an analysis of analogies with other monuments documented in Petra that have similar structures or in other archaeological sites of the ancient Nabataean Kingdom. Despite the importance of analogical studies, it must be emphasized that the Petra Arch is unique, as it rests against the natural walls of the Siq, defining its spatial limits.

Direct observation and the point cloud generated by Zamani Project (2023), commissioned by the PDTRA, reveal that, in addition to the decorations on the side walls, on the left side just above the arch impost, there are five rows of voussoirs suggesting the curvature radius at a point hardly deformable by compression forces **(fig. 32)**.

The following is the known and published graphic material describing the Nabataean Arch at the entrance to the Siq of Petra and it was compiled by the UPV colleague Yang Wang (2023). **Figure 33** shows the arch curvature analysed by Yang Wang (2023).

Painted by: C. H. Smith, 1818

Painted by: L. de Laborde, 1828

n.d. 1843

n.d, 1844

Painted by: D. Roberts, 1845

Painted by: J. C. Bentley, 1849

Painted by: C. Bertrand, 1880

Fig. 30. Edited graphic material of the Nabataean Arch (compiled by Yang Wang, 2023)

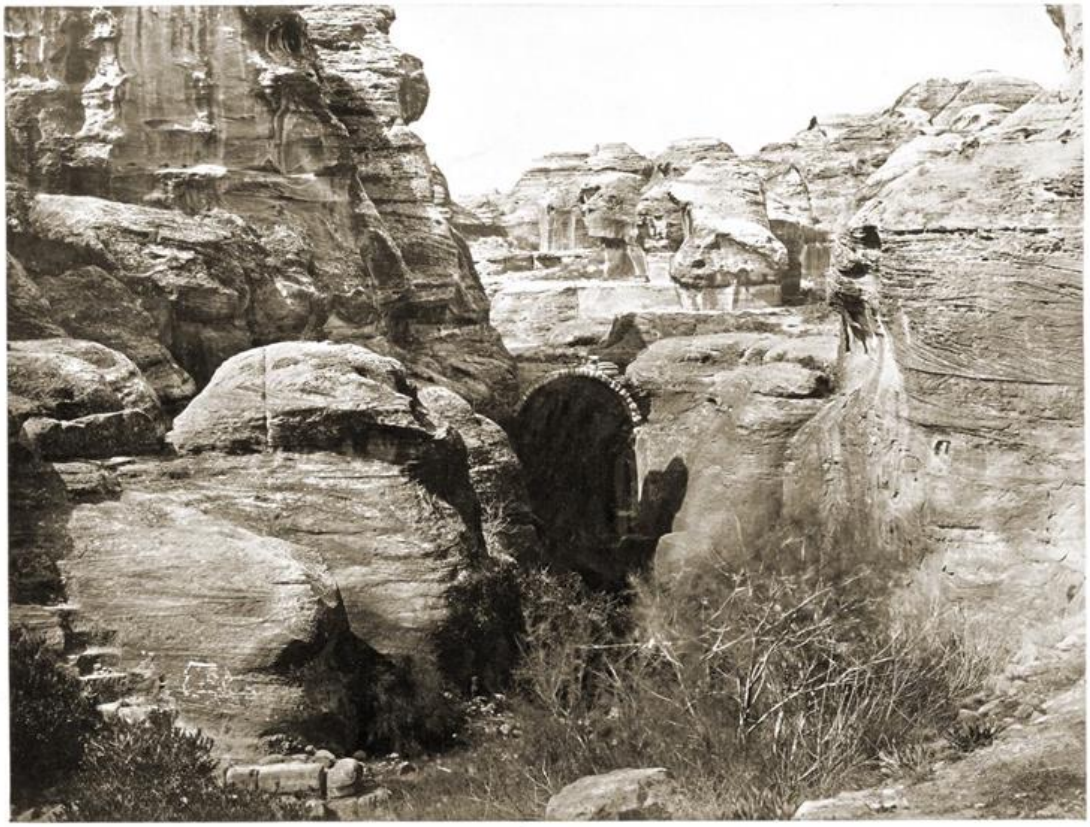


Fig. 31. The unique existent photo of the Nabataean Arch. Francis Frith (1839)

Fig. 32. The remaining ashlars of the Arch (point cloud: Zamani Project, 2023)

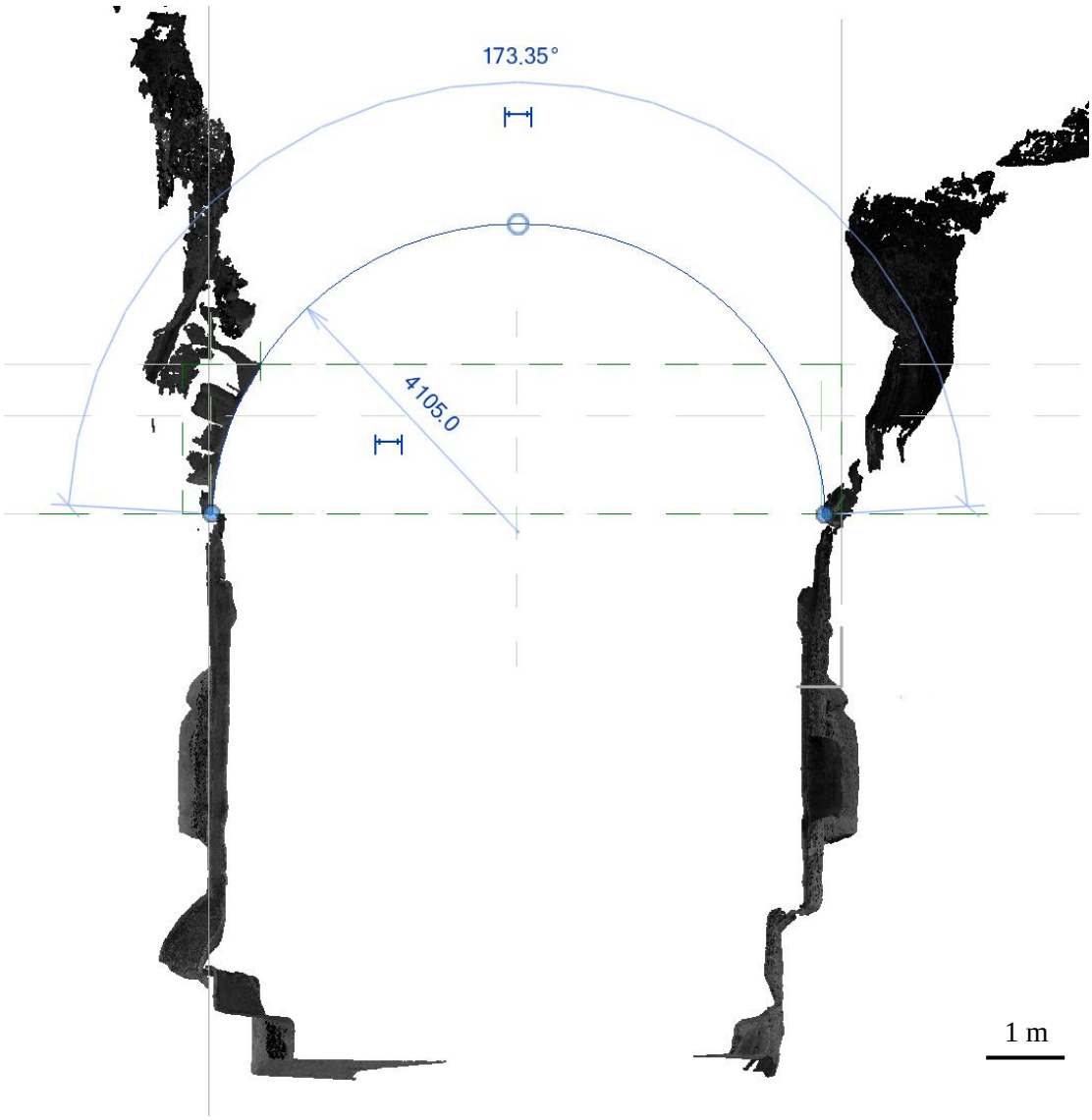


Fig. 33. Study of the Arch curvature. Y. Wang (2023)

4.2 THE THEME OF RECONSTRUCTION: INTERNATIONAL CHARTERS OF RESTORATION AND UNITED NATIONS VALUES

4.2.1 International charters of restoration

The principles for reconstructions in UNESCO World Heritage Site have been sought primarily in the international restoration charters promoted by ICOMOS (International Council of Monuments and Sites) of UNESCO, containing recommendations on the conservation of monuments in relation to their context. International restoration charters selected as follow, establish a series of guidelines that, if followed, responds to archaeological heritage conservation needs and, in addition, the application of these principles contributes to achieving various objectives, set by the UN (United Nations). Some guidelines for the proper implementation of heritage projects at UNESCO sites have been thoroughly outlined in the Nara Document on Authenticity (1994), which contextualizes the issue of authenticity with the cultural and social specificities of the contexts where each project may be situated.

Italian Restoration Charter, 1883

This document, drafted by Camillo Boito in the context of the *Terzo Congresso degli Ingegneri e degli Architetti Italiani*, although old, is the first one that revealed the importance of strategies for the conservation of architectural heritage. It includes comments on the reconstruction of heritage elements and provides the foundation for the development of all subsequent charters, especially from a technical content perspective. Even then, the initial guidelines on reconstruction were identified, which over time and in subsequent documents, have been significantly deepened and revisited from both an ideological and technical standpoint.

> ***Art. 3:*** *... the additional or renewed blocks, whilst taking the original form, should still be made of obviously different material, or that they be clearly marked with an engraved sign ... so that not even here a careful observer be misled. In monuments of Antiquity and in others of particular archaeological interest, any parts which must be completed ... should only be built with plain surfaces and using only the outlines of solid geometry - even when they do not appear to be other than the continuation or a firm attachment to other moulded or ornamental antique parts.*

Italian Restoration Charter, 1932

Following the previous document, others like the Italian Charter of Restoration of 1932 appeared. It was drafted by the *Consiglio Superiore per le Antichità e Belle Arti* and it takes up the principles of the Athens Charter (1931), introducing Gustavo Giovannoni's (1873 – 1947) position on scientific and demonstrated restoration, thus showing openness to new techniques to achieve the concept of restoration science. This charter provides a more updated reading on the principles and techniques of conservation, as well as reconstruction, emphasizing the importance of using materials and techniques from the period to avoid the risk of producing historical falsehoods.

> ***Art. 3:*** *that in monuments far removed from our customs and civilisation ... any completion should ordinarily be ruled out, and only anastylosis should be considered, that is, the recomposition of existing dismembered parts with the possible addition of those neutral elements that represent the minimum necessary to integrate the line ...*

> ***Art. 7:*** *that in additions that prove to be necessary ... or to achieve the aim of total or partial reintegration ... the essential criterion to be carried out must be not only to limit these new elements to the minimum possible, but also to give them a character of naked simplicity and correspondence to the constructive scheme ...*

> ***Art. 8:*** *that in any case, such additions must be carefully and clearly designated either by the use of material other than the primitive, or by the adoption of simple, unadorned frames ... so that a restoration carried out can never mislead scholars and represent a falsification of a historical document.*

International Charter for the Conservation and Restoration of Monuments and Sites, 1964 (Venice Charter)

This document, drafted by the Second International Congress of Architects and Technicians of Monuments following the destruction caused by the Second World War, reiterates the immutable principles of restoration and reconstruction. It expands the consideration of monuments to their urban surroundings and underscores the historical significance of building's appearances.

> ***Art. 15:*** *... All reconstruction works should however be ruled out "a priori". Only anastylosis, that is to say, the reassembling of existing but dismembered parts can be*

permitted. The material used for integration should always be recognizable and its use should be the least that will ensure the conservation of a monument and the reinstatement of its form.

The Burra Charter, 1981

The Burra Charter, or the ICOMOS Australia Charter for Cultural Significance, updated in 2013 establishes definitions and guidelines for the conservation and management of cultural heritage places. This document also refers to reconstruction from both a definitional and a criterial perspective.

Art. 20.1 *Reconstruction is appropriate only where a place is incomplete through damage or alteration, and only where there is sufficient evidence to reproduce an earlier state of the fabric …*

Art. 20.2 *Reconstruction should be identifiable on close inspection or through additional interpretation.*

Charter for the Conservation and Restoration of Cultural and Art Object, 1987

Approved at the International Conference on Cultural and Environmental Heritage (Siena, August 1987), it was written for the conservation of all objects with artistic, historical, and cultural significance. This charter constitutes one of the earliest and most widely recognized documents providing recommendations on criteria and techniques applicable to the intervention on any type of item of interest. Subsequently, general articles have been mentioned involving additions, reintegration and anastylosis works.

Art. 6: *In connection with restoration operations that concern the material nature of each work, they should be rejected from the moment the restoration itself is planned:*

a) Additions in a stylistic or analogous manner, even in simplified forms, are not allowed, even if there are graphic or plastic documents indicating what the finished appearance of the work was or should have been …

Art. 7: *Regarding restoration operations affecting the material nature of each work, the following operations and reintegrations are allowed:*

a) *... reintegrations of historically verified small parts, clearly marking additions and reintegrations, though without excessive signage to avoid disturbing the harmony of the context. In such cases, a different material may also be adopted, chromatically in line with the context, provided it is the most akin and compatible, in terms of its physico-chemical characteristic ... In any case, these insertions must be distinguishable at a glance, albeit in a close view, by using execution forms different from historical ones, particularly at the points of connection with the ancient parts. Finally, these insertions should be marked and dated, where possible, but always with due discretion.*

...

c) *Documented anastylosis; recomposition of works made from pieces; systematization of works with gaps, reconstructing small interstices with a clearly distinguishable technique at a glance, or with neutral zones placed at a different level than the original parts, or leaving the original support visible; in any case, never integrating new areas with figuration or inserting elements crucial to the figurativeness of the work.*

The Charter for the Protection and Management of the Archaeological Heritage, 1990

This ICOMOS Charter, prepared by the International Committee for the Management of Archaeological Heritage (ICAHM) and approved during the 9th General Assembly in Lausanne in 1990, establishes principles related to the management of archaeological heritage. The charter, which outlines globally applicable principles, investigate topics concerning the responsibility of public authorities and legislators, the professional execution of various processes related to the heritage, such as inventorization, survey, excavation, documentation, research, maintenance, conservation, preservation, reconstruction, information, presentation, public access, and the qualification of the professionals called to operate on heritage.

In particular, the charter addresses the theme of reconstruction in Article 7 of the text.

Art. 7: *... Reconstructions serve two important functions: experimental research and interpretation. They should, however, be carried out with great caution, so as to avoid disturbing any surviving archaeological evidence, and they should take account of evidence from all sources in order to achieve authenticity. Where possible and appropriate,*

reconstructions should not be built immediately on the archaeological remains, and should be identifiable as such.

The Charter of Cracow, 2000

This Charter on Principles for the Conservation and Restoration of Built Heritage was adopted by UNESCO on October 26, 2000. It addresses the principles for the conservation and restoration (as well as reconstruction) of built heritage in the contemporary era characterized by rapid transformation of the cultural landscape.

Art. 4: *The reconstruction of entire parts "in the style of the building" should be avoided. Reconstruction of very small parts having architectural significance can be acceptable as an exception on condition that it is based on precise and indisputable documentation ... Reconstruction of an entire building, destroyed by armed conflict or natural disaster, is only acceptable if there are exceptional social or cultural motives that are related to the identity of the entire community.*

Art. 5: *... In the protection and public presentation of archaeological sites, the use of modern technologies, databanks, information system and virtual presentation techniques should be promoted.*

Art. 10: *... Although the in-situ application of new techniques may be relevant to the continued well-being of original fabric, they should be continually monitored in the light of the achieved results, taking into account their behaviour over time and the possibility of eventual reversibility ...*

Principles for the analysis, conservation and Structural Restoration of Architectural Heritage, 2003

This document, ratified by the 14th General Assembly of ICOMOS in Victoria Falls, Zimbabwe, addresses the challenges in applying current regulatory provisions in the field of construction to historical architectural heritage. It outlines principles and guidelines for analysing and restoring historical structures, which typically face unique and complex issues. This document, furthermore, treats about reversibility and compatibility of new interventions on architectural heritage.

Art. 3.9: *Where possible, any measures adopted should be reversible so that they can be removed and replaced with more suitable measures when new knowledge is acquired. Where they are not completely reversible, interventions should not limit further interventions.*

Art. 3.10: *The characteristics of materials used in restoration work (in particular new materials) and their compatibility with existing materials should be fully established. This must include long-term impacts, so that undesirable side-effects are avoided.*

The reconstruction of the Nabataean Arch in Petra requires consideration of environmental, cultural, social, and economic themes; these issues are addressed in the Sustainable Development Goals (SDGs) set by the UN for 2030 (fig. 34). Interventions carried out in World Heritage Sites and world major tourist destinations provide an opportunity for states, management organizations, and local communities to demonstrate their commitment to achieving the SDGs and to protect both cultural and social heritage of specific geographical areas.

Fig. 34. United Nations Sustainable Development Goals

To achieve the objectives set by the UN for 2030, within the context of the reconstruction of the Arch, it is essential to evaluate the project's response to the following related and summarized themes:

Satisfaction of Local Needs

Every project on heritage must address the primary needs of the local community and facilitate overcoming challenges that collective commitment must face in terms of climate change and contemporary social transformations. This particularly refers to fostering creativity, community cohesion and protecting disadvantaged categories. A crucial role in this process is played by the

implementation of programs that increase local awareness and sensitivity towards the environmental, historical, and cultural heritage of the area, generating employment opportunities in the cultural sector, promoting cooperation between the local workforce and highly specialized individuals and fostering technological advancements.

Sustainability and Feasibility

The sustainability of any intervention on World Heritage Sites must be considered from environmental, cultural, and economic perspectives and it must ensure continuity in short-term and long-term benefits.

The project must consider economic and social effects on the surrounding communities and the social and economic benefits must be evaluated during the project, construction, maintenance, and dissemination phases. This should also consider the benefits of the quality of the visit within the site and the impact that changes in visitor flows may have on environmental balances and cultural heritage.

Involvement of Stakeholders, Partners and the Local Community

Throughout the design process of a project, it is of fundamental importance to keep in consideration the initiative capacity to involve public and private entities, national and international educational institutions and academics, as well as civil society, is crucial for the recovery and strengthening of the cultural significance of the reconstructed monument.

Social Acceptance

Before the commencement of any project on that involving a World Heritage Site, it is essential to understand the level of acceptance of the initiative within the local and international community. Preliminary evaluations of the project's short and long-term effects on the society and on the economy, must be explicitly detailed.

Visibility

An evaluation must be carried out to determine if the project, during the conception, construction, and enhancement phases, increases and qualifies the visibility of the Heritage Site and the local community at the national and international levels. In the case of the Petra’s Nabataean Arch reconstruction, it is crucial to assess the impact of the closure of the main entrance of the Park on tourist flows and visitor expectations at the Archaeological Site.

4.2.3 Consideration about the international guidance documents

The international documents considered earlier, starting from the Italian Restoration Charter of 1883, have undergone a progressive update of their respective contents, which have been deepened to respond to the conservation needs of the contemporary era characterized by rapid environmental, cultural, social and technical changes. In the charts of recent decades, in addition, the concept of sustainability in all its facets is primarily being considered, with specific focuses on the emergence of new intervention criteria. In these recent documents, sustainability is considered not only from an environmental perspective but also from a social and economic standpoint, involving local communities and international opinion in the conservation processes.

Considering the contents of the international charts and relating them to the reconstruction program of the Nabataean Arch, it can be stated that a preliminary study justifying the entire intervention is necessary. Initial research aimed at understanding and interpreting the monument to be reconstructed must re-establish its cultural significance, aesthetic appearance, and formal continuity, as well as the traditional construction techniques used to build it, leaving no room for assumptions.

It is important to remind that the reconstruction by anastylosis, the only method currently contemplated and allowed for sites damaged by natural or anthropogenic causes, is considered not applicable for the Petra Arch; the voussoirs that constituted the development of the monument have not been found, making repositioning impossible. The monument collapse occurred almost a hundred and thirty years ago following an earthquake in the area and the current gapped appearance of the Arch is part of the monument's history, explaining its picturesque image. To carry out a reconstruction in line with the principles of international restoration charts, and since anastylosis cannot be applied, it is necessary to create a recognizable completion that adopts the same construction scheme as observable in the remaining part of the Arch. In a case like this, the reconstructed part must have an appearance that harmonizes with what remains of the monument and the surrounding environment, visually unobtrusive, not decontextualized, not altering the established picturesque image of the Arch and the Siq, and avoiding the deception of historical falsehood. The added parts must not be materially invasive on archaeological remains and the rock walls of the Siq, and the consolidation of the remaining parts of the monument must ensure the preservation and integrity of the remnants and preserving its authenticity. Furthermore, any contemporary addition must be reversible without

compromising the few remaining parts of the Arch, ensuring reversibility from a formal, technical, and material perspective and allowing for future conservation interventions.

It is furthermore important to remember that an alternative hypothesis to a physical reconstruction of the Nabataean Arch is also supported by Preservation Principle No. 4 *(Minimum Repairs)* of the Petra World Heritage Site Integrated Management Plan, coordinated by Giorgia Cesaro and Aylin Orbasli in 2019. This principle states that:

> *"The purpose of conservation should be to protect a monument from further decay, rather than works that will return it to a previous form. Proposals for re-construction or anastylosis should be considered in exceptional circumstances only and be approved by a committee formed for this purpose by the DoA* (Department of Antiquities) *and PAP* (Petra Archaeological Park).*"*

In accordance with international documents governing interventions in World Heritage sites, and the UN values, the reconstruction of the Nabataean Arch must consider, throughout the entire design, construction, and enhancement process, the local environment, the surrounding landscape, the culture, society, and economy of the geographical area directly affected by the intervention. Recent documents also require an in-depth assessment, especially of the socio-economic context, in order to implement strategies that empower the local community and promote awareness of the recovered heritage element, thus implementing a concrete and effective program for enhancing the Site at the local and international levels.

4.3 AN ALTERNATIVE STRATEGY: REBUILD THE ARCH WITH AUGMENTED REALITY

4.3.1 Concerns about physical reconstruction of the Arch

The reconstruction of the Nabataean Arch in Petra, vanished for over a century due to natural causes and perceived as incomplete by all living generations, could alter the landscape to the extent of causing a lack of acceptance for the architectural reproduction. In compliance with international standards for monument conservation, the reconstruction of the Arch would only be possible after a preliminary study ensuring no interpretative doubts about the ancient architecture and structure of the monument. However, this condition might not be met due to the scarcity of sufficiently exhaustive material for an accurate reconstruction. In the absence of sufficiently data to enable an exact reconstruction of the Arch, it is fundamental to ensure the possibility to add details depending on growing of knowledge about the monument over time, possibility not easily feasible in case of a physical reconstruction.

4.3.2 Appropriateness of the use of digital technology in heritage reconstructions

In a world undergoing rapid changes, primarily due to technological advancements, the experience of cultural assets is also evolving. It is enriching itself with experiential possibilities made feasible through the use of digital technologies. Extended reality techniques in the cultural sphere have been introduced to facilitate the interpretation of inaccessible or no longer existing heritage due to natural or anthropic causes. The adoption of these techniques is accelerating globally. contemporary society and the new generations of tourists show a growing familiarity with technology, expressing interest in it as an evolving tool for ordinary and extraordinary experiences. In the cultural and tourist context, this set of characteristics demands a rapid evolution of the exhibition concept, influencing a shift in the narrative of knowledge related to heritage.

The processes of technologization and digitalization of culture constitute a vanguard in heritage appreciation, both for museum collections and different types of sites. Given the technological affirmation for culture and tourism, there is a global demand for updating new strategies to transmit cultural content. These strategies should ensure the expansion of current flows by attracting new visitor targets (more specialized audiences, younger individuals, and tourists seeking contemporary and stimulating cultural experiences).

The simulated reality becomes most captivating and understandable when reproducing natural, urban, or monumental scenarios that once existed but are now challenging to comprehend due to alterations or erasures. In these cases, to ensure broader and more engaging access to cultural heritage, facilitating the understanding of informational content, three-dimensional visualization tools can be employed. Thanks to technology, the experience of digitally reconstructed contexts can become immersive, providing immediate and stimulating comprehension of the architectural consistency of disappeared monuments, especially in the field of archaeology.

In line with the ICOMOS Charter for the Interpretation and Presentation of Cultural Heritage Sites ratified by the 16th General Assembly of ICOMOS in 2008, the digital reconstruction propose has to respect the point n. 4 of its second principle *(Information Sources)*:

> *"Visual reconstructions, whether by artists, architects, or computer modelers, should be based upon detailed and systematic analysis of environmental, archaeological, architectural, and historical data, including analysis of written, oral and iconographic sources, and photography. The information sources on which such visual renderings are*

based should be clearly documented and alternative reconstructions based on the same evidence, when available, should be provided for comparison."

Initially, to achieve some of the objectives of this work, namely the visualization of the digitally reconstructed volume of the Nabataean Arch in its real environment, the use of video mapping or holograms was hypothesized. However, such technologies, whose application requires expensive and particularly advanced technological tools, require backgrounds on which to project the images or are applicable only in technically suitable exhibition halls. For these reasons, more economic solutions were analysed, easier to apply, and stimulate greater interaction between users and technological support. Extended reality applications were considered the most suitable for meeting and achieving all the set objectives.

The use of extended reality applications (virtual, augmented, and mixed) allows for sensory immersions, depending on the devices used, which, in some cases and with additional support, can engage all five senses synchronously (Neamtu et al., 2024).

The adoption of extended reality for the reproduction of a disappeared monument, as in the case of the Petra Nabataean Arch, contextualizes the digitally reconstructed monument in its natural environment and in a real and physical space, simulating its presence at full scale. The first step in implementing the idea is therefore scanning the Arch site and rendering the solid structure of the natural scenario, which will be summarized with the digitally reconstructed missing element (the Arch).

For the reconstruction of the Nabataean Arch, two widely used and potentially applicable solutions describing an increasing interaction between users and digital content have been considered and compared. After analysing both functionalities, the one most adaptable to the Arch context has been determined.

Head-Mounted Display Virtual Reality

Virtual reality is one of the most immersive techniques for visualizing heritage that no longer exists, as it allows complete detachment from the real environment by wearing optical devices that reproduce an entire scenario in virtual form. This advanced and immersive visualization involves using an optical visor (video see-through glasses) to perceive the virtual scene in which users can navigate physically, adopting natural gestures (Neamtu et al., 2024). In this case, it is virtually reproduced a real environment; it allows for a total immersion in the virtual scenario denying direct contact with the real landscape.

When using visors for virtual reality, the observer loses contact with the real scenario and enters the virtual one and the use of visors undoubtedly allows for an amplified and upgradeable experience. It is important to remind that the mayor part of visors is usable only indoor and that, for the correct and safe use of its in outdoors conditions, the presence of one or more operators is required to interact with users, controlling their experience and movement.

Table 02 shows the differences between virtual and augmented reality.

Mobile Device Augmented Reality

Augmented reality has found applications in various fields, from healthcare (Calle-Bustos et al., 2017), psychology (Juan et al., 2005), or education (Mendez-Lopez et al., 2022) to industrial applications (Morillo et al., 2020), and tourism (Boboc et al., 2022). It has particularly excelled in enhancing archaeological and architectural heritage. This simulation allows the visualization of a three-dimensional object on a mobile device (smartphone or tablet), with which users can interact through a touch screen. Augmented reality does not reproduce an existing environment; rather, it enhances it by adding details and allowing visitors to maintain visual contact with reality (Neamtu et al., 2024). To use this technology, it is necessary to install the augmented reality application on the device, which opens, queries, and interrupts interaction with the digitized object in three dimensions; the application must also incorporate localization sensors and an extension that allows scanning the matrix (real environment) from any angle through the three-dimensional scanning of the scenario (Neamtu et al., 2024).

ELEMENTS TO COMPARE	VIRTUAL REALITY	AUGMENTED REALITY
Technological device	Various (headset)	Mobile device (smartphone or tablet)
Tipe of experience	Fully immersive (no visual contact with the real world)	Not fully immersive (maintains visual contact with the real world)
Environment	Virtual scenario only	Real environment with added virtual elements
Object visualization	Objects viewed within the virtual environment, often static or responding to specific interactions	Objects viewed in real-time within the actual physical surroundings
Usage limits	Restricted (depends on physical space and equipment)	Unrestricted
Costs	Project Devices Maintenance and application updates	Project Maintenance and application updates
User guide	Necessary (requires instruction for setup and use)	Intuitive usage without formal instructions
Interaction	Gestural and controller-based	Touch-based or gesture-based on the device screen
Environment influence	No perceived impact on physical environment	Perceived impact, overlaying virtual elements with real environment
Comfort	Potential for disorientation, motion sickness, or discomfort from immersive experiences when wearing headsets	No disorientation or motion sickness problems Potential for physical strain on arms from carrying the device
Compatibility with large dimensions	Typically limited to defined virtual spaces	Can adapt to various real-world settings and dimensions
Responsability	PDTRA	Device owner

Table 02. Comparison diagram between Virtual Reality and Augmented Reality

4.3.3 Choice of the most adequate technology for the reconstruction of the Nabataean Arch and its benefits

Some experiments with augmented reality have noted improvable drawbacks, including high sensitivity to mobile device movements, long waiting times for loading the three-dimensional image, and difficulties in using zoom functionality (Neamtu et al., 2024). Moreover, there is an uncontrollable drawback in this type of visualization: the natural lighting conditions, which may hinder optimal viewing of the reconstructed scene on a mobile device screen. Another problem connected to the usage of smartphones or tablets is that in the Petra Archaeological Park, distraction imposed by the perception of the busy external environment could disturb the viewing experience.

Currently, smartphones are widely used safely and confidently by almost all visitors to Petra; the use of a mobile or tablet application provides access without requiring specific usage instructions, and its intuitiveness promotes autonomy in usage. Augmented reality applications are easily installable from their operating systems stores, and the application interface and scenario visualization are shared and equal for all users. Therefore, solving usage problems is easily achievable through mutual assistance.

Another important advantage of the augmented reality is that all devices that permit the visualization is under user's responsibility; this is not possible in the case of virtual reality, that requires the use of headset or glasses, easily breakable and property of the PDTRA (if the case).

On the other side, the highly engaging experience of virtual reality results in a tangible loss of contact with physical reality which, as known through experiments detailed in the bibliography, has often caused disorientation. However, in the case of Petra, considering the congestion and crowds generated around the Arch, users are exposed to the risk of accidents. The immersive experience with visors is also incompatible with the dimensions of the Archaeological Park, which, being particularly extensive, does not allow for sufficient intervals in a normal visit plan for wearing and removing visors, educating users on their usage, and satisfying navigation in the virtual scene. In conclusion, the prolonged exposure to the sun in the areas preceding the Arch would also compromise the proper functioning of the visors, which are recommended for indoor use.

Considering the previous pros and cons analysis, an augmented reality application was chosen as best technology for Petra and to give an alternative to the project to reconstruct its Nabataean Arch. To make the application usage experience highly efficient, cooperation among a team of archaeologists, graphic experts, and technologists is necessary. The process, after conducting preliminary investigations focusing on the Nabataean Arch (researches and scanning of monument

remains), involves initiating the phase of three-dimensional modelling and rendering of the object, ultimately leading to the insertion of the virtually reproduced volume into its virtual scenario and into the augmented reality application.

Following guidelines imposed by international organizations and some UN recommendations, it is crucial to assess the benefits that such a digital reconstruction would have on local social and economic balances, always considering that governments prioritize the solution of local communities' needs. The archaeological site of Petra, despite being a UNESCO Heritage Site, as described, has significant deficits requiring a timely solution with substantial investments. These investments could face a decline considering the commitment required for the expensive project and reconstruction of the Nabataean Arch.

A sufficiently in-depth preliminary analysis of the Arch necessitates a three-dimensional study as the basis for a multimedia representation, avoiding the invasiveness of physical reconstruction and economizing on design and reconstruction phases. This allows the allocation of more resources to the qualification of the Archaeological Site of Petra, gradually contributing to the solution of the critical issues identified during on-site analyses.

Digital reconstruction, in addition to preserving the current landscape, is more attractive and inclusive from a tourist perspective. It is also more sustainable and acceptable concerning the needs of the local community. In conclusion, this type of Arch reconstruction allows for an acceptable approach to simulating a physical reproduction of the disappeared monument, optimizing costs and implementation speed.

4.3.4 Examples of Augmented Reality use in archaeology

A successful example in the use and diffusion of a simple application for augmented reality in archaeological field is the use of the Erleb-AR application for the visualization of some partially vanished monuments of the archaeological and architectural heritage of some Swiss cities. The app was sponsored by the Swiss Confederation (Federal Department of Home Affairs FDHA - Federal Office of Culture FOC), and Swisslos Lotteriefonds Kanton Bern. In particular, the application allows the visualization of the Roman settlements of ancient Aventicum, now Avenches, and Augusta Raurica, and other more recent elements of the nation's cultural heritage. Aventicum is a city of Celtic origin founded by the Helvetians but contains some Roman ruins such as the Gallo-Roman Theatre **(fig. 35)**, the Amphitheatre **(fig. 36)**, and the Cigognier Sanctuary **(fig. 37)**. These complexes were large, but currently, especially in the case of the Cigognier Sanctuary, it is not possible to understand their architectural development. Only the Theatre and Amphitheatre remain formally recognizable; however, digital reconstruction allows for a comprehensive understanding.

Similarly to the ruins of Avenches, some structures of ancient Augusta Raurica, a large ancient Swiss commercial city controlled by Romans, have been reproduced and those are the Theatre **(fig. 38)** and the Gallo-Roman Shonbuhl Hill Temple **(fig. 39)**. The last one is appreciable and viewable only through a complete digital reconstruction; this monument it was built in Roman times in the name of the gods and the emperor and it was part of a particularly complex structure composed of multiple parts of which no traces remain today.

For each monument, Erleb-AR has been equipped with an interactive floor plan, which suggests the positions from which to frame the ruins and activate the display of the digital reconstruction on the device screen. The reproduced volume can be manually dragged onto the remains framed with the camera to achieve optimal overlap.

All the reconstruction of the commented Swiss heritage, the augmented reality results and, finally, the effect of the usage of the Erleb-AR application can be appreciable using the follow link:

https://www.youtube.com/watch?v=VFwQi99fLGY&list=PLkbJdKr7pgnyl769aA59t0rFRsZ3PlWM-&index=5

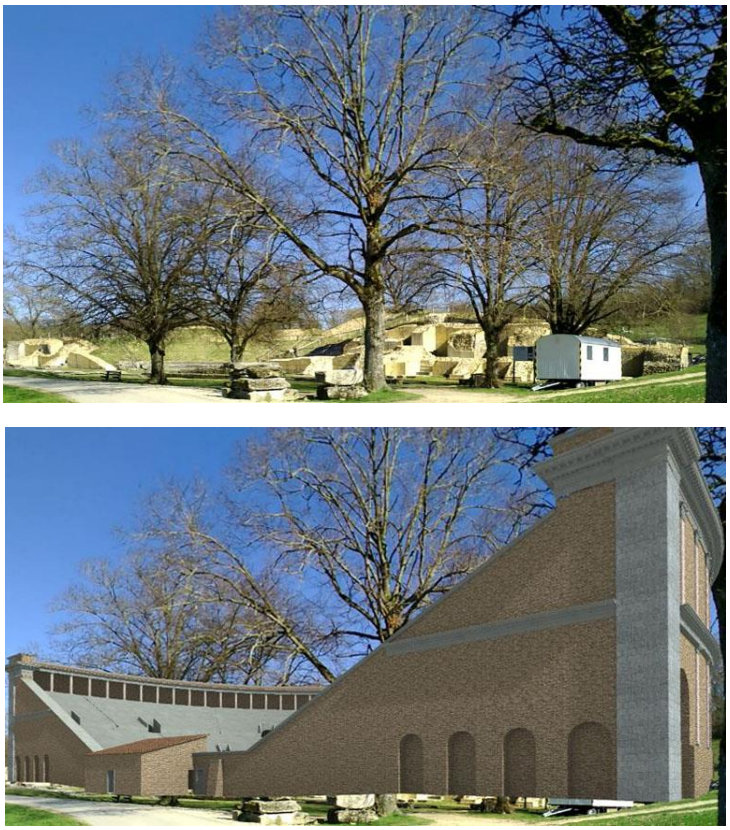


Fig. 35. Aventicum Gallo Roman Theatre, A.R. visualization (erleb-ar.bfh.science)

Fig. 36. Aventicum Anphitheatre, A.R. visualization (erleb-ar.bfh.science)

Fig. 37. Aventicum Cigognier Sanctuary, A.R. visualization (erleb-ar.bfh.science)

Fig. 38. Augusta Raurica Theatre, A.R. visualization (erleb-ar.bfh.science)

Fig. 39. Augusta Raurica Gallo-Roman Shonbuhl Hill Temple, A.R. visualization (erleb-ar.bfh.science)

The example of the Erleb-AR application was identified and illustrated because the range of locations where it can be used is similar to the case of the Petra Archaeological Park. Avenches and Augusta Raurica are small towns, similar to the ancient settlement of Petra, and the application is equipped with location sensors that allow the visualization of monuments distributed within the urban fabric, just as it would be in the case of Petra.

In the previous example, the potential of augmented reality can be recognized, proposed through the adoption of an application and through its use, it is possible to immediately realize the void left by the vanished volumes through continuous visual contact between the real and digital scenarios. The realism of the reconstructions (especially of the textures) can be improved, but this can be done during the processing and rendering of the three-dimensional model.

4.4 DEFINITION OF THE PROPOSAL

4.4.1 Design of an Augmented Reality application for the Nabataean Arch

The current work outlines, first and foremost, a strategy for the protection and for the interpretation and presentation of the vanished Nabataean Arch, an essential element in the ancient Petra's urban disappeared landscape, serving as a pilot case. The use of augmented reality for narrating the Lost Petra, beginning from the Arch, incorporates the intention to preserve the archaeological and cultural memory of monuments no longer visible, to protect the site from invasive works, to encourage visitors to understand and appreciate its cultural significance and to encourage more efforts to solve the main problems affecting the Park and it surrounding, described in previous chapters.

The presentation of interpretative content, focusing initially on the Nabataean Arch and subsequently on other monuments in Petra that are challenging to comprehend in three dimensions, is accomplished through a multimedia application to explore the ancient urban landscape of the city. The interpretative infrastructure deemed most suitable for Petra is an augmented reality application.

Based on the analysis conducted prior to formulating the proposed strategy, the intention is to suggest an alternative for interpreting and presenting heritage that aligns the cultural experience in Petra with the principles of the ICOMOS Charter for the Interpretation and Presentation of Cultural Heritage Sites, namely:

Principle 1: Access and Understanding

Principle 2: Information Sources

Principle 3: Attention to Setting and Context

Principle 4: Preservation of Authenticity

Principle 5: Planning for Sustainability

Principle 6: Concern for Inclusiveness

Principle 7: Importance of Research, Training, and Evaluation

And it addresses the objectives:

1. Facilitate understanding and appreciation of cultural heritage sites and foster public awareness and engagement in the need for their protection and conservation.

2. Communicate the meaning of cultural heritage sites to a range of audiences through careful, documented recognition of significance, through accepted scientific and scholarly methods as well as from living cultural traditions.

3. Safeguard the tangible and intangible values of cultural heritage sites in their natural and cultural settings and social contexts.

4. Respect the authenticity of cultural heritage sites, by communicating the significance of their historic fabric and cultural values and protecting them from the adverse impact of intrusive interpretive infrastructure, visitor pressure, inaccurate or inappropriate interpretation.

5. Contribute to the sustainable conservation of cultural heritage sites, through promoting public understanding of, and participation in, ongoing conservation efforts, ensuring long-term maintenance of the interpretive infrastructure and regular review of its interpretive contents.

6. Encourage inclusiveness in the interpretation of cultural heritage sites, by facilitating the involvement of stakeholders and associated communities in the development and implementation of interpretive programmes.

7. Develop technical and professional guidelines for heritage interpretation and presentation, including technologies, research, and training. Such guidelines must be appropriate and sustainable in their social contexts.

The augmented reality application for the vanished monuments of Petra, beginning from the Arch, must be promoted and funded by the PDTRA. It should be designed and programmed with the input of technicians and specialists recruited through international cooperation projects who have already developed similar works in the archaeological field.

The official channels for promoting the application should include:

1. The official website of the Archaeological Park;

2. Information flyers in the Visitor Center and distributed in all Wadi Musa hotels;

3. Posters displayed inside the Visitor Centre and at the second entrance/exit of the Park;

4. Tour operators;

5. Scientific journals.

The application can be downloaded from the Android and Apple stores at a fixed cost for the user. It should be programmed for augmented reality visualization as well as a scalable and rotatable three-dimensional model. The application interface must be intuitive and must show, in order of the Main Trail, the digitally reconstructed monuments encountered along it beginning form the Arch.

The application's introduction page may consist of a scrolling sequence of the icons of all the monuments that can be digitally reconstructed along the Main Trial and, once the users enter the page related to the monument they want to view, they can access augmented reality or a window for manipulating the three-dimensional model. The augmented reality should only function near the visited monument while the latter should be usable anywhere and anytime.

Pages opened for the monument visualization can be closed to continue navigating among other ruins or exit from the application. The app's position sensor, set to be valid for 72 hours from application download, allows the display of the reconstructed monument in its correct environment. However, the application can remain active indefinitely for the sole functions of navigating the three-dimensional model.

When users are at the location of the monument to be viewed through augmented reality, at first the Nabataean Arch, they should position their mobile device taking, with camera, the physical environment where it is placed (in the case of the Arch, the Siq). This allows them to view the virtual overlay of the reconstructed and rendered volume on the remaining parts of the monument **(fig. 40)**. In the case of the Nabataean Arch have been identified just one position from which users can frame the real scenario in which the monument is located and allow the application augment the environment **(fig. 41)**. The position has been chosen to allow a complete visualization of the known side of the Arch (front) and because it is located in sufficiently spacious area to avoid congestion in the context of the incoming and outgoing flows from the Siq.

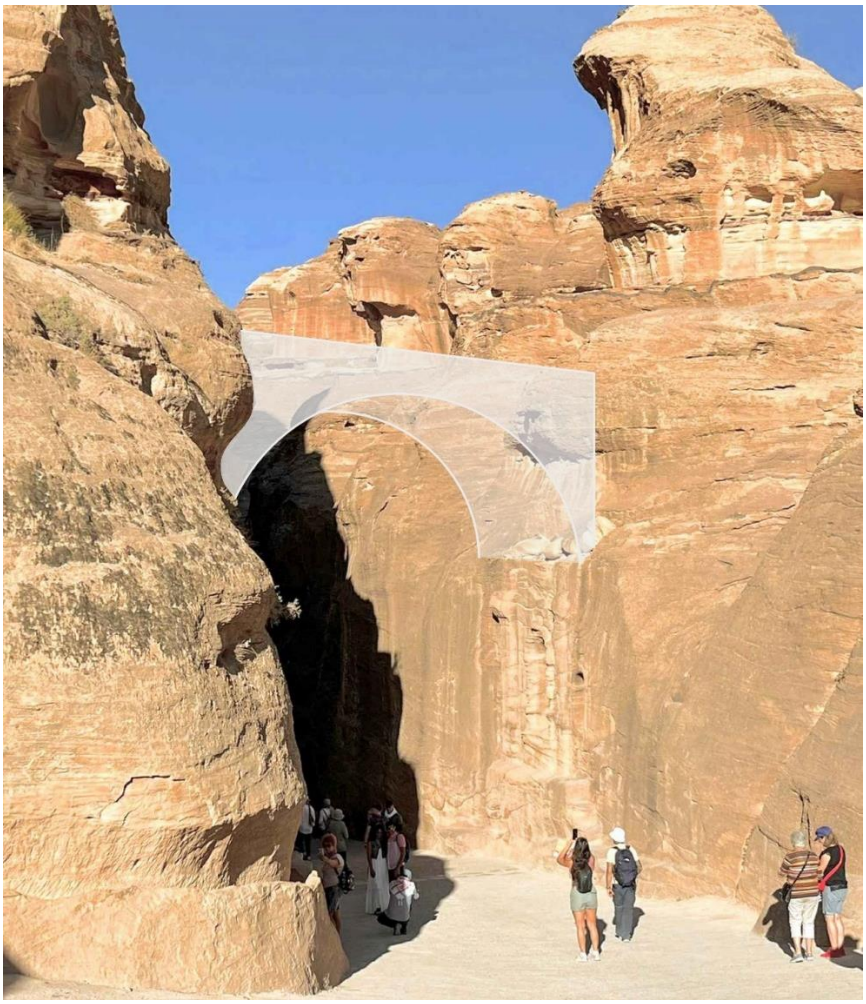


Fig. 40. Suggestion of the Arch volume visualization. Author: G. Cantore (2023)

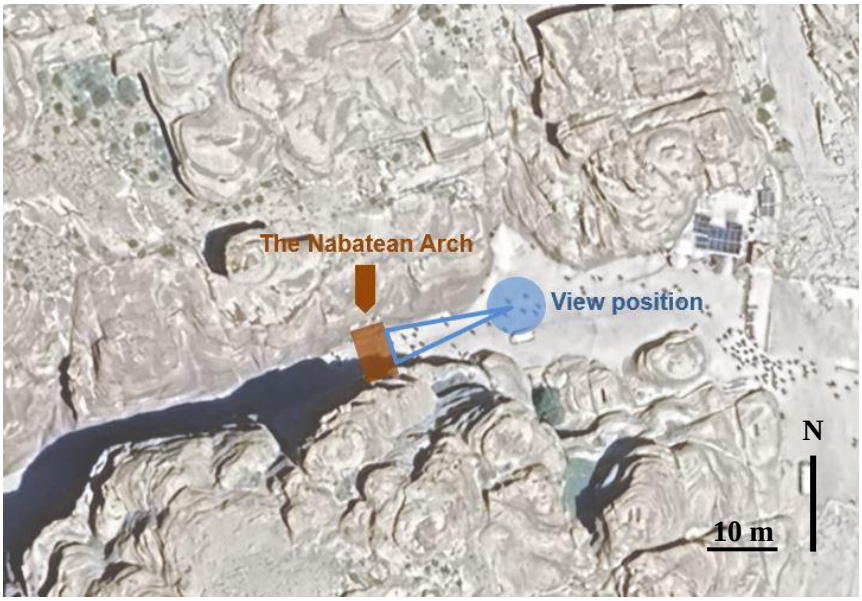
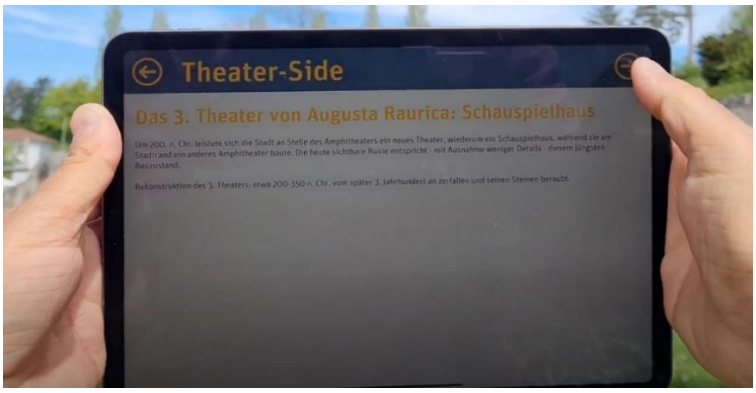


Fig. 41. Arch visualization positions (A and B). Aerial image from Google Earth (2023)

To understand the steps from the initial interface of the application, where the series of monuments viewable through augmented reality must appear, to the visualization of each of them, some demonstrative images of the operation of the Erleb-AR app for the digital enjoyment of the ancient theatre of the Swiss city Augusta Raurica, have been inserted **(fig. group 42)**.

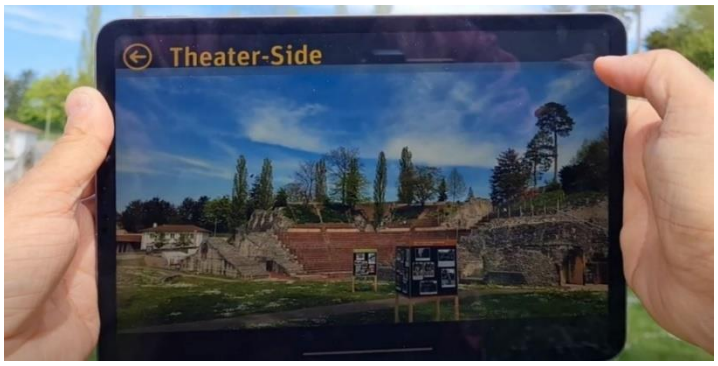
Step 1: on place selection of the monument from the start interface

Step 2: position selection on site's plan



Automatic opening of a page with informative notes about the monument

Step 3, before the previous page, confirm of right position and passage to the sequent step



Step 4, capture of the matrix with camera

Automatic visualisation of the digitally reconstructed monument

Step 5, manual overlap positioning and navigation

Fig. group 42. Example of Erleb-AR application from arriving to visualisation for the Augusta Raurica Theatre visualization (erleb-ar.bfh)

Initially, it is suggested to experiment the application with the pilot case of the Nabataean Arch, including it for a limited period within the cost of ordinary tickets. Subsequently, for each application sold, a fixed percentage of the revenue must be earmarked for investments related to environment and monument conservation and social inclusion. This measure fosters collaboration between the local community and the Region Authority, tying the digital reconstruction initiative of Petra's vanished monuments to the implementation of local investments.

An implementable strategy around the adoption of the augmented reality application in Petra could be aimed at increasing tourist overnight stays in the surrounding urban centers of the Park. This strategy involves facilitating visitor participation in an event dedicated to discovering the Lost Petra and leveraging the potential of augmented reality. Such a strategy of cultural, social, and economic promotion allows for fully harnessing the potential of the application and enhancing its utilization. The direct outcome of the initiative is to attract more tourist flows to Wadi Musa and, possibly, Uum Sayhoun, thereby providing greater benefits to local businesses and promoting social inclusion. The principle of the strategy is based on the idea that by enhancing the cultural offering of the Park through augmented reality, it can encourage visitors to stay longer in Wadi Musa and Uum Sayhoun, provided they spend two nights in them.

A recent project aligned with the theme of promoting overnight stays while facilitating visits to heritage sites has been applied in Granada (Spain) through the "Bono Pernocta" (Vallejo S., GranadaHoy: https://www.granadahoy.com/granada/Granada-estrena-bono-pernocta-Alhambra-entradas-card_0_1896410930.html). It was recently introduced as part of the Granada Card, implemented through the Chamber of Commerce, allows visitors staying for minimum two nights in the city accommodations to access the Alhambra for free. This boosts the economy of accommodation facilities, ensuring increased entries to the monument. The subscription requires the hotel to declare to the Chamber of Commerce that the tourist's stay is for minimum two nights, and it is the Chamber that purchases the monument entries on behalf of the tourist. The subscription is personalized and guarantees entry to the Alhambra and other city monuments. Such an initiative can also be proposed for Petra, including the cost of the application for tourists staying at least two nights in Petra or Wadi Musa when this initiative gains and confirm sufficient traction.

4.4.2 Relevance and feasibility of the Augmented Reality application for the Nabataean Arch

The digital reconstruction of the Arch ensures, first and foremost, the application of certain criteria identified in the documents of international charters for the conservation of heritage. In the case of a physical reconstruction, these criteria would be difficult to apply and they are:

Conservation of the existing

It should consider the conservation of materiality (to preserve the actual appearance and each remaining architectural element in detail). The application of this criterion permits to avoid destruction of portions of material.

The adoption of an application for the visualization of the three-dimensional reconstruction of the Arch through augmented reality preserves the remains of the monument from further potential damage. Even the paths and rocks that served as support for the Arch structure would not suffer any alteration.

Minimal intervention

It consists into act only on what is strictly necessary to generate the least possible impact on existing parts. The application of this criterion ensures the least possible manipulation, it is linked to the criterion conservation of the existing and to the criterion of sustainability (particularly with the saving of resources and energy).

The digital reconstruction allows for reallocating part of the investments planned for the reconstruction of the Arch to the consolidation and restoration of the currently remaining and visible components of it. Adopting the application to appreciate the digital reconstruction of the monument is non-invasive for the heritage element and meets all the sustainability criteria considered in restoration interventions. The resources not used for the physical reconstruction of the Arch can be allocated to solving some conservation problems of many monuments in the Park, implementing more frequent maintenance interventions.

Environmental sustainability

This criterion pretends to minimize CO_2 emissions and energy expenditure in the production of the work, to minimize waste production and to control contamination related to withdrawal and eventual recycling or dumping.

The lack of physical reconstruction of the Arch prevents the emission of pollutants into the atmosphere and in rainwater runoff. Digital reconstruction avoids the need for excavation to source materials necessary for the physical reproduction of the Arch and, in relation to this, does not involve the production of waste materials. Environmental sustainability is also expressed in maintenance, as no operations need to be carried out.

Economic sustainability

It requires to predict and minimize the expense for the maintenance of the monument and minimize the expense of the intervention and, finally to promote the local economy during the construction phase and after it (movement of money at the local level).

The physical reconstruction of the Arch entails significant labor and maintenance costs, which are largely mitigated through digital reconstruction. Currently, the major attractions of Petra do not reside in the Nabataean Arch, nor is it expected that the reconstruction of the Arch could generate a new attraction. The lack of physical reconstruction of the Arch would allow for the allocation of resources to address the urgencies of the Park, and the adoption of an augmented reality application, being paid, fosters new and consistent earnings for the Park management entity.

The implementation and contextualization of the application facilitate the implementation of specific visitation programs and promotion of new modes of enjoyment that can extend visitor's stay in Petra in a short time.

Sociocultural sustainability

This criterion pretends to promote the social dynamization of the place during and after the work through the implementation of specific heritage interpretation programs and pretends to gain the conservation of the identity of the landscape and its integrity.

Digital reconstruction fosters greater interest from the local community in heritage enjoyment technologies, enhancing their potential for specialized employment and, at the same time, promoting new visiting experiences. Extending overnight stays near the Park, in the event that the application is implemented promoting longer stays, allows for prolonged interaction with the local community, thereby increasing economic benefits and promoting social equality and cohesion.

4.4.3 Possible implementation of the proposal

The experimentation of the proposal for the pilot case of the reconstruction of the Nabataean Arch in Petra, if positively verified in its application, might give rise to scenarios for its implementation within the visitation of the Main Trail of the Archaeological Park of the ancient Nabataean capital, which already hosts the Nabataean Arch.

Technological development for cultural heritage enjoyment comes to the aid for a more immediate understanding of the ruins. As explained and proposed in this work, it allows public access to digital reconstructions capable of reproducing entire urban landscapes. Strategies of this kind overcome the need for physical reconstruction or invasive interpretative installations, preserving monuments and their context from works that, although reversible, have a material aesthetic impact.

To ensure that the use of the three-dimensional visualization application is not limited to the case promoted by the Petra Development & Tourism Region Authority, it is proposed to extend digital reconstruction to other monuments along the Main Trail. The proposed strategy for implementing the application is motivated by justifying the initial investment for its activation and dissemination. Additionally, it aims to provide a more stimulating experience for visitors, fostering greater awareness of the cultural heritage of the ancient city and promoting longer stays in Wadi Musa and Uum Sayhoun.

The theme identified for the application's use along the entire main visitation path is the "Lost Petra". Therefore, the proposal is to reproduce the Nymphaeum, the Colonnaded Street, the Great Temple and the Temple of The Winged Lions, with augmented reality by providing an idea of their importance within the urban landscape, starting from the remarkable size and scenic qualities that characterized them.

The application could include these additional five monuments, and the scanning of the real scenario onto which the ensemble of reconstructions will be visualized requires the scanning of the entire complex from the beginning of the Colonnaded Street, just after the Theatre, to Quast Al Bint, a process already initiated by the PDTRA in collaboration with Zamani Project (https://www.zamaniproject.org/site-jordan-petra.html).

Extending digital reconstructions to these additional monuments enhances the level of analysis and knowledge about them. It also contributes to the technologization and experiential appeal of the site, leaving visitors more informed about the architectural significance that characterized Petra's current archaeologies. Finally, the inclusion of such monuments in an augmented reality activity program allows for the extension of overnight stays in Wadi Musa and Uum Sayhoun.

The Nymphaeum (fig. 43 and 44)

This monument marks the beginning of the colonnaded street towards the Siq, situated at the convergence point of the Wadi Musa and Wadi al-Mataha streams. It is a semi-circular public scenic fountain (the most important of the ancient Petra) enriched, in the past, with six Nabataean facade columns (Bourbon, 2021).

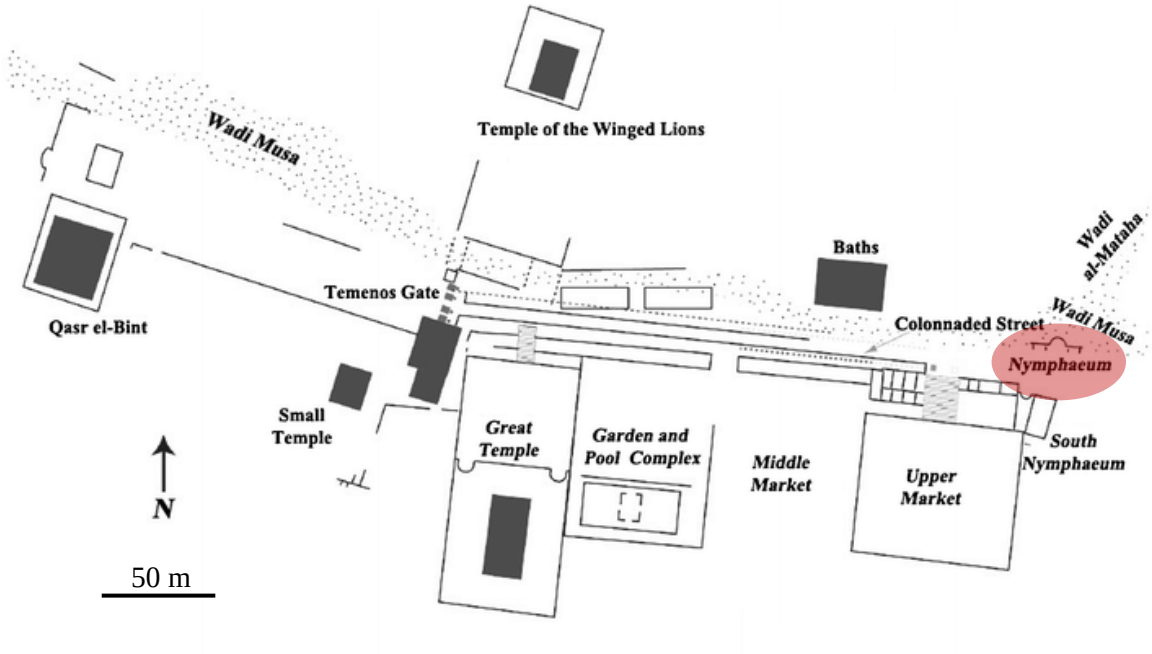


Fig. 43. The Nymphaeum. Author: Bedal L. (2017)

Fig. 44. The Nymphaeum (madainproject.com)

The Colonnaded Street (fig. 45 and 46)

This Nabataean-origin track, modified in Roman times, constituted the city's commercial axis with numerous shops. In Roman times, the street was lined with mostly two-level buildings, ending at the Roman tripartite gate, providing access to the area of Quasr al-Bint (Bourbon, 2021).

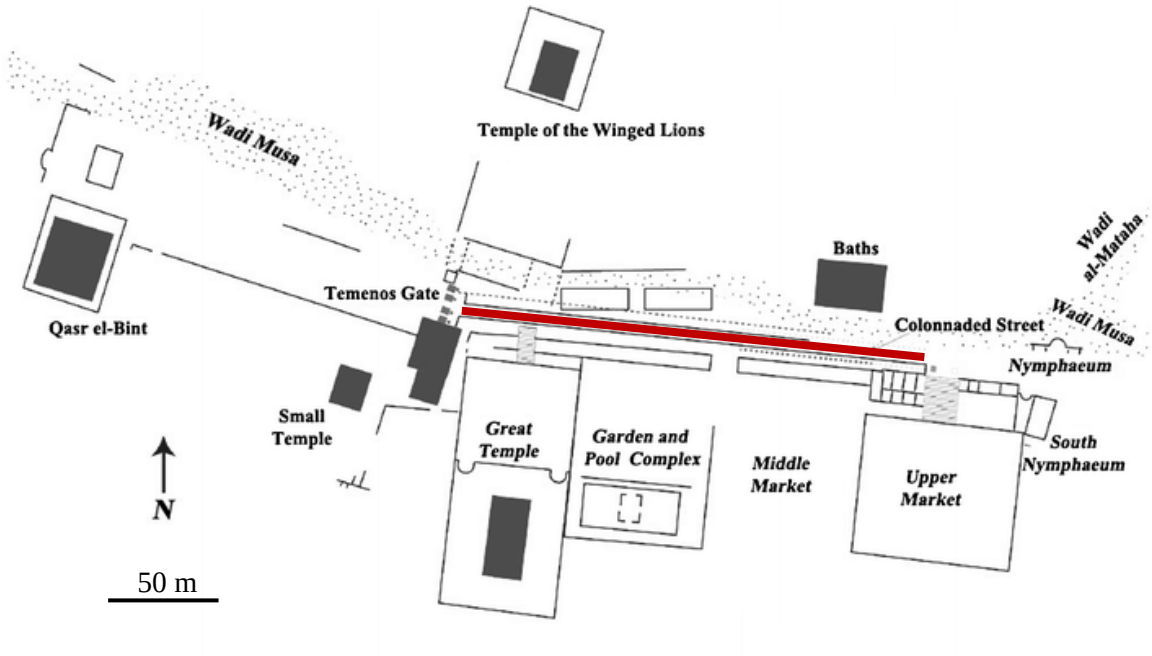


Fig. 45. The Colonnaded Street. Author: Bedal L. (2017)

Fig. 46. The Colonnaded Street. Author: Architexty (2011)

The Great Temple (fig. 47, 48 and 49)

Unearthed in 1993, this monument covers almost 7,000 square meters and constitutes the largest and most monumental complex in ancient Petra. It is a rather complex building with a monumental entrance, a vast sacred area, two lateral rows of triple colonnades, and the heart of the temple, featuring a tetra-style roofed structure surrounded by continuous walls. The Temple stood approximately 18 meters high, with a plan dimension of about 28 x 40 m (Bourbon, 2021).

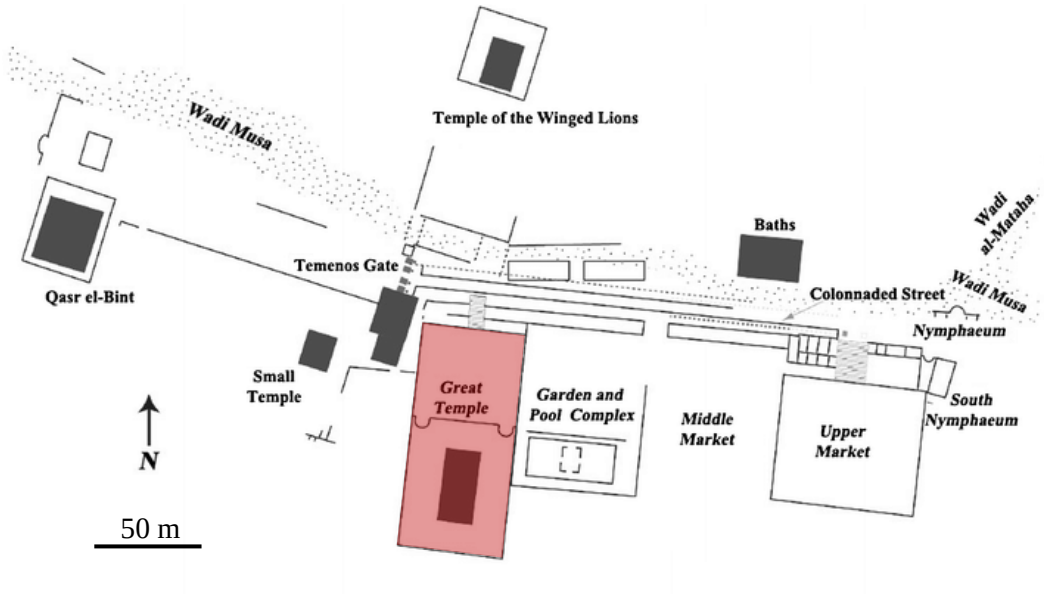


Fig. 47. The Great Temple. Author: Bedal L. (2017)

Fig. 48. The Great Temple. Author: Osseman D. (2013)

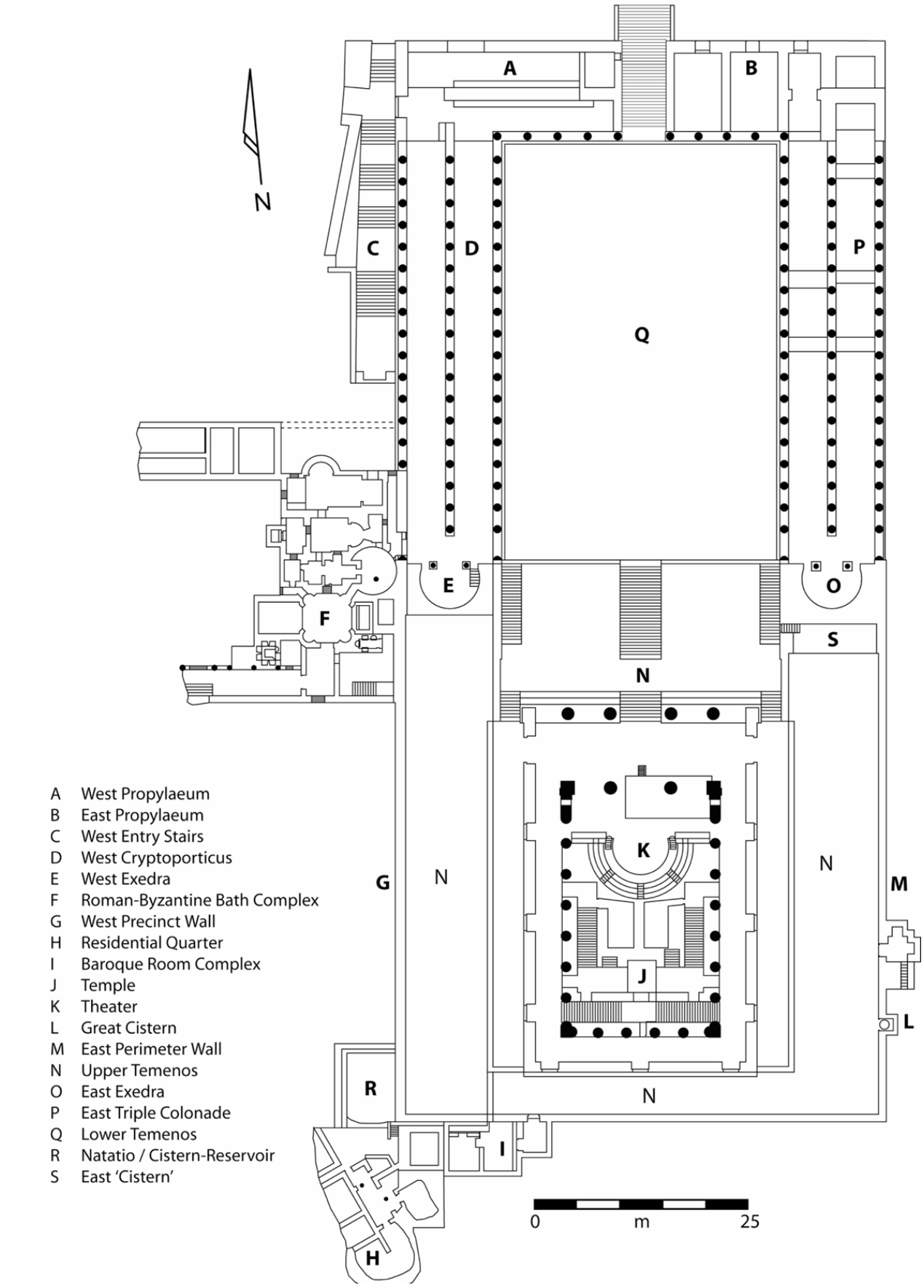


Fig. 49. The Great Temple, plan. Author: Agnew M. C. (2006)

Temple of the Winged Lions (fig. 50, 51 and 52)

The Temple consisted of a portico leading into an internally colonnaded cell. It is named after the winged lions sculpted at the corners of the capitals of some columns. This temple, albeit small in size, was one of the most scenic in Petra as it was situated on the top of a hill to the right of the colonnaded street.

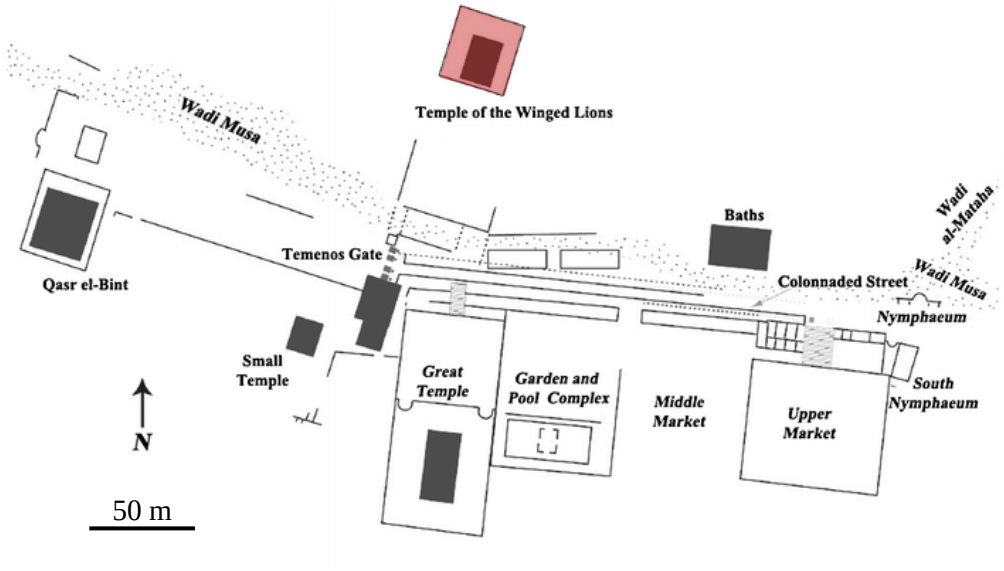


Fig. 50. The Temple of the Winged Lions. Author: Bedal L. (2017)

Fig. 51. The Temple of the Winged Lions. Author: C. Tuttle (2009)

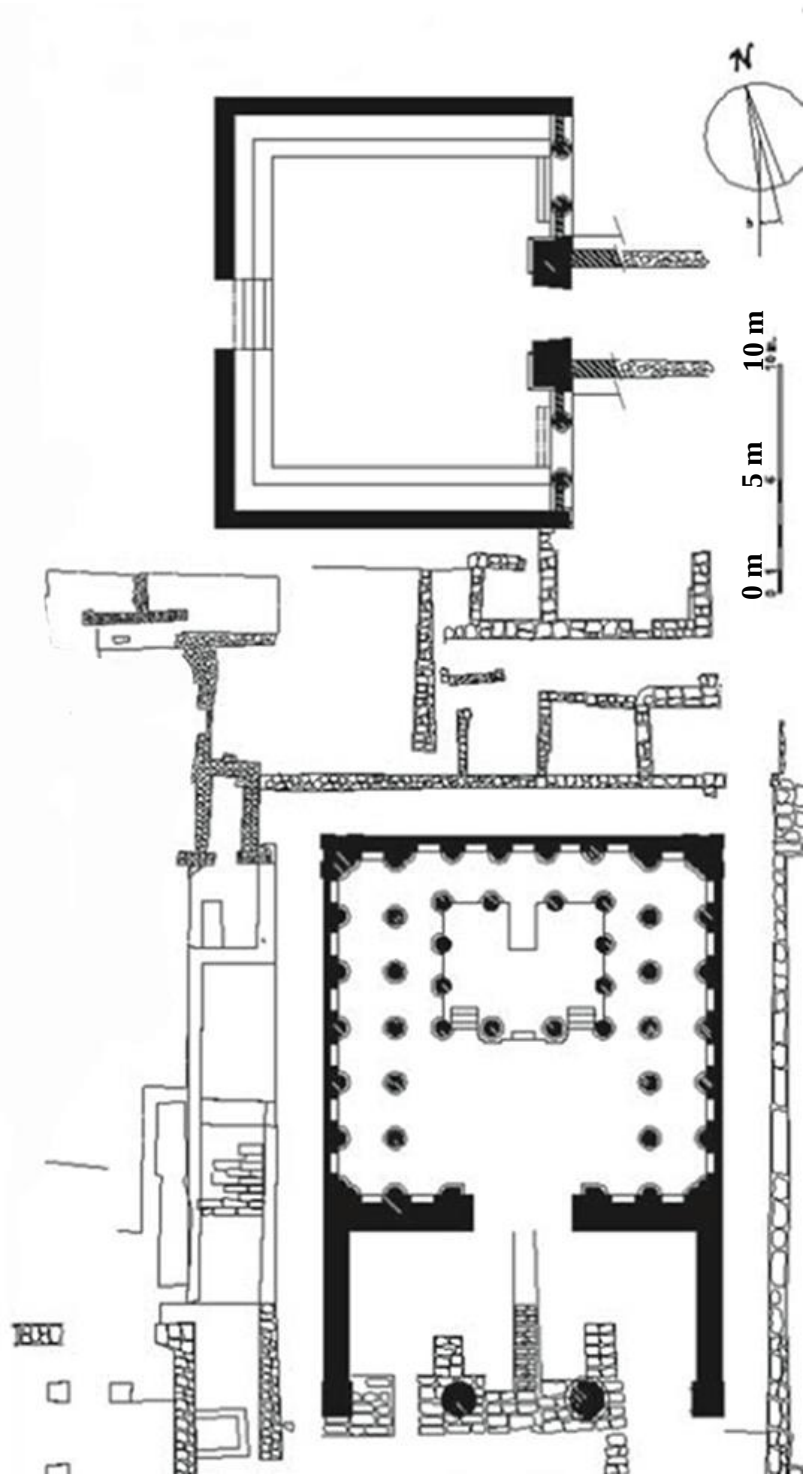


Fig. 52. The Temple of the Winged Lions, plan (theclassicjournal.uga.edu)

5. CONCLUSIONS

5.1. EFFECT OF THE PROPOSAL

The proposal for adopting an augmented reality application for visualizing the reconstruction of the Nabataean Arch of Petra and, subsequently, other monuments of the ancient city, has been formulated in accordance with the guidelines outlined by international organizations (UNESCO and UN) for the restoration of heritage elements and for the protection of the environmental, cultural, social, and economic context of heritage enhancement projects.

The adoption of the proposal to showcase the digital reconstruction of the Nabataean Arch in Petra through augmented reality application, especially the expansion of the strategy to other ruins in the Park, at first positively aligns with the principles of social, environmental, and cultural sustainability recognized by the United Nations.

5.1.1 Social benefits

In light of observed criticality, from a social perspective, government strategies should design a plan for social cohesion among the communities of Wadi Musa and Uum Sayhoun, starting with mutual involvement in the understanding of the cultural value of the Archaeological Site and adapting the Park and the nearest urban centers to international standards of sustainability. It is also urgent to expand tourism experiences within the Bedouin community; in this way, some solutions can be negotiated with it to allow only limited and authorized access to the local community into the Park. It is necessary, in this perspective, to activate new activities and workshops in Uum Sayhoun.

The proposal supports social sustainability through an initial participatory process involving the local community in the analysis and dissemination of the cultural value of the Nabataean Arch and other monuments in Petra. This cultural action enhances touristic offerings, bringing the local population into contact with professionals and research groups from other countries, fostering opportunities for international cooperation.

The knowledge of digital technology adopted to enhance the accessibility of the Archaeological Site and for a better interpretation of its architectural heritage must be conveyed to the local community, starting from younger generation. A proper dissemination of digital knowledge can generate new employment opportunities in the technology sector in Wadi Musa.

From a standpoint of technology access for tourists, the adoption of an augmented reality application enhances accessibility to the Site, and, most importantly, technological advancements can potentially make the location universally accessible, including for individuals with reduced mobility or during temporary restrictions on Park access.

Aligned with the United Nations Sustainable Development Goals, the proposal can contribute to the achievement of targets within Goal 1 *(End poverty in all its forms everywhere)* and Goal 11 *(Make cities and human settlements inclusive, safe, resilient, and sustainable):*

- Target 1.3: *Implement nationally appropriate social protection systems and measures for all, including floors, and achieve substantial coverage of the poor and the vulnerable by 2030.*
- Target 1.4: *Ensure that all men and women, particularly the poor and the vulnerable, have equal rights to economic resources, access to basic services, appropriate new technology, and financial services by 2030.*
- Target 1.b: *Create sound policy frameworks at the national, regional, and international levels, based on pro-poor and gender-sensitive development strategies, to support accelerated investment in poverty eradication actions.*

- Target 11.4: *Strengthen efforts to protect and safeguard the world's cultural and natural heritage.*

By implementing the proposal, these targets can be achieved through a training program on digitally reconstructed monuments and the technology used for their visualization, targeting economically vulnerable individuals within the local community. This measure promotes cultural awareness among residents who may not benefit as much from the economic advantages of tourism and provides them with access to the tourism sector.

The implementation of the proposal for the digital reconstruction of the Arch and other monuments in Petra, whether integrated into an interpretative thematic itinerary or developed as an additional cultural attraction in the Park, can promote an extension of overnight stays in Petra, fostering increased contact with the local community and greater utilization of the city's economic activities.

5.1.2 Cultural benefits

The proposal also addresses cultural sustainability by involving educational strategies for the Jordanian population, specifically in the Petra Region. Knowledge processes related to the Arch, a focus of the preliminary design phase, must be shared entirely with the local community.

Through strategies to enhance the Arch, is necessary to consolidate the interdependence between the heritage element, its environment and the memory of the local community. The most relevant aspects to achieve good success regarding the knowledge of the heritage is to link it to the local community as part of its history; the local population and the international community have to understand that the Nabataean Arch is part of a habitat that describes a precise sociocultural group.

Simultaneously, on a large scale and in the long term, the proposal aims to strengthen the comprehensive understanding of the Archaeological Site of Petra among the local community and visitors. The use of technology, starting with augmented reality, can reinforce the narrative of the construction processes and use of monuments and inhabited spaces of ancient Petra, triggering an increase in the understanding of the historical value of the site, whose integrity is being preserved. From a comfort of visit perspective, it is crucial to conduct a complementary review of the Park's facilities (first at all informative boards, benches and shading structures).

Through augmented reality, creativity can also be fostered by contextualizing this type of visualization within programs and cultural activities of international appeal, allowing a more agile learning of the complexity of the place and its monuments.

Educational strategies related to the Arch, if implemented, address one specific target within Goal 4 *(Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all):*

- Target 4.4: *By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs, and entrepreneurship.*

The international cooperation in digitally reconstructing Petra's disappeared heritage allows the Petra Development & Tourism Region Authority to achieve one target of Goal 17 *(Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development):*

- Target 17.6: *Enhance North-South, South-South, and triangular regional and international cooperation on and access to science, technology, and innovation and enhance knowledge sharing on mutually agreed terms.*

5.1.3 Environmental benefits

From an environmental point of view, Jordan is a country suffering from severe water scarcity, and changes in consumption in the Petra's geographical area to meet tourist needs require, at first, an awareness campaign directed primarily at hotel chains and tourists to regulate their consumption, secondly, another campaign need to guide the local community and government authority towards a transition in favour of protecting the fragile natural and urban environment. In compliance with Article 2 *(Integrated Protection Policies)* of the Charter for the Protection and Management of the Archaeological Heritage (1990), a robust urban planning regulation is necessary to minimize soil impermeabilization. The article states that:

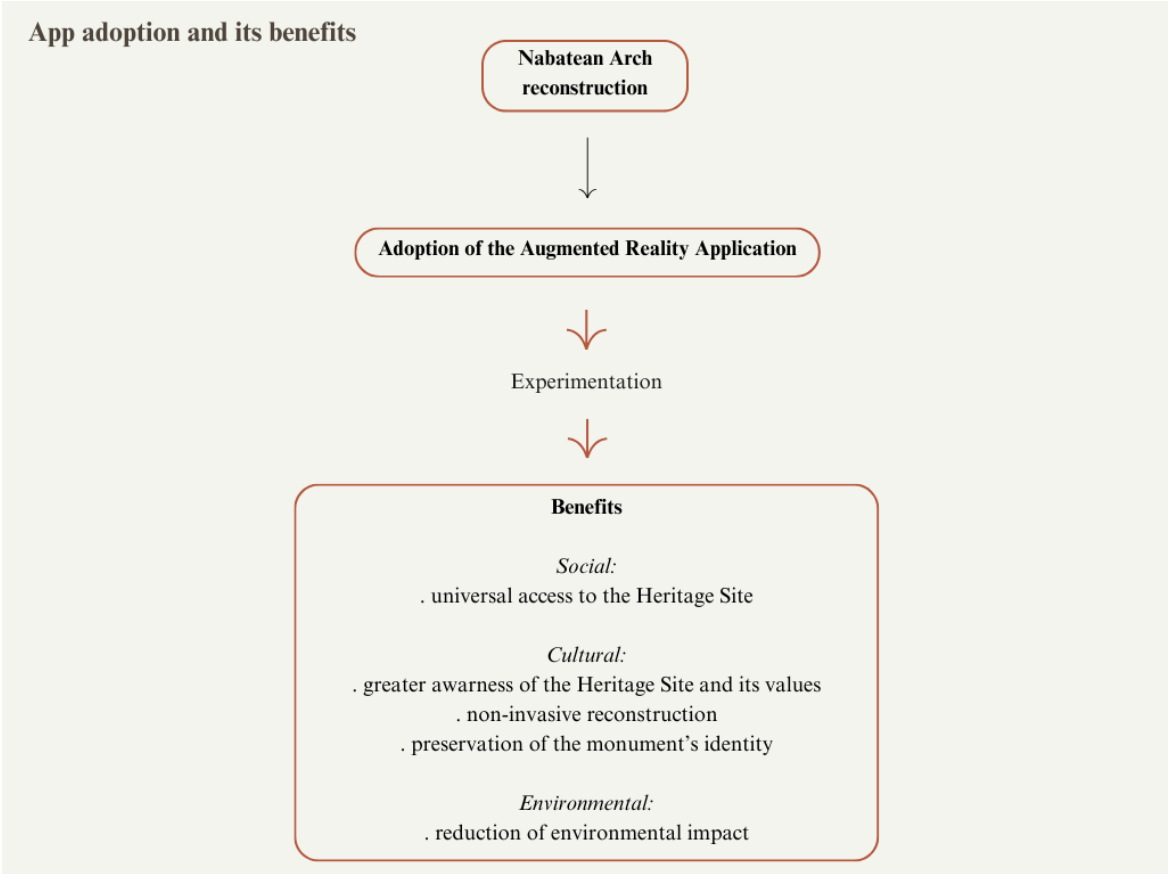
"The archaeological heritage is a fragile and non-renewable cultural resource. Land use must therefore be controlled and developed in order to minimise the destruction of the archaeological heritage".

The proposal, by promoting digital reconstruction over physical one, aligns with the goal of ensuring environmental sustainability. Avoiding physical reconstruction helps reduce the environmental impact associated with material production, transportation, and construction processes. This approach supports Goal 6 *(Ensure availability and sustainable management of water and sanitation for all):*

- Target 6.3: *By 2030, improve water quality by reducing pollution, eliminating dumping, and minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally.*

A purely digital reconstruction minimizes the environmental impact, reducing emissions, noise, and water pollution associated with habitual construction methods. This aligns with the overarching goal of ensuring water availability and sustainable management, a critical consideration in the water-scarce region of Jordan.

In **figure 53 a/b**, all benefits derived from the adoption of the augmented reality application are summarised in both cases: for the Nabataean Arch reconstruction and for its extension to the disappeared monuments in Petra.



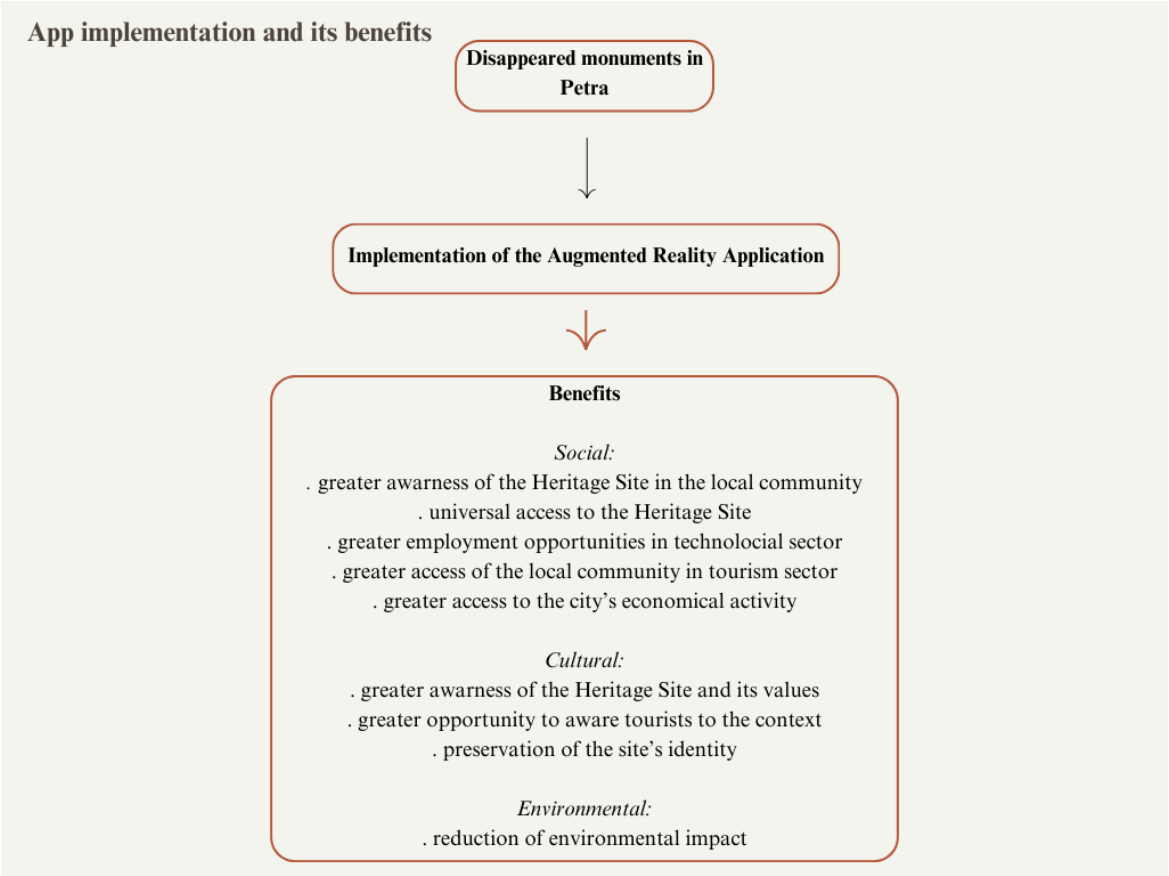


Fig. 57 a/b. The benefits of the adoption and implementation of the augmented reality application

Finally, it concludes by affirming that this Master's Thesis could constitute the basis for PDTRA to develop a tender document to hire the creation and implementation of an augmented reality application for the reconstruction of the Nabataean Arch of Petra. The adaptation of this solution would be welcomed by UNESCO and local communities. Therefore, it is possible that various cooperation agencies are willing to finance its costs. The adoption of an augmented reality application constitutes a first step towards the introduction of a digital tool aimed at enhancing the tourist experience within the Park, adhering to principles of cultural innovation.

In summary, this is a sustainable and beneficial proposal for enhancing the knowledge and understanding of the UNESCO World Heritage Site of Petra.

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