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The Role of Modern Techniques in Preservation of Archaeological Sites

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Abstract

Archaeological sites have always suffered from loss and degradation due to many human and natural hazards. In recent decades, interest in preserving archaeological sites has increased dramatically. Many modern techniques have emerged from the different disciplines that can be used in preservation works, and a large number of the techniques and their capability made it difficult for decision-makers and specialists to determine the appropriate technique that gives the best results in preserving the archaeological site. The research aims to identify the project needed to preserve the archaeological site and then choose the appropriate technique for it, based on the opinions of experts using the analytic hierarchy process (AHP) method, which helps decision-makers and specialists to choose the most appropriate technology. The archaeological site of Babylon was chosen as a case study. As a result of applying the AHP method, the priority weights of preservation stages for the archaeological site of Babylon were determined as follows: (diagnosis and monitoring 30.8 %), (intervention 21.2 %), and (tourism and media 16.6 %), while the appropriate technique was determined as follows: (infrared thermography 29.4 %), (maintenance 49.3 %), and (augmented reality 38.7 %).

Introduction

Archaeological sites are significant properties that must be preserved for future generations, as they represent remnants of their ancient civilizations, culture, and identity. In recent years, the preservation of architectural monuments has become one of the most pressing issues facing the general public [1]. Archaeological sites are collections of physical evidence that have survived the passage of time. The physical evidence includes ancient buildings, monuments, and ruins fully or partially loosen [2]. Due to increasing natural and human threats, archeological sites are continually critically endangered [1].

The term "preservation of archaeological sites" means a complicated process, including many various methodologies and professions to prevent loss in the future [3]. Preservation of archaeological sites should be addressed as part of the planning process [4].

From the beginning of the twentieth century, scientific methods have been increasingly used in archaeological preservation work. Many modern technical devices and means were invented to search for the past and its physical evidence. The years following the Second World War witnessed great cooperation between archaeologists and specialized scientists from other sciences, such as chemistry, biology, geology, physics, engineering, especially architecture, and other disciplines, which opened new horizons in work. The innovative modern techniques become very useful for archaeological works because it reduces cost, time, and efforts. On the other hand, due to the large number and diversity of the techniques, it has made it difficult for decision-makers and specialists to determine the appropriate technique for the preservation works [5].

The focus of this research was on archaeological site preservation, specifically the role of modern techniques in the preservation stages of archaeological sites, while the lack of sufficient knowledge about modern technologies, in addition to the diversity of their sources and uses, constituted the main research problem.

The main goal of the research was determined to assist decision-makers and specialists in choosing the

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appropriate conservation stage and techniques for preserving the archaeological site of Babylon.

To achieve the main goal of the study, the following questions have been discussed:

- What are the main stages for the preservation of archaeological sites?
- How to classify modern techniques due to the preservation stages?
- What is the best way to choose appropriate techniques for each preservation stage?

I. Methods

A. The Archaeological Site of Babylon (Case Study)

Numerous archaeological sites in Iraq date back to thousands of years BC, majority of these archaeological sites have poor preservation work; many of these sites are in danger of being destroyed or lost due to reliance on traditional methods and the lack of preservation works depending on modern techniques. In this paper, the archaeological site of Babylon was chosen as a case study, which is 85 km south of Baghdad (the capital of Iraq) and dates back to the Neo-Babylonian period 626–539 BCE. Within the area site, there are many ancient buildings, structures, and monuments, for example, city walls, gates, palaces, and temples, which represent a unique testament to one of the ancient world's most powerful empires. In 2019, Babylon was named a UNESCO World Heritage Site [6]. Figure 1 shows the map of the Babylon archaeological site.

B. Preservation Stages for Archaeological Sites and the Role of Modern Techniques

In general, the preservation stages of archaeological sites can be determined according to the stated conditions of the archaeological site since the discovery began, then comes the work to ensure its recording, safety, the appropriate intervention, and finally opening it to visitors and storing of all the data in the best possible way for future generations, Based on that the preservation stages of archaeological sites can be determined as follows.

C. Detection and Excavation

It is the stage that aims to uncover and excavate more buried ancient buildings in the archaeological site [7]. At this stage, the role of modern techniques appear in contributing to the discovery of sites as an alternative to

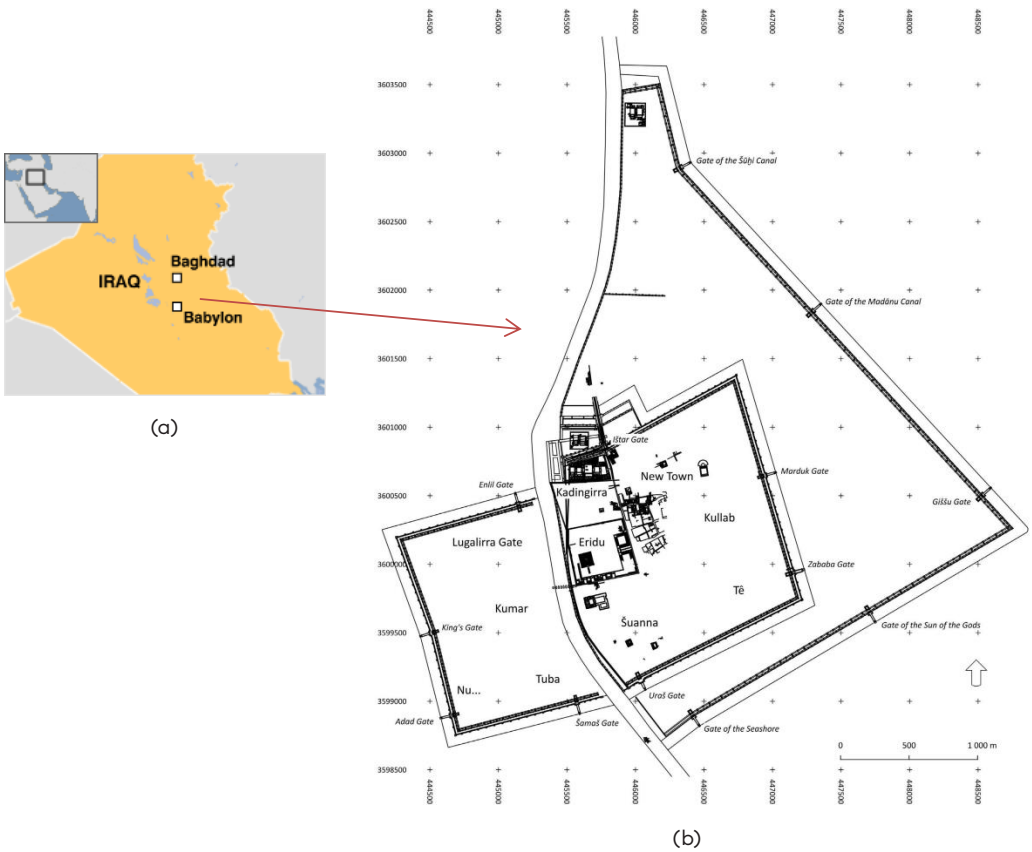


Fig. 1. Map of Iraq (a) and Babylon archaeological site (b) [Pedersén, O. *Babylon: the great city*. Muenster: Zaphon, 2021, pp. 41].

the traditional methods of conducting field pedestrian surveys for detection or excavation work, which saves time, effort and money [8].

D. Documentation

The stage of documenting the archaeological site begins after the completion of the exploration and excavation work. In general, it is necessary to document built cultural heritage to safeguard and preserve it from climate change, natural catastrophes, and human-caused threats [9]. The documentation process is defined as an organized collection and archiving activity to prepare records about the monuments and archaeological buildings in the archaeological site [10]. In recent years, digital documentation of architectural heritage can help to preserve our most valuable legacy, as modern technologies (such as digital cameras, photogrammetry, laser scanning, and LiDAR, etc.) allow the possibility of collecting and recording information to provide accurate and comprehensive data. Taking actions of preservation without relying on prior accurate documentation will often lead to poor results [11].

E. Diagnosis and Monitoring

The diagnosis and monitoring phase aims to assess the state of the structural condition of the archaeological building units and examine the level of damage. The role of modern technologies at this stage (such as infrared thermography, ultrasonic testing, geodetic network, etc.) appears in the possibility of diagnosing and monitoring various visible and even hidden damage accurately and quickly compared to the traditional methods which mainly depend on direct visual observation [12].

F. Interventions

In this stage, appropriate levels of intervention are determined based on data collected in the previous stages. To determine the appropriate level of intervention to preserve archaeological sites requires complete knowledge of all historical, architectural and engineering aspects of the archaeological site.

The use of materials and treatments should follow the standards and foundations recommended by international conventions and organizations in preserving such as compatibility, reversibility, distinction, and minimum intervention (the level of intervention from lower to higher is described in [13]).

In the study, the levels of intervention were divided into four main categories: maintenance, emergency rescue, regeneration, and environmental protection.

G. Tourism and Media

The importance of the tourism and media promotion stage appears in developing a greater understanding of the cultural values possessed by archaeological sites. The use of modern technologies and means to attract tourists contributes to achieving a high level of competitiveness in the archaeological tourism sector [14]. It includes providing tourists during their wanderings with a digital guide with three-dimensional images, providing information directly or indirectly – through virtual tours supported by three-dimensional computer technologies, by determining cultural and tourist itineraries in physical and virtual sites, providing Internet access for tourists in historical areas, and online reservation of tickets for museums and archaeological sites via smart mobile phone applications [14].

H. Creating Database

The final stage, which aims to create a database, aims to collect integrated data that includes all past, current and future information about the preservation work of the archaeological site and is subject to continuous updating, and shows the role of modern technologies in providing software systems specialized in data management on computers that provide the possibility of storing, tabulating, analyzing and retrieval of data as needed easily, with the possibility of updating constantly, compared to the traditional methods of using papers and records or even saving them in the form of random files on computers [15]. Figure 2 shows the stages of development of projects to preserve archaeological sites.

II. Choosing Appropriate Technique

Nowadays, many techniques from different disciplines can be used in the preservation stages of archaeological sites, each one of these techniques has its own set of features and benefits [16]. As a result of that, it became difficult for the decision-makers and specialists to choose the appropriate techniques that fit with the features of the archaeological sites [17].

The main factors that affect choosing the appropriate techniques can be divided into as follows [17]:

- Archaeological site factors: These factors include the features related to the archaeological sites such as physical site condition, size of the area, accessibility, safety, etc.
- Technical factors: These factors include the features related to the techniques such as cost, efficiency of the techniques, and time required to finish the work.

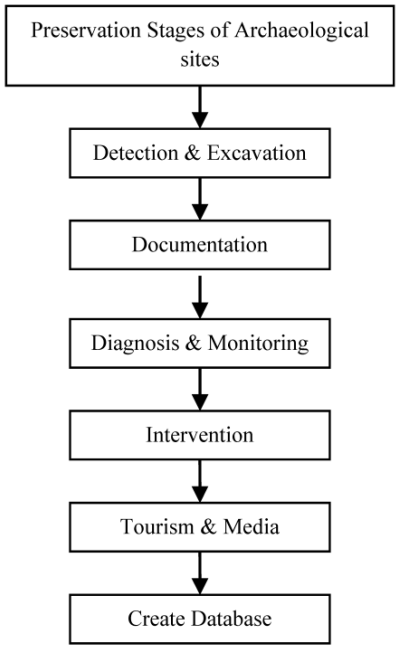


Fig. 2. Stages of development of conservation projects [developed by authors].

Table I presents the main available techniques selected and classified in the study, with their capabilities for the preservation stages of archaeological site.

J. Application of AHP Method

According to the main aim of the research in helping decision-makers and specialists to choose the appropriate technique in the process of preserving archaeological sites, in this study, the analytic hierarchy process (AHP) method, developed by Saaty and Tavana, was chosen [18]. The task of this method is to help in determining the best choice through a set of options. In general, the AHP method consists of three main steps:

- Step 1. Identify the hierarchy structure: A set of options or criteria that help reach the goal. In general, the AHP hierarchy structure has the main and secondary criteria.
- Step 2. Assessment of the identified criteria: Using the pairwise comparison method, based on expert opinions, it is a process of evaluating criteria in pairs to decide which criterion is favored. The pairwise comparison assessment scale in the AHP method, according to [18], has definitions of equal, moderate, strong, very strong, and extreme intermediate values for weight intensities of 1, 3, 5, 7, 9, and 2, 4, 6, 8, respectively.
- Step 3. Verifying the reliability of the assessment: In the AHP method, it is required to calculate the consistency ratio (CR), which must be equal to or less than 0.1, to be acceptable.

III. Results and Discussion

K. Identifying Archaeological Site Issues

Following the site visit, the main issues in the archaeological site connected to the stages of preservation were identified:

- Detection and excavation: Only about a quarter of the site has been excavated.
- Documentation: The absence of integrated documentation of the building units discovered in the archaeological site.
- Diagnosis and monitoring: The structural structure suffers mainly from the presence of moisture due to its proximity to the Euphrates River, as well as cracks due to the influence of erosion factors and rain water because the building material is fragile (mud brick).
- Interventions: The archaeological site suffers from previous interventions that are inappropriate to UNESCO recommendations.
- Tourism and Media: The rate of visitors from abroad is low, not commensurate with the level of the global importance of the site.
- Creating a database: The lack of integrated databases for the building units in the archaeological site.

L. Team Expert

In this study the team consisted of ten experts (engineers, conservators, architects, and archaeologist who had worked in Babylon sites for a long time) to get an accurate assessment. Figure 3 shows the main characteristics of the selected experts in relation to age, professions, and years of experience.

M. The AHP Hierarchy Structure of the Study

The AHP hierarchy structure used in the study was identified as follows:

- Level 1 represents the main goal (to choose the appropriate techniques).
- Level 2 represents preservation stages of archaeological sites: Detection an excavation, documentation, diagnosis and monitoring, interventions, tourism and media, and creating a database.
- Level 3 represents the modern techniques, as shown in Figure 4.

N. Experts' Assessment

The results of the experts' assessment for the selection of the appropriate preservation project for the archaeological site of Babylon (the criteria) were as follows:

- detection and excavation (8.2 %), documentation (13.2 %), diagnosis and monitoring (30.8 %),

TABLE I

Main Available Techniques and Their Capabilities for Preservation Stages of Archaeological Site (developed by authors using [1], [7], [19]–[36])

Stage of preservation	Technique	Capabilities
Detection and excavation	Ground penetrating radar (GPR)	Detection, identification, and drawing of plans for the locations of the buried underground walls before excavation [19]
	Satellite imagery	Conducting an archaeological survey of vast areas of land to identify potential locations for archaeological sites above the surface of the earth [20]
	Robotics application	To detect what is hidden inside narrow gaps [21]
	Soil resistivity	Detecting changes in the geological structure of the soil that indicate the presence of archaeological remains [22]
	Magnetometry	Detecting buried archaeological materials with iron properties [23]
	Portable X-ray fluorescence (pXRF)	Detecting changes in the geological structure of the soil that indicate the presence of archaeological remains [24]
Documentation	Areal photogrammetry	Creates a 3D digital model by imaging from the air for wide areas [1]
	Terrestrial photogrammetry	Creates a 3D digital model by imaging from the ground for limited areas [1]
	Laser scanning	Creates a three-dimensional point cloud digital model [7]
	LiDAR	Creates 3D maps for the site of the type digital elevation model (DEM) [25]
	Digital camera	Creating a two-dimensional image archive [26]
	Total station	Identifying the coordinates of the archaeological site boundaries or discovered objects; measuring the distances between two points [27]
	GPS	Identifying the coordinates of the archaeological site boundaries or discovered objects [27]
Diagnosis and monitoring	Infrared thermography	Detecting the difference in thermal distribution enables to determine the problems such as moisture, atmospheric temperature, and cracks [28]
	Ultrasonic testing	To determine the place that gives a different acoustic response, which contributes to the diagnosis of damaged and separated parts, especially in the finishing materials for the walls [28]
	Ion chromatography	To determine the concentration of salts and then remove them from porous building materials such as stone, bricks and others [28]
	FTIR spectroscopy	To analyze the components and structures of the elements in the archaeological materials by an infrared spectrum of the materials, which represents a "fingerprint" of the sample [28]
	Spectroscopy (NMR)	To detect the water content (moisture) in materials [28]
	Capacitance moisture measuring	To detect the water content (moisture) in materials [29]
	Fiber optics microscope	To determine the differences in texture and surface composition, study the phenomenon of decay, determine defects in building materials, and evaluate cleaning work interventions for materials and others [28]
	Geodetic network	To estimate the potential relative motion of displacement in the ground [30]
	Endoscopy	To check tight, hard-to-reach places [28]
	Portable X-ray generator	To detect defects hidden under the surface of the observed objects such as walls, ceilings, etc. [28]
Interventions	Restoration techniques	It includes modern restoration techniques that are being carried out to perpetuate archaeological structures in accordance with UNESCO recommendations [28]
	Emergency rescue techniques	Modern techniques include the transfer of antiquities in the event of risks threatening their existence [31]
	Renovation techniques	Innovation techniques by new materials such as the use of glass and iron elements for the purpose of reuse [31]
	Environmental protection techniques	Innovative techniques such as shelters and enclosures to protect sites from the environmental risks [32]
Tourism and media	Augmented reality	Augmented reality allows users to visualize ancient sites in their original form, based on software applications that insert computer graphics, virtual objects, and 3D models into the real world [33]
	Virtual reality	It provides the possibility of creating a 3D virtual environment that simulates reality with the possibility of roaming inside it, adding visual and audio effects that increase the content's fun, attractiveness, and scientific value [33]
	Hologram	Creating three-dimensional visual historical scenes with sound in the archaeological site contributes to attracting tourists [34]
	Sheet of Perspex	To engrave a linear plan on a sheet of Perspex to compare the differences between the original and the existing one [35]
	Scale models	Creating a small 3D model similar to the original (replica) allows viewing the original feature up close [28]
	Scenic illumination	Outdoor lighting increases the perception of the archaeological landmark and encourages visiting at night; the most effective type of lighting is ground light [28]
Creating a database	GIS (geographic information system)	Geographical information systems are the systems that acquire, store, analyze, manage and display data related to the archaeological site [36]
	BIM (building information modelling)	Creating a 3D model on the computer that contains all the details of the elements related to the ancient building allows adding the data and information about it
	Microsoft Excel	Creates tables to save the required data
	Microsoft Excel	Provides the ability to store data in the form of tables

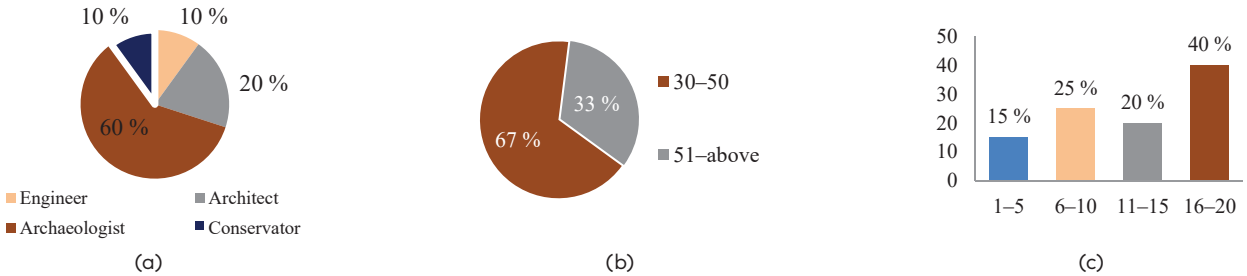


Fig. 3. Some characteristics of experts: age (a), profession (b), and years of experience (c) [created by authors].

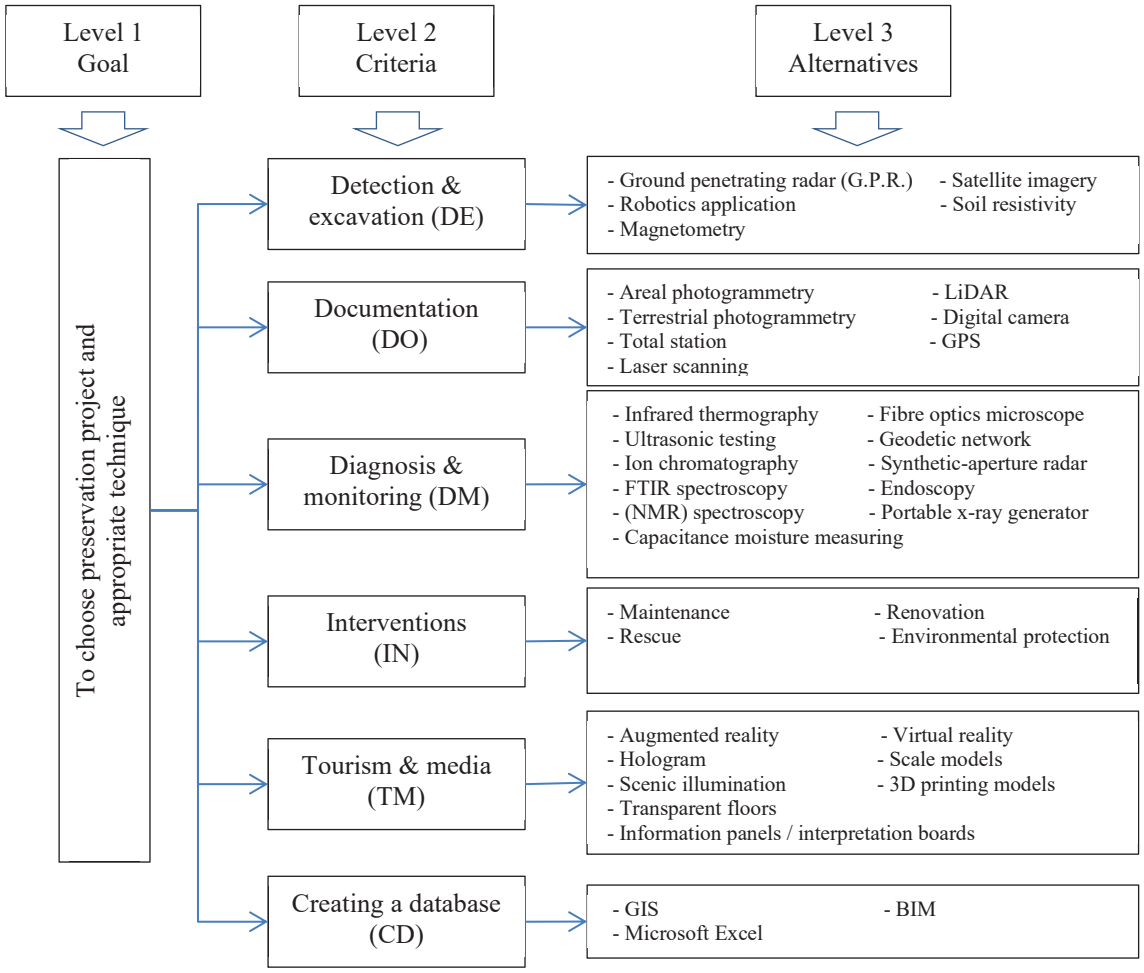


Fig. 4. The AHP Hierarchy structure of the study [created by authors].

interventions (21.2 %), tourism and media activation (16.6 %), creating a database (10 %), as shown in Figure 5 and Table II.

O. Identified Priorities of the Preservation Work

The results and analysis of the experts' assessment, which identified the priorities of the preservation work (the main criteria in the study) of the archaeological site of Babylon, are as follows:

The first priority level was assigned to "diagnosis and monitoring", because the archaeological site of Babylon has been neglected and exposed to many risks and threats that have caused many damages at various levels that require periodic and urgent diagnosis and monitoring, and this was confirmed by UNESCO reports when the archaeological site of Babylon was included in 2019 on the list of World Heritage site.

The second priority level was assigned to "activating tourism and media", which confirms the importance of the

TABLE II

The Weight Ratio of Stages of Conservation Projects and Modern Techniques [created by authors]

Stage of conservation (the main criteria)	Weight ratio	Technique (the secondary criteria)	Weight ratio
Detection and excavation	8.2 %	Ground penetrating radar (GPR)	41.2 %
		Satellite imagery	11 %
		Robotics application	6.7 %
		Soil Resistivity	7.6 %
		Magnetometry	13 %
		Portable X-ray fluorescence = pXRF	19.6 %
Documentation	13.2 %	Areal photogrammetry	50.4 %
		Terrestrial photogrammetry	23.8 %
		Laser scanning	13 %
		LiDAR	4.5 %
		Digital camera	8.3 %
		Total station	7.7 %
		GPS	13.8 %
Diagnosis and monitoring	30.8 %	Infrared thermography	29.4 %
		Ultrasonic testing	9.1 %
		Ion chromatography	2.1 %
		FTIR spectroscopy	2.6 %
		Spectroscopy (NMR)	4.8 %
		Capacitance moisture measuring	14.8 %
		Fibre optics microscope	5.6 %
		Geodetic network	6.2 %
		Endoscopy	8.4 %
		Portable X-ray generator	17.1 %
Interventions	21.2 %	Maintenance	49.3 %
		Emergency rescue	19.4 %
		Renovation	8.9 %
		Environmental protection	22.4 %
Tourism and media	16.6 %	Augmented reality	38.7 %
		Virtual reality	20.3 %
		Hologram	10.1 %
		Information panels/interpretation boards	2.3 %
		Scale models	8.2 %
		Scenic illumination	11.9 %
		3D printing models	5.1 %
		Transparent floors	3.4 %
Creating a database	10 %	GIS (geographic information system)	63.2 %
		BIM (building information modelling)	25.6 %
		Microsoft Excel	11.1 %

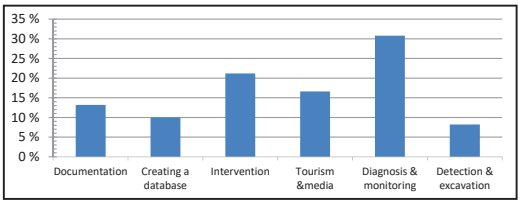
archaeological site of Babylon to an increase in attracting tourists and introducing the discovered building units because of its great importance at the local and global levels as one of the UNESCO World Heritage Sites.

The third priority level was assigned to "intervention". For the case study (Babylon) the "intervention" was determined as "maintenance", because most of the building units in the archaeological site of Babylon that were completely or partially reconstructed have been neglected and need periodic maintenance and restoration, they are also left in the open without any protection measures from the dangers that threaten them.

The fourth level of priority was assigned to "documentation", because the site has witnessed several documentation campaigns in the past few years by a number of specialists and international organizations, and the necessary data was recorded and collected on some building units located in the archaeological site of Babylon.

The fifth level of priority was given to "creating a database".

And finally, the sixth level of priority was assigned to "detection and excavation", although the Babylon site has not been excavated for many years, dating back to the eighties of the last century, the opinions of experts was



	Criterion	Weights	+/-
1	Documentation	13.2 %	2.2 %
2	Creating a database	10.0 %	2.0 %
3	Intervention	21.2 %	4.2 %
4	Tourism & media	16.6 %	3.1 %
5	Diagnosis & monitoring	30.8 %	5.5 %
6	Detection & excavation	8.2 %	1.6 %

Matrix	Documentation	Creating a database	Intervention	Tourism & media	Diagnosis & monitoring	Detection & excavation	Normalized principal Eigenvector
Documentation	1	1 2/3	1/2	2/3	2/5	1 8/9	13.25 %
Creating a database	3/5	1	1/2	1/2	3/8	1 4/7	10.03 %
Intervention	2	2	1	1 2/3	1/2	2 1/4	21.16 %
Tourism & media	1 4/9	2 1/8	3/5	1	1/2	2	16.61 %
Diagnosis & monitoring	2 3/7	2 2/3	1 5/6	2 1/9	1	2 6/7	30.77 %
Detection & excavation	1/2	5/8	4/9	1/2	1/3	1	8.18 %

Fig. 5. Results of the AHP pairwise comparison scale by experts [created by authors using the AHP method].

that detection and excavation should be stopped now and it is important to move towards focusing on preserving the discovered building units, especially because many of them are still buried underground and have not been excavated yet.

As for the modern techniques (the secondary criteria in the study), the same previous procedures were used in the AHP method to determine the weights of the appropriate techniques for each stage of conservation in the study area. The results were as shown in Figure 6.

The modern techniques (the alternatives) were assessed for preserving stage of the archaeological site, according to experts' opinions using the AHP method. The techniques with a highest weights ratio (ground penetrating radar for detection and excavation, areal photogrammetry for documentation, infrared thermography for diagnosis and monitoring, maintenance for interventions, augmented reality for tourism and media, and GIS for create a database) are the techniques recommended by experts to be used in the preservation of archaeological site of Babylon.

Conclusions

The research, based on the opinions of experts, shows the possibility of using the AHP method in determining the priorities of the preservation work of archaeological sites, as well as helping to suggest appropriate techniques for each stage of preservation.

The methodology used in the research helps decision-makers and specialists in managing archaeological sites in introducing the available modern technologies and their

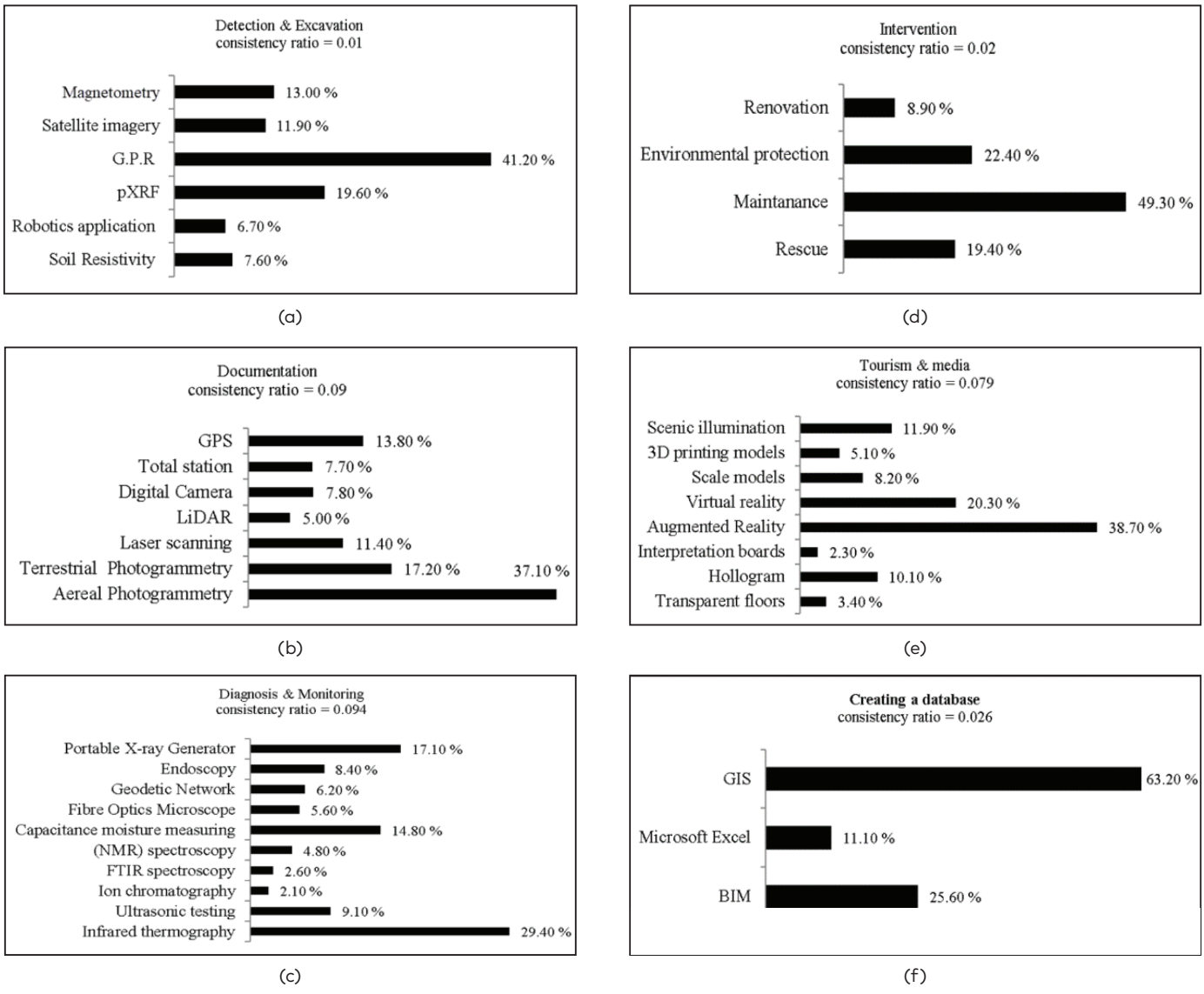


Fig. 6. Results of AHP assessments of: (a) detection and excavation stage, (b) documentation stage, (c) diagnosis and monitoring stage, (d) intervention stage, (e) tourism and media stage, and (f) creating a database stage [created by authors using AHP method].

uses, and thus, they play a major role in decreasing time, effort, and money.

The study showed the diversity of modern technologies that can be used in the preservation of archaeological sites and the different method of using them and their sources, and that each stage of preservation has its own techniques.

The methodology used in the research can be applied to other archaeological sites that are on the UNESCO list or that fall on the UNESCO danger list, which helps to remove archaeological sites from the list of risks and prevent the addition of new sites to the list of risks in the future.

The techniques identified in the study are subject to development, and new technologies may appear in the future as a result of the rapid scientific developments in this field.

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