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Research Article

Digital Reconstruction of Issos-Epiphaneia: Cultural Heritage with Interactive Information Panels

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Abstract

The ancient city of Issos-Epiphaneia, located within the borders of Erzin District in Hatay Province, represents a multilayered archaeological landscape with an uninterrupted settlement history spanning approximately 7,500 years, from the Late Neolithic Period to the Ottoman period. Its rich stratigraphy, reflecting the diverse cultures of the Eastern Mediterranean, together with the fact that no modern settlement was constructed directly over the ancient remains, has made Issos-Epiphaneia one of the best-preserved ancient cities in Hatay. Public buildings dating to the Roman, Byzantine, and Medieval periods, the colonnaded street system, and its connections to maritime trade routes demonstrate the city's historical continuity and urban significance. This study examines the transmission of cultural heritage through next-generation methods within the framework of the digital reconstruction of Issos-Epiphaneia, using 3D modelling and interactive information panels. Digitalisation of cultural heritage is particularly crucial in earthquake-prone regions; following the 6 February 2023 earthquakes, accelerated digital documentation efforts at the site contributed significantly to the preservation and sustainability of archaeological data. Unlike traditional site panels, which are characterised by dense textual information and limited visual content, this project proposes an inclusive visitor experience through 3D reconstruction accessible via QR codes, accompanied by concise text, multilingual content, and audio narration. This approach enables not only specialists but also members of the general public of all ages and with diverse accessibility needs to better understand the archaeological remains. At Issos-Epiphaneia, where preliminary preparation and evaluation studies are being conducted for UNESCO World Heritage nomination, the historical landscape associated with the Battle of Issos and the unique Zodiac Calendar Mosaic depicting rural activities are presented through narrative-based digital reconstructions designed to reach wider audiences. The study ultimately proposes a sustainable digital cultural heritage communication model integrating scientific accuracy, transparent data management, and digital production processes.

Keywords: Hatay, Issos-Epiphaneia, digital cultural heritage, UNESCO World Heritage, tourism, digital reconstruction, 3D modelling.

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Araştırma Makalesi

İssos-Epiphaneia'nın Dijital Rekonstrüksiyonu: Etkileşimli Bilgi Panelleriyle Kültürel Miras

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Öz

Hatay ili Erzin ilçesi sınırları içerisinde İssos Ovası'nda yer alan Epiphaneia Antik Kenti, Geç Neolitik Dönem'den Osmanlı Dönemi'ne kadar yaklaşık 7.500 yıllık kesintisiz yerleşim geçmişine sahip, çok katmanlı bir arkeolojik peyzaj sunmaktadır. Doğu Akdeniz'in farklı kültürlerini yansıtan zengin stratigrafisi ve modern yerleşimin antik kalıntıların doğrudan üzerine inşa edilmemiş olması, İssos–Epiphaneia'yı Hatay'daki en iyi korunmuş antik kentlerden biri hâline getirmiştir. Roma, Bizans ve Orta Çağ dönemlerine tarihlenen kamu yapıları, sütunlu cadde sistemi ve deniz ticaret yollarıyla bağlantıları, kentin tarihsel sürekliliğini ve kentsel önemini ortaya koymaktadır. Bu çalışma, İssos–Epiphaneia'nın dijital rekonstrüksiyonu çerçevesinde, 3B modelleme ve etkileşimli bilgilendirme panoları aracılığıyla kültürel mirasın yeni nesil yöntemlerle aktarımını incelemektedir. Kültürel mirasın dijitalleştirilmesi, özellikle deprem riski taşıyan bölgelerde büyük önem arz etmektedir; 6 Şubat 2023 depremlerinin ardından alanda hız kazanan dijital belgeleme çalışmaları, arkeolojik verinin korunmasına ve sürdürülebilirliğine önemli ölçüde katkı sağlamıştır. Yoğun metin içeren ve görsel bakımdan sınırlı kalan geleneksel ören yeri panolarından farklı olarak bu proje, QR kodlar aracılığıyla erişilebilen 3B rekonstrüksiyonlar, kısa açıklayıcı metinler, çok dilli içerik ve sesli anlatım eşliğinde kapsayıcı bir ziyaretçi deneyimi önermektedir. Bu yaklaşım, yalnızca uzmanların değil, her yaştan ve farklı erişilebilirlik ihtiyaçlarına sahip genel ziyaretçilerin de arkeolojik kalıntıları daha iyi anlamasını mümkün kılmaktadır. UNESCO Dünya Mirası adaylık sürecine yönelik ön hazırlık ve değerlendirme çalışmalarının yürütüldüğü İssos–Epiphaneia'da, ünlü İssos Savaşı ile ilişkilendirilen tarihsel peyzaj ve kırsal faaliyetleri betimleyen özgün Zodyak Takvim Mozaiği, daha geniş kitlelere ulaşmayı hedefleyen hikâye temelli dijital rekonstrüksiyonlar aracılığıyla sunulmaktadır. Çalışma sonucunda, bilimsel doğruluk, şeffaf veri yönetimi ve üretim süreçlerini bir araya getiren sürdürülebilir bir dijital kültürel miras iletişimi modeli önerilmektedir.

Anahtar Kelimeler: Hatay, İssos–Epiphaneia, dijital kültürel miras, UNESCO Dünya Mirası, turizm, dijital rekonstrüksiyon, 3B modelleme.

Introduction

The ancient city of Epiphaneia in the Issos Plain[1], located within the borders of Erzin District in Hatay Province, represents a multi-layered archaeological site that preserves uninterrupted settlement traces from the Late Neolithic Period to the Ottoman Period. Its dense architectural fabric, dating to the Roman, Byzantine, and Medieval periods including public buildings situated around a colonnaded street (fig. 1), a bouleuterion-odeion (fig. 2), baths (fig. 3), a temple (fig. 4), a prytaneion, a theatre (fig. 5), aqueducts (fig. 6), and harbour connections demonstrates the city's significance within the trade and cultural networks of the Eastern Mediterranean[2]. The Catabolos Harbour, located approximately 9 km southwest of the city, constituted one of the main drivers of urban prosperity through maritime trade[3]. The fact that no modern settlement was established directly over the ancient city has made Issos-Epiphaneia one of the most well-preserved archaeological sites in the Hatay region. This condition provides significant research potential for both traditional archaeological investigations and large-scale digital documentation studies.



Figure 1: Colonnaded Street and *Stoa (Özdilek et al. 2024a, 217, fig. 7)*



Figure 2: Bouleuterion-Odeion *(Özdilek et al. 2024b, 365, fig. 41)*



Figure 3: Eastern Bathhouse *(Tıbıkoğlu and Özdilek 2024, 268, fig. 7)*



Figure 4: Temple-Basilica *(Özdilek 2025, 384, fig. 4)*

[1] The official name of the project conducted within the framework of the excavations and archaeological research at Epiphaneia in the Issos Plain is "Issos-Epiphaneia Excavations and Archaeological Research". The project is conducted by Hatay Mustafa Kemal University under the authority of the General Directorate of Cultural Heritage and Museums of the Ministry of Culture and Tourism of the Republic of Türkiye, pursuant to a Presidential Decree.
[2] Özdilek et al. 2024a, 197; Tıbıkoğlu and Özdilek 2024, 266.
[3] Özdilek and Tıbıkoğlu 2025a, 175; Özdilek and Tıbıkoğlu 2025b, 228.

1. Excavation and Research History

The new phase of excavations at the site was initiated in 2022 by the scientific team of Hatay Mustafa Kemal University[4]. This process has not only enabled the discovery of archaeological remains but has also allowed for a comprehensive reassessment of the historical development of the region. Recent investigations have demonstrated that the settlement was not limited to the Hellenistic and Roman periods but extended back to much earlier prehistoric phases. Research conducted in the stoa–porticus structures (fig. 1), the bouleuterion–odeion (fig. 2), the theatre (fig. 5), industrial production areas, water systems (fig. 6), and the harbour settlement of Catabolos has enabled a reinterpretation of the city's urban organisation and economic structure in antiquity[5]. At the same time, the excavations have provided an important scientific foundation, contributing a cultural heritage–based perspective to Hatay's post-earthquake reconstruction process.



Figure 5: Theatre *(Özdilek and Tıbıkoğlu 2025b, fig. 9)*



Figure 6: Aqueduct *(Özdilek and Tıbıkoğlu 2025b, fig. 28)*

2. Digital Archaeology Studies at Issos-Epiphaneia

With the commencement of the excavations in 2022, digital archaeology applications were introduced by Dr. Tıbıkoğlu, and a site-specific data management system was established. Within this framework, photogrammetry, LiDAR (Light Detection and Ranging), three-dimensional modelling, Geographic Information Systems (GIS), and digital documentation methods began to be systematically implemented[6]. Through artificial intelligence–supported techniques, automation was achieved in processes such as surface texture enhancement, interpretation of missing parts, classification, and segmentation. However, these procedures were evaluated in accordance with the principles of scientific transparency and accuracy.

3. Data Management and Digital Documentation Against Disaster Risk

The earthquakes centred in Kahramanmaraş on 6 February 2023 had severe impacts on cultural heritage in Hatay. This process demonstrated that digital documentation is not only an academic tool but also a fundamental component of disaster risk management.

[4] Özdilek 2025, 380-381; Özdilek and Tıbıkoğlu 2025a, 176-177; Özdilek and Tıbıkoğlu 2025b, 215-216; Özdilek and Sönmez 2025, 99-100; Özdilek et al. 2023, 29; Özdilek et al. 2024a, 198; Özdilek 2024, 24-25; Özdilek and Tıbıkoğlu 2023, 24-25; Özdilek and Tıbıkoğlu 2024, 27.

[5] Özdilek et al. 2024b, 335; Özdilek et al. 2025a, 151; Özdilek et al. 2025b, 265-266; Özdilek and Tıbıkoğlu 2026.

[6] The master's thesis of our Issos-Epiphaneia excavation team member, M. Naif Sönmez, titled "Digital Archaeology Applications and Database Systems of Issos-Epiphaneia," is currently ongoing at the Department of Archaeology, Hatay Mustafa Kemal University.

Digitalisation efforts initiated before the earthquake were accelerated afterwards in order to prevent data loss. Digital data production enabled the recording of the current condition of archaeological remains, ensured the traceability of restoration decisions, and created reliable references for future conservation practices. This approach is grounded in the transparent documentation of data production processes, in accordance with the principles of scientific transparency and paradata documentation outlined in the ICOMOS Seville Principles. Demir and Çilingiroğlu, while evaluating the impact of the 6 February 2023 earthquakes on cultural heritage sites in Hatay, presented important methods and examples relating to post-disaster digital documentation processes. In their study, they assessed the condition of cultural heritage affected by the earthquakes by combining ARIA damage maps, Sentinel-1/InSAR-based displacement data, and data collected by volunteers through social media. These methodological approaches enabled the active monitoring of post-disaster damage, risk status, and digital documentation techniques[7].

In recent years, the digitisation and reconstruction of cultural heritage have evolved into an interdisciplinary field of research extending beyond techniques based solely on visualisation. This field encompasses the documentation, analysis, interpretation, preservation, and public accessibility of archaeological data. In the digital age, archaeology and the topography, architectural remains, materials, and cultural components of archaeological sites have increasingly been transferred into three-dimensional virtual environments. These datasets can be academically remodelled and used for presentation purposes for visitors and the wider public through open-access platforms[8]. For institutionally grounded activities in digital reconstruction studies, computer-based visualisations are increasingly emphasised as scientifically robust, transparent, traceable, methodological, and academically verifiable processes. In particular, the London Charter stresses that digital visualisation studies should be considered not merely as aesthetic presentations, but as scientific models grounded in evidence-based data, including hypothetical, interpretative, and inferential components[9]. Similarly, the Seville Principles recommend that such virtual reconstructions in digital archaeology be evaluated according to the principles of academic rigour, scientific reliability, uncertainty management, and transparency[10]. In line with these principles, digital reconstruction should be understood not simply as a means of visualising the past, but as an integral part of the scientific interpretation and communication of archaeological data.

One of the most critical questions in digital reconstruction studies concerns how these datasets should be presented to visitors. Traditional archaeological site information panels are static tools, generally positioned at specific locations within the site, often limited in visual content and heavily dependent on dense textual explanations written in an overly formal and difficult-to-read style. With the development of technology, interactive panels equipped with multilayered digital interfaces have increasingly begun to be introduced at archaeological sites. The kiosk-based systems developed by Fabio I. Apollonio and colleagues have enabled visitors to experience three-dimensional models of museum collections and inventories. Through such applications, artefacts have ceased to function merely as passive objects and have instead become active tools for knowledge exploration[11]. Today, kiosk systems in museums and cultural heritage sites facilitate stronger interaction and engagement between visitors and three-dimensional representations of the archaeological sites. From a similar

[7] Demir and Çilingiroğlu 2024, 119.
[8] Apollonio et al. 2025, 3.
[9] Denard 2012, 60.
[10] ICOMOS 2017.
[11] Apollonio et al. 2025, 1-2.

perspective, the use of augmented reality (AR), virtual reality (VR), and extended reality (XR) technologies in the field of cultural heritage has become increasingly important in shaping new visitor experiences[12]. The TeosVR project can be cited as a significant example of this approach. From this perspective, three-dimensional reconstruction models alone are insufficient; photograph-based models more effectively convey the spatial, temporal, and physical characteristics of surviving remains. However, photograph-based models alone have also been shown to be insufficient for communicating temporal information. For this reason, by combining both methods, researchers proposed what they termed an "overlaid model," in which both the extant architectural remains and the reconstruction are presented simultaneously within the same visual system, thereby providing reliable and transparent information[13]. Such approaches constitute an important model for the digital reconstruction and interactive information panels currently being developed for the ancient city of Issos-Epiphaneia. Within the framework of digital archaeology studies at Issos-Epiphaneia, the digital models to be produced are intended not only for architectural visualisation and reconstruction, but also to play a significant role in data documentation, analysis, interpretation, and visitor experience. In particular, through interactive information panels, it is planned to present to both visitors and researchers an integrated system consisting of the material and structural condition of the remains, the proposed reconstruction model, and the accompanying scientific interpretation. In this way, visitors will be able to evaluate, simultaneously and spatially, the visible physical remains, the proposed hypothetical model, and the possible architectural organisation of the structures.

Therefore, the digital archaeology studies at Issos-Epiphaneia have the potential to establish an original model integrating the documentation, interpretation, and visitor experience of cultural heritage through innovative interdisciplinary methods. In this way, the remains of Issos-Epiphaneia can be preserved in accordance with scientific principles, while its cultural heritage can also be effectively communicated to wider audiences through accessible open platforms beyond the physical boundaries of the site.

4. Tourism, Promotion, and Public Outcomes

Post-earthquake studies have not been limited to scientific research; they have evolved into practices that strengthen the role of cultural heritage in the process of social recovery. Through digital reconstructions and interactive information panels, visitors can access three-dimensional visualisations, multilingual narratives, and audio content via QR codes. Compared with traditional text-heavy information boards, this system offers a more inclusive, educational, and memorable experience. Digital storytelling tools that support accessibility for disadvantaged individuals also contribute to the democratisation of cultural heritage[14]. For example, the landscape associated with the Battle of Issos and the rural activity-themed Zodiac Calendar Mosaic, considered unique worldwide, are presented to wider audiences through digital storytelling methods. These initiatives serve as significant promotional tools supporting the nomination of the site for inclusion on the UNESCO World Heritage Tentative List by enhancing its international visibility, interpretative accessibility, and documented cultural significance.

5. Method

The methodological framework of this study consists of seven main stages: (1) archaeological data acquisition, (2) digital documentation, (3) data pre-processing, (4) two-

[12] Soto-Martin et al. 2020.
[13] Varinlioğlu 2020, 162.
[14] Tomay 2025, 484-485.

and three-dimensional modelling, (5) AI-assisted reconstruction, (6) continuous ethical review, and (7) public dissemination through interactive information panels. This study is based on a multi-stage methodological framework that integrates digital archaeology and artificial intelligence–assisted production processes in order to document, preserve and make accessible the cultural heritage of the ancient city of Issos-Epiphaneia. The research process was conducted through interconnected phases consisting of data acquisition, digital documentation, three-dimensional modelling, data management, and visitor-oriented digital dissemination (Tab. 1).

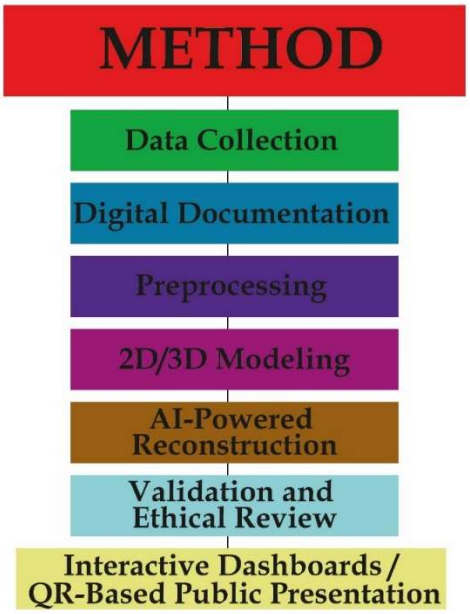


Table 1: Seven main stages of the digital methodological analysis of Issos-Epiphaneia

5.1. Digital Data Acquisition and Documentation

Within the scope of the fieldwork, archaeological structures and finds were documented using high-resolution photography, photogrammetric techniques, and laser scanning (LiDAR). The collected images were processed to record the current condition of the architectural remains with millimetre-level accuracy, resulting in the generation of three-dimensional point-cloud datasets. All data were spatially referenced within a geographic information system (GIS), enabling the establishment of a layered, relational database integrating spatial and descriptive information.

5.2. AI-Supported Three-Dimensional Modelling and Digital Reconstruction

The digital reconstruction and AI-assisted three-dimensional modelling of Issos-Epiphaneia are grounded in three principal archaeological practices: realistic three-dimensional documentation; the completion and reinterpretation of fragmented or missing archaeological finds; and the transparent presentation of interpretative reconstruction through paradata[15]. Artificial intelligence–supported image enhancement, combined with Structure-from-Motion and Multi-View Stereo (SfM–MVS) workflows, enables improvements such as noise reduction, depth and density enhancement, feature clarification, and mesh quality optimisation[16]. These processes form the technical backbone of archaeological three-dimensional modelling.

[15] Bentkowska-Kafel et al. 2012; Barratt 2020, 7; Dogan and Kan 2020, 76-77.
[16] Remondino 2011, 1104; McCarthy 2014, 175; Sapirstein and Murray 2017, 337; Tong et al. 2017.

Neural Radiance Fields (NeRF)-based approaches facilitate the learning of implicit scene representations derived from photographs, drawings, and heterogeneous visual datasets, allowing new viewpoints to be reconstructed as coherent three-dimensional environments[17]. This method aims to reproduce real-world conditions while maintaining metric accuracy, scalability, and effective reconstruction, even when only limited imagery is available. Similarly, Three-Dimensional Gaussian Splatting (3DGS), which has been widely adopted since 2023, provides visualisation quality comparable to that of NeRF while enabling significantly faster rendering speeds. Its efficiency makes it particularly suitable for archaeological excavation environments requiring rapid output generation, VR/AR presentation, and interactive visualisation of large datasets[18].

Diffusion-based modelling techniques are employed to reconstruct missing elements; however, the outputs must be critically distinguished as either evidence-based reconstructions or hypothetical interpretations. Accordingly, all results are labelled according to their evidential reliability and supported by a systematic literature review to ensure scientific transparency.

Within the Issos-Epiphaneia project, AI contributes to multiple stages of the production process, including mesh generation and surface reconstruction from raw imagery, SfM-MVS-based reprocessing, image quality enhancement, depth and density generation, mesh repair and smoothing, texture reconstruction, completion of fragmented elements, controlled visualisation within NeRF and 3DGS environments, standardised archival outputs, scalable three-dimensional production, metadata and paradata generation, and integration into digital platforms.

5.3. Pre-Processing Workflow

Pre-processing constitutes a critical phase in determining the quality and reliability of AI-assisted outputs. In cultural heritage applications, pre-processing prioritises transparency, measurability, repeatability and archival sustainability rather than solely visual enhancement[19]. Studies indicate that many geometric and radiometric inconsistencies in SfM-based photogrammetric production originate from insufficient pre-processing at the image, metadata, or geometric levels[20].

Accordingly, raw datasets in RAW or JPG/JPEG formats, together with field and measurement notes, are archived in read-only form without alteration, while processed outputs are stored in separate structured directories to preserve data integrity and traceability. Each processing step is recorded, together with software parameters, dates, and researcher information, as metadata and paradata. Image pre-processing includes focus consistency control, critical evaluation of image acquisition geometry, masking and background segmentation, and radiometric corrections to ensure tonal consistency essential for photorealistic outputs. Geometric pre-processing procedures include point-cloud cleaning, classification, mesh repair, and simplification. This workflow enables the production of both publication-ready datasets and standardised AI-compatible inputs (Tab. 2).

The prepared datasets subsequently undergo AI-assisted enhancement through two principal stages: (1) input standardisation, including resolution, format, dataset diversity, viewing angles, and semantic structuring; and (2) architectural classification, artefact identification, and segmentation.

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[17] Murtiyoso et al. 2023, 115; Croce et al. 2024; Maté-González et al. 2025.
[18] Uzunel 2015, 79; İşler and Karaarslan 2022, 23; Lee et al. 2025, 215; Shrestha et al. 2025, 2; Yu et al. 2025.
[19] Clini et al. 2024, 93-94; Maté-González et al. 2025; Atik 2025, 3.
[20] Tong et al. 2017; Morelli et al. 2022, 163; Panagiotopoulou et al. 2023, 2701.

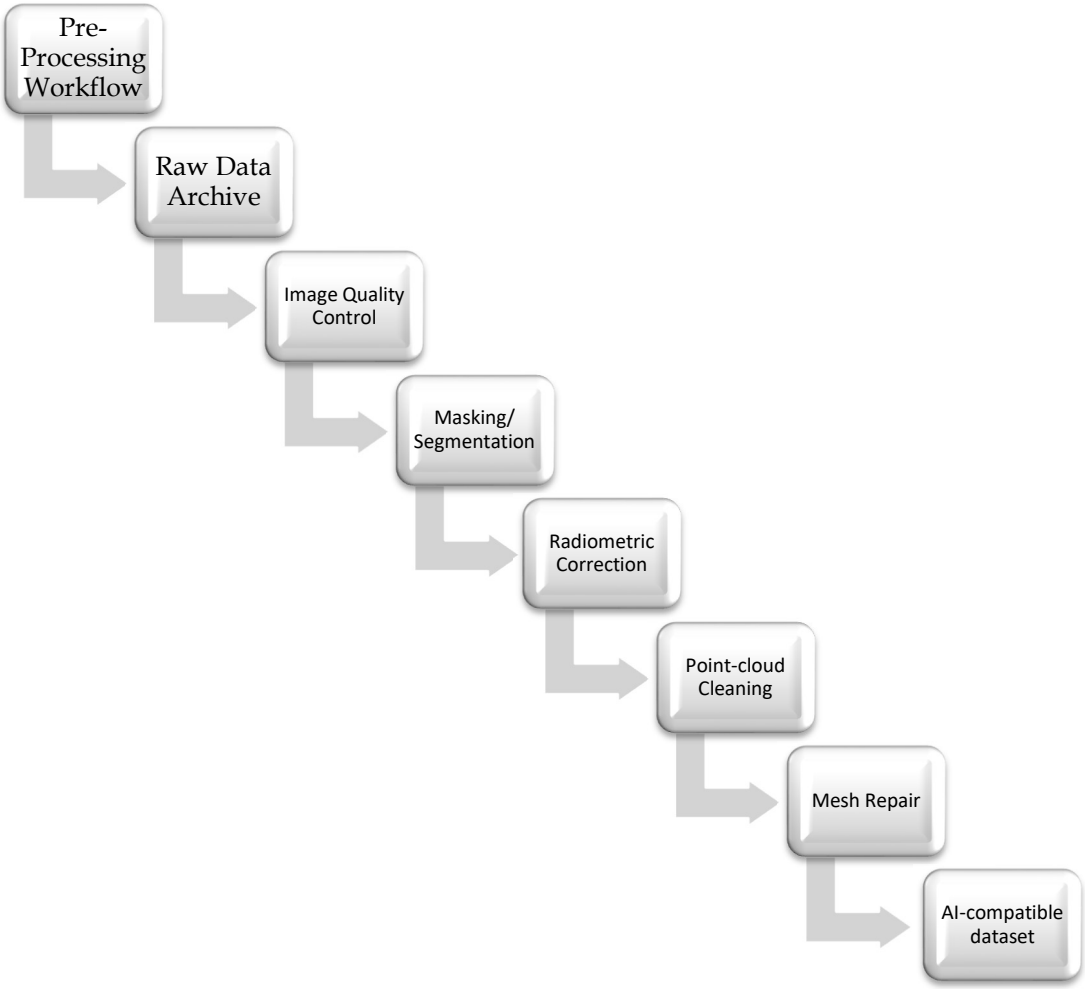


Table 2: Pre-processing workflow table

5.4. AI Integration, 3D Production Accuracy and Data Quality

From a general perspective, this section discusses the importance of accuracy and quality control in three-dimensional production workflows, with particular emphasis on AI-assisted reconstruction and restructuring processes. Three-dimensional production in archaeological excavation and cultural heritage contexts primarily relies on two methodological approaches: image-based photogrammetry[21] and active sensor technologies. Depending on project requirements, these approaches may be combined within hybrid workflows[22].

SfM–MVS photogrammetry plays a central role owing to its low cost, high spatial resolution, flexibility in field conditions, and rapid processing capabilities[23]. SfM identifies overlapping image features to estimate camera positions and generate sparse point clouds[24], while MVS produces point clouds, meshes, and textures in subsequent stages[25]. This workflow is widely accepted as the standard pipeline for archaeological photogrammetry[26].

[21] Özdilek 1970a, 55-74; for a general overview, see: Özdilek 1977a; Özdilek 1977b, 79-86.
[22] Yakar and Doğan 2017, 11-12; Polat et al. 2021, 175-176; Ulvi and Adıgüzel 2025, 15-16.
[23] Historic England 2022.
[24] Schönberger and Frahm 2016.
[25] Furukawa and Ponce 2010, 1362.
[26] Rahaman and Champion 2019, 1848.

Best-practice standards for SfM production involve three interconnected components: data acquisition with sufficient image overlap and angular diversity; metric control through scaling and georeferencing; and continuous quality assurance procedures. At Issos-Epiphaneia, data acquisition strategies included circular and environmental image acquisition sequences at architectural scales, such as walls, structural blocks, and stoas, supplemented where necessary by UAV-based aerial imaging. Smaller artefacts were documented under controlled environmental conditions using standardised lighting, backgrounds, and scale references.

Calibration parameters and metric control minimised cumulative errors on extensive surfaces, such as mosaics, pavements, and planar architectural elements, while preserving focal length stability and minimising lens distortion. Quality control was undertaken during data acquisition through real-time image preview, enabling the early detection of issues such as image blur, insufficient overlap, reflections, inconsistent lighting, and texture deficiencies. This workflow ensured accurate, rapid, and controlled data production, forming the basis for AI-supported reconstruction at Issos-Epiphaneia[27].

Hybrid production methods integrating photogrammetry, UAV imaging, and terrestrial laser scanning (TLS) were also employed. The aim of this fusion approach is to combine the geometric precision of laser scanning with the colour, texture, and accessibility advantages of photogrammetry[28]. The combined use of TLS and UAV technologies enhances both spatial accuracy and site-scale coverage[29].

5.5. Interactive Presentation and Public Accessibility

The interactive information panels are designed with interpretative interfaces that clearly distinguish between evidence-based reconstructions and hypothetical reconstructions. A key component of the study involves presenting digitally produced data in accessible formats for visitors. QR-code-supported digital information panels installed throughout the archaeological site enable visitors to access three-dimensional visualisations, concise explanatory texts, multilingual narratives, and audio content. Compared with traditional text-based information systems, this approach provides a more inclusive, comprehensible, and experience-oriented learning environment.

Pre-processing for interactive information panels extends beyond the optimisation of three-dimensional models and includes contextual explanation, source attribution, and the transparent communication of uncertainty[30]. Based on collected datasets, three-dimensional models of architectural remains were generated using archaeological evidence, excavation reports, and comparative architectural analyses. Restitution proposals were evaluated against existing scientific literature, while AI-assisted tools functioned as supporting instruments for texture enhancement, interpretation of missing elements, and visual coherence. Throughout all reconstruction processes, the distinction between measurable data and interpretative reconstruction was explicitly documented to maintain scientific reliability and transparency.

6. Issos-Epiphaneia Study Area and Digital Database System

All digital content produced at Issos-Epiphaneia is stored within a structured database designed in accordance with sustainable data management principles. Data production processes are documented using the paradata approach in compliance with international

[27] Özdilek and Sönmez 2025, 105.
[28] Luhmann et al. 2019, 753; Kan et al. 2022, 625.
[29] Chatzistamatis et al. 2018, 143-144.
[30] Potenziani et al. 2015, 129; Apollonio et al. 2025, 20; Bachi and Fresa 2025, 163.

digital heritage standards, ensuring the traceability of modelling decisions and scientific transparency. This system is intended primarily to safeguard cultural heritage data against disaster risks, particularly earthquakes. The database infrastructure was developed to document the datasets, standards, workflows, and transparency strategies employed in the digitalisation of the ancient city. Accordingly, the datasets integrated into the database system developed for the archaeological excavations and research at Issos-Epiphaneia are presented below.

6.1. Datasets

The primary archaeological dataset consists of contextual and stratigraphic records, plan–section relationships, artefact inventory records, and storage management records[31]. These data groups represent the entire research cycle, including data acquisition, production, analysis, interpretation, and digital reconstruction processes, while project management components such as documentation, metadata, licensing, and copyright information play a critical role in maintaining workflow continuity[32].

At the urban scale, integrated spatial datasets form the backbone of the digital ecosystem, including Total Station (TS) and GNSS measurements, artefact locations, architectural elements, excavation units, pathways, conservation-risk records, and grid polygons represented in vector and raster formats, as well as orthophotos[33], digital elevation models (DEMs) and digital terrain models (DTMs)[34], and hillshade visualisations. Standardisation of spatial data enables future reanalysis under different research questions and supports the generation of distribution, accessibility, visibility, and risk maps (fig. 7).

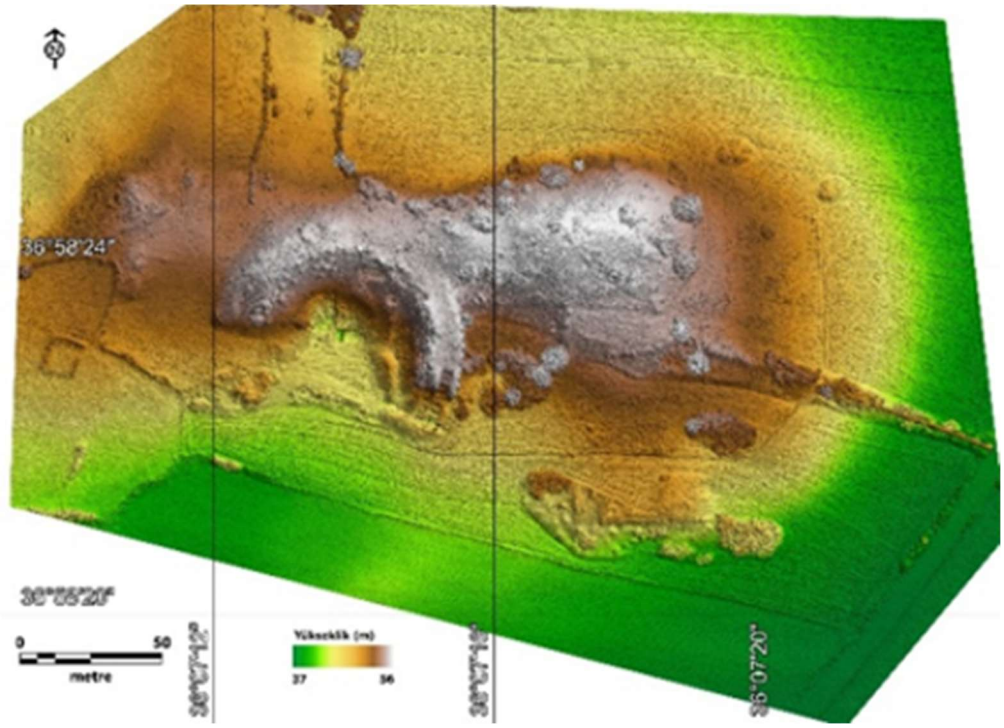


Figure 7: Digital elevation model of the Issos-Epiphaneia theatre *(Özdilek et al. 2024a, 216, fig. 1. Modelling: Şimşek and Tıbıkoğlu)*

[31] Sandoval 2021, 496.
[32] Wallace and Farmer 2024, 58.
[33] Özdilek 1970a, 55-74; Özdilek 1970b, 1-39; Özdilek 1970c, 149-154; Özdilek 1970d, 155-159; Özdilek 1971a, 5-9; Özdilek 1971b, 5-9; Özdilek 1972, 52-57; for a general overview, see: Özdilek 1973a, Özdilek 1973b, 158-167.
[34] For a general overview, see: Özdilek 1977a; Özdilek 1977b, 79–86; Özdilek 1980.

Structure-from-Motion (SfM)-based photogrammetry has enabled the generation of orthomosaics and georeferenced datasets through the documentation of reference points, surfaces, and textures. Due to its relatively low cost and high-resolution output, SfM represents a powerful and versatile method for multi-scale archaeological data production. The combined use of photogrammetry and three-dimensional sensing technologies ensures accurate digital documentation and facilitates the long-term preservation and transmission of reliable information for future research and future generations. Laser scanning (LiDAR), particularly at architectural and artefact scales, provides highly accurate point-cloud datasets suitable for deformation analysis[35]. Although such datasets require substantial storage capacity, environmental and operational parameters, including device configuration, lighting, climatic conditions, surface texture, and recording accuracy must be carefully controlled.



Figure 8: Orthophoto modelling of the Issos-Epiphaneia public area *(Issos-Epiphaneia Excavation Archive 2024. Modelling: Tıbıkoğlu)*

Remote sensing and UAV-based aerial imaging constitute another critical category of datasets[36]. UAV-derived topographic products, including orthophotos and Digital Elevation Models (DEMs), support decision-making processes related to urban morphology, environmental context, and site management (fig. 8). These datasets are essential for large-scale spatial assessment and long-term monitoring[37]. Derived and dissemination-oriented data products are optimised for interactive platforms, enabling web-based visualisation, two- and three-dimensional annotations, explanatory texts, and QR-code-based access to digital models and datasets[38].

6.2. Data Management and Standardised Data Structure

The datasets produced, collected, processed, and archived during the archaeological excavations and research at Issos-Epiphaneia including excavation records, inventories, surveys, photographs, drawings, measurements, reference points, photogrammetry outputs, GIS datasets (fig. 9), laser scans (figs. 10–11), attribute tables (fig. 12), and three-dimensional

[35] Uzunel and Özdemir 2022, 270.
[36] Güngör 2022, 287-288.
[37] Karamurat 2022, 47; Özgüner 2022, 115; Taşkıran 2022, 320-321; Kan et al. 2022, 627.
[38] Kalaycı 2022, 83-84.

models (figs. 13–16) form a multi-layered, multi-format data structure[39]. The adopted data management approach encompasses the entire data lifecycle, from production and archiving to reuse, revision, and dissemination. The objective is not merely to store data but to create traceable, accurate, and sustainably preservable datasets.

The data lifecycle integrates both field and office workflows. Data production begins with excavation forms, trench notebooks, measurement records, digital survey outputs, drawings, three-dimensional scans, and photographic documentation. These datasets undergo preliminary verification through reference-point control, format validation, coordinate confirmation, and integrity checks. Subsequently, standardisation procedures establish controlled classification systems, including typologies, naming conventions, coding systems, and unit definitions. Integration within a GIS environment enables relational links between inventories, visual materials, and three-dimensional datasets. All corrections and additions are recorded with user identification, processing date, and justification, enabling version control and change tracking. Long-term preservation is ensured through multiple backups, periodic archiving procedures, and sustainable storage formats. Finally, derivative datasets are generated for reporting, visualisation, publication, and public dissemination. The project's data standards comprise structural, semantic, and technical components. Structural standards define data fields, data types (text, numeric, and date), mandatory entries, and stable primary identifiers (IDs) assigned to artefacts, inventories, architectural elements, drawings, photographs, scans, and three-dimensional records. Semantic standards regulate interpretative fields, such as context, function, material, form, decoration, state of preservation, production technique, and chronological attribution, thereby enabling controlled descriptive input while maintaining consistency. Technical standards govern spatial referencing systems, stratigraphic layers, and the processing of visual datasets, including photographs, drawings, and three-dimensional scans.

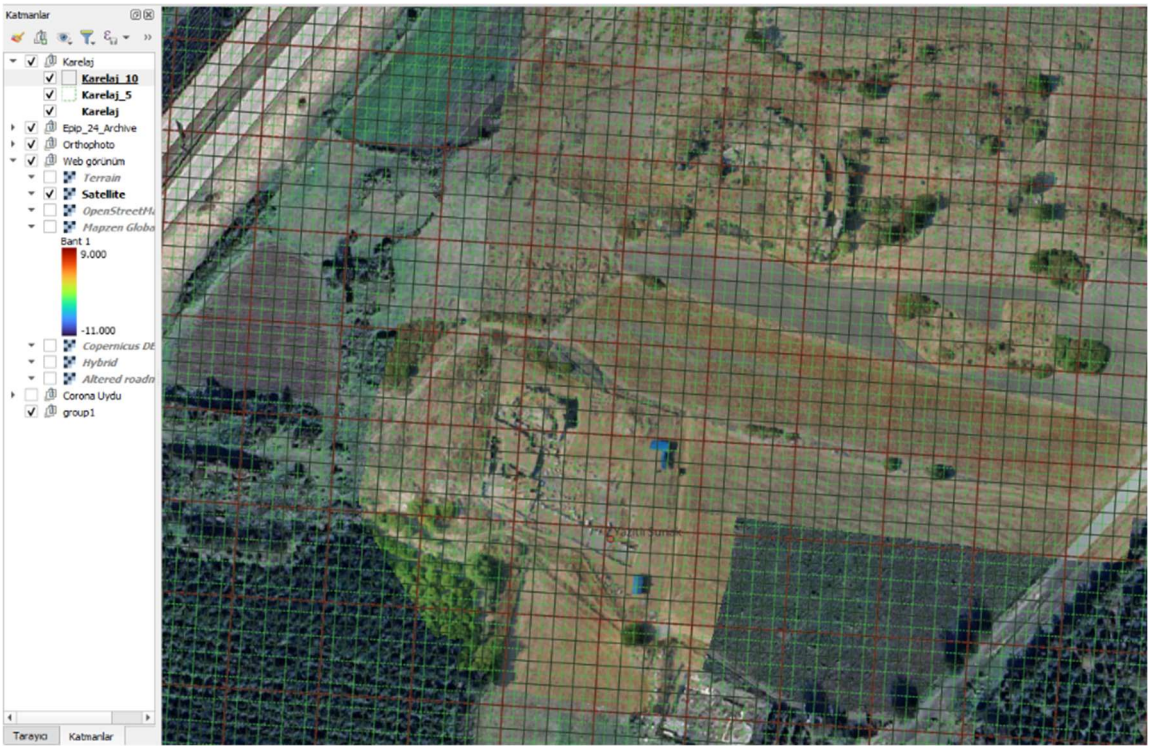


Figure 9: QGIS model and grid system of Issos-Epiphaneia *(Issos-Epiphaneia Excavation Archive. Modelling: Sönmez 2025)*

[39] Özdilek and Sönmez 2025, 99-134.

6.3. Identification, Data Quality, Versioning, and Access/Sharing

Data management at the Issos-Epiphaneia excavation site emphasises systematic identification, quality control, and controlled accessibility. Each record and inventory category is assigned a unique, human-readable identifier, while associated files including photographs, drawings, and three-dimensional models are named according to standardised ID conventions, enabling relational linkage through shared primary keys.

Data consistency is ensured by enforcing mandatory fields, including chronological and coordinate information, while numerical datasets adhere to standardised units of measurement, such as centimetres, metres and grams. All corrections and additions are documented together with the identity of the responsible researcher and the date of modification.

The GIS-based database system, implemented through a QGIS pilot framework, undergoes regular version updates. Versioning principles include the periodic duplication and chronological preservation of datasets, ensuring recoverability and long-term archival stability. To minimise software dependency, sustainable archival formats such as CSV, GeoPackage, and TIFF are preferred. Access management within the Issos-Epiphaneia data system follows a multilayered structure. Raw datasets remain restricted and accessible only through defined user roles, whereas publicly shared outputs are derived from processed datasets. This approach simultaneously supports scientific transparency and the accurate dissemination of knowledge while safeguarding the security of cultural heritage data. Overall, the digitalisation and data management strategy implemented at Issos-Epiphaneia integrates fieldwork and office-based processes within a unified, secure, and sustainable system, representing a comprehensive academic framework for the long-term preservation and accessibility of archaeological information[40].

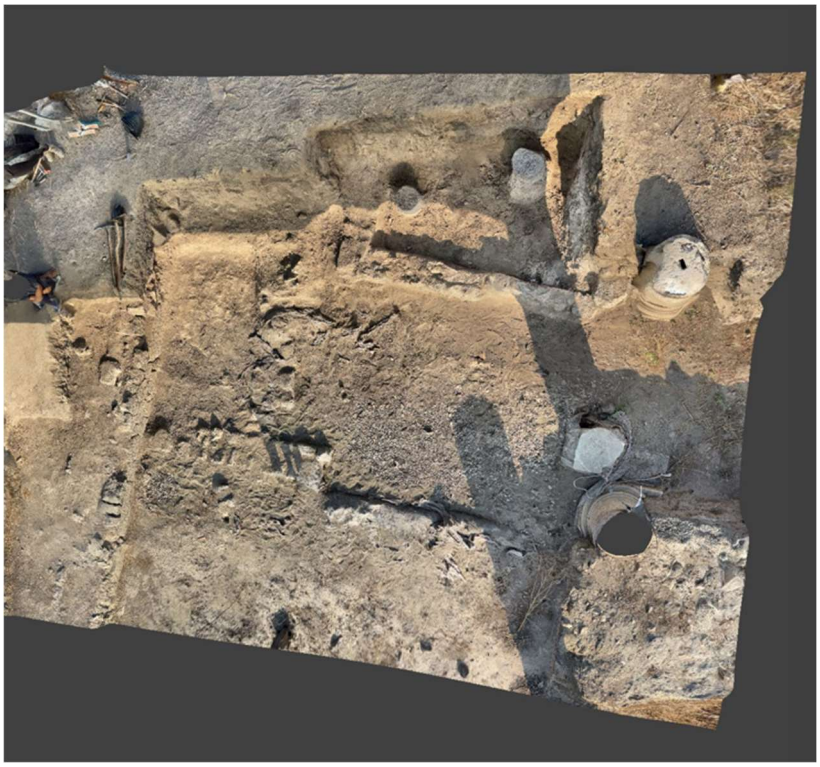


Figure 10: LiDAR Scan of the Issos-Epiphaneia South Stoa *(Özdilek et al. 2025b, 280, fig. 3. LiDAR Scan, Sönmez 2023)*

[40] Özdilek and Sönmez 2025, 99-134.



Figure 11: LiDAR Scan of the Issos-Epiphaneia column capital *(Scan: Sönmez 2025, Excavation Archive)*

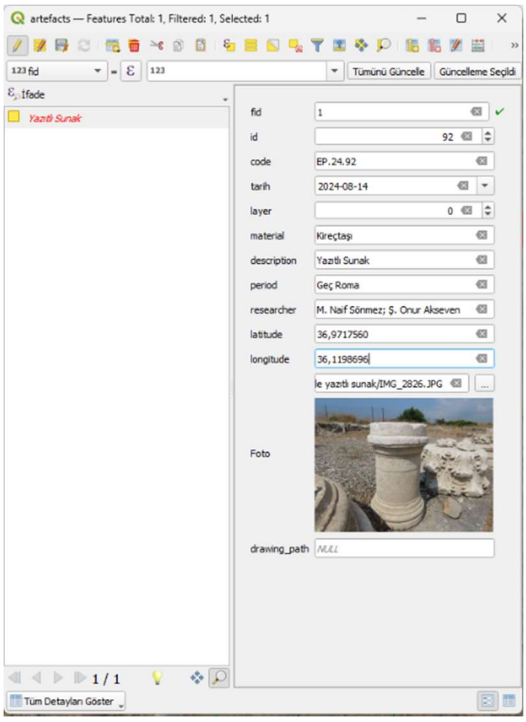


Figure 12: Example of an attribute form *(Issos-Epiphaneia Excavation Archive)*



Figure 13: 3D model of the Issos-Epiphaneia Stoa *(Özdilek et al. 2025b, fig. 7, Drawing: Sönmez 2024)*



Figure 14: 3D modelling of the Issos-Epiphaneia bouleuterion-odeion *(Drawing: Sönmez 2024, Excavation Archive)*



Figure 15: 3D model of the Issos-Epiphaneia Colonnaded Street *(Drawing: Sönmez 2024, Excavation Archive)*



Figure 16: 3D model of the Temple of Epiphaneia at Issos *(Özdilek et al. 2025b, 276, fig. 2, Drawing: Sönmez 2023)*

7. Interactive Information Panels

7.1. Design Principles and Content

Interactive information panels located within archaeological sites and cultural heritage environments function not merely as tools for presenting information but primarily as interpretative media aimed at conveying the spatial, architectural, and contextual integrity of a site to visitors. Within this framework, the initial design considerations focus on identifying the target audience including local communities, students, tourists, researchers, and educators and clearly defining the core message to be communicated. Content development must therefore be grounded in the principles of transparency, accuracy, contextual interpretation, and verifiable sources. Sections containing confirmed data, scholarly interpretation, explanatory commentary, or hypothetical reconstructions must be clearly distinguished in accordance with international heritage interpretation principles[41].

Because panel content in archaeological contexts is typically consumed rapidly, textual materials should be structured in layered formats that are concise, explanatory, and accessible. Titles should be short yet impactful, preferably consisting of two or three words, while additional explanatory material should be available for visitors seeking more detailed information. The effectiveness of information panels depends on maintaining clear, concise and readable language supported by a balanced relationship between textual and visual elements[42].

User interface design must follow user-centred design principles. Archaeological site testing, iterative prototyping, scenario evaluation, and usability testing should be conducted in accordance with established user-centred design methodologies[43]. Essential interface components include clearly defined touch targets, responsive touchscreen feedback mechanisms, intuitive navigation systems, homepage accessibility, consistent animation behaviour, icon clarity, and secure exit functions[44]. Accessibility considerations require high visual contrast, legible typography, non-distracting motion elements, and optional audio content to accommodate diverse visitor needs[45].

In Türkiye, informational panels at archaeological sites and museums are produced within an institutional framework governed by national standards. The Ministry of Culture and Tourism's directive concerning entrance, information, and directional signage establishes parameters relating to dimensions, typology, and visual hierarchy[46]. Accordingly, the interactive information panels designed for Issos-Epiphaneia comply with these institutional standards while integrating scientifically transparent, AI-supported interpretative content that enhances visitor learning experiences.

7.2. Technological Components and 3D Outputs

Interactive information panels supported by digital technologies aim to facilitate on-site learning by integrating visual materials, textual explanations, maps, and three-dimensional models into a unified digital experience tailored to diverse audiences. The technological infrastructure typically consists of touchscreen kiosks or LCD displays, embedded mini-computers, audio input and output devices such as headphones and speakers,

41 ICOMOS 2017.
42 Serrell and Whitney 2024, 250.
43 ISO 2019.
44 Burmistrov 2015, 3.
45 W3C 2024.
46 T.C. Kültür ve Turizm Bakanlığı 2007.

sensor systems, QR/NFC technologies, local network connections, and offline caching capabilities[47].

Interface design prioritises clarity, navigability, readability, consistency, and effective user feedback. Observations of museum kiosk interfaces in Anatolia demonstrate that effective usability depends on coherent colour schemes, typography, iconography, spatial layout, and intuitive interaction principles[48]. Within the production of three-dimensional digital content, archaeological datasets, including artefact-level point data, surface textures, geometric meshes, and photogrammetric models, are optimised for interactive presentation through multiple Levels of Detail (LODs) and adapted to web- and application-based formats embedded directly within panel systems.

Comparable applications include the audiovisual presentation of a three-dimensional model of a Hittite stele at Aksaray Museum[49] and the web-based and augmented reality presentation of photogrammetric models at Kütahya Museum[50]. In accordance with the ICOMOS Seville Principles, the information architecture must remain transparent and reliable, and three-dimensional reconstructions must clearly distinguish between empirically verified data and interpretative or hypothetical components[51]. Real-time visualisation of three-dimensional outputs within kiosk environments emphasises web-based interactive infrastructures designed for cultural heritage presentation[52]. Furthermore, implementation workflows should comply with European documentation standards, ensuring that three-dimensional data types, delivery packages, publication processes, and management stages follow standardised workflows extending from initial production to long-term archiving. Such standardised workflows enable efficient decision-making, sustainable dissemination, and the long-term preservation of optimised panel and signage content[53] (fig. 17).

7.3. QR Codes as a Mobile Bridge

QR code technology represents a scalable, low-cost access layer that connects physical interpretative media with expanded digital content through reference points distributed across the archaeological landscape. Rather than functioning solely as supplementary information links, QR-based systems can be integrated into visitor-oriented spatial storytelling strategies and structured site itineraries. By establishing designated stops throughout the site, digital narratives can be linked to mobile experiences, thereby creating interactive visitor routes[54]. Similarly, QR codes embedded within interactive information panels enable seamless integration between physical installations and mobile devices, allowing visitors to continue accessing interpretative content beyond the site visit and transforming the experience into a continuous learning process[55]. Within the context of Anatolian museums, institutional QR applications are also used to collect visitor feedback, evaluations, and experiential data, thereby enabling performance assessment and service improvement.

In the case of Issos-Epiphaneia, QR technology has been implemented to expand interpretative capacity beyond the spatial limitations of physical information panels. Through QR code access, visitors are able to explore extended visual and textual materials, multilingual

[47] Cai 2015, 2; Apollonio et al. 2025, 25.
[48] Kurt 2020, 25-26.
[49] Tosun-Çolak and Çolak 2024, 238-240.
[50] Uslu and Uysal 2020, 1024.
[51] ICOMOS 2017.
[52] Potenziani et al. 2015.
[53] EUreka3D Consortium 2024, 58.
[54] Martínez-Graña et al. 2013, 83.
[55] Burmistrov 2015, 5.

content, and audio narratives without overcrowding the panel design with excessive text. The system supports sustainable dissemination of accessible digital archives and three-dimensional models while enabling integration with mobile mapping applications that guide visitors along interactive site routes. In addition, feedback mechanisms allow visitors to communicate their expectations and experiences, thereby contributing to the continuous evaluation and refinement of interpretative strategies[56]. As a result, QR-supported interactive information panels enhance visitor engagement, improve interpretative accessibility, and facilitate rapid dissemination of information within the archaeological environment. By encouraging curiosity-driven exploration and providing layered access to knowledge, the system strengthens both visitor engagement and site management at the ancient city of Issos-Epiphaneia.



Figure 17: Interactive dashboard display interface design created with AI *(Modelled by: Sönmez)*

8. Conclusion

This study demonstrates the transformative role of digitalisation in the preservation, interpretation, and dissemination of cultural heritage through the case of the ancient city of Issos-Epiphaneia. In contrast to traditional archaeological interpretation methods, which are often expert-oriented, text-dense, and limited in accessibility, the approach developed through AI-supported three-dimensional modelling, digital reconstruction, and interactive information panels aims to make cultural heritage more comprehensible and accessible to wider audiences.

Through digital archaeology applications, the ancient city is transformed from a site primarily reserved for academic research into a living cultural learning environment in which visitors can actively experience the past. QR code–based systems, multilingual texts, audio

[56] Atsan et al. 2023, 214; Ekinci 2025, 3414.

narratives, and three-dimensional visualisations enable equitable access to cultural heritage regardless of age, language, physical accessibility, or level of expertise. Consequently, knowledge transmission moves beyond text-based communication towards a multisensory visual, auditory, and interactive experience, significantly reducing linguistic and accessibility barriers.

The integration of next-generation technologies into archaeological site presentation also strengthens the tourism potential of ancient cities. Digital reconstructions allow visitors to perceive structures that survive today only as ruins within their original spatial and architectural contexts, thereby deepening the visitor experience and enhancing the qualitative value of cultural tourism. Furthermore, the dissemination of digital content through open-access online platforms supports the global visibility of Issos-Epiphaneia beyond its physical location.

Digital documentation initiatives conducted in earthquake-prone regions provide a sustainable safeguard against potential physical loss of cultural heritage. Digital data production and transparent data management establish a permanent reference framework for future restoration, conservation, and scientific research. In this respect, the project demonstrates that digitalisation functions not only as a tool for presentation but also as a fundamental component of disaster risk management and the long-term continuity of cultural heritage.

The presentation of universally significant elements, such as the historical landscape associated with the Battle of Issos and the unique Zodiac Calendar Mosaic depicting rural activities, through narrative-driven digital storytelling constitutes an important cultural communication strategy that strengthens the site's potential for inclusion on the UNESCO World Heritage Tentative List. By integrating scientific accuracy, paradata transparency and AI-supported production processes, this model offers a practical framework for sustainable digital transmission of cultural heritage.

In conclusion, the digital reconstruction and interactive interpretation approach developed at Issos-Epiphaneia proposes a new-generation paradigm for cultural heritage preservation, promotion, tourism integration, and equitable public access. The model demonstrates that a future-oriented, inclusive, and sustainable approach to cultural heritage, centred on digital technologies, is both achievable and applicable to the management and presentation of ancient cities.

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