Towards a Data Management System for Historic Hajj Pilgrimage Routes: Lessons for Managing Serial Transnational World Heritage Nominations

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Abstract

This paper addresses the current lack of a transnational data management system to support the management of historic Hajj Pilgrimage Routes, which hold significant cultural value and cross multiple national boundaries in the Arab States region and beyond. A data management system that integrates geospatial and visual information, historical documentation, and continuously generated new data types, such as multimedia recordings of intangible cultural heritage practices associated with the Hajj Pilgrimage Routes, is envisioned. The study aims to develop the theoretical knowledge necessary for designing such a data management system. In its first stage, the paper conducts a literature review and case study analysis of existing heritage data management tools, including those employed in academic research, national heritage inventories, and comparable UNESCO World Heritage serial transnational sites. This analysis assesses the technological strengths and limitations of market-available platforms, including Arches, an open-source geospatial inventory and digital archiving platform, and custom-built spatial information systems. The research employs a comparative analysis of these platforms based on key criteria for effective data management, including general functionality, compliance with international standards, customizability, cost, accessibility, community support, and scalability. The results of this analysis indicate a preference for Arches as the selected platform for hosting the Hajj Routes data management system due to its open-source nature, user-friendliness, robust community support, and ability to manage large datasets. Future directions include designing and implementing a workflow for transnational data management and establishing a large dataset encompassing the Hajj Routes and their associated cultural heritage.

1. Introduction

1.1 Hajj Pilgrimage Routes

The Hajj Pilgrimage Routes are cultural and religious routes connecting far-flung destinations to the geographic and spiritual center of the Muslim world, the Holy City of Makkah. These historic Hajj Routes hold great religious, social, and historical value for a transnational community of Muslims (Moscatelli, 2024). They are particularly interesting to historians and archaeologists specializing in Islamic history and archaeology, as well as scholars of the Hajj as an enduring annual religious journey since the dawn of Islam, one that is required for all capable Muslims at least once in their lifetimes (Al-Rashid, 1977).

A few Hajj Routes are listed on UNESCO's tentative lists for potential inscription on the World Heritage List, indicating that UNESCO Member States are highly interested in developing tools and technologies for the documentation, management, and sustainable development of these routes (UNESCO World Heritage Centre, 2024). The roads on the tentative list include the Darb Zubaydah, which begins from the ancient city of Kufa in Iraq and crosses the Arabian Peninsula from the northeast to the southwest towards Makkah. The Egyptian and Syrian Hajj Roads are also listed separately, including key road stations from the northwest to the southwest of Saudi Arabia.

Importantly, these routes sit at the crossroads of tangible and intangible heritage. They challenge many preconceived notions and limitations imposed on the valorization of the advanced engineering and architectural capacities of successive Muslim civilizations in devising these routes, all created with one shared purpose: administering the Hajj and easing the complex spiritual and physical journey for a transnational community of Muslims.

1.2 Managing Data for Hajj Pilgrimage Routes

The Hajj Pilgrimage Routes are highly significant cultural heritage sites at the intersection of tangible and intangible heritage. Their preservation, physically and digitally, is paramount. This research project aims to develop the theoretical knowledge necessary for developing a Hajj Routes Database. Such a database is necessary and currently lacking for heritage researchers and authorities responsible for studying, documenting, and managing the historic Hajj Routes.

The first phase of the project focuses on conducting a literature review and case study analysis of data management tools in a variety of cases, including the Endangered Archaeology in the Middle East and North Africa project, various national heritage inventories, and comparable transnational cultural routes listed as UNESCO World Heritage sites, such as the Silk Roads in Central Asia. The outcomes of this analysis will include identifying technological limitations for archiving data on market-available database platforms, including Arches and custom-built Spatial Information Systems. The final phase of the study aims to create a workflow for future database design and dataset collation as an initial step toward creating a preliminary Hajj Routes Database.

Initial predictions of the research direction anticipate using Arches, an open-source data management platform developed by the Getty Conservation Institute and the World Monuments Fund, as a geospatial inventory and digital archiving platform. By using Arches' GIS-based features to plot the sites of waystations along Hajj Routes, this project aims to link spatial databases to multimedia resources and data on Hajj Routes.

2. Methodology

2.1 Literature Review

This literature review examines the process of building heritage data management systems, focusing on the potential of the Arches platform for documenting and managing historic Hajj Routes. Drawing on comparative case studies, leading theoretical literature on geospatial inventories, and analyzing the implications of building a heritage database for Hajj Routes, this review provides a comprehensive overview of the theoretical and practical considerations for such a project.

Myers highlights the opportunities and challenges of implementing Arches for diverse heritage documentation and management needs. He emphasizes the purpose-built nature of Arches, designed specifically for managing inventories of all types of cultural heritage places, including archaeological sites, buildings, cultural landscapes, and cultural routes (Myers and Hansen, 2024). He underscores the importance of Arches' open-source nature, which enables its free use, customization, and enhancement by heritage institutions worldwide. Myers argues that Arches offers a cost-effective solution compared to developing digital inventories from scratch and fosters a collaborative community of information technology professionals and heritage practitioners (Myers, 2016).

Myers also highlights the role of inventories in supporting effective heritage management. He argues that knowing what heritage exists is essential for its safeguarding, making inventories fundamental to protection and management efforts. Myers underscores the diverse applications of inventories, including recognizing cultural diversity, urban planning, heritage impact assessments, and disaster preparedness. He stresses the importance of consistent, accurate, and up-to-date inventory information for effective decision-making (Myers et al., 2016). Additionally, he advocates for robust infrastructure, resources, and activities to support inventory effectiveness, including legal frameworks, skilled personnel, and stakeholder engagement. Ultimately, Arches champions a collaborative approach to heritage management involving community participation, partnerships with diverse stakeholders, and knowledge sharing within the Arches community (Lee Enriquez et al., 2024).

The Arches platform is based on a data structure following international standards for heritage inventories, such as those of the International Council of Museums’ Committee for Documentation’s Conceptual Reference Model (CIDOC CRM). This CRM is one of the most widely used in the field of cultural heritage (Aspöck and Masur, 2015). It allows for “machine-readable data that is interoperable and portable,” (Lee Enriquez et al., 2024). The CRM includes standards for showing relationships between different “resources” in a database. For spatial relationships, which is the focus of this study, the CRM sets “properties” and “classes” to differentiate between different types of relations (Figure 1).

The ability to display spatial relations in the Arches platform is a powerful tool for inventories spanning expansive geographical networks of heritage sites, as in the case of Hajj Routes (Figure 2). For heritage sites, called “heritage places” on Arches, they are defined as resources with the denotation “Physical Thing (E18).” In practice, users can utilize the “Related Resource” function to plot relational data on a given database (Figure 3).

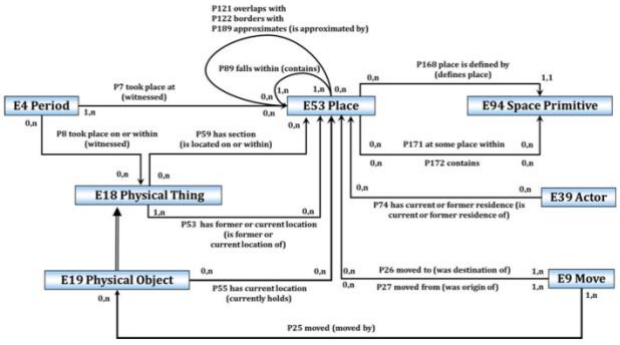

Figure 1. CIDOC CRM Properties and Classes for Spatial Relationships (ICOM, 2024).

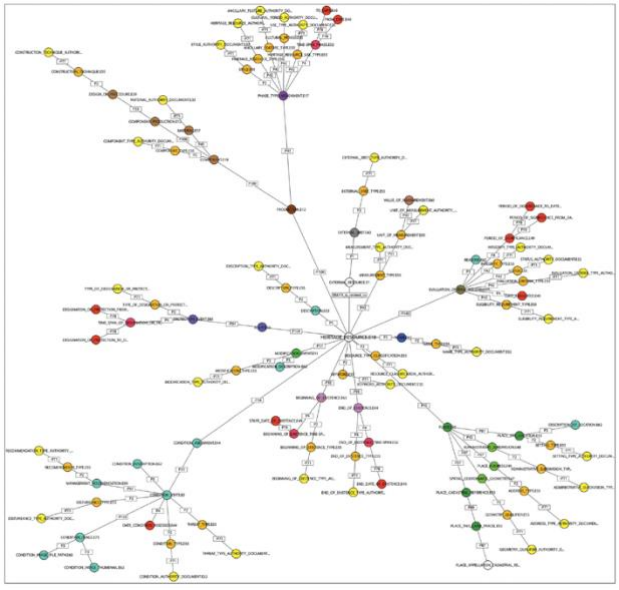

Figure 2. Arches E18 Resource Relational Graph © Getty Conservation Institute (Zerbini, 2018).

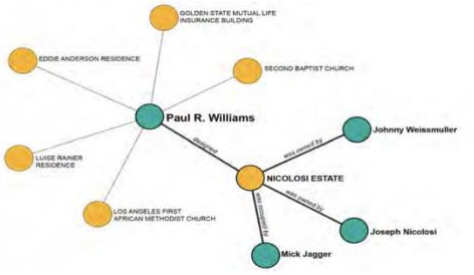

Figure 3. In the Los Angeles Historic Environment Record, the Related Resource graph displays relationships between heritage resources. In this case, the graph shows an architect, entered as an “Actor,” and the buildings he designed, as well as other persons related to those buildings, such as owners and occupants. Annabel Lee Enriquez © Getty Conservation Institute (Lee Enriquez et al., 2024).

2.2 Case Study Analysis

Zerbini and Sheldrick's work offers valuable insights into the potential of the Arches platform for documenting cultural

heritage, particularly in the Middle East and North Africa (MENA) region (Sheldrick and Zerbini, 2017). Their discussion of the Endangered Archaeology in the Middle East and North Africa (EAMENA) project, which utilizes a customized version of Arches, illuminates both opportunities and challenges relevant to this context.

The EAMENA Arches-hosted database contains over 370,000 heritage places (Figure 4). Zerbini highlights the platform's suitability for managing diverse and complex datasets, a crucial requirement for documenting Hajj Routes (Zerbini, 2018). He emphasizes Arches' ability to integrate remotely sensed data, such as satellite imagery and aerial photography, with ground-based observations and archival materials. This multi-layered approach allows for a comprehensive understanding of heritage sites, including their spatial distribution, physical characteristics, and historical context. Applying this to Hajj Routes, Arches could facilitate the documentation of not only the physical pathways but also associated archaeological sites, architectural landmarks, and intangible cultural practices, creating a holistic and interconnected dataset.

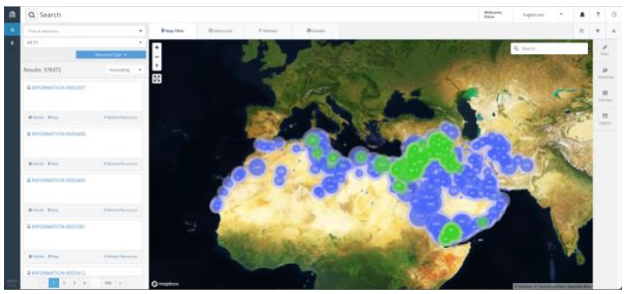

Figure 4. Screenshot of the EAMENA database on Arches, with over 370,000 logs of E18 Heritage Places (in this case, archaeological sites).

Zerbini's discussion of the EAMENA project also underscores Arches' capacity to support collaborative documentation efforts. He notes the platform's role in facilitating data sharing and communication among archaeologists working across a vast geographical region (Zerbini, 2018). This collaborative aspect is particularly relevant to documenting Hajj Routes, which often traverse multiple countries and involve diverse local, national, and transnational stakeholders. Arches could serve as a central platform for researchers, heritage managers, and local communities to contribute data, share knowledge, and coordinate conservation efforts.

However, Zerbini also acknowledges the challenges inherent in adapting Arches to meet the specific needs of regional contexts. He details the EAMENA project's efforts to customize the Arches platform, including developing new resource data models based on the CIDOC CRM to better represent the nature of the information being recorded. Similarly, documenting Hajj Routes would require careful consideration of the unique characteristics of these cultural landscapes and the development of tailored data structures and workflows within Arches. This may involve incorporating specific categories for recording information related to Hajj Routes, historical events, and associated intangible heritage practices.

Mahdy and Zerbini further emphasize the importance of language accessibility for promoting local ownership and participation (Figure 5). They describe the translation of EAMENA's Arches interface into Arabic, alongside the development of Arabic-language controlled vocabularies to ensure data consistency and searchability (Mahdy and Zerbini, 2016). This approach highlights the need for similar efforts in a Hajj Routes Database, considering the linguistic diversity of the communities along these routes. Multilingual interfaces and controlled vocabularies are essential for ensuring the archive's relevance and usability for local stakeholders.

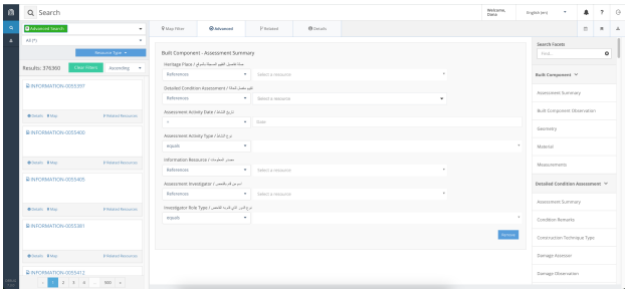

Figure 5. Screenshot of EAMENA’s bilingual (English and Arabic) interface on Arches.

The value of Arches as a flexible platform to create and manage heritage inventories can be seen in case studies from Bhutan, England, Taiwan, and Greece. Williams describes the adoption of Arches in Bhutan to create a national heritage inventory (Williams, 2016). This project arose from a UNESCO initiative focused on the Silk Roads in South Asia and discussions with the Bhutanese Division for Conservation of Heritage Sites (DCHS). The DCHS aimed to raise public awareness and access to Bhutan's heritage, reflecting the categories outlined in their draft Heritage Sites Bill. Williams highlights the capabilities of Arches to manage and present diverse tangible heritage information, both to an international audience and within Bhutan, enhancing heritage management strategies.

Carlisle and Lee examine the English Heritage (now Historic England) inventory network, highlighting its complexity and challenges, including duplication of content and inconsistent recording practices (Carlisle and Lee, 2013). They propose Arches as a solution to these issues, noting its open-source nature, which enables cost-effective implementation and customization for diverse projects. They emphasize Arches' compliance with international heritage and IT standards, ensuring interoperability and data exchange across platforms. Arches could serve as an intermediary information carrier within the network, promoting standardized recording practices and facilitating data sharing between national and local inventories.

Further illustrating the benefits of Arches for managing diverse heritage resources, Jan presents a case study from Taiwan (Jan, 2018). The project focused on documenting community heritage resources through geotagged photographs, 360-degree panoramas, and other data uploaded to a WebGIS built on Arches. Jan emphasizes the platform's cost-effectiveness and scalability, especially beneficial for community-based projects with limited resources. Additionally, Arches empowers community members to participate in heritage documentation, interpretation, and analysis, fostering public awareness and support for conservation efforts. Jan concludes that Arches is well-suited for creating customized heritage management systems, enabling effective data management, geovisualization, and spatial analysis for diverse heritage resources.

Furthermore, Aspöck and Masur's work examines the application of the Arches platform for documenting and researching early farming cultures in Neolithic Greece and

Anatolia (Aspöck and Masur, 2015). The authors set out to build a research database encompassing these two regions, which are often studied independently despite their close archaeological connections. They identify fragmentation as a key issue hindering research across the area, with data organized according to differing knowledge schemes, terminologies, and chronologies.

Aspöck and Masur utilize a graph database incorporating international standards to organize data in a way that reflects their research model and facilitates interoperability for online publication. They chose the Arches Heritage Inventory and Management System (HIP) for its open-source nature, customizability, and built-in CIDOC CRM ontology, the most widely used ontology for cultural heritage.

The authors highlight specific challenges in adapting Arches to their needs, including Arches' default mapping to CIDOC CRM, which can be general, using superclasses instead of subclasses. Aspöck and Masur aim for a more specific mapping to preserve semantic expressiveness, for example, mapping their archaeological sites to a more specific subclass within the broad "Heritage Resource. E 18" category. They argue the Arches vocabulary needs to be expanded to accommodate all their data in a CIDOC-compatible way. For instance, they require the CRMarchaeo extension to represent their archaeological excavation data.

Aspöck and Masur clearly understand Arches' strengths and limitations, and they are actively working to customize the platform to meet their specific research requirements. Their approach aligns with Myers' emphasis on Arches' flexibility and adaptability. Both projects highlight the need to configure Arches to particular contexts and data types to ensure its effectiveness as a heritage documentation and research tool.

Barton et al. showcase the adaptability of the Arches system through various cultural heritage projects, illustrating its capacity to cater to diverse needs and data structures (Barton et al., 2017). They highlight Arches' open-source nature, comprehensive documentation, accessible training, and supportive community as key advantages. The authors solidify their argument by presenting case studies of successful Arches implementations across different contexts, including the national-level inventory for England, specialized records for maritime heritage in England and the Isle of Man, the community-driven Jamaican inventory, and the detailed London record incorporating archaeological assessments. These diverse examples demonstrate Arches' flexibility and its potential as a robust and adaptable platform for managing and documenting a wide range of cultural heritage projects.

In contrast to Barton et al.'s broad examination of Arches, Vacca et al. present a custom-built Spatial Information System (SIS) specifically designed for managing the architectural heritage of Sardinia (Vacca et al., 2018). While Arches offers a pre-built platform, Vacca et al. develop their own system from the ground up, utilizing open-source software components and tailoring the data structure and functionality to their specific needs. This bespoke approach allows for greater control over the system's architecture and ensures alignment with the unique characteristics of Sardinia's architectural heritage. The authors highlight the need for a system that can handle large datasets, facilitate comparative analysis across diverse building typologies, and enable the extraction of chronological insights from masonry data. Their system, unlike the more generic Arches platform discussed by Aspöck and Masur, is specifically tailored to the architectural context of Sardinia. It incorporates a multi-layered knowledge structure, allowing for the continuous addition of information and constructing a complex understanding of the region's built heritage.

The researchers employ a hierarchical database structure organized into two main categories: descriptive data and coded values. This structure, combined with a robust system of keywords, enables a high level of automation in data analysis, comparison, and synthesis operations. Using coded values facilitates the querying of the database across multiple thematic categories, fostering an interdisciplinary approach to heritage research. This aligns with Vacca et al.'s goal of moving beyond a purely thematic perspective to achieve a more holistic interpretation of complex architectural phenomena.

The SIS, as implemented by Vacca et al., demonstrates a strong emphasis on data standardization and interoperability. The authors adhere to Italian national standards for architectural heritage documentation and utilize controlled vocabularies to ensure consistency in data entry and retrieval. Furthermore, the system embraces Open Geospatial Consortium (OGC) standards, enabling the sharing of data with other platforms and institutions, as highlighted by their plans to share WMS services with the Sardinia Autonomous Region. This focus on interoperability aligns with the principles advocated by Myers in his discussion of Arches. Both projects recognize the importance of creating systems that can communicate effectively with other platforms, promoting collaboration and data exchange within the wider heritage research community.

Vacca et al.'s SIS employs a hierarchical database structure, organizing information into levels of detail. They distinguish between "architectural units," which represent individual structures, and "construction elements," which describe specific components within those units. This hierarchy allows for efficient data retrieval and facilitates the analysis of relationships between different architectural elements.

Arches, on the other hand, utilizes a relational database model, allowing for more complex relationships between different data entities. As described by Aspöck and Masur, Arches employs the CIDOC CRM, a widely used ontology for cultural heritage, to structure and organize data in a semantically meaningful way. This ontological approach enables sophisticated querying and analysis, particularly for research-oriented projects.

Barton et al. highlight Arches's customizability through various examples of projects that have tailored the platform to their specific needs. This customization often involves modifying the underlying data model, creating new controlled vocabularies, and translating the user interface into different languages.

Vacca et al., however, opt for a more comprehensive level of customization by building their own system from scratch. This decision likely reflects the specialized nature of their project, which focuses on the architectural heritage of a specific region. By designing their own system, they can ensure that the data structure, functionality, and user interface are perfectly aligned with their research objectives and the specific characteristics of Sardinian architecture.

Both approaches demonstrate the importance of tailoring heritage documentation systems to meet specific project needs. Arches offers a flexible platform that can be adapted to diverse contexts, while Vacca et al.'s approach showcases the benefits of a more bespoke system for highly specialized projects.

Ultimately, the choice between these approaches depends on factors such as project scope, available resources, and the level of control desired over the system's architecture and functionality.

2.3 Assessment of Spatial Database Platforms

The previous section highlighted the potential for the Hajj Routes Database to use either the Arches platform or a custom-built spatial information systems database. A tool for assessing these two possible pathways is developed (Appendix 1), highlighting 7 key criteria mentioned in the experiences of various database managers (Zerbini, 2018).

2.4 Database Design

Following the methodology discussed, this paper develops a workflow for designing a spatial heritage database for Hajj Routes. A clear and structured workflow is necessary to guide future work on establishing the database (ICOM, 2024). A general workflow is developed, acknowledging the steps required for data assessment, entry, and maintenance to establish the future Hajj Routes Database.

2.5 Dataset Creation

Building a Hajj Routes Database requires gathering publicly available information on the stations along the routes, including their spatial coordinates. Three historic Hajj Routes (Darb Zubaydah, the Syrian Hajj Road, and the Egyptian Hajj Road) are registered on the UNESCO tentative list for World Heritage status, with some preliminary data available on the spatial coordinates of the listed component parts of the routes (UNESCO World Heritage Centre, 2024). These are extracted from the UNESCO online platform and entered into a preliminary database for future entry into the Hajj Routes Database.

3. Results and Discussion

3.1 Case Study Analysis

A tool for assessing the different database platforms considered in this study is developed and applied, considering key criteria from the experiences of heritage database managers and the needs of the Hajj Routes Database. The results show a significant preference for Arches as the selected platform (Table 1).

Arches, being an open-source platform, is free to use but requires investment in long-term hosting, configuration, and potential customization. It is designed to be user-friendly, requiring minimal technical training for basic functions. It is also characterized by a strong user community, offering valuable resources, and can handle large datasets with proven success and potential for accommodating growing needs (Lee Enriquez et al., 2024). While custom-built spatial information systems offer the greatest control over the system’s architecture, they can be expensive to develop and maintain. Additionally, while platforms like ArcGIS have commercial licenses and large user bases, they can have steep learning curves for users unfamiliar with geographic information systems (GIS). Based on the assessment, an informed decision can be made with Arches as the selected platform to host the Hajj Routes Database.

Assessment Results for Spatial Database Platforms		
Criteria/platform	Arches	Custom-built Spatial Information Systems Database (ArcGIS or otherwise)
Functionality	3	2
Standards Compliance	3	2
Customizability	2	3
Cost	2	1
Accessibility	3	1
Community and Support	3	2
Scalability and performance	3	1
Total	19	12

Table 1. Results of the assessment tool for Arches and custom-built spatial information systems.

3.2 Database Design

With Arches as the selected platform for the Hajj Routes Database, a general workflow is designed to guide future work on establishing the database (Figure 6).

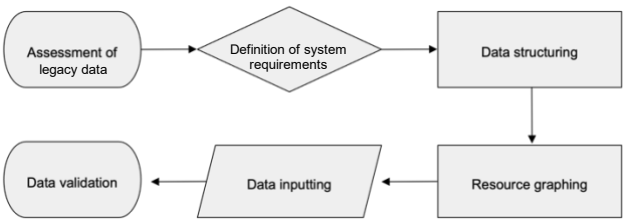

Figure 6. General workflow for establishing the Hajj Routes Database on Arches.

The workflow begins with a thorough assessment of legacy data to understand the existing information landscape. This involves identifying all relevant data sources, evaluating their quality, and determining their relevance to the new platform. Data conversion to formats compatible with Arches may be necessary at this stage.

Next, system requirements must be defined to guide the platform's development. This step involves clearly outlining the project's goals and scope, identifying the needs of the intended users, and determining the essential functionalities required. Compliance with international standards like CIDOC CRM ensures interoperability and long-term data viability (ICOM, 2024).

The third stage focuses on data structuring, which involves developing a comprehensive data model, establishing controlled vocabularies, and defining semantic relationships between data entities. This process ensures data consistency, facilitates efficient querying and analysis, and promotes data exchange

and integration. A detailed data dictionary documenting all data elements and relationships is also essential.

Resource graphing, a key aspect of Arches implementation, involves selecting and customizing resource graphs to represent the data structure and relationships accurately. Resource graphs can be modified or created to cater to specific project needs. This step ensures the data aligns with the CIDOC CRM model, promoting interoperability and sharing.

The next stage focuses on data inputting, where legacy data is migrated into Arches using appropriate methods, such as CSV or JSON import. Manual data entry for new resources and information is also conducted during this phase. Data entry templates and batch uploading functionalities can streamline the process and ensure consistency.

Finally, data validation is crucial to ensure the data’s accuracy, completeness, and consistency. This involves implementing data quality checks, validation rules, and a robust review and approval process. Data cleaning and documentation of any encountered data quality issues are also essential to this stage.

By following this structured workflow, establishing a new platform on Arches can be executed efficiently and effectively, resulting in a robust and valuable resource for heritage documentation and management.

3.3 Datasets

As a necessary first step towards establishing a Hajj Routes Database, information was collected from the UNESCO Tentative List listings of three historic Hajj Routes, the Darb Zubaydah, the Egyptian Hajj Road, and the Syrian Hajj Road. The information collected includes the names of components and their coordinates, and at this stage only consists of the sites under Saudi Arabia’s tentative list. They were gathered into a database to be plotted as E18 Heritage Places on the Arches platform. In the future, each component part may be attributed an identification number after plotting as a resource, and an additional coding system for attributes may be implemented.

4. Conclusion

This research project aimed to establish the theoretical knowledge necessary for developing a heritage database for researchers and management professionals interested in historic Hajj Routes. The initial phase of the project focused on a case study analysis of data management and dissemination tools in a variety of cases, including the Endangered Archaeology in the Middle East and North Africa project, national heritage inventories, and comparable transnational cultural routes listed as UNESCO World Heritage sites, such as the Silk Roads in Central Asia. This analysis sought to identify any technological limitations that might impact the archiving and sharing of data transnationally. The final phase of the project aimed to develop a workflow for future database design and dataset collation as a step toward creating a preliminary Hajj Routes Database.

This study predicted that Arches, an open-source data management platform developed by the Getty Conservation Institute and the World Monuments Fund, would be used as a geospatial inventory and digital archiving platform for Hajj Routes. Using an assessment tool that measured the efficacy of Arches against custom-built SIS, Arches was deemed appropriate for this project due to its accessibility and multi-functionality. Using Arches' spatial relation graphing features to plot the locations of waystations along Hajj Routes, the future directions of the project aim to link spatial databases to multimedia resources and data on Hajj Routes.

The paper’s findings highlight the importance of Arches as a suitable platform for the Hajj Routes Database due to its open-source nature, user-friendliness, robust community support, and ability to manage large datasets. Arches offers a cost-effective and adaptable solution for documenting, managing, and disseminating information related to historic Hajj Routes. Future work will focus on implementing the database design workflow, including data assessment, conversion, structuring, resource graphing, inputting, and validation. The initial dataset, comprising components of Hajj Routes listed on the UNESCO Tentative List of Saudi Arabia, will be expanded to include a wider range of sites from other State Parties and their associated information.

The successful future development of the Hajj Routes Database holds significant potential for advancing research and understanding of these culturally and historically significant sites. It can serve as a valuable resource for scholars, heritage professionals, and the general public, promoting awareness, preservation, and sustainable management of these significant cultural landscapes.

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Appendix

Assessment Tool for Spatial Database Platforms			
Criteria/score	3	2	1
Functionality	The system provides all necessary tools for data collection, storage, management, analysis, and visualization relevant to a Hajj Routes Database. It also includes features for spatial analysis, data import/export, reporting, and user management.	The system provides most necessary tools for data collection, storage, management, analysis, and visualization relevant to a Hajj Routes Database. It also includes features for spatial analysis, data import/export, reporting, and user management.	The system does not provide the necessary tools for data collection, storage, management, analysis, and visualization relevant to a Hajj Routes Database. It also includes features for spatial analysis, data import/export, reporting, and user management.
Standards Compliance	The system adheres to international standards for heritage data, such as CIDOC CRM standards.	The system adheres to some international standards, but not all.	The system does not adhere to international standards.
Customizability	The system can be tailored to the specific needs of the project easily. Data models, workflows, user interfaces, and reporting features may all be customized freely.	The system can be tailored to some needs easily. Data models, workflows, user interfaces, and reporting features may all be customized, but within given parameters of the system.	The system cannot be tailored to the specific needs of the project easily. Data models, workflows, user interfaces, and reporting features may not be customized at all.
Cost	The initial cost of software acquisition, implementation, customization, and ongoing maintenance is near zero.	The initial cost of software acquisition, implementation, customization, and ongoing maintenance is low, but some investment is required.	The initial cost of software acquisition, implementation, customization, and ongoing maintenance is high.
Accessibility	The user interface is accessible to most internet users, training requirements are low, and availability of documentation and support are ample.	The user interface is accessible to some internet users, some training is required, and documentation and support are available, but not easy to acquire.	The user interface accessible only for trained professionals, and documentation and support are not available and must be developed on an ad-hoc basis.
Community and Support	There is an active community of users and developers providing support, documentation, and shared resources.	There is a small community of users and developers providing support.	There is no active community of users and developers for the system.
Scalability and performance	The system can handle the expected volume of data and user traffic, with established successful experiences.	The system is expected to handle the anticipated volume of data and user traffic, but it has not been tested beforehand.	The system is not expected to handle the anticipated volume of data and user traffic, and it has not been tested beforehand.

Table 1. Assessment tool for Arches and spatial information systems.