



## HBIM-Based Cultural Heritage Information Management and Sustainability Framework for Monumental Mosques: The Case of Konya

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### Abstract

The inventorying and documentation of monumental and historical mosques, which are valuable elements of cultural, religious, and architectural heritage, is of great importance. Additionally, monumental mosques, with their traditional and climate-adapted design properties, are inspiring for contemporary designers. Historical Building Information Modeling (HBIM) is the application of traditional building information modeling to heritage buildings. In this context, this study develops an HBIM-based sustainability framework to create a systematic inventory of data and develop a physical environment model. Following the proposed framework, the Sahip Ata Mosque, built in Konya during the Anatolian Seljuk period and one of the most important centers of Turkish-Islamic culture and art, was examined. The findings demonstrate the applicability of the proposed framework by holistically addressing the documentation, information management, and evaluation of the physical environment performance of monumental religious buildings. Furthermore, this study offers an approach to evaluating the relationship between the architectural design properties and environmental performance of mosques.

**Keywords:** Monumental and Historical Mosques, Historic Building Information Modelling, Monumental Mosques Sustainability Assessment.

## Anıtsal Camiler için HBIM Tabanlı Kültürel Miras Bilgi Yönetimi ve Sürdürülebilirlik Çerçevesi: Konya Örneği

### Öz

Kültürel, dini ve mimari mirasının değerli öğeleri olan anıtsal ve tarihi camilerin envanterinin oluşturulması ve belgelenmesi büyük bir öneme sahiptir. Ek olarak, anıtsal camiler, geleneksel ve iklimle uyumlu tasarım özellikleri ile günümüz tasarımcılarına ilham verici niteliktedir. Tarihi Yapı Bilgi Modellemesi (HBIM), geleneksel yapı bilgi modellemesinin miras yapılarına uygulanmasıdır. Bu bağlamda çalışmada, verilerin sistematik bir envanterinin oluşturulması ve fiziksel çevre modelinin geliştirilmesi amacıyla HBIM tabanlı bir sürdürülebilirlik çerçevesi geliştirilmiştir. Önerilen çerçeve doğrultusunda, Türk-İslam kültür ve sanatının en önemli ana merkezlerinden biri olan Konya'da Anadolu Selçuklu Dönemi'nde inşa edilen Sahip Ata Camii ele alınmıştır. Elde edilen bulgular, önerilen çerçevenin, anıtsal dini yapıların belgelenmesi, bilgi yönetimi ve fiziksel çevre performansının değerlendirilmesini bütüncül bir şekilde ele alarak uygulanabilirliğini göstermiştir. Ayrıca çalışma, camilerin mimari tasarım özellikleri ile çevresel performansı arasındaki ilişkinin değerlendirilmesine yönelik bir yaklaşımdır.

**Anahtar kelimeler:** Anıtsal ve Tarihi Camiler, Tarihi Yapı Bilgi Modellemesi, Anıtsal Camilerin Sürdürülebilirlik Değerlendirmesi.

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## **1. Introduction**

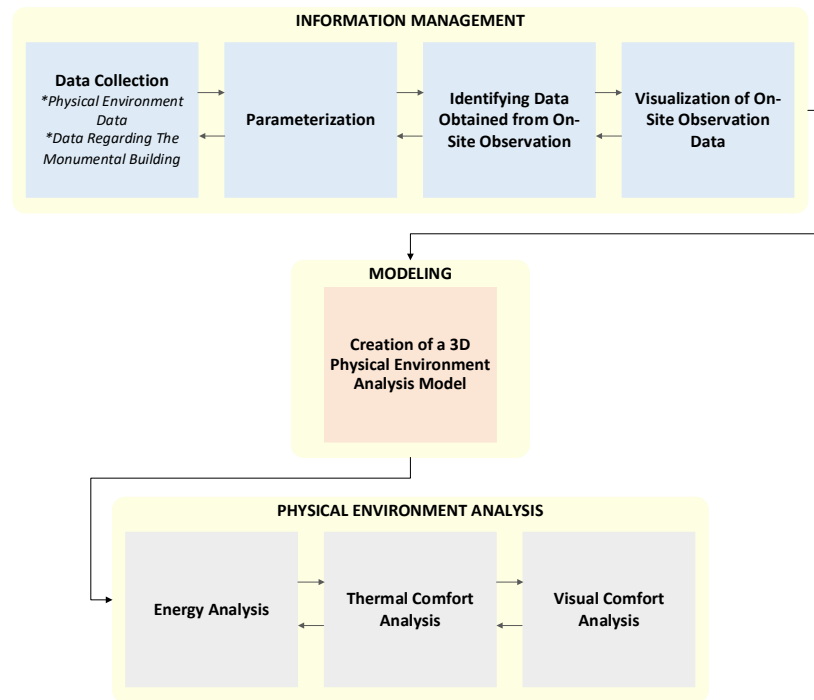
The built environment is responsible for a significant portion of global energy consumption and carbon emissions and has a major impact on the environment (Azmi & Kandar, 2019). The operating of mosques, characterized by their unique operational plans, affects the energy demand of mosques depending on the climate zones (Al-Homoud et al., 2005). Climate-dependent design properties of mosques affect comfort conditions in the interior and the thermal performance of the mosque (Abdou et al., 2005). In their study, Al-Homoud et al. (2009) stated that the energy efficiency of a mosque largely depends on the overall thermal performance of building components such as walls, roof, and windows, which work together as a system. Studies also indicate that historical mosques, particularly those featuring characteristics such as the use of traditional methods, local materials, and environmentally friendly design principles, are inspiring for contemporary designers who want to design sustainable and eco-friendly buildings (Naghipour et al., 2025). In this context, documenting the architectural design properties of monumental mosques, which are valuable elements of cultural and architectural heritage, and evaluating them in terms of environmental sustainability is of great importance.

Historic Building Information Modelling (HBIM) is the application of BIM, an information management and digital modeling approach for building sustainable environments, to historically significant buildings defined as cultural heritage (Lovell et al., 2023). The HBIM concept has been used since the early 2010s for the documentation, preservation and effective modeling of historical architectural buildings (Khan et al., 2022). It is a current concept that extends traditional building information modeling (BIM) towards the preservation, management and analysis of heritage structures (Ávila et al., 2024). Data management is important for geometric and non-geometric (historical or architectural) information in historical buildings. Ávila et al. (2024) stated in their study that the HBIM methodology can be handled in three basic stages: data collection, data processing, and modeling and management. During the data collection phase, geometric and non-geometric data (historical context, architectural details, material properties, etc.) are collected. The documentation process plays a crucial role in systematically creating an inventory of the data and collecting all the information necessary for the development of the model. HBIM is an approach that can provide documentation of historical buildings and improve decision-making processes throughout the life cycle of these buildings (Puerto et al., 2024). However, due to deficiencies in the difficult integrated data collection and modeling process, the use of HBIM and studies in this field are limited.

This study aims to propose an HBIM-based information management and sustainability framework for monumental religious buildings, which are valuable elements of cultural and architectural heritage. Before 3D modeling of historical buildings, systematic definition and management of the information inventory is necessary. Systematic documentation and management of the inventory is crucial in terms of the characteristic design properties of monumental mosques, and information management is a key focus of this study. Furthermore, the study aims to investigate the relationship between the architectural design properties and environmental performance of monumental mosque buildings, and to develop a guide evaluating the design principles of monumental mosques in terms of environmental sustainability. Konya was chosen as the case study area because it is a city that has maintained its importance for many years as the capital of the Anatolian Seljuk State and one of the important provincial centers of the Ottoman Empire, hosting many civilizations and possessing valuable elements of Turkish Islamic architecture. Studies in this area are limited, and the proposed framework will contribute to filling the gap in the literature for an HBIM-based sustainability assessment system.

## **2. Material and Method**

The HBIM-based information management and sustainability assessment framework proposed in this study for monumental historical mosques is shown in Figure 1.



**Figure 1.** HBIM-based information management and sustainability assessment framework for monumental religious buildings (created by the authors)

The proposed framework consists of three basic modules: Information Management, 3D Modeling, and Physical Environment Analysis. The Information Management module includes sub-modules such as data collection, parameterization, identifying data obtained from site observation, and visualization of on-site observation data. The data collection sub-module refers to the data collection related to the physical environment and monumental religious buildings. This study focuses on the information management and sustainability framework. The proposed framework is designed not to be dependent on a specific digital platform and has a structure that can be applied in alternative (digital or non-digital) information management environments. The case study demonstrates the applicability of the proposed methodology through a systematic workflow independent of any specific digital HBIM platform.

Climate, as a physical environmental factor, is a significant element determining the energy and thermal performance of a building and is considered during the data collection phase. Data regarding the monumental mosque structure will serve as input for later stages of the proposed framework and will determine the entire evaluation process. Parameterization, which will provide the classification of data related to monumental religious buildings with characteristic design properties, is an important sub-module of data management and will provide for the systematic identification of the building's characteristics. The parameter system developed for data management is shown in Table 1.

**Table 1.** Parameterization systematics

|                 |                                        |
|-----------------|----------------------------------------|
| Design Typology | Period                                 |
|                 | Building Form                          |
|                 | Plan Organization                      |
|                 | Top Cover                              |
|                 | Building Order                         |
|                 | Entrance-Garden/Street Relation        |
|                 | Total Area of Mosque (m <sup>2</sup> ) |
|                 | Total Height of Mosque (h)             |

|                                       |                      |                                                  |
|---------------------------------------|----------------------|--------------------------------------------------|
| Construction Techniques and Materials | Wall Properties      | Bond Technique                                   |
|                                       |                      | Material                                         |
|                                       |                      | Wall Thickness (cm)                              |
|                                       |                      | Openings                                         |
|                                       |                      | Windows--Wall Ratios (%) (South-North-East-West) |
|                                       | Flooring Properties  | Material                                         |
|                                       | Top Cover Properties | Bond Technique                                   |
|                                       |                      | Material                                         |
|                                       |                      | Dimensions (Diameter/Thickness)                  |
|                                       |                      | Openings                                         |
|                                       | Minaret Properties   | Bond Technique                                   |
|                                       |                      | Material                                         |

The parameter system is defined to provide the identification and systematic classification of architectural properties, as well as sustainability assessments, particularly focusing on passive design strategies. In line with the parameter system, the identification and visualization of field data based on on-site measurements and observations constitute other sub-modules forming the information management module. In addition to on-site observations or measurements, literature is used as a source for data related to the historical building. The information inventory obtained through this approach is transformed into a standardized and reusable information structure that can be used in the modeling process. The architectural properties defined in the information management module a basis and framework for the 3D model. In the Model basic module, a three-dimensional (3D) physical environment analysis model is being developed. Physical environment analyses include energy, thermal, and visual comfort analyses. In this study, DesignBuilder software, integrated with BIM, was used to provide the integrated performance of energy, thermal, and visual comfort analyses, as well as geometric modeling for physical environment analyses, and to support comprehensive building performance analyses.

### 2.1. Case Study Description

Konya is a city that has maintained its importance for many years due to its location on the caravan routes of the Silk Road in Anatolia, its geographical properties and as the capital of the Anatolian Seljuk State and one of the important provincial centers of the Ottoman Empire. It has been one of the most important main centers of Turkish-Islamic culture and art in Anatolia (Baykara, 2002). Konya, which has hosted many civilizations throughout its history and where multi-layered culture and architectural elements of these cultures coexist, has gained a valuable identity throughout history. In this respect, Konya was chosen as the study area. In order to demonstrate the applicability of the HBIM-based sustainability framework proposed in the study, the Sahip Ata Mosque, built in the Anatolian Seljuk Period in the 13th century, was taken as a case study. Additionally, thermal performance data of the monumental mosque was included in the evaluation process.

### 3. Findings and Discussion

In accordance with the HBIM-based cultural heritage information management and sustainability assessment framework proposed in this study, the Monumental Erdemşah Mosque was analyzed. The evaluation systematic is shown in Figure 2.



**Figure 2.** Sahip Ata Mosque evaluation systematic (created by the authors)

In the data collection phase, information regarding Konya's climate data was first defined. Thermal comfort is achieved by balancing heat gains and losses in the human body and controlling environmental conditions such as temperature and humidity. In this respect, environmental or climatic data such as air temperature, air humidity (relative humidity), mean radiant heat, and air velocity are of great importance. Data regarding the Sahip Ata Mosque, built in the 13th century during the Anatolian Seljuk period, were collected through literature review and on-site observation. On-site imaging of the buildings was provided using a drone, and photographs and properties were documented. After on-site observations, the electronic drawings obtained from the Konya Regional Directorate of Foundations were colored, and the current situation and its relationships with the immediate surroundings were plotted on the drawings based on the on-site observations. The documented data was classified according to the parameterization system proposed in the study. The architectural design properties of the monumental religious buildings, which were documented and visualized, were prepared for a 3D physical environment analysis model. Models have developed specific to mosque buildings with characteristic features, taking into account occupancy rates and usage times, using the DesignBuilder simulation program.

The climate-related design characteristics of mosques, which affect the thermal performance and indoor comfort conditions of the building, can be evaluated in line with passive design strategies. These strategies, also defined as energy-efficient design strategies, consider the building's location, orientation, distance from other buildings, building form, optical and thermophysical properties of the building envelope, solar control, and natural ventilation layout. In their study, Ahriz et al. (2021) identified the mosque building components affecting thermal comfort conditions as the building's orientation, the surrounding area, the building's size and geometric shape, architectural form, roof shape, prayer halls, the height of the prayer hall, openings, building materials, and surface colors. In addition to passive design strategies, the characteristic properties of the mosques should be considered as factors to be evaluated. The orientation of the mosque building is towards the qibla. The mihrab, one of the important characteristic properties of the mosque, is located in the direction of the qibla. The direction in which these characteristic properties affect passive design strategies should be defined in terms of sustainability assessment.

When the thermal comfort graphs were examined, it was seen that the outdoor air temperature, radiant temperature and indoor air temperature values for the Sahip Ata Mosque were generally close to each other. The main reason for this situation can be stated as phase shift. Phase shift is a condition that supports thermal comfort, and the wall thickness and material properties of the structure examined provide this situation. In terms of results regarding heat balance, heat leakage occurs especially in cold periods when heating is required. It can be stated that the main reason for this is the openings in the building envelope. It is seen that indoor fresh air rates are higher between June and September compared to other months. The main reason for this is natural ventilation, which is an important factor in indoor air circulation.

The findings show that the proposed HBIM-based information management and sustainability assessment system is applicable in evaluating the physical environmental performance of monumental religious buildings. With the proposed framework, monumental mosque buildings, which are valuable elements of architectural heritage, are documented and a systematic input is created for physical environmental analysis. Managing this data is as critical as collecting data about heritage buildings that are important to document. Additionally, the proposed framework provides an evaluation mechanism for the basic design and environmental performance of monumental religious buildings. The traditional design properties of the Anatolian Seljuk Period Konya monumental mosque and its importance in terms of thermal comfort and sustainability are other important achievements of the study.

#### **4. Conclusion and Suggestions**

Creating an inventory and documenting of mosques, which are important elements of religious and cultural heritage, is crucial. Furthermore, providing sustainable comfort conditions within mosque interiors, where the sense of sacred worship is of great importance, is essential. The harmonious architectural design properties of monumental religious buildings are inspiring for contemporary

designers. In this context, this study proposes an HBIM-based sustainability assessment framework for monumental mosque buildings. HBIM is an approach that aims to coordinate the storage of semantic and historical information while targeting geometric accuracy. In this study, an HBIM-based framework has been developed.

The HBIM-based information management and parameterization system proposed in this study provided the integrated management of on-site observation data, visual documents, technical documents, and physical environment data, and provided for the development of a physical environment analysis model based on this data. In this respect, the proposed system offers a significant approach in terms of information management and data quality. Focusing on developing a basic methodological framework, the proposed framework was developed independently of digital platforms. In future studies, the developed framework can be applied in BIM-compatible digital and shared data environments. The study aimed to demonstrate the applicability of the proposed framework and analyzed the Sahip Ata Mosque in terms of thermal comfort. Furthermore, the proposed framework also provides for performance analysis in terms of energy performance and visual comfort. In conclusion, this study presents an HBIM-based sustainability assessment approach, serves as a guide for climate-friendly sustainable mosque design, and provides a foundation for further studies.

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The article complies with national and international research and publication ethics. Ethics Committee approval was not required for the study.

### Author Contribution and Conflict of Interest Disclosure Information

All authors contributed equally to the article. There is no conflict of interest.

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