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Design and Development of Heritage Building Information and Maintenance Management System for Architectural Heritage

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Abstract

The notion of Information Management (IM) is fundamental to the field of heritage building rehabilitation and preservation. Historically, preservation and reconstruction have been inadequately recorded, resulting in no standardization and education regarding past practices. This deficiency challenges fresh restoration efforts and the preventive maintenance of heritage components. This study presents the Design and Development of a Heritage Building Information and Maintenance Management System (DD-HBIMMS) for Architectural Heritage (AH). The HBIMMS literature emphasizes the necessity for additional research regarding the comprehensive operations of AH projects, their practical execution, and the requirement for improved cultural preservation. This study employs Design Science Methodology (DSM) to establish a protocol to enhance working processes in collaborative AH projects. HBIMMS is proposed as an online framework designed to store AH information and delineate operations. Consequently, a straightforward and visual HBIMMS protocol has been formulated and implemented in a practical case study.

Keywords: Architectural Heritage, Information Management, Management System, Design Science Methodology, Maintenance.

1. Introduction

This work presents an overview of the options for IM associated with elements, particularly concerning the restoration and preservation efforts. The study identifies pertinent features to assess each option independently, facilitating comparison with the requirements and resources of each organization, its target group, and the AH assets it oversees [1]. Additionally, guidelines are suggested for integrating various tools into an individualized approach that addresses the standards and requirements of the public and organizations regarding the sustainable preservation of AH.

IM technology systems offer an array of resources and options that can greatly enhance the administration, preservation, and restoration of AH and historical sites. By adopting technology, heritage professionals can enhance their understanding, documentation, conservation, and dissemination of historical and cultural significance [15]. Consequently, Geographic Information Systems (GIS) technology can be employed to create online maps that superimpose archaeological sites and buildings, facilitating the understanding of spatial connections, planning conservation efforts pertinent to the ecological context of AH, and assessing potential hazards. On the contrary, the HBIMMS domain may facilitate more comprehensive analyses of AH and interior elements [3].

In preserving AH, a primary objective is to identify approaches that reduce ongoing measures while sustaining their significance, worth, and originality [4]. Scheduled maintenance is an efficient method to attain this goal through the precise and thorough organization of operations and tasks, guaranteeing the asset's heritage and sustainability.[19]. This process must include precise and stringent timing to avert the emergence of abnormalities or risks that may affect the asset's quality over time [17].

The Main10ance project "https://main10ance.eu/" seeks to streamline the collection, archiving, IM, and representation of information related to the AH and its historical and prospective preservation activities. [2]. This initiative was executed via the trial project of the Sacri Monti system, designated as a UNESCO World AH site [6]. This system exemplifies a significant heritage with intrinsic complications, where the outdoor landscape, architectural edifices, and interior assets enhance its immeasurable value. The creation of this new comprehensive IM system facilitates its adaptability to analogous contexts.[5]. The present instance illustrates the design and development of a web-connected compatible HBIMMS database solution that addresses the IM challenges of complex, broad AH, including artworks, structures, and environments, benefiting experts and public-interest entities.

2. **Related works**

Various terminology associated with AH conservation, safeguarding, and restoration in an urban setting pertains to avoiding the deterioration of a city's ecological, social, cultural, and economic legacy elements. A record of extant buildings and documentation of those that have vanished would facilitate the preservation of physical assets in the area, including AH and memorials. At the same time, the term encompasses the methods and guidelines for archiving and safeguarding existing edifices [17]. Regeneration, preservation, and conservation seek to amalgamate extensive methods and instruments to address architectural and urban challenges. The primary objective is to develop more sustainable and habitable cities while maintaining their historical and cultural setting. [7].

Heritage preservation entails various activities and interventions that, although primarily physical, also address social, cultural, and economic concerns. This aims to improve physical and spiritual surroundings by documenting and repurposing current structures as historic elements and enhancing infrastructure. It also seeks to improve people's quality of life and save the city's legacy, as the UNESCO treaty (1972) advocates. This pertains to identifying, safeguarding, conserving, and presenting cultural and natural assets for the next generation, as mandated by municipal planning and legislative statutes for AH conservation [20].

Cities, although seen as centers of business, innovation, and culture, also include traditions and a distinctive character that contribute to developing a unique legacy identity, which is fundamental to effective city planning. [10]. The significance of legacy has been increasing as a determinant that might influence the globalization of cities, therefore preserving and promoting their distinctive traits [9]. Authors argue that artwork and AH should be effective instruments to facilitate effective restoration initiatives: "The contribution of culture has gained novel importance, and its reconsideration as a resource has allowed it to address both ideological and socio-economic issues." [18].

The 18th century witnessed the first artistic preservation and revival endeavor, as authorities, creators, colleges and universities, and social organizations collaborated to create informal alliances of cultural initiatives aimed at regenerating urban areas [11]. The function of the cultural industry is to rejuvenate a city locally and globally.[8]. The authors emphasize the significance of recognizing the creativity and abilities of urban inhabitants. Cultural rehabilitation and heritage conservation initiatives are vital as they foster city symbols that boost its national and worldwide reputation [12]. These endeavors encapsulate the concepts of rejuvenation, innovation, and modernity. They provide an interactive representation of the city's relationships within regional and global economics and identity frameworks. The significance of social and cultural pursuits lies in their

Fig. 1 HBIMMS for the AH Lifecycle Concept

ability to cultivate healthy rivalry among cities in shaping their representative identities [13].

3. Materials and methods

This section delineates the definition of HBIMMS, its advantages, the management of BIM data, and the commissioning of HBIM, and presents notable case studies of HBIM application. It presents a life cycle concept, illustrated in Figure 1, encompassing various phases (asset identification, literature survey, identifying objectives, intervention, handover, and operation). This guide notably contributes by defining the Level of Development (LOD) in HBIM, a topic overlooked in prior protocols.

Suggestions on AH intervention techniques are also accessible. International Restoration Conventions developed various documents outlining effective intervention strategies and methodologies. Various AH organizations have been revising their intervention instructions, developing specialized AH guidelines for distinct heritage categories (e.g., commercial, sacred, protective), and advocating for legislation. The current HBIMMS protocols and guidelines aim to integrate conservation guidelines with BIM technologies. Nonetheless, HBIMMS remains an evolving field, necessitating additional research to ascertain particular stakeholder requirements, enhance alignment with conventional heritage practices, and assess these through practical applications of HBIMMS.

Every phase is succinctly delineated as follows:

Phase 0: Asset identification

This encompasses the initial assessment of the AH building's condition, the formulation of the predetermined AH-BIM Implementation Plan (AHBIP), and the prospective cultural dissemination ideals of the AH. The planning segment is more comprehensive than in standard projects, as AH typically necessitate thorough prior investigations of their architectural, historical, and archaeological significance. Creating a General Information Environment (GIE) facilitates information distribution during the Intervention Strategy (IS) venture. The obtained LOD is LOD 100, and an original HBIMMS consisting of masses is sufficient for acquiring measurements and archiving preliminary data. An IS was established based on existing protocols.

HBIMMSlegacy encompasses all phases of IS in an AH building; however, not every project necessitates such comprehensive modeling. The requirements for every venture should be established at the outset, in alignment with the client's IS goals and the construction team's capabilities regarding BIM. The objective of implementing HBIMMS for each particular scheme must be established in stage 0.

Stage 1: Literature survey and AH registration

AH registration encompasses the architectural review and the compilation of all cultural, archaeologic, and urban development data. The 3D modeling utilizes the point cluster from the scanning laser as a framework to initiate the model. The HBIMMS modeling of the structure encompasses creating HBIM elements and databases of construction details, along with HBIM families featuring unique and recurring decorative components. This phase also includes delineating its historical evolution with particular recommendations for the LOD of various construction hypotheses. For instance, modeling the twelfth-century phase of a church necessitates LOD300, yet insufficient information is available to achieve this level of detail.

This supervision instructs on how to develop it and the level of element required based on the available data. Modeling the present deterioration state of the structure involves depicting disorders, documenting archaeological stays representing geological studies if required, and modeling aesthetic sculptures. Furthermore, if the initial blueprints are accessible, the modeling and the construction must be depicted. The AH recording possesses a minimum LOD 200. Yet, modeling the prevailing state should achieve an LOD 300 level of particulars, as the opinion offers precise evidence and pertains to the more pertinent reconstruction stage.

Stage 2: Identifying objectives and intervention alternatives

Identifying intervention alternatives for the potential renovation, restoration, or conservation of the AH, which involves a comprehensive assessment of the structure and/or site. The explanation of the IS requirement encompasses the construction and design parameters, such as the kind of concrete utilized or the choice to build fundamentals physically. The BIM heritage consolidates information during this phase and facilitates practical interaction among stakeholders.

Stage 3: IS design

It involves formulating the IS design, encompassing the preservation, restoration, or renovation venture and its accompanying certification. Plans will be created utilizing 3D models as the foundation for the IS project. Various participants will collaborate with the 3D representations. Architects, archaeologists, and building professionals will create distinct models that will be integrated for quality assurance. Energy usage in HBIM simulations must be conducted during this phase to guarantee the appropriate sustainability practices of the AH. After the stage, a schematic HBIMMS framework should be generated.

Stages given above, were formulated based on the Patio Sur case research insights and the accompanying literature review. Subsequently, these phases were verified and finalized in the AH experts' target group.

Strategizing the practical IS (construction activities). This scheduling must adhere to particular rules within the restoration domain and account for uncertainties associated with an antique structure (e.g., unforeseen physical harm, moisture in interior sides). In conjunction with the design and asset stakeholders, the building participants will oversee this stage. HBIMMS will be utilized to create a 4D architectural model. Each HBIMMS component will be associated with its corresponding price within designated cost estimation software. The building plan is formulated using specialized 4D BIM software. Reconnaissance must be conducted during this phase to mitigate problems during construction. Physical Intervention

Historical edifices typically require particular materials and construction methods to preserve their integrity and prevent undesirable chemical processes. An as-built HBIMMS will be created in this phase, utilizing data gathered during development. The LOD must be set at 500 to achieve the requisite detail.

Stage 4: Handover

It pertains to the service and contract evaluation, enabling the team to convene and analyze decisions, identify IS issues, and deliberate on solutions for future projects. The transparency fostered by HBIMMSlegacy enhances the comprehension of stakeholders' concerns. All participants can examine the HBIMMS final structure model to verify the dimensions. Professional users could view the HBIM model via architectural and technical BIM software, whereas non-technical users would utilize the web-based system and its user-friendly viewers. Upon completion of this phase, the 'as-built' HBIM design shall be provided to the formal owner, as previously designated in the AHBIP.

Phases 4 to 6 have incorporated components informed by the insights gained from the Fixby Hall investigation, particularly from its most recent restoration. Subsequently, these steps were finalized by analyzing analogous instances in the literature and assessed with all parties involved in the process.

Stage 5: Operation and Preservation

Historic edifices necessitate meticulous care to sustain their infrastructure and safeguard artistic and inventive significance. The 'built model' is essential for HBIM maintenance; however, research indicates that preservation directors of AH require a straightforward system for preservation oversight. Consequently, integrating preservation information into the HBIMMS and associating it with the property's custom IM system is crucial. If the 'built model' is overly composite or contains excessive information, it will be ineffective for service managers.

AH buildings typically possess a profound legacy that renders them appropriate as enduring community landmarks or tourist attractions. HBIMMSlegacy asserts that such applications necessitate specific management systems about public visitation control, promoting the building's cultural attributes within the surroundings and its designation as an archaeological site. This phase involves the incorporation of inherent AH processes into HBIMMSlegacy. It suggests utilizing HBIMMS as a data stream to elucidate the AH to prospective visitors.

Stages 4 and 5 encompassed procedures formulated after evaluating the maintenance and AH dispersal of each of the structures examined in this study. The components have been verified during the workshop conducted for the Fixby Hall case research.

4. **Discussion**

The chart delineates the essential features of various digital tools and platforms used in cultural heritage management, emphasizing their unique functionalities and constraints. SDS concentrates on geographic data using fundamental geospatial techniques aimed at specialists and featuring modest development expenses. Open Data Digital Guides give a wider array of information, including texts, maps, and photographs, available to professionals and the general populace at a reasonable cost. University repositories address historical and environmental aspects; nevertheless, they

lack sophisticated processing capabilities and depend on aggregators for indexing. Conversely, 3D Databases like HBIMMS concentrate on historical components, providing sophisticated tools for 3D modeling, but they are constrained by restricted internet accessibility and need elevated development expenses. The chart highlights how each platform is customized to meet particular requirements, balancing accessibility, functionality, and cost for efficient legacy management.

This study introduces a procedure called HBIMMSlegacy, designed to assist heritage stakeholders engaged in medium-sized building interventions. It emphasizes structures controlled by private entities and highlights the potential advantages and challenges of HBIM. The following points are addressed:

Advantages for Heritage Organizations to Adopt HBIMMSlegacy:

Heritage architectural depiction needs a high degree of aspect to fulfill artistic recording and design standards. The automated refreshing of design views and the development of HBIMMS communities and collections significantly enhance the standard of legacy projects [14]. This study indicates that producing a high-quality HBIMMS is time-intensive. HBIMMSlegacy includes modeling guidelines to expedite HBIM modeling and delineates the Levels of Development for each step. Comprehensive modeling equips the modeler with an extensive understanding of the structure. For instance, the designer must acquire metric principles while modeling a medieval vault. Normalization and AH-BIM libraries were deemed less pertinent to the protocol's achievements than previous literature suggests. AH encompasses unique elements with specific characteristics, limiting standardized object libraries' efficacy.

HBIMMSlegacy determines the LOD based on each construction hypothesis's information volume; historical stages are often challenging to model due to little information on the building's appearance in the past. The depiction of old historical periods is essential for documenting the AH structure. Moreover, historical periods provide significant potential for cultural transmission, as the study findings show.

Previous HBIM research examined the possibility of shared data ecosystems and advocated for more investigation in the context of AH. The study participants identified the novel web-based interface of HBIMMSlegacy as a crucial element for the protocol's effectiveness. The literature emphasizes the need to incorporate conventional historic stakeholders and procedures into the BIM workflow. HBIMMSlegacy incorporates

Table 1: Comparison of IM strategies

Characteristics	Spatial Data Structure (SDS)	Open Data Digital Guide	University Repositories	HBIMMS
1. Type of Information Provided	Geographic coverage	Texts, maps, images, and thesauri	General content	3D models
2. Focus on Heritage or Surrounding Context	Primarily environment	Both heritage and environment	Both	Primarily heritage
3. Advanced Tools for Data Processing	Basic geospatial tools	None	None	Available
4. Online Accessibility and Interoperability	Supported	Supported	Supported	Not supported
5. Target Audience (Experts or General Public)	Experts only	Both experts and general users	Both	Experts only
6. Management Delegated to External Organizations	Yes	No	Yes	No
7. Development Cost	Low	Moderate	Low	High

conventional heritage processes and aligns stakeholders' actions with the HBIMMS via the suggested internet-based stage, facilitating their lively involvement in the IS. The study respondents also emphasized this as an advantage of HBIMMSlegacy.

Integrating information inside HBIM models and conflict detection might reduce reworking and, subsequently, the expenses associated with legacy interventions, owing to decreased mistakes often arising from data dispersal. Despite the initial expense of using HBIMMSlegacy, project development durations are expected to decrease with time. The harmonization of work processes offered in HBIMMSlegacy facilitates heritage teams' organization of data and procedures, potentially yielding long-term economic advantages. The straightforwardness of HBIMMSlegacy, particularly created to facilitate comprehension by non-technical participants, may assist in choice-making. The interactive online interface of HBIMMSlegacy promotes real-time collaboration among stakeholders, enabling essential creative dialogue and allowing all consultants to view each other's work, such as legal paperwork and building reports, following workshop discussions. This was one of the findings drawn from the workshop with multidisciplinary participants.

4D and 5D HBIMMS may mitigate disputes and alterations during building while enhancing the precision of the AH spending limits, the feasibility of the intended procedures, and energy consumption efficiency. The established procedure facilitates this by delineating modeling criteria, including LOD computations and the specifications for the " built" historical models.

Preservation data associated with the HBIMMS model enhances the eminence and precision of the building's operating systems. This study indicates that the outcomes of the center group suggest upkeep models should be as simple as feasible, including just necessary data for maintenance tasks.

A primary feature emphasized in the literature on HBIM is its capacity for centralized documentation collection. However, this may result in the HBIM models being burdened with superfluous information while excluding certain stakeholders' data, as shown by the analysis of the interviews. HBIMMSlegacy considers the comprehensive documenting of AH interventions on a digital platform associated with 3D representations, which will be tailored for various determinations (e.g., a preservation or a historical documenting model). Moreover, authorization constraints inside the add-on and web platform enable the prevention of information redundancy.

5. Conclusion

This research introduces the Design and Development of a Heritage Building Information and Maintenance Management System (DD-HBIMMS) for Architectural Heritage (AH). The HBIMMS literature underscores the need for more investigation into the holistic functioning of AH projects, their real-world application, and the need for enhanced artistic preservation. This research utilizes Design Science Methodology (DSM) to grow a strategy to advance operational procedures in collaborative AH projects. HBIMMS is an online architecture intended to archive AH information and outline activities. HBIMMS presents a life cycle concept encompassing various phases (asset identification, literature survey, identifying objectives, intervention, handover, and operation). As a result, a clear and visible HBIMMS technique has been developed and used in a real case study.

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