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Enhancing heritage building preservation with MCDM and HBIM: A research proposal

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Abstract

Conservation and management of architectural heritage is gaining importance in the context of responsible development and environmental awareness. The integration of Heritage Building Information Management (HBIM) and Multi-Criteria Decision-Making (MCDM) is capable of addressing the challenges of heritage preservation decision-making. HBIM, tailored to historic structures, serves as a digital repository of geometric and semantic data of any kind related to these buildings, while MCDM provides a structured framework for decision-making, considering technical and subjective aspects.

This research proposal aims to optimize heritage preservation decision-making processes by identifying possible decisions, designing user-oriented workflows, and integrating them into a cohesive framework. This approach seeks to foster collaboration, provide practical guidelines, and contribute to effective informed decision-making by all stakeholders involved in heritage management. Despite limitations, the research proposal has the potential to improve the effective integration of decision-making processes in the management of heritage structures.

Keywords: HBIM; MCDM; decision-making; data management; stakeholder engagement

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1. Introduction

1.1. Heritage preservation

Achieving responsible and forward-thinking development requires preserving architectural heritage in the face of growing environmental awareness and the quest for sustainable practices (Vitasek, 2022). As the global community addresses climate change, resource depletion, and environmental degradation, the focus extends beyond constructing new structures to responsibly managing and conserving existing buildings in general and built heritage in particular.

Heritage preservation involves conserving structures, and sites with historical, cultural, or scientific value, that hold tangible and intangible qualities. These structures are valuable reservoirs of human history, reflecting craftsmanship and cultural identity. Conservation of architectural heritage is a sustainable practice with multi-faceted benefits, promoting efficient resource use and aligning with the principles of the circular economy.

Balancing tradition and modernity through adaptive reuse not only reduces the environmental impact compared to new construction but also safeguards cultural and historical significance. This aligns sustainability with heritage conservation, establishing connections to the past and fostering a sense of identity. Recognizing the intricate relationship between history and the future, the conservation of architectural heritage is a sustainable approach to development, embodying responsible management.

1.2. Heritage Building Information Management

Heritage Building Information Management (HBIM) is a specialized subdomain of Building Information Management (BIM) tailored to address the challenges of preserving historical structures (Murphy et al., 2009). Unlike traditional BIM, which primarily focuses on new construction, HBIM adapts digital modeling techniques to the unique needs of historical buildings (Mansuri et al., 2022). This marks a paradigm shift in digital modeling, offering a purposeful approach that contributes to sustainable conservation by placing special emphasis on preserving cultural and historical values (Guzzetti et al., 2021; Vitasek, 2022).

HBIM models (Fig. 1 (a) and (b) illustrate an example) function as comprehensive repositories (Liu et al., 2023). The objects, relationships, properties, and other components that constitute the HBIM models are organized in a hierarchical structure within the vendor-neutral Industry Foundation Classes (IFC) scheme defined by buildingSMART International (Borrmann et al., 2018). These components function as data containers that capture both geometric and semantic information about the historical structures represented by the models (Taher Tolou Del et al., 2020). This integration is facilitated by historical documentation, archival information, and on-site measurements. Serving as digital archives, HBIM models offer valuable information for researchers, conservationists, and decision-makers engaged in heritage preservation. These models find application in documentation (Marzouk, 2023), inventory management (Saricaoglu and Saygi, 2022), risk mitigation (Altohami et al., 2021; Andrich et al., 2022; Radanovic et al., 2021), and simulations (Lupica Spagnolo et al., 2022) among others, addressing the specific needs inherent to heritage conservation (Barontini et al., 2021).
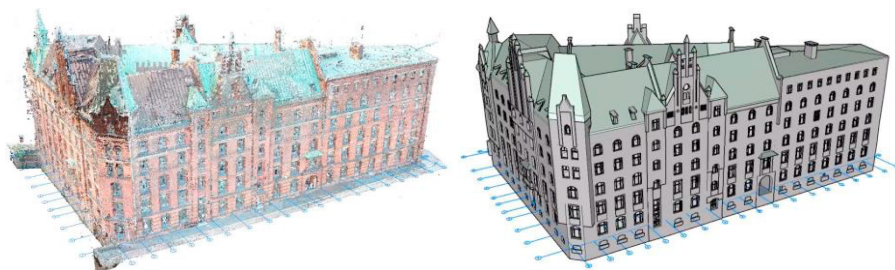

Fig. 1. (a) sample of a point cloud of a historic building; (b) sample of a HBIM model of a historic building.
Source: BIMLab HCU Hamburg Project 0-CO2-WSHH

1.3. Decision-making

Decision-making is the process of choosing one option from a set based on available information and preferences. This process involves identifying a problem, gathering information, evaluating alternatives, balancing evidence, making a choice, implementing it, and assessing outcomes (Lunenburg, 2010). Informed decision-making requires understanding the influence factors, such as individual preferences, biases, external pressures, and information quality.

Heritage preservation decisions consider multidimensional criteria that have to be balanced, including modern requirements, cultural significance, architectural integrity, and historical importance (Menzel et al., 2022). Since decisions affect the longevity of these structures, a long-term perspective is needed (Liu et al., 2023). In addition, compliance with conservation regulations and legal frameworks must be ensured (Lupica Spagnolo et al., 2022). To make a decision, various stakeholders, such as historians, architects, and community members, must be involved and reach a consensus.

Heritage preservation decision-making goes beyond the technical aspects and includes educational and public outreach, effectively communicating decisions to communities, and emphasizing historical significance and justification (Lupica Spagnolo et al., 2022). This process requires a balance of technical expertise, cultural sensitivity, and long-term perspective. Decisions not only impact structures but contribute to the cultural narrative and societal understanding of a place.

1.4. Multi-Criteria Decision-Making

The Multi-Criteria Decision-Making (MCDM) process involves problem definition, criteria identification, goal setting, alternative evaluation, criteria scoring and ranking, and technique selection (Sabaei et al., 2015). After that, sensitivity analysis, interpretation, documentation, and communication are also needed for effective heritage preservation decision-making (Santini et al., 2023). MCDM techniques offer a structured and analytical approach, particularly valuable when evaluating multiple, often conflicting, criteria (Tan et al., 2021). MCDM provides a criteria-weighting framework for assessing heritage preservation, considering both technical and subjective aspects, such as aesthetic considerations, economic implications, and community sentiments. It ensures that decisions are aligned with a broad set of considerations, promoting stakeholder participation, transparency, and consensus.

MCDM facilitates forward-looking evaluations by analyzing alternatives for their lasting impacts (Santini et al., 2023), aligning with the long-term perspective in heritage preservation. The use of MCDM techniques results in a transparent and well-documented decision-making process, justifying choices to stakeholders, regulatory bodies, and the general public. It reinforces accountability in decisions, demonstrating a systematic approach beyond subjective judgments.

HBIM can offer a collaborative platform for evaluations using MCDM techniques, involving stakeholders in criteria weighting and decision-making (Tan et al., 2021), and justifying choices to them. Moreover, the visualization capabilities of HBIM enhance understanding.

1.5. Current challenges in integrating MCDM with HBIM

Preserving architectural heritage requires ensuring the longevity and cultural significance of these structures. Decision-making in heritage preservation is intricate, and it deals with the need to balance diverse criteria, engage stakeholders, comply with regulations, and plan for a sustainable future. While HBIM shows promise for preservation, its implementation faces hurdles. To reach the full potential in informed decision-making in historical building preservation, the integration of MCDM with HBIM must overcome, among others, challenges related to data, stakeholders, and processes.

1.5.1. Data challenges

The integration of MCDM with HBIM in heritage conservation is impeded by several data-related challenges that must be overcome to ensure effective decision-making and sustainable conservation practices:

- Data acquisition: Obtaining precise architectural information is affected by the diverse nature of older structures (Hossain and Yeoh, 2018). There is a wide array of systems, tools, and data sources in use (Khan et al., 2022; Mansuri et al., 2022). This situation is further magnified by the dispersion of information across digitized and non-digitized archives (Lasarte et al., 2021), impeding the seamless retrieval of data necessary for well-informed decision-making. Overcoming these obstacles demands addressing format disparities and facilitating the integration of multidimensional data (Menzel et al., 2022).
- Data management: Inefficient data management leads to redundant processes (Hossain and Yeoh, 2018). A centralized data platform could streamline access to relevant information for the right individuals within the different organizations involved in heritage preservation.
- Uncertainty integration: Accounting uncertainty in heritage buildings involves handling intricate architectural details, non-standard dimensions, age-related factors, deterioration, and historical changes (Hossain and Yeoh, 2018). Specialized analysis and approaches are necessary to integrate this uncertainty into HBIM and MCDM, acknowledging the dynamic nature of heritage buildings.
- Data reliability: The lack of comprehensive and reliable data not only introduces bias in assessments but also affects the overall efficacy of the decision-making processes (Lunenburg, 2010). Addressing incomplete or inconsistent data requires the maintenance of data quality and availability, ensuring optimal functionality of the processes.
- Criteria evaluation: The multifaceted nature of the criteria for the MCDM processes poses a complicated task in isolating and evaluating each one individually (Santini et al., 2023). Quantifying, assessing, and managing qualitative criteria, especially those that are subjective presents a challenge. Employing standardized assessments requires the establishment of common metrics or frameworks for evaluating the intangible aspects of heritage buildings (Tan et al., 2021). The difficulty lies in ensuring the consideration of all relevant criteria without oversimplification.

1.5.2. Stakeholder challenges

In addition, it is necessary to address several challenges related to stakeholders to guarantee inclusiveness and collaboration in conservation efforts:

- Public involvement: It is necessary to recognize the role of public participation in heritage conservation due to the profound social impact of historical buildings (Lupica Spagnolo et al., 2022). Disseminating knowledge on the importance of safeguarding historical legacy fosters public enlightenment. This, in turn, builds support, understanding, and a shared responsibility for protecting heritage structures. The challenge lies in aligning decisions with community expectations. Actively involving the public narrows the gap between technical intricacies and community desires.
- Stakeholder engagement: The preservation of heritage involves a multifaceted decision-making process that engages a wide range of stakeholders, including historians, architects, local communities, and regulatory bodies. Successful decision-making in this context necessitates active engagement of each stakeholder, who brings unique perspectives and priorities to the table (Liu et al., 2023). Incorporating these stakeholders' considerations fosters their interest and a sense of involvement in the projects.
- Collaboration barriers: Effective preservation of historical structures relies on collaboration between diverse professionals (Sagarna et al., 2022). The successful decision-making process in heritage preservation encompasses achieving the harmonious integration of different perspectives cohesively (Liu et al., 2023).
- Technical expertise: Ensuring efficient digitization of heritage processes requires technical skills (Lupica Spagnolo et al., 2022). The challenge lies in overcoming stakeholders' resistance to unfamiliar digital tools. Successful implementation of digital technologies relies on the active engagement and understanding of professionals across diverse disciplines. To tackle this, there is a need for capacity building in technical skills through comprehensive training programs tailored to heritage preservation (Hossain and Yeoh, 2018), and user-oriented workflows.

1.5.3. Process challenges

Furthermore, this integration is confronted with some challenges related to the process:

- Level of abstraction: The effective integration of geometric and semantic data in HBIM necessitates the standardization of data representation. Achieving an adequate level of abstraction within HBIM models requires a balance between precision and efficiency (Liu et al., 2023). The creation of highly detailed models can impose demands on resources and expertise.
- Model maintenance: The models must be designed with a forward-looking perspective, ensuring a defined long-term process for updates to keep the information current. Guaranteeing timely updates, particularly in the dynamic context of evolving preservation requirements, introduces additional challenges (Liu et al., 2023).
- Interoperability: The difficulties in achieving interoperability within HBIM arise from the interaction with the variety of systems, tools, and data sources (Khan et al., 2022; Mansuri et al., 2022). The lack of standardized processes leads to the need for synchronizing multiple tools with the existing procedures (Gerbino et al., 2021). To improve the consistency and effectiveness of decision-making, regulations and standardized processes must be implemented. Additionally, given the long-lasting nature of historical buildings, both models and processes have to maintain their viability over time.
- Resource management: Effectively managing preservation projects poses challenges in resource allocation and management (Liu et al., 2023). In projects constrained by limited budgets, successful resource management requires consideration of constraints, which can also affect the processes and the level of abstraction of models.
- Legal landscape: Navigating the legal landscape in heritage preservation involves adherence to regulations and attention to legal requirements (Lupica Spagnolo et al., 2022). Achieving regulatory compliance requires decision-makers to harmonize proposed alterations with preservation guidelines. This process often involves also documentation and thorough compliance checks.
- Adaptation to today's needs: Decision-makers must be able to navigate the tension between preservation and adaptation to meet contemporary needs. To this end, stakeholders must proactively respond to the changing contemporary demands, ensuring that decisions are in line with both tradition and today's needs (Vitasek, 2022).

2. Research objectives

Preserving and managing heritage structures is needed for maintaining architectural legacy and fostering sustainable development. The decision-making process for heritage-protected structures is complex, requiring a profound understanding of their condition, historical significance, and potential impacts of alterations. Acknowledging the challenges faced by administrations and other stakeholders, the proposed research aims to integrate HBIM with MCDM techniques.

For that, the first step is to identify potential decisions and their triggers. Additionally, the specific stage in the preservation process for each decision and the necessary and available levels of information should be understood. For instance, when deciding whether to renovate a historic building, stakeholders must make decisions based on preliminary information usually limited to old, un-updated, basic 2D plans, diverse historical documents, and visual assessments. Once the first decision to intervene or not has been made, the subsequent phases involve gathering more in-depth information. This includes testing materials, documenting installations, and obtaining precise measurements. The goal is to decipher the available information at each stage of the process and determine the decisions to be made with that information, in order to develop a process for applying MCDM techniques. This includes identifying what information is still needed, in what form, and how it can be acquired at each stage of the preservation process.

Another objective is determining the optimal way to store and manage the information needed within a common repository, specifically an HBIM model accessible to all involved decision-makers. This involves assessing the level of abstraction and the information needed for decision-making, allocating data within the data containers of the HBIM model, and connecting the retrieval process to the use of MCDM techniques. The research explores whether external tools are necessary or if the process can be directly facilitated through the HBIM model in IFC format.

Lastly, the research aims to make this information easily accessible. While acknowledging a potential learning curve, the goal is to develop a user-oriented process for collecting, inserting, organizing, and retrieving information throughout the building's life cycle. This process will enable stakeholders to apply MCDM techniques when making decisions about heritage preservation.

3. Research methodology

The proposed methodology is divided into four phases (Fig. 2), aiming to enhance decision-making processes in HBIM by integrating MCDM techniques to create a framework for heritage management and preservation delving into current practices, stakeholder needs, and digitization challenges.

3.1. Phase 1 – Holistic analysis

In this phase, the focus is on an exploration of existing heritage building management and preservation practices. A multifaceted approach encompasses a literature review, stakeholder interviews, and content analysis. Through these, the intricacies of stakeholder perspectives, decision triggers, and the benefits and limitations of HBIM will be unraveled. Additionally, the minimal data requirements for effective HBIM usage and factors influencing its adoption will be scrutinized.

3.2. Phase 2 – Optimized workflow design

Building upon the insights garnered from the holistic analysis phase, the second phase is dedicated to crafting an optimized workflow for decision-making. The patterns and critical decision points will be identified from the qualitative content analysis of phase 1. This tailored workflow will accommodate stakeholder needs, address data prerequisites, and establish coherent data structures. The output of this phase serves as a guideline for effective decision-making processes, aligned with the requirements identified in the first phase.
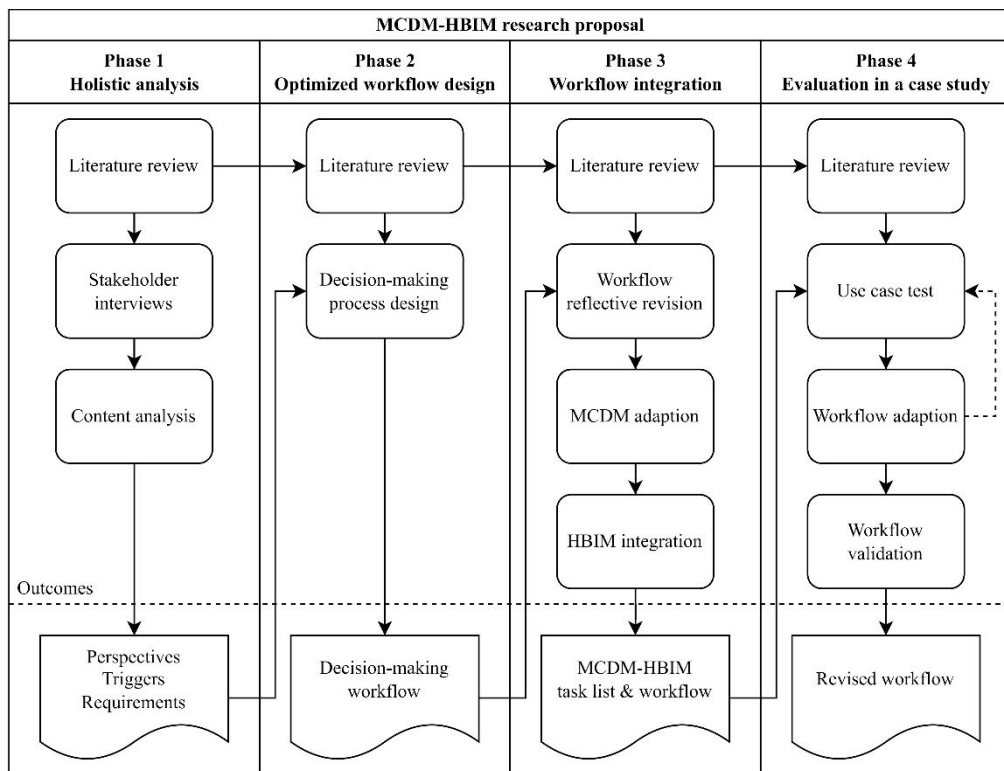

Fig. 2. research methodology.

3.3. Phase 3 – Workflow integration in MCDM and HBIM

The third phase involves a reflective revision of the workflow to adapt it to the MCDM techniques and integrate it into the HBIM framework. Employing an inductive approach, the insights from phase 2 will be synthesized to refine decision-making processes for the different stages of a building's life cycle. This phase culminates in the development of a task list and a flow chart, outlining a decision-making methodology through MCDM that caters to diverse users, addresses data uncertainty, and ensures adaptability to varying situations within the HBIM framework.

3.4. Phase 4 – Evaluation in a case study

The final phase tests the newly developed workflow in a real-world context. This practical application unveils the workflow's strengths, identifies areas for improvement, and validates its practicality. Insights gained from this phase contribute to the ongoing refinement and enhancement of the decision-making processes, ensuring their applicability and efficacy in the conservation of architectural heritage.

4. Significance and contribution

The proposal aims to enhance decision-making processes in heritage preservation by focusing on the integration of HBIM in the management of historic buildings. One of the objectives is to streamline the effective use of HBIM, fostering collaboration among stakeholders and promoting a multidisciplinary approach to heritage conservation.

The initiative can not only provide valuable insights, solutions, and practical guidelines for embedding decision-making into HBIM processes but also aims to promote heritage preservation forward by incorporating MCDM techniques. By addressing challenges such as data accuracy, stakeholder engagement, and interoperability, this approach can foster a more informed decision-making process.

5. Limitations

Despite the aspirations of the research proposal, certain limitations need acknowledgment, which could impact the implementation and outcomes of the proposed framework:

- Interdisciplinary challenges: The interdisciplinary nature of the integration, may lead to communication and collaboration challenges among experts from diverse fields.
- Resource constraints: The application of these processes can require significant time, funding, expertise, and access, often very limited, to heritage structures and data sources.
- Limitations in generalization: Generalizing findings to different heritage structures types, cultural contexts, and regions may be limited, necessitating careful adaptation and validation of the proposed framework to each case.
- Evolution of techniques and technology: The rapid evolution of MCDM techniques and HBIM technology is acknowledged as a potential limitation. This evolution might render some framework components obsolete or may require frequent updates to keep pace with advancements.

6. Conclusion

This research proposal underscores the significance of architectural heritage as tangible and intangible reservoirs of human history, advocating for their sustainable conservation. It emphasizes the importance of balancing tradition and modernity through adaptive reuse, reducing environmental impact, and safeguarding cultural identity. The integration of HBIM and MCDM is proposed as a solution to address the challenges associated with heritage preservation decision-making, considering data management, stakeholder engagement, and process intricacies.

The outlined objectives aim to identify potential decisions, develop processes for applying MCDM techniques, optimize information storage within HBIM models, and ensure accessibility for stakeholders throughout a building's lifecycle. The proposed four phases, focusing on stakeholder feedback, workflow improvement, methodology design and practical validation, can streamline decision-making processes in heritage preservation by fostering

collaboration among stakeholders. Despite its limitations, the proposed research holds the promise of contributing to the effective integration of decision-making processes into the management of historic buildings by reaching the development of a task list and a user-oriented workflow for the integration of MCDM and HBIM.

Acknowledgments

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