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Assessing the Utilization of Building Information Systems for Data-Driven Decision

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Abstract

Heritage buildings face various challenges such as degradation, structural deterioration, and loss of historical significance over time. Traditional preservation methods which involve manual processes and paper-based documentation that are consistent with historical construction techniques are inefficient or insufficient in addressing the challenges leading to the preservation of heritage buildings. This paper explores the potential for innovative approaches to heritage building preservation that leverage modern technologies like Building Information Systems (BIS), Geographic Information Systems (GIS), photogrammetry, Virtual Reality (VR) and Augmented Reality (AR) to improve effectiveness and efficiency. BIM, particularly through Historic Building Information Modeling (H-BIM), facilitates efficient management and documentation of heritage structures, empowering stakeholders to make more informed decisions. GIS applications enable interactive presentations of spatial information, enriching educational experiences and aiding in data conversion for educational materials about heritage buildings. By using these advanced technologies, people can effectively tackle preservation challenges, ensuring that heritage buildings are protected for the future.

Keywords – *Building Information Systems, Heritage Buildings, Historic Building Information Modeling (H-BIM), Building Information Modeling, Heritage Preservation*

Introduction

Heritage buildings are valuable cultural assets that contribute to the identity and heritage of communities, making their preservation important. Building Information Systems offer advanced tools and methodologies that have the potential to revolutionize heritage building preservation practices. By using BIS, stakeholders can enhance decision-making processes (Pocobelli, et al., 2018), improve resource allocation, and ensure the long-term sustainability of heritage buildings. This paper discusses the potential of using BIS to address the issues facing the preservation of heritage buildings. Modern technologies enhance the preservation of a country's history and culture by providing interactive environments with realistic depictions of historical eras (Papandreou & Vergados, 2022). Structures that no longer exist or have structural faults require documentation for virtual reconstruction, serving as an effective method of preserving the authentic image of their historic context as realistically as possible (Papandreou & Vergados, 2022) in such a manner that they can easily be experienced through modern-day technology like AR and VR. In education, the digitization of historic buildings, structures, and monuments helps engage students and deepen their understanding of the past (Vassigh, et al., 2016) by conveying the “historical, cultural and artistic meaning” of the sites (Chin, et al., 2017). Technology such as virtual reality (VR) and augmented reality (AR) can benefit tourism by serving as guides for visitors exploring archaeological and cultural sites. Digitizing culture helps preserve history, making these digitized worlds valuable resources for research and future scientific projects.

Literature review

Technological Advancements in Heritage Preservation

Heritage conservation practices have been increasingly digitized by using computers and various software tools to develop computer-based systems that simulate heritage realities and conservation conditions, to make professional work more accurate and convenient. Among these systems, the most advanced and commonly utilized is the Building Information Modeling (BIM) system, particularly in the modeling and restoration of architectural and built heritage sites (Pocobelli, et al., 2018). It is a three-dimensional (3D) computational representation that connects all available information to each 3D object of the model (Azhar, et al., 2015). One of the major advantages of using BIM systems is its interoperability. It allows different professionals in the built environment to input all the information about different components of the building into one system allowing every stakeholder to access all the information they need (Pocobelli, et al., 2018; Azhar, et al., 2015).

Building information modeling methods like 3D visualization, GIS applications, digitization, and documentation techniques, can help enrich the learning experience of students, the public, and all other stakeholders by keeping them informed on the cultural significance of heritage buildings, hence letting them make strategic decisions based on the data collected through Building Information Systems (BIS) (Ziye, et al., 2020). Buildings can also be virtually reconstructed primarily for educational and recreational purposes and quite often can even be integrated into a digital game (Papandreou & Vergados, 2022). The use of BIS facilitates distance learning as against traditional preservation methods which include documentation of building documents in archives, photographs, maps, etc. Technologies like terrestrial laser scanning and GIS offer a quick and accurate way to obtain historical building information. This approach helps avoid damage to cultural relics caused by manual operations (He, et al., 2021) such as physical measurement and documentation of building features, manual inspection and assessment of structural integrity, and hand-drawing architectural documents.

While many buildings may have remained unchanged over the years, it's important to acknowledge that their surroundings may have changed. A significant aspect of understanding the historical context of a building involves understanding the environment in which it is situated. Methods such as GIS have made it easier today to experience buildings and sites without having to visit the site. Geographic Information Systems (GIS) have been developed for spatial and non-spatial purposes in heritage conservation. GIS serves as a valuable tool for educating about cultural heritage as it can interactively present geographical and spatial information using sounds, videos, and photos (Ziye, et al., 2020). With numerous parties collecting cultural heritage data worldwide, converting this data into educational materials using technologies like GIS is essential. This approach enables the transmission of new knowledge to students (Kwok & Fan , 2016). Current traditional preservation methods are still being used by providing materials like photographs, architectural plans, and maps in archives. They, however, still fall short when it comes to visiting the site. According to (Miyoshi , et al., 2004), the digitization of geographical sites can be categorized into two methods. One involves creating them directly from aerial photographs, utilizing GPS technology. The other method involves digitizing from existing maps through raster-vector conversion techniques.

Educational and Recreational Benefits of Digitized Heritage Buildings

According to (Chin, et al., 2017; Azuma, n.d.; Zhi, et al., 2020; Pocobelli, et al., 2018; Ziye, et al., 2020), technology like BIM software, Web3D, AR, and VR in architectural visualization create an experience for stakeholders that will enable them to appreciate the cultural aspects of the building like its historical context, form, and its environment. In the context of history and archeology, "Archeoguide" is another method being used to preserve heritage buildings (Papandreou & Vergados, 2022). It involves the use of interaction technology such as augmented reality, interactive maps, virtual tours, etc. as a tool to educate tourists about a particular cultural site they are visiting. It merges virtual scenes with the real world, enhancing the user experience by presenting them on display devices (Azuma, n.d.; Zhi, et al., 2020).

During on-site visits to historic sites and buildings, tools such as tourist pamphlets, Interpretive inscriptions or informational signs, and multimedia information systems such as touchscreen kiosks are used to guide tourists around the architectural spaces. Despite the potential for these tools to be retained for further reference, there is a prevalent issue of them being discarded after the tour, thereby compromising the tourists' ability to fully engage with the experience beyond the conclusion of their visit. In some cases, there would not be a human tour guide or interpreter unless a minimum number of tourists took part in the tour. This challenge could be addressed by integrating a virtual tour guide into modern tools such as augmented reality (AR) and virtual reality (VR) technologies (Chin, et al., 2017).

Information Management in Built Environment Projects

Due to the vast amount of information being generated by different professionals in the built environment during the project's lifecycle, methods and technologies for information management such as the application of Building Information Models (BIM) should be utilized to manage this information (Bi, 2016). According to (Bi, 2016), the traditional method of managing information in the built environment is 'disordered'. It involves manual processes and paper-based documentation. This includes methods such as keeping physical files, drawings, and documents organized in cabinets or storage rooms, relying on handwritten notes and drawings for communication, and manually updating records as needed. This approach tends to be time-consuming, prone to errors, and inefficient in handling large volumes of information and does not favor collaborative work (Mazzoli, et al., 2021). The advent of BIM brought about the integration of various information from all professionals at various stages of the building life cycle which makes information sharing, collaboration, and preservation of information a lot easier.

Building conservation is a 'multi-layered process' that involves collaboration among various specialists (Pocobelli, et al., 2018). Several types of data involved in this process could potentially be incorporated into building models to enable collaboration. According to (Guo, et al., 2010), while managing building information, different professionals make use of different software systems. To successfully share and use the data generated by these software systems, a database is built to ensure continuous application of information across different disciplines to avoid duplication of inputs. The database forms the core of the information management framework, while the model serves as the carrier. This framework comprises three different layers, the data layer (database), the model layer (informational models), and the function module (the main lifecycle information model). The data layer acts as a storage platform and enables the transfer of building information amongst various professionals during various stages. Data is stored in the BIM database by professionals, facilitating its application in subsequent phases and maximizing project benefits. It contains information like forms, drawings, sketches, photographs, videos, etc. (Pocobelli, et al., 2018). The main purpose of the data layer is to ensure that all professionals and stakeholders can have enough information to perform their specific tasks conveniently. The model layer acts as a bridge between the data layer and the function module. The model layer of the management framework consists of the design information model, construction information model, and operation management information model. It comprises three main components: the design model by architects, the structural model by structural engineers, and the operations (water and electricity) model. The function module layer represents the main application throughout the lifecycle of the project where each model is a child BIM model. The function module can be adjusted or expanded based on the specific needs of the project at any given time (Bi, 2016). The function module automatically provides analysis results to the relevant professionals based on the information model.

Since construction professionals design projects independently, pipeline collision issues often arise, necessitating pipeline collision detection. Collision detection involves inspecting building components, structural elements, mechanical equipment, and utility pipelines to prevent collisions. A comprehensive pipeline collision model based on BIM ensures timely delivery of design change information by allowing for related adjustments (Guo, et al., 2010). This model contains detailed information about entity objects in the parametric three-dimensional model, visually presenting conflicts between components of the entire project as they relate to each other. Professionals can accurately identify and address problems on time, which remains beneficial even after the construction phase of the project. This extracted data is integrated into a subsystem, and corresponding detection indices, specification requirements, or empirical data are inputted to form sub-models used for collision detection. Conflicts detected during this process are highlighted to ensure prompt adjustments by the necessary party.

Historic Building Information Modeling (H-BIM)

A study by (Karasaka & Ulutas, 2023) states that incorporating Building Information Modeling (BIM) technology into historical and cultural heritage structures has given rise to Historic Building Information Modeling (H-BIM), providing an efficient means to manage and document information about heritage buildings. Historic Building Information Modeling (H-BIM) involves the design, restoration, and maintenance of historical buildings by integrating parametric data and thoroughly evaluating semantic information, thus improving the functionality of 3D models. contributes to systematic Cultural Heritage (CH) studies by integrating 3D modeling techniques and information management. The initial step involves conducting a precise geomatic survey to create accurate 3D models (Ziye, et al., 2020; Karasaka & Ulutas, 2023), with the most efficient method being the utilization of 3D point cloud data obtained through terrestrial laser scanning.

ICT and Sustainability in Heritage Preservation

A study by (Bottaccioli, et al., 2017) focuses on using Building Information Models (BIM) and Information and Communication Technologies (ICT) to reduce waste and CO2 emissions, thereby, combatting climate change and creating a more sustainable environment. ICT advancements enable real-time monitoring of a building's energy usage through sensors and communication, making this data widely available through IoT devices. Devices such as Wireless Sensor Networks (WSN) and smart meters help monitor energy consumption in buildings (Queen, 2011) while also tracking temperature and electricity usage giving insights into the building's energy usage and patterns. On the other hand, the development of digital documents with the use of BIM software creates detailed energy models of buildings and their environment. The digital models of buildings include details like construction materials and energy usage patterns (Sacks, et al., 2018). These models can simulate and predict energy usage patterns. By combining these technologies using cloud-based software, we can understand the energy usage and patterns in historic buildings to ensure that preservation efforts also focus on sustainability without compromising their historical integrity (Bottaccioli, et al., 2017). We can also assess the energy performance of heritage buildings by identifying areas of inefficiency and implementing strategies to preserve their heritage while reducing energy waste and improving environmental impact. Monitoring energy usage helps to preserve these buildings for future generations while also being environmentally responsible.

Challenges persist in using Building Information Modeling (BIM) for energy simulations, particularly regarding factors such as the specific software employed, the nature of the analysis performed, the expertise level of the model creator, the building's characteristics, and individual preferences regarding workflow organization. These aspects currently shape the extent of BIM adoption. This can be a problem for historic buildings too, as their unique characteristics may not always fit neatly into standardized software models. So, while BIM holds promise for improving energy efficiency in historic buildings, there is still work to make it more effective and user-friendly in this context (Bottaccioli, et al., 2017).

Advanced Photogrammetry and Laser Scanning Techniques in Heritage Documentation

Another building information modeling method used to preserve heritage buildings is the use of photogrammetry (Pocobelli, et al., 2018). This involves the conversion of two-dimensional images into a new three-dimensional model.

This helps to improve the user experience by introducing the 3D models into a unique environment (Papandreou & Vergados, 2022). Digital photogrammetry relies on the principle of triangulation, where images captured from various viewpoints are used to create a 3D model. Combining this method with laser scanning produces high-resolution materials textures which in turn produces detailed information on the material degradation (Pocobelli, et al., 2018; Worrell, 2015). Laser scanning allows for precise measurement of real 3D objects such as artistic statues, traditional vehicles, and historical buildings or cities significant for cultural, historical, and industrial purposes. The collected data typically consists of large-scale 3D point data, often containing millions or even billions of points (Tanaka, 2014).

Conclusion

Heritage buildings are valuable cultural assets that contribute to the identity and heritage of communities, making their preservation important. The integration of modern technology such as Building Information Modeling (BIM) technology and other advanced tools offers significant potential for revolutionizing heritage building preservation practices. By implementing BIM systems, stakeholders can enhance decision-making processes, improve resource allocation, and ensure the long-term sustainability of heritage buildings. The adoption of technologies such as GIS, digital photogrammetry, and laser scanning further enriches preservation efforts by providing accurate documentation and enabling detailed analysis of historical structures. By embracing these digital tools and methodologies, we can effectively address the challenges facing the preservation of heritage buildings and ensure that these invaluable cultural assets are safeguarded for future generations.

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