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Exploring the application of heritage building information modelling (HBIM) for heritage conservation: insights from industry practitioners

Jamiu A. Dauda [a], Neall Bower[a], Waris A. Adebisi[a], Ali Saad[b], Abdullahi B. Saka[c], Hadi Kazemi[a] and Saheed O. Ajayi[a]

[a]School of Built Environment, Engineering and Computing, Leeds Beckett University, Leeds, UK; [b]School of Architecture, Building and Civil Engineering, Loughborough University, Leicestershire, UK; [c]Westminster Business School, University of Westminster, London, UK

ABSTRACT

Heritage or Historic BIM (HBIM), a specialised application of Building Information Modelling (BIM) for the preservation and management of historic buildings, offers transformational opportunities for the heritage conservation sectors. However, this has not been fully explored, with HBIM applications mostly used as mere archival documentation for heritage architecture. As such, this study proposes to investigate the opportunities and challenges in adopting HBIM in preserving and managing heritage buildings. The study adopts a qualitative research strategy comprising literature review and expert interviews to explore the perspective of heritage conservation stakeholders on HBIM. The collected data were analysed using thematic analysis to identify the current state of HBIM adoption, its benefits, and its challenges. Findings reveal that while HBIM offers significant opportunities, such as improved archival documentation, visualisation, and maintenance planning, its adoption remains limited due to high costs, lack of expertise, and resistance to new technologies. This study acts as a reference point illuminating the need for increased awareness, training, and investment in HBIM to fully harness its potential, positioning it as a crucial tool for the sustainable management of heritage assets. This study originality is in its primary focus on HBIM, an application that has been under explored unlike BIM.

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Conservation challenges; documentation tool; heritage BIM; HBIM; interoperability; thematic analysis

1. Introduction

Building Information Modelling (BIM) is described by National Building Specification (NBS) as a process for creating and managing information on construction projects across the project lifecycle. A version of BIM that is designed specifically for heritage and architectural conservation/preservation is referred to as Heritage or Historic BIM

CONTACT Jamiu A. Dauda j.a.dauda@leedsbeckett.ac.uk School of Built Environment, Engineering and Computing, Leeds Beckett University, Leeds, LS2 8AG, UK

(HBIM).[1] HBIM was first introduced in Dublin Institute of Technology and it offers a comprehensive platform for documenting, analysing, and conserving architectural heritage using parametric objects created from physical analysis of the building and historic data through laser scanning and photogrammetric techniques.[2] The goal of HBIM is to create a robust visual and informational model with a database for preservation, as traditional methods like manual surveys and 2D drafting often fail to capture the intricate details and complexity of heritage structures.[3] Hence, HBIM acts as a digital methodology that utilises BIM capabilities against changes in buildings with respect to time.

The need to preserve the world's heritage is linked to the global climate crisis, which is driving various sectors to decarbonise including the housing sector. Buildings contribute significantly to greenhouse gas (GHG) emissions due to the energy required for construction, operation, and demolition.[4] In Europe, the housing sector features many old and historic buildings, with the UK having about 400,000 historical buildings in conservation sites.[5] These buildings protected under the Planning (Listed Buildings and Conservation Areas) Act 1990 are vital for their status, identity, economic, social, and cultural benefits[6,7] Heritage buildings are often damaged due to age and exposure to environmental changes, disaster, and excessive structural loads.[8] Thus, requiring regular maintenance, management and retrofitting to prevent failure, satisfy modern environmental standards and preserve their cultural significance.[9]

Meanwhile, modern construction techniques, particularly BIM have revolutionised the Architecture, Engineering, and Construction (AEC) industry.[10] It provides a platform for communication among stakeholders, facilitating design, review, scheduling, and planning for projects within AEC including the conservation of historic buildings.[11] Although, there is no common agreement among practitioners as to whether BIM is a revolution in the AEC industry or just a transformation of the CAD systems,[12] it is unanimously agreed that it is an innovation that has become a necessary tool in the construction industry.[13] Its success can be linked to the support received from government. The UK government published the construction strategy in 2011 which sought to reduce the cost of construction and for the first time introduced and mandated the use of BIM Level 2 on all projects by 2016.[14]

The BIM level 2 requires that all project information, documentation, and data are accessible electronically to enhance efficient delivery. BIM as a technology uses International Foundation Class (IFC) files, which are open format, platform neutral and allow information to be shared irrespective of software choices.[15] This enables collaboration and early engagement on projects by all disciplines. Although, because of the complexity of building projects, the issue of interoperability usually limits the successful operation of BIM.[16] Earlier study,[17] confirm that interoperability has many shortcomings, and the bigger and more complex buildings are, the more complicated information transfer is. Nonetheless, BIM remains effective in improving the efficacy and accuracy of project documentation.[18] Hence, although not flawless, the capabilities of BIM remain critical to the advancement of the built environment sector, and the greater the adoption rates, the more these capabilities are exploited.

Although there is continuous growth on the rate of BIM adoption, but its adoption is typically applicable to buildings under construction, rather than to existing ones.[19] Similarly, study[20] argued that while BIM is common in new buildings, it has not been well considered for heritage conservation. Previous studies[21,22] opined that implementing

BIM in heritage conservation faces several challenges, including the perception that some heritage professionals are too conservative and sceptical.[23] This may also be attributed to the high level of effort required to model and convert data into smart objects,[24] making some heritage professional favouring traditional approaches such as 2D CAD drawings,[25] numerical modelling.[26] Meanwhile, Historic England, the government's statutory advisor on the historic environment considers BIM a valuable tool in heritage projects. Given that heritage projects significantly contribute to the UK construction output, estimated at £9.6 billion annually, HBIM should be considered for the conservation of heritage.[27] HBIM seemingly offers an opportunity to address some of the longstanding challenges, but its application is yet limited. As such, this study aims to explore the application of BIM in heritage conservation in the UK. The objectives are to understand the extent of HBIM applications, opportunities, and challenges impacting HBIM adoption through review of literatures and expert interviews.

2. Materials and method

The study utilised a qualitative approach in the form of semi-structure interviews to collect data from qualified participants based on their experience with HBIM in the conservation sector. The interview questions comprise demographic data of the respondents in section 1 and ten (10) different questions including the definition of BIM, understanding of HBIM, rate of HBIM adoptions, factors and challenges of adopting HBIM in line with the study aim in section 2. The choice of qualitative approach for this study allows for comprehensive evaluation of participants' understanding. Qualitative method is well-suited for relatively underexplored areas like HBIM, where the depth of insight required would be hindered by the superficial binary outcomes often associated with quantitative method.[28] The resulting data is subjected to thematic analysis using a coding method in section 2.2.

2.1. Participants and sampling method

The sampling procedure for interviews was purposive with focus on participants that are working or have considerable engagement with the heritage building and conservation sector in the UK. The selected participants are deemed to have knowledge to provide a view on HBIM, and its adoption in the UK. Such set conditions reflect the careful selection of interviewees by the authors. Because of the limited pool of participants that have these characteristics, the purposive approach enabled utilising the authors' connections in relevant organisations such as Historic England and various Local Planning Authorities, which led to finding eight (8) interviewees in this study. Although, between 9 and 17 interview participants are considered sufficient, depending on research questions[29,30] However, the concept of 'saturation', which is the point at which no new information or themes are observed in the data should be considered in determining the number of interviewees.[31] In this study, saturation is observed after interview with eight (8) participants.

2.2. Thematic analysis

Following the interviews, the transcripts were prepared and subjected to thematic analysis described by Clarke and Braun[32] and previously adopted in earlier studies[33,34]

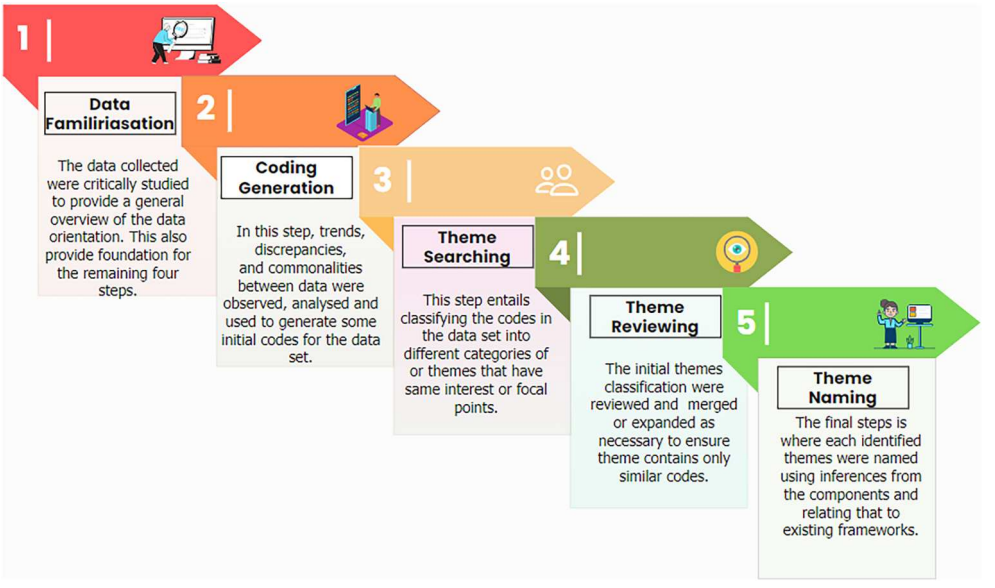

Figure 1. Thematic analysis steps adopted in this study (Source: Authors).

This study adopted the five-stage thematic analysis represented in Figure 1 because of its flexibility and in-depth analysis to identify and analyse patterns, offering rich insights into participants' experiences.

3. Results and discussions

The participants' demographics, opportunities and challenges in adopting HBIM, and emerged themes from the thematic analysis of the challenges impacting HBIM adoption were discussed in section 3.1, 3.2 and 3.3 respectively.

3.1. Demographic analysis and general discussion

The demographic distribution of respondents is presented in Table 1. The inference from this table shows least years of experience of the respondents to be five, with the most experienced having thirty years of experience. The mean year of experience is seventeen and a half, this is considered to be a good range of experience to underpin the data as claimed by Jaeger and Cardello[35] that the data quality is affected by the quality of respondents experience. In addition, 6 out of 8 (75%) of the respondents have directorship role, indicating their core relevance to decision-making process of their department or organisation. Thus, it can be established that the participants in this study possess adequate experience and knowledge of the subject matter and thus making the data collected reliable and appropriate to provide insight on the adoption of HBIM.

3.2. Opportunities and challenges of adopting HBIM

The first inference from this study indicates a consensus on the opportunities and wider benefits of HBIM applications in heritage conservation. According to the study's

Table 1. Participants' characteristics (Source: Authors).

ID	Profession	Role	Experience (years)	BIM awareness (years)	BIM Training	HBIM Adoption	HBIM value to BIM
Res-1	Architectural Technologist	Director	15	10	Self-taught	Yes	Less
Res-2	Chartered Architect	Director	30+	10	No	sometimes	Less
Res-3	Chartered Architect	Senior Architect	10	13	No	Less often	Less
Res-4	Chartered Architect	Head of Department	18	10	No	Less often	Less
Res-5	Building surveyor	Building officer	10	7	Yes	Sometimes	Same
Res-6	Chartered Architect	Director	21	10	Yes	Sometimes	Less
Res-7	Chartered Architect	Director	30	9	No	Less often	Less
Res-8	Chartered Architect	Architect	5	3	Yes	Sometimes	Same

participants, HBIM will improve collaboration, aids early clash detection, enhances data capturing and improves overall project coordination. In his response, Res-4 reckoned that

> HBIM is beyond just the 3D-visuals or Revit Model, it's actually how you operate the project, having that ability to exchange information easily and effectively between all the different parties of the project so that clashes can be detected earlier, and the risk can be effectively managed.

The responses from Res-4 summarises the sentiments of all the 8 respondents about the opportunities and potential benefits of HBIM in derisking heritage conservation projects that have widely recognised as complex and high risk in nature compared to new build.[36]

Despite the obvious potential benefits of HBIM and its application to ease the coordination of heritage projects, its application is still relatively limited and faced several challenges including difficulties in obtaining accurate data from existing structures, high costs of software and training, and a lack of tailored methodologies for heritage-specific projects. These challenges were repeatedly pointed out by Res-1, 2, 5, 6, and 8 with Res 3, 4 and 7 pointing out that heritage clients not seeing the value in HBIM due to the project's scale or complexity is also a major challenge. A comparison of responses revealed that respondents with less experience such as Res 5 and 8 were more optimistic about HBIM's potential for collaboration and decision-making, while experienced once like Res 2 and 7 were more sceptical due to cost, lack of guidance and legal requirement on HBIM implementation. Additionally, uncertainty over client demand was shared across respondents with participants claiming that HBIM is seldom requested for heritage projects, except driven by specific legal or public project requirements. These views were in line with several earlier studies who have recommended for these challenges to be studied in detail to promote BIM application.[37,38] As such, thematic analysis of the challenges facing HBIM implementation which produces 4 themes were subsequently discussed in section 3.3.

3.3. Emerged themes of challenges with using BIM for heritage

Figure 2 shows the identified challenges facing the implementation of HBIM for conservation which were subsequently discussed in detail under four distinct themes.

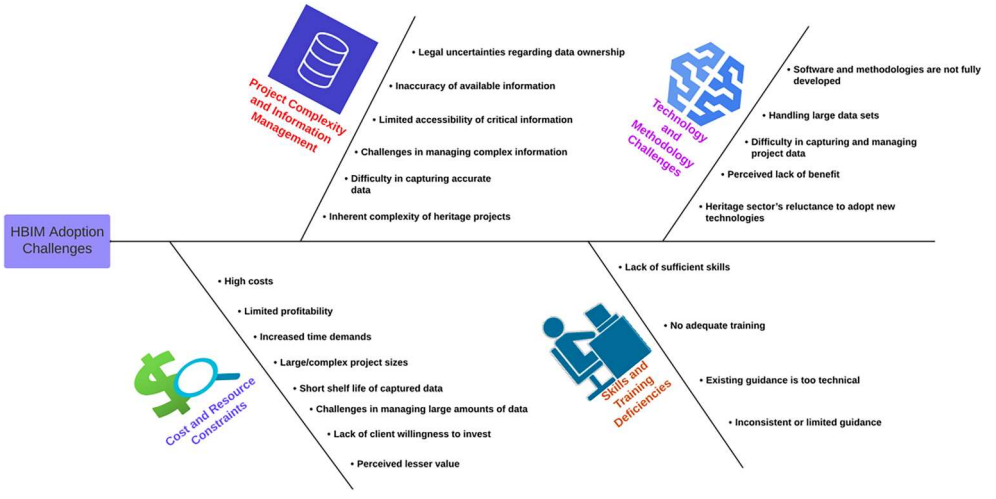

Figure 2. Challenges impacting HBIM adoption (Source: Authors own work).

3.3.1. Cost and resource challenges

The high cost associated with BIM software, hardware, and staff training and development have been identified as significant challenges impacting HBIM implementation in heritage conservation. All the respondents in this study frequently pointed to these financial burdens. Unlike BIM in new projects that have been argued that its benefit outweighs these financial burdens,[39] participants in this study argued that HBIM has less value to conservation projects and are not always required by clients hence leading to low rate of adoption. For instance, Res-7, a company director with 30 years of experience, claimed that *It's a lot of money just for something that may only be used on one project* reflecting concerns about the return on investment. Similarly, respondents revealed that most clients on heritage projects are often unwilling to invest in BIM technology. For instance, Res-4 stated that *It's really about whether the client is prepared to pay for it,* this particular response emphasises the importance of client buy-in for improved adoption of HBIM.

Beyond the initial cost, time and other resources required for HBIM adoption have also been identified as major challenges. Specifically, Res-3 emphasised the complexity in the resource's requirements for HBIM application stating that

> With an existing building, you've got to invest the time to do the model … but it's probably not as accurate as with a new build. These time-consuming processes contribute to increased project costs, especially in larger and more complex heritage projects where greater detail and more frequent updates are required due to the short shelf life of captured data'.

This is in line with the findings of previous studies[40,41] that have affirmed that high initial costs and time resources are a primary deterrent to BIM adoption in smaller firms and heritage projects, where profitability is perceived as limited. There are long-term benefits of BIM to all kinds of projects including heritage projects, but the initial investment in resources may deter smaller, low-profit margin projects, which heritage projects often are. As such, cost and resource constraints are a substantial barrier to HBIM adoption as substantiated in this study.

3.3.2. Skills and training deficiencies

Effective implementation of HBIM or any other innovative technologies in projects required sufficient training and skilling of personnel.[42] While all the respondents in this study claimed to have awareness and knowledge of BIM, only three (Res-5, 6 & 8) have obtained certification or training on BIM with the rest been either self-taught or some unstructured learning on BIM. This is situation mostly across the heritage-built sectors as claimed by Res-4

> 'I don't have any training on BIM, but I know what it is and the benefits it can provide … There is no desire to invest in any training on it and this is not only me or our company but across the sector, many of our contemporaries that I know don't channel their resources towards training employee on BIM, instead we focus on challenges of dealing with heritage building projects.

These lack of required trainings and skills have been highlighted as major challenges, with Res-1 further affirming that *We're not trained properly for it … the skill set is not quite there, especially for heritage buildings.* This gap in skills is compounded by the fact that BIM, originally developed for new construction[43] requires additional knowledge to be effectively applied to complex heritage conservations.

Unanimously across the responses, the inference from this study is that there is inadequate training specifically tailored to heritage projects. For instance, Res-8 stated that *The training we get is usually for new builds … heritage is a whole other challenge*. These findings reinforce the submission that lack of targeted training leaves professionals ill-equipped to extend BIM to handle complexities of historical conservations.[44] Meanwhile, the findings also revealed that practitioners found most existing guidance too technical or impractical for real-world applications. For instance, Res -5 claimed that … *the guidance that's out there is too complex; it's not something you can just apply easily*. This is pointing to the difficulty in using existing resources and is in line with the submission that BIM guidance available is inconsistent and limited in scope, particularly for heritage applications.[45,46] Previous studies[47,48] have highlighted these challenges of insufficient training and skilling opportunity for HBIM as BIM training programmes tend to focus on new-build contexts, neglecting the specific needs of heritage projects. To alleviate this, respondents in this study have called for the availability of comprehensive industry-wide standards and guidance on adopting HBIM as earlier recommended.[49]

3.3.3. Project complexity and information management

The two previous themes have acknowledged the need for tailored guidance on HBIM and increased cost requirements due to the complexity of heritage building projects. This means that the inherent complexity of heritage projects is a significant challenge for the successful implementation of HBIM. This study identified that the unique project complexity and information management required for heritage projects makes it difficult to capture accurate data and create reliable models that is needed to adopt HBIM. In Res-4 submission … … *the complexities of these old structures mean you're often working with incomplete or inaccurate information, which makes the whole HBIM process less reliable*. This issue is further complicated by the difficulty in managing vast amounts of data associated with historical assets as supported by existing submission.[50] Also, capturing precise data from heritage structures is very challenging because the

structure is often irregular or deteriorated.[51] This claim has been supported by the finding of this study with Res-2 directly quoted saying that *With heritage, you can't just scan a building and expect accurate results … there are hidden elements and inconsistencies that throw everything off.*

The main inference from the participants' claim is that the inconsistencies in the building information can result in building models that are not reflective of the building reality, making HBIM less effective for heritage conservation. Managing detailed historical and architectural data is essential to the adoption of HBIM, however these are often fragmented or difficult to access.[52] Thus, making information management as critical challenges to HBIM adoption as supported by Res-5 *the information we need is scattered, and not always easy to access or integrate into BIM.* Another major complication on this front are the issues surrounding legal uncertainties around data ownership and liabilities resulting from unclear regulations about who controls the information. This aligns with findings from previous studies[53,54] that have identified information fragmentation challenges and the risks of inaccurate data leading to costly project errors in heritage BIM projects. Conclusively, it is clear from the findings of this study and several others in the past that project complexity and poor information management will negatively impact the effectiveness of HBIM in heritage conservation.

3.3.4. Technology and methodology challenges

This theme comprises of technical challenges in the form of a lack of interoperability between BIM tools and other heritage-specific software. This is particularly challenging because many software and assessment methodologies for building and projects are not fully developed for heritage applications making HBIM application more difficult. These in addition to the perceived lack of benefit in using HBIM make some professionals within heritage sector's cautious to adopt new technologies, slowing progress of HBIM adoption. This is in line with the submission that pointed out that the technological limitations and undeveloped methodologies specific to heritage projects create significant hurdles for HBIM implementation.[55] For instance, Res-6 stated that … *the software we use for BIM doesn't always talk to the programmes we need for heritage work, which causes delays and extra work.* This mismatch complicates workflows and increases the time required for data integration, reducing HBIM's effectiveness in heritage contexts as discussed by other respondents including Res-1, 2, 4, 6 and 8. Meanwhile, it has submitted that the current BIM software and methodologies are not fully developed to address the unique intricacies of the heritage projects.[56] This is also supported by findings that existing BIM platforms are primarily designed for new constructions, and their application to heritage buildings is still evolving.[57] These assertions are in line with several of the respondents in this study sustaining this. For instance, Res-3 remarked that … *the tools we have are great for modern builds, but they're just not built for the challenges of heritage, there's no proper methodology yet.* This variance in BIM application approaches and lack of enough technical support to create tailored approaches for HBIM adoption leaves heritage professionals struggling to adapt generic solutions to complex, irregular structures that often encountered on heritage projects. Managing large data sets also presents technical challenges, particularly in heritage projects where point clouds, scans, and historical records can be enormous. For instance,

Res- 8 explained that *Our hardware struggles to process the sheer size of the data we collect*. This stresses the difficulty of managing large, resource-intensive datasets.

4. Implication of findings

This study affirms that BIM applications are primarily oriented towards new buildings, leaving a substantial gap in the adoption of HBIM. It identifies significant gaps in understanding, training and application of HBIM, emphasising the urgent need for further research in effective integration of strategies for heritage projects. Practically, the study calls for the actions of industry practitioners on developing cost-effective procedures for HBIM adoption. One of such approach could be creation of modular or tiered BIM packages that allow for incremental adoption based on project size and available resources.

Academically, this study underscores the need for the scholars' community to research on the development of specialised methodologies and approaches that address the interoperability challenges of BIM tools for heritage conservation. This includes extensive collaborative research to develop and validate optimised frameworks that will account for the unique complexities of heritage assets. It is highly essential that the development of this framework should be supported by case studies and pilot projects that test and refine these approaches. Such efforts will help in overcoming the rigidity and technical complexity of the current guidance, making HBIM easily adoptable by the practitioners.

In addition, technical challenges related to data irregularities in heritage projects and handling massive volumes of data implies the need for research into innovative data management that will aid BIM adoption for heritage projects. This might include the development of more efficient algorithms or software tools that can better handle the unique data requirements of historical buildings. Overall, the implication of this study is in the clarion calls for academics to support industry professionals with accessible and practical resources in form of educational materials, training suites, actionable insights and workshops that promotes HBIM adoption.

5. Conclusion

Heritage BIM has potential to be an invaluable resource in handling complex projects, demonstrating its potential to enhance conservation efforts significantly. However, its application remains limited owing to some challenges that have not been widely studied. Because of this, the study adopted a qualitative data collection by interviewing eight stakeholders working in heritage conservation sector to uncover the rate of HBIM adoption, perceived opportunities, and the challenges impacting the HBIM adoption. The qualitative data collected was subject to demographic data analysis and thematic analysis. The demographic data analysis was used to uncover the variation of responses across different characteristics of the respondents while thematic analysis was used to identify the themes of the challenges facing the adoption of HBIM.

The consensus from the participants in this study is that HBIM is currently being underused. Only one respondent answered affirmatively to HBIM adoption while the other seven claimed to use HBIM less often and sometimes under compulsory client or contract's requirements. All the participants claimed to have knowledge and awareness of HBIM

through self-taught or unstructured learning programming, claiming that there are no adequate training and development opportunities for HBIM application. A comparison of responses revealed that respondents with less experience were more optimistic about HBIM's potential for collaboration and decision-making, while the experienced one were more cautious due to cost, lack of guidance and legal requirement on HBIM implementation. It was clear from this study that the main challenges to the adoption of HBIM are high cost and resources requirement, low profit margin of heritage projects, and lack of willingness from client. Also, the complex nature of heritage projects and lack of precise building information for accurate modelling hinder the adoption of HBIM. There was also a consensus from the participants that HBIM did not equate to better results on all projects, and it was best used on larger or projects with high-profit margin, which by their nature occur less frequently. Summarily, the thematic analysis of these challenges provided four themes: cost and resource challenges; skills and training deficiencies; project complexity and information management; and technology and methodology challenges.

Although the study addressed the initial research questions, it is important to acknowledge its limitations, particularly the concentration of respondents' professions within the architectural domains. The broad and complex nature of HBIM process makes it challenging for a small sample size, focused on a certain professional domain such as the one used in this study to capture all variables that may influence the successful implementation of HBIM. Despite these limitations, this study identified the basic social, technological, economic, and environmental dependencies. These factors may impact the successful implementation of HBIM, particularly as they can occur in various combinations across project cycles. This highlights the need for multidisciplinary studies that will incorporate perspectives from other professionals such as Engineers, Archaeologists, Project Managers working in the field. In light of this, the study recommends further research that will employ quantitative methods, using the insight from this study as construct of a Likert-scale questionnaire to reach a wider audience within the heritage conservation sector. This will help to confirm the validity of the insights provided by this study and could help generalise the findings and conclusions drawn regarding HBIM adoption in the UK.

No doubt this study affirmed that Heritage BIM holds immense opportunities to transform the field of heritage conservation by providing precise, comprehensive, and integrated data that can improve decision-making and long-term management. While there are notable successes in its application, significant barriers as identified in this study still need to be addressed to ensure that Heritage BIM is not a missed opportunity but a well-utilised resource. As such, this study also recommends further commitment through focused research on HBIM from the academic community, practical solutions and industry-wide initiatives from the industry stakeholders to advance the use of HBIM in preserving and managing historical assets. Adequate investment and regulatory guidance on HBIM from government and control authorities should also be considered to fully unlock the potential of HBIM beyond it being a mere archival documentation tool.

Notes

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Notes on contributors

Jamiu A. Dauda is an Associate Professor of Sustainable Buildings and Digital Construction. His research portfolio includes dealing with challenges of ageing building stock, with a particular emphasis on the smart retrofit of historical construction. He explores innovative approaches that integrate sustainability with digital technologies to enhance the performance and longevity of existing infrastructures.

Neall Bower is a Principal Conservation and Design Officer with expertise in adaptive reuse and daylighting strategies for building retrofits. He specialises in providing heritage advice and

preparing heritage statements to support planning and listed building consent applications. His role includes advising on appropriate repair methods as part of heritage grant funding processes.

Waris A. Adebisi is a Civil Engineer and PhD Candidate at Leeds Beckett University. His research interests include sustainable infrastructure and building retrofitting. He has contributed to the analysis of UK retrofitting policies and barriers to achieving net-zero construction practices.

Ali Saad is a Lecturer in Digital Construction. His work focuses on Modern Methods of Construction (MMC), Building Information Modelling (BIM), and the psychology of innovation adoption in construction. He is actively engaged in the development of BIM tools and the digital transformation of construction workflows.

Abdullahi B. Saka is an Associate Professor in Sustainable Digital Construction and Enterprise. His research philosophy is to improve status quo and provide practical solutions to problem of productivity, safety, and sustainability in the construction and other sectors including heritage conservation sector.

Hadi Kazemi is a Chartered Institute of Building (CIOB) trustee and Course Director in Construction Project Management at Leeds Beckett University. His research spans digital transformation in construction, Industry 4.0 technologies, smart cities, IoT, and sustainable infrastructure.

Saheed O. Ajayi is a Professor of Digital Construction and Project Management. His research focuses on BIM, sustainable construction, construction decarbonisation, and digital compliance. He explores digital technologies including BIM, IoT, big data, and machine learning to advance construction informatics and support data-driven decision-making in the built environment.

ORCID

Jamiu A. Dauda http://orcid.org/0000-0001-9332-1986