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DEVELOPING A CONCEPTUAL PROJECT FRAMEWORK FOR BLOCKCHAIN-ENABLED HERITAGE BUILDING INFORMATION MODELLING (HBIM) IN MALAYSIA

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Abstract

The challenges in heritage building documentation and management in Malaysia highlight the need for a more secure and integrated digital framework. Although Heritage Building Information Modelling (HBIM) has improved digital documentation and lifecycle management, current practices remain constrained by data fragmentation, limited transparency, and inefficient stakeholder collaboration. While blockchain technology offers considerable potential to enhance data security and trust, its integration with HBIM in heritage conservation projects remains underexplored. This paper aims to develop a conceptual framework in exploring the interrelated themes influencing the implementation of blockchain integration with HBIM in Malaysian projects. Using a qualitative approach, semi-structured interviews were conducted with industry professionals, and the data were analysed using thematic analysis. The proposed conceptual framework is empirically informed by practitioner interviews, allowing the study to capture both technological possibilities and implementation realities within the Malaysian heritage project context. The findings suggest that blockchain-enabled HBIM has the potential to strengthen data integrity, transparency, traceability, stakeholder accountability, and lifecycle decision-making, although these benefits require further validation through pilot implementation. Future research should further validate the proposed framework through pilot projects, and blockchain governance guidelines tailored to the Malaysia's heritage conservation sector.

Keywords: Heritage Building Information Modelling (HBIM), Blockchain Technology, Blockchain-HBIM framework, Malaysia

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INTRODUCTION

Heritage buildings represent irreplaceable repositories of cultural identity and architectural legacy. In Malaysia, only approximately 183 buildings have been gazetted as national heritage, yet many continue to deteriorate due to poor documentation, insufficient maintenance records, and limited technology adaptation. These systemic deficiencies threaten the country's cultural values and underscore the urgent need for more robust digital frameworks for heritage building management (Ismail et al., 2026). It is further complicated by fragmented documentation, inconsistent maintenance records, limited digital heritage databases, and the absence of integrated systems that can support long-term monitoring and accountability across multiple stakeholders.

Heritage Building Information Modelling (HBIM) has emerged as a promising approach to addressing these challenges. HBIM enables the creation of comprehensive digital representations of heritage assets, facilitating documentation, lifecycle management, condition monitoring, and conservation planning (Baharuddin et al., 2024; Sampaio et al., 2021). It is widely regarded as one of the most reliable tools for the digitisation and management of historical building information (Baharuddin et al., 2023). However, despite its recognised potential, HBIM adoption in Malaysia remains at a nascent stage, constrained by the demand for specialised skills, limited collaboration among stakeholders, high costs of scanning equipment, and the absence of standardised protocols (Ismail et al., 2026; Baharuddin et al., 2024; Yusoff & Brahim, 2021; Ali et al., 2018). Notably, HBIM is not currently required as part of Conservation Permission submissions to the Malaysia National Heritage Department (JWN). This indicates an important institutional gap, as HBIM-based documentation has not yet been acknowledged into conservation procedures, heritage asset monitoring, or formal digital record-keeping practices under Malaysia's heritage-management framework.

According to Zhou et al., (2024) and Adegioriola et al., (2021), critical limitation of current HBIM practice concerns data security, integrity, and stakeholder trust. Heritage conservation involves multiple stakeholders whose decisions must be transparent and accountable, yet existing systems remain vulnerable to data fragmentation, unauthorised access, and the absence of a single source of truth. On the other hand, blockchain technology, as a decentralised and distributed ledger characterised by immutability and traceability, offers a compelling solution to these challenges transparency (Zhou et al., 2024; Rubino et al., 2024). In the Architecture, Engineering, and Construction (AEC) industry, blockchain has been increasingly explored for enhancing data security, information sharing, and collaborative decision-making. Recent studies have demonstrated its applicability to cultural heritage, including provenance verification, digital rights management, and decentralised collaboration in

restoration projects (Rubino et al., 2024; Zhou et al., 2024; Vacchio & Bifulco, 2022).

Nevertheless, the integration of blockchain with HBIM for heritage conservation remains largely underexplored, particularly in the Malaysian context. Although previous studies have examined HBIM adoption and blockchain applications separately, limited research has explored how blockchain-enabled HBIM can be conceptualised as a project-level framework for heritage conservation, especially in Malaysia. Existing studies also provide limited empirical insight into practitioner perceptions, institutional readiness, data-governance challenges, and stakeholder coordination in the Malaysian heritage sector. While Malaysia has taken initial steps towards blockchain adoption across sectors such as manufacturing, healthcare, and real estate (Salleh et al., 2023; Hira et al., 2022), persistent barriers including limited technical expertise, high implementation costs, and the absence of comprehensive regulatory frameworks suggest that sector-specific investigation is essential. Therefore, this paper aims to develop an empirically informed conceptual project framework for blockchain-enabled Heritage Building Information Modelling (HBIM) in Malaysia.

LITERATURE REVIEW

Heritage Building Information Modelling (HBIM): Concept and Development

Heritage Building Information Modelling (HBIM) represents the application of Building Information Modelling (BIM) technology to the documentation, conservation, and management of historic structures. First proposed by Murphy at the Dublin Institute of Technology, HBIM is a system for modelling historic structures from laser scan and photogrammetric data using BIM software, whereby parametric objects representing architectural elements are mapped onto survey data to construct comprehensive digital models (Ismail et al., 2021; Ali et al., 2018). The methodology encompasses three major workflow stages: data acquisition, data processing, and three-dimensional modelling (Baharuddin et al., 2023; Salleh et al., 2023; Ali et al., 2018). Unlike conventional BIM for new construction, HBIM requires a distinct perspective that accounts for historical construction techniques, material degradation, and the complex geometries characteristic of heritage assets (Sampaio et al., 2021). HBIM is widely regarded as one of the most reliable tools for the management and digitisation of documents associated with historical buildings and artefacts, enabling the storage of both graphical and non-graphical information within semantically enriched parametric models (Baharuddin et al., 2023; Ali et al., 2018).

HBIM facilitates improved documentation, lifecycle management, condition monitoring, and conservation planning by integrating digital representations across the building lifespan (Sampaio et al., 2021). It creates a collection of historical data and different types of design that result in automated documentation for precise preservation and conservation.

Furthermore, HBIM supports interdisciplinary collaboration by providing a centralised platform for data exchange and information management, enabling stakeholders such as architects, engineers, conservators, and project managers to work within a shared digital environment (Adegioriola et al., 2021; Sampaio et al., 2021; Zhou et al., 2024). Studies have also demonstrated the utility of HBIM for facility management, structural analysis, augmented and virtual reality applications, and fire safety design in existing buildings (Adegioriola et al., 2021). The technology has been described as a traceable and sustainable method of lifecycle information management, with a central database that allows easy retrieval, extraction, and use of various types of architectural heritage information (Agwa and Celik, 2025).

HBIM Adoption in Malaysia: Status and Challenges

Despite the global recognition of HBIM's potential, its adoption in Malaysia remains at a nascent stage. Within Malaysia, the value of HBIM should not be limited to three-dimensional modelling but should also be understood in relation to conservation permission, measured drawing records, maintenance documentation, condition assessment, heritage databases, and coordination between heritage agencies, local authorities, managers, consultants, building owners, and conservators. Salleh et al. (2022) attributed this to the demand for new skill sets, including three-dimensional modelling expertise, a thorough understanding of the approach, extensive collaboration requirements, and the psychological challenges of transitioning to new working paradigms. Ismail et al. (2026) confirmed that current facility management practices for heritage buildings in Malaysia do not employ advanced technology for upkeep and maintenance, particularly in producing dilapidation reports and measured drawings (Yusoff and Brahim, 2021). Ismail et al. (2021) found that while awareness of HBIM is increasing among stakeholders, significant challenges persist in terms of data management, collaboration, and system reliability. The challenges restricting BIM implementation in heritage buildings were categorised into three elements: people, process, and technology (Yusoff & Brahim, 2021). Additionally, Malaysia also faces additional barriers, including limited historical datasets, high costs associated with advanced scanning equipment, and the absence of standardised HBIM protocols for heritage assets (Jalaluddin, 2025; Ismail et al., 2021).

Blockchain Technology and Its Potential for Heritage Data Management

In the heritage domain, blockchain has been identified as a potential promising tool for addressing persistent challenges related to data integrity, provenance verification, and collaborative decision-making. It has been explored for cultural heritage preservation, particularly in addressing issues related to data authenticity and long-term digital preservation. Blockchain properties have led to its increasing adoption in the Architecture, Engineering, and Construction (AEC) industry for enhancing data security, information sharing, and trust among stakeholders (Zhou et al., 2024). Zhou et al. (2024) proposed the Architectural Heritage Restoration Distributed Common Data Environment (AHR-DCDE) framework, integrating blockchain and InterPlanetary File System (IPFS) technologies to create a decentralised collaborative design process that achieves data immutability, traceability, and efficient large-scale file processing. The framework was validated through a heritage restoration project in Wuhan, China, demonstrating significant improvements in data security and collaborative efficiency (Zhou et al., 2024). Recent studies have also linked blockchain with Web3 and decentralised digital heritage systems, highlighting its potential to support more open, distributed, and user-centric heritage data ecosystems (Rubino et al., 2024).

However, the integration of blockchain with HBIM remains relatively scarce in the literature. Zhou et al. (2024) noted that while blockchain exhibits considerable promise for mitigating cybersecurity threats in collaborative HBIM projects, its integration into Common Data Environment management for architectural heritage restoration encounters obstacles, including the uniqueness and complexity of historical buildings, which often lead to large and complex HBIM models. The management of architectural heritage using digital technologies, while making the process of saving and updating documents more agile and accessible, also introduces vulnerabilities related to data tampering and the lack of a single source of truth among diverse stakeholders (Sampaio et al., 2021). Adegoriola et al. (2021) highlighted that new research directions are being geared towards leveraging emerging technologies to optimise heritage building maintenance, yet acknowledged that the process is not yet efficient. These findings collectively suggest that while blockchain-enabled HBIM holds significant promise for improving data integrity, transparency, and stakeholder coordination in heritage conservation, substantial barriers, including limited technical expertise, high implementation costs, and the absence of regulatory and standardisation frameworks, must be addressed to achieve effective adoption, particularly in developing contexts such as Malaysia (Jalaluddin, 2025; Zhou et al., 2024; Salleh et al., 2022).

This highlights the need for a framework derived from practitioner insights. Unlike existing blockchain-HBIM studies that primarily focus on

technical architecture, decentralised data storage, or general digital heritage applications, this study focuses on the Malaysian heritage conservation context and develops a practitioner-informed project framework that links the blockchain potential with HBIM adoption, data-management problems, implementation barriers, and institutional readiness.

RESEARCH METHODOLOGY

This study adopts a qualitative research approach to develop a conceptual framework to captures the interrelated themes influencing the implementation of blockchain integration with HBIM in Malaysia. It is chosen because blockchain-enabled HBIM remains an emerging and underexplored phenomenon in Malaysian heritage conservation. The approach allows the study to examine professional perceptions, constraints, institutional conditions, and implementation requirements that may not be adequately captured through quantitative methods at this exploratory stage. According to Jabareen (2009), in qualitative research, a conceptual framework can be developed from themes identified in the data and organised to explain the key dimensions and relationships underlying the phenomenon being studied.

Data Collection and Analysis

Data were collected through semi-structured interviews. Participants were purposively selected based on their expertise and direct involvement in heritage building projects, BIM implementation, or digital technology adoption within the Malaysian construction and conservation sectors.

The participants consisted of individuals with minimum five years of experience in their respective fields. Participants were selected from Kuala Lumpur and Selangor, as these regions host significant heritage assets and active government or private heritage projects. Participants were contacted through professional networks and social media platforms such as WhatsApp, and email. Detailed notes were also taken to supplement the recordings. To enhance the response rate and broaden the range of perspectives, snowball sampling was employed. At the conclusion of each session, participants were invited to recommend other potential participants with relevant expertise in heritage building conservation or BIM.

Table 1: Details of Interviewees

Interviewee	Position	Year of Professional Experience
P1	Curator	15 years
P2	Conservator	17 years
P3	Assistant Curator	10 years
P4	Government Officer	8 years

Interviewee	Position	Year of Professional Experience
P5	BIM Expert	16 years
P6	Architect	15 years
P7	Project Management Executive	5 years

Although the number of participants was limited, the selected participants represented relevant professional roles in heritage conservation, project management, and BIM practice. This was considered appropriate for an exploratory qualitative study seeking in-depth practitioner insight rather than statistical generalisation.

The interview data were analysed using thematic analysis. The analysis followed the practical guidance provided by Braun and Clarke (2022), informed by the widely adopted six-phase approach to thematic analysis. The process involved data familiarisation, generation of initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. Data collection was considered sufficient when repeated responses began to emerge, and no substantially new themes were identified from subsequent interviews. This indicator was used to consider that thematic saturation had been reached within the scope of the study.

The analysis began with repeated reading of interview notes and transcripts to gain familiarity with the participants' views. Meaningful statements related to HBIM adoption, blockchain integration, heritage data management, stakeholder coordination, and implementation barriers were then identified and assigned initial codes. The initial codes were compared across participants and grouped into related categories. These categories were then refined into sub-themes, including technological readiness, documentation fragmentation, data security, auditability, collaboration, cost, regulatory support, and resistance to change. Through this process, four overarching themes were developed: current awareness and adoption, data management challenges, perceived potential benefits of blockchain, and barriers to adoption. The proposed framework was developed by linking the four themes to the implementation logic of blockchain-enabled HBIM. Therefore, the framework is conceptual in structure but empirically grounded in the thematic patterns derived from practitioner interviews. To enhance trustworthiness, the coding process was reviewed against the interview data to ensure that the themes accurately reflected participants' responses. The use of purposive sampling, participant role diversity, systematic coding, and theme refinement helped improve the credibility and dependability of the qualitative findings.

FINDINGS AND DISCUSSION

The thematic analysis of semi-structured interviews revealed four overarching themes shaping the implementation of blockchain integration with HBIM in Malaysia: (i) current awareness and adoption, (ii) data management challenges, (iii) perceived benefits of blockchain, and (iv) barriers to adoption. These themes collectively explain both the need for integration and the conditions influencing its feasibility, as reflected and further discussed in the results shown in Figure 1.

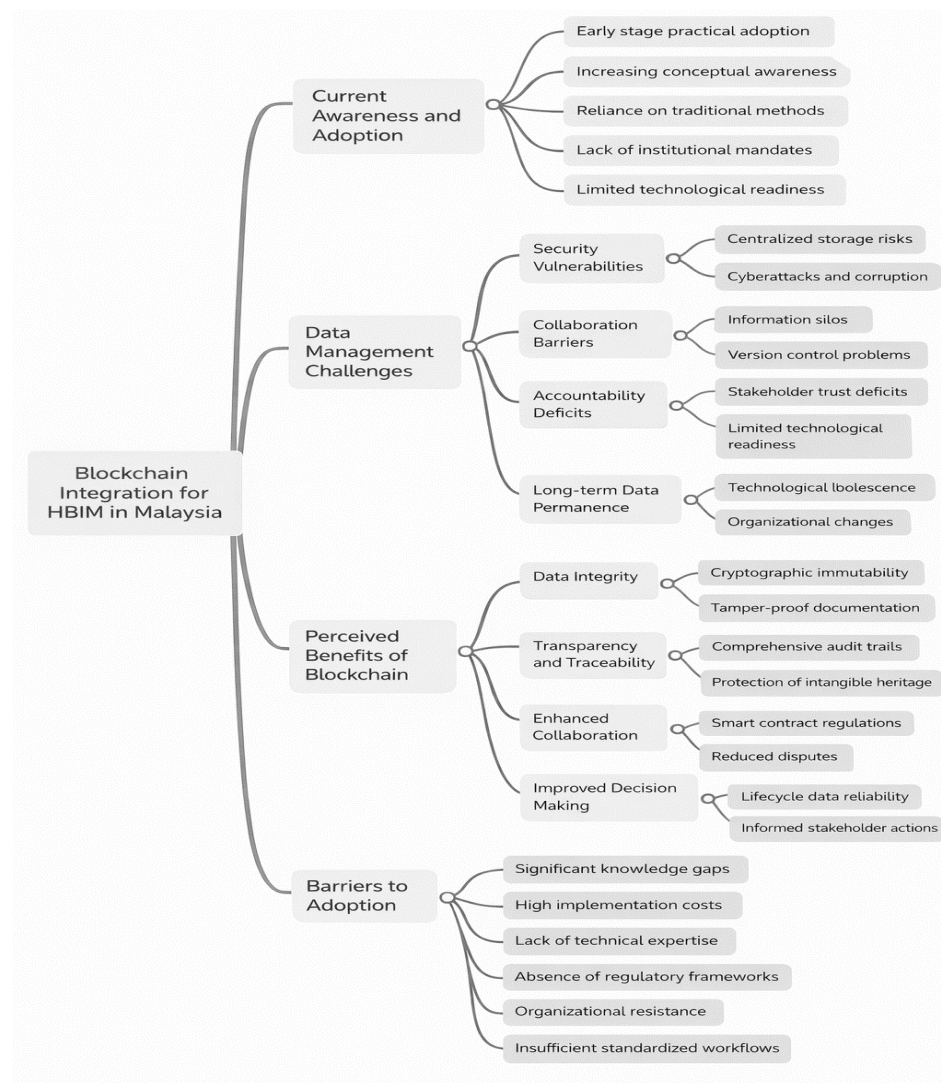


Figure 1: Thematic analysis on blockchain-HBIM integration in Malaysia

Current Awareness and Adoption of HBIM in Malaysia

Participants recognised HBIM as a valuable platform for integrating historical documentation, structural information, and lifecycle data within a unified digital environment. Despite this recognition, implementation remains limited, with most organisations continuing to rely on conventional documentation practices. As participants mentioned, “adoption of HBIM is very limited” and that most agencies still rely on “manual documentation methods such as manual measurements, photography, and manual defect mapping,” mainly due to limited budget and technical expertise (P2, P3, P7). The findings indicated that awareness of HBIM among heritage professionals in Malaysia is increasing; however, its practical adoption remains at an early stage.

This gap between awareness and adoption suggests a readiness deficit, where stakeholders acknowledge the benefits of HBIM but lack the institutional and technical capacity to implement it effectively. This finding aligns with previous studies such as Ismail et al. (2021) highlighting the slow adoption of BIM-related technologies in Malaysia due to skill shortages, high costs, and organisational inertia. From a theoretical perspective, this reflects weak facilitating conditions and high effort expectancy, which constrain adoption despite positive perceptions. The absence of regulatory mandates, particularly the lack of HBIM requirements in conservation approval processes, further reinforces this limitation. As such, awareness alone is insufficient to drive adoption; it must be supported by institutional frameworks, policy enforcement, and capacity development. These responses indicate that HBIM awareness is developing among Malaysian heritage practitioners, but awareness has not yet translated into consistent project-level implementation.

Challenges in Heritage Building Data Management and Collaboration

The interview findings reveal that challenges in heritage building data management are deeply systemic and extend beyond isolated technical limitations. One participant explained that heritage projects often face delays because “documents get lost” or different parties work with “different versions,” suggesting that fragmented communication and inconsistent records remain major project coordination problems. Heritage projects often involve architects, conservators, engineers, contractors, and public agencies, yet existing HBIM practices frequently lack an integrated data environment. This leads to information silos, inconsistent data sharing, version control conflicts, and communication inefficiencies. As a result, project coordination becomes more difficult, increasing the likelihood of delays, duplication, and inconsistencies in documentation and decision-making.

Another dominant issue is the vulnerability of centralised storage systems, which expose heritage records to risks such as cyberattacks, data

corruption, and unauthorised modification. These data-management problems are particularly critical in heritage conservation because documentation must remain accurate, traceable, and accessible across long periods of maintenance, repair, restoration, and official review.

The findings also highlight limited transparency and accountability in current systems. Without clear audit trails, it is difficult to verify who made changes, trace decisions, monitor material usage, or confirm compliance with conservation requirements. This lack of traceability reduces trust among project participants and weakens confidence in digital heritage management processes.

A further concern relates to long-term data permanence as highlighted by few of the participants (P1, P2, P5). Existing systems often do not provide sufficient assurance that heritage information can be preserved and accessed consistently across future technological, organisational, or institutional changes. This raises important concerns for heritage asset management, where continuity of information is essential for long-term conservation planning and intervention.

Participants (P5, P7) also highlighted that current HBIM practices are constrained by broader data governance limitations rather than by technical issues alone. Weaknesses in security, collaboration, transparency, and permanence reduce the effectiveness of HBIM in supporting heritage conservation. These findings indicate that current HBIM practices are constrained by systemic data governance limitations, which undermine their effectiveness in heritage conservation. In Malaysia, such challenges may affect the reliability of conservation records, measured drawings, dilapidation reports, maintenance histories, and documentation submitted to heritage agencies or local authorities. These challenges serve as primary drivers for the need to integrate blockchain technology, as they directly correspond to the capabilities that blockchain is designed to address.

Perceived Benefits of Blockchain Integration with HBIM

The findings indicate that participants perceived blockchain as having potential to improve HBIM-based heritage building management, particularly in relation to data integrity, traceability, transparency, and stakeholder trust (P1, P2, P3, P4, P6). Participants generally linked these benefits to blockchain's core features, particularly decentralisation, immutability, transparency, and security, which they considered highly relevant to the long-term management of heritage information.

One of the most frequently emphasised benefits was data integrity and immutability. Participants viewed blockchain as a secure way to preserve heritage records without the risk of unauthorised alteration (P3, P6). This perception is consistent with the literature, which explains that once validated, blockchain records cannot be changed or removed, thereby improving the reliability of stored

data (Zhou et al., 2024). In the interviews, participants associated this feature with stronger protection of heritage documentation, especially in comparison with centralised storage systems that are more vulnerable to tampering or loss.

A second important benefit identified by participants was transparency and traceability. Several participants (P2, P6) believed that blockchain could provide a clear and verifiable history of actions, updates, and decisions related to heritage assets. This would allow stakeholders to trace who made changes, when they were made, and what information was involved. Such a view aligns with existing research showing that blockchain supports traceability, accountability, and resistance to manipulation in collaborative digital environments (Zhou et al., 2024). Participants considered this especially valuable in heritage projects where documentation accuracy and accountability are essential.

Participants (P2, P4) also highlighted enhanced collaboration and trust as a major benefit. They suggested that blockchain could support a more reliable shared environment for multiple stakeholders, including managers, consultants, and authorities. By improving confidence in the accuracy and ownership of shared data, blockchain was seen as a tool that could reduce disputes and strengthen cooperation. This supports previous work which notes that blockchain can enhance information sharing, trust, and collaborative project delivery in HBIM-related applications (Zhou et al., 2024).

Finally, participants also linked blockchain integration with improved decision-making. They believed that more secure, transparent, and trustworthy data would help stakeholders make better-informed decisions throughout the heritage building lifecycle. Overall, the findings suggest that blockchain is perceived not only as a technical solution, but also as a governance mechanism that can strengthen data reliability, stakeholder trust, and long-term heritage management. However, these benefits should be interpreted as perceived potential rather than confirmed performance outcomes, as this participants of this study did not involve in the development, testing, or piloting of an actual blockchain-HBIM system.

Barriers to Blockchain-Enabled HBIM Adoption

The findings indicate that, despite the recognised benefits of blockchain integration, the adoption of blockchain-enabled HBIM remains constrained by a range of organisational, technical, financial, and institutional barriers. These barriers suggest that implementation is not merely a matter of technological availability, but depends on broader conditions of readiness, capability, and support.

Technical and financial barriers were also strongly evident. This concern was consistent with participants' views (P3, P4, P5, P7) that the main issues are "cost, lack of standardized workflows, and professionals who

understand both heritage conservation and BIM technology.” Participants pointed to the complexity of integrating blockchain with existing digital systems, particularly where organisations already face limitations in software capability, infrastructure, and specialist expertise. High implementation cost further compounds this challenge, making adoption difficult for institutions with constrained financial resources. This reflects previous findings that heritage-focused digital systems are often hindered by the cost of model development, hardware and software limitations, and the need for specialised competencies (Lovell et al., 2023; Lovell et al., 2025). Resistance to change further complicates adoption. Several participants (P3, P4, P5) suggested that established practices and institutional inertia continue to discourage the transition to new digital systems. This indicates that adoption is influenced not only by perceived usefulness, but also by effort expectancy and facilitating conditions.

Across the themes, a broader causal pattern can be observed: existing data management problems create the need for transformation, and the benefits of blockchain justify interest in adoption, yet implementation remains limited by weak organisational readiness, low awareness, and insufficient institutional support. The findings is further illustrated as a conceptual project framework to explain the conditions influencing the adoption of blockchain-enabled Heritage Building Information Modelling (HBIM) in Malaysian heritage conservation projects.

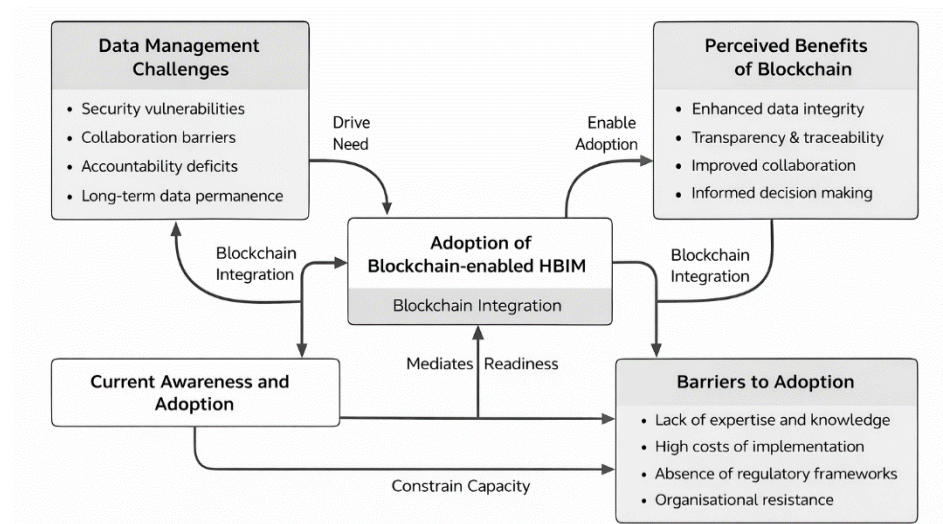


Figure 2: Conceptual project framework for blockchain-enabled HBIM in Malaysia

As illustrated in Figure 2, the framework integrates four interrelated themes: Data Management Challenges, Current Awareness and Adoption, Perceived Benefits of Blockchain, and Barriers to Adoption. At the centre of the framework is the Adoption of Blockchain-Enabled HBIM, representing the proposed integration of blockchain capabilities into HBIM-based information management processes. The conceptual framework explains blockchain-enabled HBIM adoption as the result of interactions among data management challenges, stakeholder readiness, perceived benefits, and implementation barriers. Data management problems, including security vulnerabilities, collaboration difficulties, accountability gaps, and concerns over long-term data permanence, create the initial need for improved heritage information management. These challenges motivate consideration of blockchain integration but do not imply that blockchain will automatically resolve existing weaknesses. Current awareness and adoption influence implementation readiness, as successful integration depends on stakeholders' understanding, acceptance, experience, and organisational preparedness. Limited awareness may restrict the ability to evaluate blockchain applications, build internal capabilities, and integrate the technology into existing HBIM workflows.

At the same time, perceived benefits, such as improved data integrity, transparency, traceability, collaboration, and decision-making, provide the value justification for adoption. However, implementation may be constrained by limited expertise, high costs, inadequate regulatory support, and organisational resistance. The framework therefore presents adoption as a balance between technological need, readiness, perceived value, and constraints. From a project perspective, the framework supports systematic assessment of information-management weaknesses, organisational readiness, expected benefits, and implementation risks. It should be viewed as a conceptual project-level structure that supports further empirical validation and future research on practical, governance, regulatory, and technical implementation pathways.

CONCLUSION

This study developed an empirically informed conceptual project framework for blockchain-enabled Heritage Building Information Modelling (HBIM) in Malaysia. Based on semi-structured interviews with heritage project and digital construction practitioners, the study has identified four interrelated themes: current awareness and adoption, data-management challenges, perceived potential benefits of blockchain, and barriers to adoption. The study contributes to the literature by positioning blockchain-enabled HBIM as a socio-technical approach to heritage data governance rather than merely a technological innovation. Practically, the framework provides a structured reference for

relevant stakeholders seeking to improve documentation, traceability, accountability, and stakeholder coordination in heritage conservation. However, this study is limited by its exploratory qualitative design and relatively small number of participants. The proposed framework has not yet been tested through system development or real-world pilot implementation. Therefore, the findings should be interpreted as practitioner-informed conceptual insights rather than evidence of technical performance.

The findings instead indicate perceived potential, which requires further validation through pilot implementation and technical assessment. It is recommended for further research should also examine integration with national's documentation requirements, HBIM data standards, blockchain governance guidelines, interoperability testing, stakeholder training, and long-term digital preservation protocols.

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