

Exploring the Factors for the Use of Building Information Modelling in Historic Buildings

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Abstract: Global concern in the preservation of buildings has been increasing rapidly. Building information modelling (BIM) offers excellent opportunities to improve conservation practice in such buildings. This study ascertains what factors affect BIM adoption in historic buildings, taking specifically the case of Liao Cheng. The quantitative method was applied using an online questionnaire sent to 310 recipients representing experts in heritage conservation. The major challenges that emanate from the findings are: (1) the high cost of BIM implementation, (2) public awareness or specialised training and (3) dependence on political and organisational support. The argument is constructed in an exclusively diverse way for these challenges through the views of professionals from both China and Malaysia. Dealing with such issues might greatly improve BIM adoption. In this line, the study puts forward that interventions would have to result in specialised training programmes, policy frameworks and relevant BIM tools. Further research should include longitudinal studies, cross-cultural studies and integrating BIM with other emerging technologies for further studies in this field. Such findings may substantially help the employers who are the decision-makers or policy framer in promoting the awareness of adopting BIM for the preservation of historic buildings.

Keywords: Building information modelling (BIM), Historic buildings, Heritage conservation, Digital documentation, Sustainable preservation

INTRODUCTION

Building information modelling (BIM) is increasingly acknowledged as a vital tool in conserving historic buildings. It enables the generation of precise digital models, thereby, augmenting construction productivity and enhancing the accuracy of preservation efforts. This study investigates the factors influencing BIM adoption in historic buildings, particularly in Liao Cheng, Shandong Province, China, to address the gap in current research and provide insights into overcoming the challenges faced in heritage conservation. The rationale for this study stems from the need to preserve historic buildings more effectively and leverage modern technology to enhance conservation efforts (Angeloni et al., 2023). The BIM encapsulates complex architectural details, forming the basis for efficient maintenance and restoration strategies (Karasaka and Ulutas, 2023). The fusion of digital documentation with

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physical preservation through BIM provides a holistic approach to maintaining and restoring heritage structures (Angeloni et al., 2023). This comprehensive documentation is crucial for managing historical properties and it promotes sustainable and informed decision-making over time (Alshawabkeh, Baik and Miky, 2021).

Despite BIM's promising capabilities, its integration into heritage conservation projects faces several challenges that need to be addressed. These include high costs, a steep learning curve and a lack of specialised training programmes, particularly in historically rich regions like Liao Cheng (Khalil and Stravoravdis, 2022; Angeloni et al., 2023). The combination of BIM with ground penetrating radar and photogrammetry can enhance the reconstruction of historical sites but is restricted by high costs, a steep learning curve and a need for specialised BIM training for heritage applications (Ma et al., 2022). Cultural and economic factors also present obstacles to the assimilation of BIM into historic preservation. When combined with Internet of Things (IoT) technologies, BIM can substantially improve the data management and operational efficiency of historic buildings (Yuan et al., 2022). However, its widespread adoption remains limited. Additional research is needed to overcome these barriers, as traditional conservation communities may resist modern methods due to fears of losing traditional techniques (Alshawabkeh, Baik and Miky, 2021).

In urban areas like Liao Cheng, terrestrial laser scanning (TLS) and photogrammetry are instrumental in creating accurate 3D models that aid the preservation of historic buildings and foster sustainable urban development (Alshawabkeh, Baik and Miky, 2021; Bevilacqua et al., 2023). The success of conservation planning relies on this integration and the effectiveness of these technological interventions is contingent on their adaptation to local contexts and the active participation of all stakeholders (Alshawabkeh, Baik and Miky, 2021). This study seeks to identify and address the obstacles impeding the enhancement of BIM adoption in conserving historic buildings (Yuan et al., 2022). Incorporating BIM technologies in heritage conservation is paramount, as it fills a significant void in both academic research and practical application. It holds the potential to shape policy-making and strategic planning in preserving historic buildings (Solak, 2021).

LITERATURE REVIEW

Building information modelling (BIM) is emerging as a crucial tool in conserving historic buildings, enabling comprehensive documentation and effective management, thereby, playing a significant role in heritage

preservation. While extensive research has been conducted on BIM's use in modern construction, there is a notable gap in its application to historic buildings. This study addresses this gap by focusing on the unique challenges and requirements of implementing BIM in heritage conservation projects (ElWahab, Bakr and Raslan, 2019). The capacity of BIM to create accurate 3D models of historical structures facilitates a deeper understanding and preservation of architectural heritage (Ferro, Brutto and Ventimiglia, 2023). Standard BIM methodologies often fall short in addressing the unique needs of historical structures. Modifications, such as integrating laser scanning and photogrammetry, are necessary to capture intricate architectural details and historical accuracies (Khalil and Stravoravdis, 2022; Karasaka and Ulutas, 2023). These adjustments are critical for capturing the intricate details and historical accuracies unique to each heritage site (Abobakr and Reem, 2019). Consequently, advanced technologies like laser scanning and photogrammetry are integrated with BIM to improve the precision of heritage conservation efforts (Khalil and Stravoravdis, 2022).

The adoption of BIM technology in heritage conservation is often hindered by the high initial costs associated with software acquisition and specialised training (Cali, De Moraes and Valle, 2020; Cai et al., 2025). A review of the economic barriers reveals the substantial initial investment in BIM software and the ongoing costs related to data management and maintenance (Shin and Kim, 2021). In many regions, particularly those with limited budgets, these costs can significantly deter the wider implementation of BIM in historic building conservation projects (Al-Bayari and Shatnawi, 2022). Moreover, the economic challenges are compounded by the lack of financial incentives and dedicated funding for cultural heritage initiatives (Solak, 2021). The financial constraints faced by organisations may lead them to prioritise immediate and less costly conservation methods, potentially limiting the adoption of advanced BIM technologies (Ferro, Brutto and Ventimiglia, 2023).

Enhancing public awareness and professional training in BIM is vital for its broader acceptance in the heritage sector (Cao, Guo and Jiang, 2022). Comprehensive educational programmes are instrumental in improving the understanding of BIM's benefits and applications in historical preservation (Woodward and Heesom, 2021). Despite the clear advantages, traditional conservation entities often hesitate to adopt new technologies due to concerns about undermining established practices and the perceived complexity involved (Chen et al., 2023; Chashyn, Khurudzhi and Daukšys, 2024). This resistance can be mitigated by implementing targeted training programmes that address these concerns and highlight the tangible benefits of BIM in preserving heritage buildings (Hassan and Al-Kindy, 2023). Training should underscore the compatibility of BIM with traditional conservation practices to alleviate fears of technological displacement (Sampaio, 2022).

Government backing and effective policies are critical in integrating BIM to preserve cultural heritage (Ferro, Brutto and Ventimiglia, 2023). Government policies that provide financial incentives, specialised training programmes and supportive regulatory frameworks can greatly enhance the adoption and implementation of BIM in the conservation of architectural heritage (Alshawabkeh, Baik and Miky, 2021; Cao, Guo and Jiang, 2022). Additionally, mandating the use of BIM in public heritage conservation projects can encourage its wider acceptance and implementation (Sampaio, 2022). Such policy support ensures heritage conservation projects have the necessary resources and technical guidance to effectively utilise BIM technology (Ferro, Brutto and Ventimiglia, 2023). Moreover, promoting international cooperation and harmonising policies can facilitate the sharing of best practices and technological advancements, leading to a more unified approach to heritage conservation (Saleeb, Marzouk and Atteya, 2018; Sadłowska-Sałęga and Radoń, 2020).

Learning from international experiences in implementing BIM can offer valuable insights for enhancing local conservation methodologies (Yang et al., 2021). Comparative research suggests that regions with well-established BIM procedures in heritage preservation often witness increased technological advancement and resource optimisation (Angheluță, Popovici and Ratoiu, 2023). Integrating digital documentation and physical preservation through BIM provides a comprehensive platform for maintaining and restoring heritage structures, incorporating advanced technologies like laser scanning and photogrammetry (Yuan et al., 2022; Angeloni et al., 2023; Bruno et al., 2021). Maintaining historical structures and facilitating informed conservation strategies are crucial for ensuring the preservation of our heritage (Argasinski and Kuroczynski, 2023). Furthermore, international case studies underscore the need to tailor BIM methodologies to local contexts to address specific conservation challenges and opportunities (Angeloni et al., 2023; Angheluță, Popovici and Ratoiu, 2023). Factors influencing BIM adoption in historic building projects are shown in Table 1.

Table 1. Factors influencing BIM adoption in historic building projects

No.	Variable	Construct	Shortcut	Item	Source
1	Independent variable	Section A: Awareness of BIM benefits	ABB	ABB6. I am aware of the benefits of using BIM in historic building projects. ABB7. BIM can enhance the accuracy of architectural preservation. ABB8. Using BIM can improve construction efficiency. ABB9. I understand how BIM helps in the sustainable management of historic buildings. ABB10. BIM provides a comprehensive tool for managing detailed documentation of historic buildings.	Yuan et al. (2022); Xiang, Ou and Rashidi (2023)
2	Independent variable	Section B: Organisational support	OS	OS11. My department provides adequate resources for implementing BIM. OS12. In our projects, the adoption of BIM is strongly supported by leadership. OS13. My department regularly provides BIM training. OS14. Our department has an innovative culture that supports technologies like BIM. OS15. Our department actively participates in industry forums and consultations related to BIM.	Ma et al. (2022); Yuan et al. (2022)
3	Independent variable	Section C: Technological infrastructure	TI	TI16. Our department has the necessary technical infrastructure to support BIM. TI17. The BIM software we use in our projects is up-to-date and efficient. TI18. We can use advanced tools and systems to facilitate BIM integration. TI19. Our IT infrastructure can effectively handle the demands of BIM. TI20. Technical updates and maintenance are carried out regularly to support BIM.	Xiang, Ou and Rashidi (2023)

(Continued on next page)

Table 1. *Continued*

No.	Variable	Construct	Shortcut	Item	Source
4	Mediator variable	Section D: Perceived ease of use	PEU	PEU21. BIM is easy to use in our historic building projects. PEU22. It is easy for us to learn how to operate BIM software. PEU23. The interface of the BIM software is user-friendly. PEU24. We can easily integrate BIM into our existing workflows. PEU25. Technical support for BIM is readily available if needed.	Iushkin, Alamedy and Stashevskaya (2022)
5	Adjustment variable	Section E: Regulatory environment	RE	RE26. Government regulations support the use of BIM in historic building projects. RE27. The government provides clear guidelines for BIM implementation. RE28. Our projects receive incentives from regulatory bodies for using BIM. RE29. The regulatory requirements for BIM are stringent and well-enforced. RE30. The government actively promotes the benefits of BIM in the construction industry.	Alshawabkeh, Baik and Miky (2021)
6	Implicit variable	Section F: BIM adoption in historic building projects	BAHBP	BAHBP31. We frequently use BIM in historic building preservation projects. BAHBP32. BIM significantly enhances the quality of our historic building projects. BAHBP33. The use of BIM improves the efficiency of our project workflows. BAHBP34. BIM helps us make better decisions in our projects. BAHBP35. Adopting BIM is beneficial for our historic building projects.	Yuan et al. (2022); Almaini and Nawari (2019)

METHODOLOGY

Research Design and Approach

This study employs a quantitative research design, utilising an online questionnaire distributed to heritage conservation professionals, BIM specialists and government officials in China. The comprehensive questionnaire aims to collect vital data on the adoption of BIM, its challenges and its benefits. This method enables the collection of extensive data, allowing for a thorough analysis of BIM adoption rates and their impact on heritage conservation (Abd ElWahab, Bakr and Raslan, 2019).

Data Collection Methods

The research utilises a thoughtfully crafted online questionnaire to explore various aspects of BIM in heritage conservation. To ensure the findings are both reliable and valid, the questionnaire underwent a pilot test, followed by rigorous statistical analyses, including reliability and validity tests (Lu et al., 2022; Cai et al., 2025). The survey features a mix of closed-ended and open-ended questions, structured into six key sections for comprehensive data collection. Part A gauges respondents' awareness of BIM benefits in historic building projects (Biancardo et al., 2022), while Part B assesses the extent of organisational support for BIM adoption (Albourae, Armenakis and Kyan, 2017). Part C examines the adequacy of the technical infrastructure to support BIM (García-Valdecabres et al., 2022) and Part D investigates the applicability and effectiveness of various BIM tools and technologies (Rocha et al., 2020). Part E explores the influence of governmental regulations and policies on BIM implementation (Altassan et al., 2023) and finally, Part F delves into the frequency and impact of BIM implementation in historical building projects (Ferro, Brutto and Ventimiglia, 2023). To ensure a wide and diverse reach, the survey was distributed electronically through professional networks, enhancing the representativeness and diversity of the responses (Cai et al., 2025).

Respondents' Demographic and Target Selection

The respondents consisted of heritage conservation professionals, BIM specialists and government officials. The respondent sample for the study was distributed almost evenly by age and gender. The female sample accounted for 51.29%, while the male sample accounted for 48.71%. The most predominant age group among the sample was 31 years to 40 years, with a percentage of 24.19%, closely followed by 41 years to 50 years, at 23.55%. Regarding the educational background, most of them had not attended a junior high

school or anything lower than that (36.13%) and 10.32% had not gone beyond the postgraduate level. As far as the professional positions occupied by the respondents went, they were constituted by architects (49.03%), engineers (34.84%) and project managers (16.13%).

The respondents targeted are those immediately involved and knowledgeable in the practice of historic building preservation and use of BIM. Architects and engineers devote themselves to practical application and management of the BIM technologies, while project managers are to use and coordinate the projects they are engaged in. There is no way to avoid the crucial role of state officials, as it will be their policies and regulatory frameworks that either support or do not support the application of BIM in heritage conservation.

The opinions and ideas of these key stakeholders shall assist the research in understanding the multifarious factors impacting BIM adoption and come up with workable solutions that may be applied in improving the situation in the near future for replication in historic building projects.

Analysis Techniques

The analysis of the responses from the online questionnaires involves using IBM SPSS Statistics 28.0 and AMOS 26.0 (IBM Corporation, Armonk, NY, USA) to conduct various statistical tests. This includes descriptive statistics, which provides a summary of the collected data (Foreman and Liu, 2022) and inferential statistics, which employs chi-square tests and multiple regression analysis to identify key factors influencing the adoption of BIM in historic building conservation (Lu et al., 2022). Additionally, factor analysis is used to examine the underlying factors or dimensions among the barrier and benefit items, aiding in data simplification and identifying related variables that explain BIM adoption patterns (Solak, 2021).

Structural Equation Model Diagram

A structural equation model (SEM) was developed to better understand the relationships between the factors influencing BIM adoption in historic buildings. Figure 1 illustrates the hypothesised relationships among the key variables identified in this study.

The SEM diagram provides a visual representation of how various factors influence the adoption of BIM in historic building projects. This model is the foundation for further statistical analysis and hypothesis testing in this study. By visualising these relationships, the study can more effectively identify the key determinants and barriers to BIM adoption, ultimately aiding in developing targeted strategies to enhance its integration into heritage conservation.

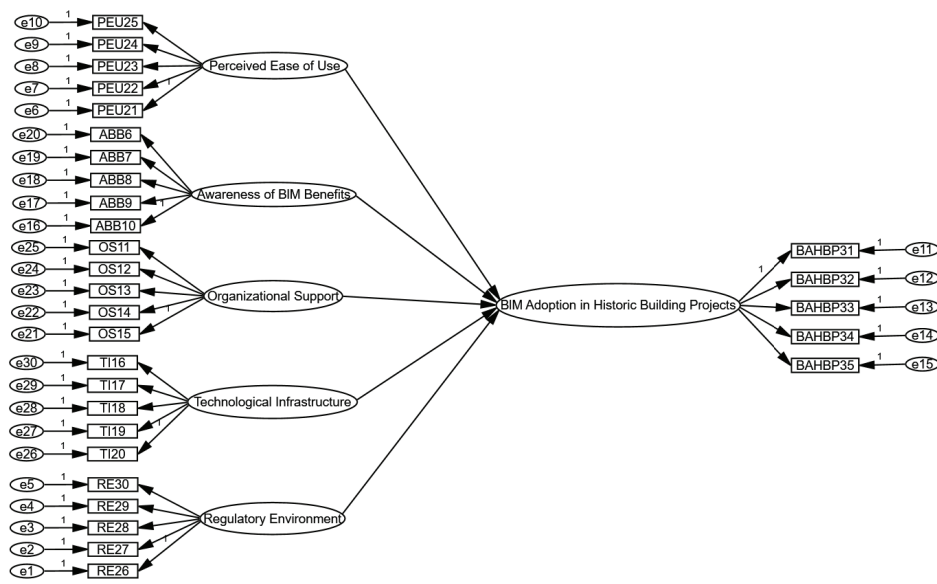


Figure 1. The SEM diagram

Pilot Test for the Questionnaire

In May 2024, a pilot test for the questionnaire was conducted, engaging a select group of professionals from the heritage conservation and BIM implementation sectors. This preliminary phase aimed to refine the questionnaire for better clarity, relevance and comprehensiveness. The valuable feedback from the pilot respondents allowed us to adjust the wording of the questions, ensure the relevance of each item and improve the overall structure. By addressing potential issues identified during the pilot test, the study ensured that the final questionnaire would effectively capture the necessary data to meet the research objectives. This step was crucial in paving the way for a successful main survey.

Data Validation and Reliability

To ensure the validity and reliability of the collected data, the research employed pilot testing and reliability testing. The questionnaire was pilot tested with selected heritage conservation and BIM professionals to refine the questions for clarity and relevance. Additionally, Cronbach's α was used to assess the internal consistency of the scales, ensuring a reliable measurement of the constructs for perceived barriers and benefits of BIM adoption in historic building preservation. These strategies enhanced the robustness of the research findings.

Reliability analysis

The reliability analysis of the questionnaire, measured by Cronbach’s α coefficient, indicates a high degree of internal consistency across all items (as shown in Table 2). The factors evaluated include awareness of BIM benefits ($\alpha = 0.895$), organisational support ($\alpha = 0.869$), technological infrastructure ($\alpha = 0.867$), perceived ease of use ($\alpha = 0.863$), regulatory environment ($\alpha = 0.856$) and BIM adoption in historic building projects ($\alpha = 0.891$). Each factor was assessed with 5 items. These α values suggest excellent internal consistency, as they are above the acceptable threshold of 0.6. This indicates that the items in the questionnaire are highly correlated and measure the same construct effectively. Therefore, the questionnaire is reliable for this study.

Table 2. Reliability statistics

Item	Cronbach’s α	Number of Items
Awareness of BIM benefits	0.895	5
Organisational support	0.869	5
Technological infrastructure	0.867	5
Perceived ease of use	0.863	5
Regulatory environment	0.856	5
BIM adoption in historic building projects	0.891	5

The reliability of internal consistency, a measure of the correlation among items in a questionnaire, is typically gauged using Cronbach’s α coefficient. This coefficient, ranging from 0 to 1, signifies the strength of correlation among the questionnaire items, thereby, indicating the reliability of internal consistency. A larger α coefficient implies that the questionnaire items effectively measure the same construct, thus, enhancing the questionnaire’s internal consistency. In this study, the overall standardised reliability coefficient is 0.926, which falls into the excellent category, demonstrating the high reliability of the questionnaire (as shown in Table 3).

Table 3. Simplified format for reliability

Cronbach’s α	Sample Size	Number of Items
0.926	310	30

Validity analysis

The validity of the results, determined by their accuracy in reflecting the content under examination, is a crucial aspect of any research study. The higher the consistency between the measured results and the content under review, the greater the validity. Conversely, higher consistency results in higher validity. Validity testing involves examining the significance of the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity. The KMO measure ranges from 0 to 1, with values closer to 1 indicating higher structural validity of the questionnaire and more reliable results. If the significance of Bartlett's test of sphericity is less than 0.05, the questionnaire can be considered to have good structural validity. In this study, the validity was confirmed using the KMO and Bartlett's tests. The KMO measure was found to be 0.920, indicating excellent sampling adequacy. Bartlett's test of sphericity yielded a chi-square value of 5027.018 with a significance level of 0.000, well below the 0.05 threshold, further confirming the excellent validity of the questionnaire (as shown in Table 4).

Table 4. KMO and Bartlett's tests

Variables		Values
KMO sampling suitability quantity		0.920
Approximately chi-squared		5,027.018
Bartlett's test of sphericity	Freedom	435.000
	<i>p</i> value	0.000

The factor extraction analysis yielded six factors, each with eigenvalues greater than 1. These factors explained variances of 11.921%, 11.481%, 11.452%, 11.067%, 10.886% and 10.508%, before rotation (as shown in Table 5). After rotation, the cumulative variance explained by these factors was 67.315%. The extraction method used was principal component analysis. Factors 7 to 30 were not included in the table as their eigenvalues were less than 1, indicating they did not contribute significantly to the variance in the data.

The data were subjected to varimax rotation to analyse the correlation between factors and research items, aiming to reveal the complex interplay of various elements within the study. Table 6 presents the extracted information for the study items and their correlation with the factors. The analysis shows a strong correlation (greater than 0.4) between all items and factors, indicating effective information extraction. After confirming that the factors capture most of the information from the study items, the study further analysed the relationship between each factor and its respective research item. A factor load coefficient exceeding 0.4 in absolute value signifies a substantial relationship between the factor and the specific item.

Table 5. Explanation rate of variance

Factor Number	Characteristic Root			Explanation Rate of Variance Before Rotation			Explanation Rate of Variance After Rotation		
	Total	Explanation Rate of Variance (%)	Accumulation (%)	Total	Explanation Rate of Variance (%)	Accumulation (%)	Total	Explanation Rate of Variance (%)	Accumulation (%)
1	9.665	32.218	32.218	9.665	32.218	32.218	3.576	11.921	11.921
2	2.803	9.344	41.562	2.803	9.344	41.562	3.444	11.481	23.402
3	2.461	8.203	49.765	2.461	8.203	49.765	3.436	11.452	34.854
4	2.290	7.632	57.397	2.290	7.632	57.397	3.320	11.067	45.921
5	1.628	5.426	62.824	1.628	5.426	62.824	3.266	10.886	56.806
6	1.347	4.491	67.315	1.347	4.491	67.315	3.152	10.508	67.315

Table 6. Rotated loading table

Item	Factor Load Coefficient						Commonality (Common Factor Variance)
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	
ABB6. I am aware of the benefits of using BIM in historic building projects.	0.789	0.158	0.074	0.119	0.220	0.120	0.729
ABB7. BIM can enhance the accuracy of architectural preservation.	0.787	0.112	0.116	0.029	0.130	0.163	0.691
ABB8. Using BIM can improve construction efficiency.	0.778	0.104	0.168	0.078	0.220	0.162	0.724

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Table 6. Continued

Item	Factor Load Coefficient					Commonality (Common Factor Variance)	
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	
ABB9. I understand how BIM helps in the sustainable management of historic buildings.	0.780	0.118	0.147	0.109	0.157	0.173	0.710
ABB10. BIM provides a comprehensive tool for managing detailed documentation of historic buildings.	0.771	0.153	0.094	0.137	0.177	0.101	0.687
OS11. My department provides adequate resources for implementing BIM.	0.114	0.780	0.080	0.035	0.082	0.157	0.661
OS12. In our projects, the adoption of BIM is strongly supported by leadership.	0.087	0.797	0.105	0.060	0.074	0.149	0.685
OS13. My department regularly provides BIM training.	0.122	0.782	0.147	0.097	0.037	0.137	0.677
OS14. Our department has an innovative culture that supports technologies like BIM.	0.103	0.789	0.045	0.109	0.065	0.114	0.665
OS15. Our department actively participates in industry forums and consultations related to BIM.	0.140	0.749	0.074	0.017	0.069	0.134	0.610
TI16. Our department has the necessary technical infrastructure to support BIM.	0.055	0.056	0.785	0.128	0.133	0.198	0.696
TI17. The BIM software we use in our projects is up-to-date and efficient.	0.077	0.165	0.778	0.036	0.016	0.151	0.662
TI18. We can use advanced tools and systems to facilitate BIM integration.	0.163	0.046	0.793	0.069	0.090	0.121	0.684

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Table 6. *Continued*

Item	Factor Load Coefficient					Commonality (Common Factor Variance)	
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	
TI19. Our IT infrastructure can effectively handle the demands of BIM.	0.116	0.083	0.782	0.077	0.059	0.072	0.647
TI20. Technical updates and maintenance are carried out regularly to support BIM.	0.116	0.100	0.741	0.082	0.069	0.167	0.612
PEU21. BIM is easy to use in our historic building projects.	0.262	0.094	0.019	0.764	0.120	0.036	0.678
PEU22. It is easy for us to learn how to operate the BIM software.	0.057	0.110	0.077	0.740	0.205	0.207	0.653
PEU23. The interface of the BIM software is user-friendly.	0.093	0.052	0.182	0.781	0.067	0.166	0.687
PEU24. We can easily integrate BIM into our existing workflows.	0.027	0.073	0.029	0.780	0.147	0.144	0.657
PEU25. Technical support for BIM is readily available if needed.	0.032	0.010	0.110	0.751	0.202	0.173	0.648
RE26. Government regulations support the use of BIM in historic building projects.	0.099	0.099	0.139	0.143	0.771	0.173	0.684
RE27. The government provides clear guidelines for BIM implementation.	0.171	0.135	0.102	0.138	0.739	0.162	0.649
RE28. Our projects receive incentives from regulatory bodies for using BIM.	0.212	0.009	0.074	0.205	0.746	0.120	0.663
RE29. The regulatory requirements for BIM are stringent and well-enforced.	0.178	0.038	0.040	0.112	0.747	0.081	0.612

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Table 6. *Continued*

Item	Factor Load Coefficient					Commonality (Common Factor Variance)	
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	
RE30. The government actively promotes the benefits of BIM in the construction industry.	0.193	0.075	0.034	0.148	0.712	0.161	0.598
BAHBP31. We frequently use BIM in historic building preservation projects.	0.123	0.227	0.254	0.210	0.140	0.708	0.697
BAHBP32. BIM significantly enhances the quality of our historic building projects.	0.140	0.109	0.135	0.170	0.201	0.749	0.680
BAHBP33. The use of BIM improves the efficiency of our project workflows.	0.165	0.200	0.270	0.161	0.220	0.729	0.746
BAHBP34. BIM helps us make better decisions in our projects.	0.252	0.208	0.127	0.164	0.154	0.742	0.724
BAHBP35. Adopting BIM is beneficial for our historic building projects.	0.193	0.241	0.198	0.228	0.153	0.685	0.679

Notes: Methods used are principal component analysis, rotation and Cäsar normalised maximum variance method. Factor loadings greater than 0.4 indicate significant associations between items and factors.

Descriptive analysis is employed to examine the overall characteristics of the quantitative data, encapsulating the broad issues of the data through metrics such as mean and skewness. As evidenced in Table 7, the absolute kurtosis values are all less than 3, indicating a flat and approximately normal distribution of the current data. With skewness values around 0, the data distribution is further confirmed to be approximately normal.

Table 7. Descriptive statistics (*n* = 310)

Variable Name	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis
ABB6. I am aware of the benefits of using BIM in historic building projects.	1.000	5.000	4.190	1.020	−1.419	1.617
ABB7. BIM can enhance the accuracy of architectural preservation.	1.000	5.000	3.935	1.071	−1.094	0.788
ABB8. Using BIM can improve construction efficiency.	1.000	5.000	4.110	1.040	−1.263	1.102
ABB9. I understand how BIM helps in the sustainable management of historic buildings.	1.000	5.000	4.026	1.097	−1.206	0.884
ABB10. BIM provides a comprehensive tool for managing detailed documentation of historic buildings.	1.000	5.000	3.848	1.155	−0.971	0.202
Awareness of BIM benefits	1.000	5.000	4.022	0.904	−1.461	1.573
OS11. My department provides adequate resources for implementing BIM.	1.000	5.000	3.865	1.065	−0.796	0.025

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Table 7. *Continued*

Variable Name	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis
OS12. In our projects, the adoption of BIM is strongly supported by leadership.	1.000	5.000	3.597	1.156	−0.624	−0.417
OS13. My department regularly provides BIM training.	1.000	5.000	3.800	1.073	−0.702	−0.166
OS14. Our department has an innovative culture that supports technologies like BIM.	1.000	5.000	3.700	1.099	−0.665	−0.196
OS15. Our department actively participates in industry forums and consultations related to BIM.	1.000	5.000	3.497	1.108	−0.559	−0.292
Organisational support	1.000	5.000	3.692	0.892	−0.807	0.325
TI16. Our department has the necessary technical infrastructure to support BIM.	1.000	5.000	4.161	0.982	−1.237	1.270
TI17. The BIM software we use in our projects is up-to-date and efficient.	1.000	5.000	3.906	1.037	−0.898	0.356
TI18. We can use advanced tools and systems to facilitate BIM integration.	1.000	5.000	4.100	1.024	−1.185	1.030
TI19. Our IT infrastructure can effectively handle the demands of BIM.	1.000	5.000	4.003	1.035	−1.082	0.800

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Table 7. Continued

Variable Name	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis
TI20. Technical updates and maintenance are carried out regularly to support BIM.	1.000	5.000	3.810	1.073	−0.880	0.344
Technological infrastructure	1.000	5.000	3.996	0.833	−1.380	1.933
PEU21. BIM is easy to use in our historic building projects.	1.000	5.000	4.048	1.015	−1.088	0.809
PEU22. It is easy for us to learn how to operate the BIM software.	1.000	5.000	3.771	1.089	−0.744	−0.002
PEU23. The interface of the BIM software is user-friendly.	1.000	5.000	3.971	1.080	−0.980	0.377
PEU24. We can easily integrate BIM into our existing workflows.	1.000	5.000	3.871	1.125	−0.911	0.278
PEU25. Technical support for BIM is readily available if needed.	1.000	5.000	3.671	1.095	−0.673	−0.149
Perceived ease of use	1.000	5.000	3.866	0.870	−1.036	0.734
RE26. Government regulations support the use of BIM in historic building projects.	1.000	5.000	3.906	1.074	−0.886	0.183
RE27. The government provides clear guidelines for BIM implementation.	1.000	5.000	3.645	1.119	−0.633	−0.239
RE28. Our projects receive incentives from regulatory bodies for using BIM.	1.000	5.000	3.842	1.072	−0.791	0.087

(Continued on next page)

Table 7. *Continued*

Variable Name	Minimum	Maximum	Mean	Standard Deviation	Skewness	Kurtosis
RE29. The regulatory requirements for BIM are stringent and well-enforced.	1.000	5.000	3.745	1.110	-0.754	-0.031
RE30. The government actively promotes the benefits of BIM in the construction industry.	1.000	5.000	3.542	1.162	-0.526	-0.471
Regulatory environment	1.200	5.000	3.736	0.882	-0.772	0.209
BAHBP31. We frequently use BIM in historic building preservation projects.	1.000	5.000	3.758	1.133	-0.816	-0.089
BAHBP32. BIM significantly enhances the quality of our historic building projects.	1.000	5.000	3.555	1.153	-0.613	-0.431
BAHBP33. The use of BIM improves the efficiency of our project workflows.	1.000	5.000	3.697	1.184	-0.723	-0.332
BAHBP34. BIM helps us make better decisions in our projects.	1.000	5.000	3.626	1.172	-0.670	-0.356
BAHBP35. Adopting BIM is beneficial for our historic building projects.	1.000	5.000	3.481	1.222	-0.598	-0.590
BIM adoption in historic building projects	1.200	5.000	3.623	0.979	-0.778	-0.371

Ethical Considerations

In this research, the ethical protocols were strictly followed to ensure the integrity and respect of the participants. Each participant received an information sheet outlining the study's purpose, their role and guarantees of confidentiality, thus, ensuring informed consent. Participation was completely voluntary and participants were free to withdraw at any time. Robust measures were implemented to protect data privacy, by removing or obscuring personal identifiers to maintain anonymity. These steps were crucial in conducting the research ethically and respecting the rights and privacy of all participants.

Potential Limitations

The research acknowledges several potential limitations. Despite efforts to ensure a broad sample, there remains the possibility of geographical or organisational bias. There is also a risk of response bias, with participants potentially providing socially desirable responses. Furthermore, the rapid evolution of BIM technology might limit the relevance of the study's findings over time. These limitations are important considerations when interpreting the research results.

ANALYSIS AND DISCUSSION

Presentation of Findings

The frequency analysis of the collected data reveals several key insights (as shown in Table 8). The gender distribution is almost equal, with females representing 51.290% and males 48.710%. The age group of 31 years to 40 years is the most represented at 24.194%, closely followed by the 41 years to 50 years group at 23.548%. The least represented age group is those aged 60 years and above, accounting for 14.194% of the respondents. Regarding qualifications, most respondents have a junior high school education or below (36.129%), while postgraduates and above are the least represented (10.323%). The respondents' roles are predominantly architects (49.032%) and engineers (34.839%), with project managers making up 16.129%. There were no respondents in the "Other" category. Most respondents have 1 year to 5 years of experience (80.968%), with less than 1 year of experience being the least common (19.032%). These findings provide a comprehensive overview of the demographic characteristics of the respondents, which can be useful in interpreting the results in the context of their background and experience.

Table 8. Frequency statistics ($n = 310$)

Characteristics	Option	Frequency	%
Gender	Female	159	51.290
	Male	151	48.710
Age group	31 years old to 40 years old	75	24.194
	41 years old to 50 years old	73	23.548
	26 years old to 30 years old	59	19.032
	51 years old to 60 years old	59	19.032
	More than 60 years old	44	14.194
Qualification	Junior high school and below	112	36.129
	High school/secondary school	73	23.548
	Polytechnic	57	18.387
	University undergraduate course	36	11.613
	Postgraduate and above	32	10.323
Role	Architect	152	49.032
	Engineer	108	34.839
	Project manager	50	16.129
	Other	–	–
Years of experience	1 to 5	251	80.968
	Less than 1	59	19.032

Correlation analysis

Pearson correlation analysis was conducted to examine the significance and direction of the linear correlation between various variables related to BIM adoption in historic building projects. The correlation coefficient (R) describes the degree of linear correlation between variables. A positive correlation ($R > 0$) indicates that as one variable increases, the other also increases. Conversely, a negative correlation ($R < 0$) implies that as one variable increases, the other decreases. If the correlation coefficient is zero ($R = 0$), there is no linear correlation between the variables. Table 9 presents the correlation analysis results, indicating the relationships between BIM adoption in historic building projects and other variables, namely organisational support, technological infrastructure, perceived ease of use, regulatory environment and awareness of BIM benefits. All correlations were tested for significance at the 0.01 level (two-tailed).

Table 9. Correlation analysis

	Mean	Standard Deviation	BIM Adoption in Historic Building Projects	Organisational Support	Technological Infrastructure	Perceived Ease of Use	Regulatory Environment	Awareness of BIM Benefits
BIM adoption in historic building projects	3.623	0.979						
Organisational support	3.692	0.892	0.464**					
Technological infrastructure	3.996	0.833	0.471**	0.277**				
Perceived ease of use	3.866	0.870	0.475**	0.229**	0.264**			
Regulatory environment	3.736	0.882	0.477**	0.246**	0.263**	0.423**		
Awareness of BIM benefits	4.022	0.904	0.480**	0.349**	0.335**	0.312**	0.477**	

Note: Correlation is significant at ** $p < 0.01$ level (two-tailed).

The correlation coefficient between BIM adoption in historic building projects and organisational support is 0.464, with a significance level of 0.01. This indicates a significant positive correlation, suggesting that increased organisational support is associated with higher BIM adoption in historic building projects. Similarly, the correlation coefficient between BIM adoption in historic building projects and technological infrastructure is 0.471, which is also significant at the 0.01 level, indicating a positive correlation between these variables. Furthermore, BIM adoption in historic building projects shows a correlation coefficient of 0.475 with perceived ease of use, which is significant at the 0.01 level, suggesting that the perceived ease of using BIM positively influences its adoption in historic projects.

The regulatory environment also has a positive correlation with BIM adoption in historic building projects, with a correlation coefficient of 0.477 and a significance level of 0.01. This indicates that a supportive regulatory environment enhances BIM adoption. Finally, the correlation between BIM adoption in historic building projects and awareness of BIM benefits is the highest among the variables, with a correlation coefficient of 0.480 and a significance level of 0.01. This suggests that greater awareness of BIM benefits strongly correlates with its adoption in historic building projects. In summary, the correlation analysis reveals significant relationships between BIM adoption and various factors such as organisational support, technological infrastructure and perceived ease of use. These findings align with the SEM conceptual model, although there are some differences in the strength and nature of these relationships. For example, while the SEM model suggests a direct influence of technological infrastructure on BIM adoption, the correlation analysis indicates that this influence is mediated by organisational support and perceived ease of use. This highlights the importance of these factors in promoting BIM adoption in the context of historic building projects.

The regression analysis table reveals the model formula for BIM adoption in historic building projects as follows:

$$\text{BIM Adoption in Historic Building Projects} = -0.776 + (0.238 \times \text{Awareness}) + (0.278 \times \text{Support}) + (0.298 \times \text{Infrastructure}) + (0.317 \times \text{Ease of Use})$$

The adjusted *R*-squared value of 0.469 indicates that the model explains 46.9% of the variance in BIM adoption in historic building projects based on the variables: awareness of BIM benefits, organisational support, technological infrastructure and perceived ease of use. Multicollinearity was checked and all variance inflation factor (VIF) values were found to be less than 5, indicating no collinearity problem within the model. The Durbin-Watson (D-W) value was near 2, suggesting no autocorrelation in the model. Additionally, the model passed the *F*-test ($F = 69.283$, $p = 0.000 < 0.01$), confirming that at least one of the variables has a significant impact on BIM adoption in historic building projects, thereby, validating the model's effectiveness.

Table 10. The regression analysis results (*n* = 310)

	Non-standardised Coefficients		Standardised Coefficients	<i>t</i>	<i>p</i>	VIF	<i>R</i> -squared	Adj- <i>R</i> -squared	<i>F</i>
	<i>B</i>	<i>SE</i>	Beta						
Constant	−0.776	0.268		−2.893	0.004		0.476	0.469	<i>F</i> (4,310) = 69.283, <i>p</i> = 0.000
Awareness of BIM benefits	0.238	0.051	0.219	4.675	0.000	1.281	0.476	0.469	<i>F</i> (4,310) = 69.283, <i>p</i> = 0.000
Organisational support	0.278	0.050	0.253	5.591	0.000	1.190	0.476	0.469	<i>F</i> (4,310) = 69.283, <i>p</i> = 0.000
Technological infrastructure	0.298	0.053	0.253	5.595	0.000	1.195	0.476	0.469	<i>F</i> (4,310) = 69.283, <i>p</i> = 0.000
Perceived ease of use	0.317	0.050	0.282	6.322	0.000	1.157	0.476	0.469	<i>F</i> (4,310) = 69.283, <i>p</i> = 0.000

Detailed analysis of the regression coefficients reveals significant positive impacts of the variables on BIM adoption in historic building projects (as shown in Table 10). The regression coefficient for awareness of BIM benefits is 0.238 ($t = 4.675, p = 0.000 < 0.01$), indicating that increased awareness of BIM benefits is associated with higher adoption rates. Similarly, organisational support has a regression coefficient of 0.278 ($t = 5.591, p = 0.000 < 0.01$), demonstrating that greater organisational support enhances BIM adoption. Technological infrastructure also shows a significant positive influence on BIM adoption in historic building projects, with a regression coefficient of 0.298 ($t = 5.595, p = 0.000 < 0.01$). This suggests that improved technological infrastructure contributes positively to BIM adoption. Additionally, the perceived ease of use has a regression coefficient of 0.317 ($t = 6.322, p = 0.000 < 0.01$), indicating that if BIM is perceived as easier to use, its adoption in historic building projects is likely to increase. The regression analysis confirms that awareness of BIM benefits, organisational support, technological infrastructure and perceived ease of use significantly and positively influence BIM adoption in historic building projects. The model effectively explains a substantial portion of the variance in BIM adoption, underscoring the importance of these factors.

Dependent BIM Adoption in Historic Building Projects

The findings of this study align with previous research that underscores the benefits and challenges of BIM adoption in heritage conservation. For instance, Angeloni et al. (2023) highlighted the importance of specialised training, while Karasaka and Ulutas (2023) discussed the technical modifications required for accurate documentation of historic buildings. These connections further validate the study's results and suggest practical steps for enhancing BIM implementation in this field. A key insight from this study is the significant awareness of BIM benefits among respondents. Most participants demonstrated a comprehensive understanding of BIM's potential to enhance the accuracy and efficiency of historic building projects. This high level of awareness is validated by a Cronbach's α of 0.895, indicating robust and consistent responses. Such widespread recognition of BIM's advantages aligns with the findings of Angeloni et al. (2023), who highlighted BIM's transformative impact on improving documentation and project management in heritage conservation contexts. This underscores the importance of awareness campaigns and educational programmes to further enhance stakeholders' understanding of BIM benefits. However, the responses indicated significant disparities in organisational support, reflecting variations in resource allocation and leadership backing for BIM implementation across different organisations. The Cronbach's α of 0.869 supports the reliability of these findings. This variation suggests a pressing need for standardised support structures to facilitate broader BIM adoption. These disparities highlight the challenges organisations face in uniformly adopting BIM practices, as discussed by Ma et al. (2022). Therefore, establishing uniform support frameworks and leadership initiatives could bridge these gaps and promote more consistent BIM adoption.

The analysis also revealed a critical gap in the technical infrastructure required for effective BIM implementation. Many organisations reported outdated software and insufficient hardware capabilities, with a Cronbach's α of 0.867 confirming the reliability of these responses. This finding aligns with Solak (2021), who identified the need for substantial investment and upgrades to leverage BIM technologies fully. Addressing these infrastructure deficiencies is crucial for organisations to realise the full potential of BIM, suggesting a need for targeted investment in up-to-date technology and training. Moreover, the perceived ease of use of BIM tools emerged as a significant challenge, with many respondents citing a steep learning curve and non-intuitive interfaces. The reliability analysis supports this finding with a Cronbach's α of 0.863. Enhancing the user experience through better-designed interfaces and functionalities could mitigate these usability issues. This is essential for broader BIM adoption, as Yuan et al. (2022) emphasised the importance of intuitive design in increasing user acceptance and efficiency. Therefore, improving the usability of BIM tools through user-centred design principles and comprehensive training programmes is recommended.

The regulatory environment also showed mixed effects on BIM adoption. While some regulations support BIM implementation, a lack of clear guidelines often hampers its broader adoption. The reliability of these responses is evidenced by a Cronbach's α of 0.856. This finding suggests a need for more transparent and supportive government policies to facilitate BIM adoption, as Karasaka and Ulutas (2023) discussed. Clearer regulatory frameworks and incentives could significantly enhance BIM uptake by providing a more conducive environment for its implementation. Finally, despite the recognised benefits of BIM, its application in actual historic preservation projects remains limited and challenging. The reliability score of 0.891 indicates consistent responses regarding these barriers. Alshawabkeh, Baik and Miky (2021) echoed these sentiments, highlighting the practical difficulties in integrating BIM into historic preservation. This calls for focused efforts to address the specific challenges of applying BIM in this context, such as developing tailored solutions that consider the unique requirements of historic buildings. Overall, the analysis underscores the need for increased awareness, enhanced organisational support, upgraded technical infrastructure, improved user-friendliness of BIM tools and clearer regulatory guidelines to promote the adoption of BIM in historic building projects. Addressing these areas could significantly enhance the implementation and effectiveness of BIM in preserving historic architectural heritage.

Relationship to Challenges of Implementing Building Information Modelling

The results of this study underscore the critical factors influencing BIM adoption in historic building projects. High costs and technical challenges are significant barriers, as confirmed by the correlation and regression analyses. Organisational support and perceived ease of use also play crucial roles in facilitating BIM implementation. These findings align with existing literature and suggest that targeted training programmes, improved technical infrastructure and supportive policies are essential for wider adoption of BIM in heritage conservation (Cao, Guo and Jiang, 2022; Hassan and Al-Kindy, 2023). Technical challenges arise from the unique architectural elements and materials of historic buildings, which complicate modelling efforts. These challenges are further exacerbated by the need for specialised BIM training for heritage professionals (Angeloni et al., 2023). Economic challenges are also significant, as high implementation costs—including software acquisition, training and data management—pose substantial obstacles, particularly in regions with constrained budgets for cultural heritage projects (Ma et al., 2022). Additionally, organisational and cultural challenges persist in the conservation sector. Resistance to new technologies is common due to organisational inertia and deeply entrenched traditional methods. This resistance complicates the transition to BIM, necessitating technical adjustments and a cultural shift within organisations to embrace modern methodologies (Angeloni et al., 2023).

Implications for Stakeholders and Policymakers

The findings have significant implications for various stakeholders, including heritage conservation professionals, policymakers and technology providers. There is a clear need for specialised training programmes to equip heritage conservation professionals with essential BIM skills, necessitating that professional associations and educational institutions prioritise BIM training in their curricula (Karasaka and Ulutas, 2023). Policymakers should consider establishing supportive frameworks that provide incentives for BIM adoption, such as subsidies or tax breaks for projects integrating BIM and formulate policies to endorse training programmes specifically tailored for BIM in heritage conservation (Yuan et al., 2022). For technology providers, there is an opportunity to develop BIM tools and software specifically designed to meet the requirements of historic buildings, thereby, facilitating the adoption process by adapting BIM tools to accommodate the unique characteristics of historical structures (Alshawabkeh, Baik and Miky, 2021).

CONCLUSION

The research has extensively examined the factors impacting the utilisation of BIM in preserving historic structures, uncovering numerous significant obstacles and potential advantages. Most participants are acquainted with the substantial benefits of BIM, such as enhanced documentation accuracy and project efficiency, which are crucial for the practical preservation of historic buildings (Angeloni et al., 2023). However, the level of organisational support and technical infrastructure for BIM implementation varies considerably, with some organisations offering robust support while others encounter resource constraints that impede effective adoption (Ma et al., 2022). Significant economic and cultural barriers also hinder the adoption of new technologies in historic building conservation, particularly high costs and cultural resistance in regions with limited budgets and traditional conservation practices (Alshawabkeh, Baik and Miky, 2021). Additionally, government regulations and policies significantly impact the adoption of BIM in heritage conservation projects, with clear guidelines and incentives crucial for fostering broader implementation (Yuan et al., 2022).

The research findings hold substantial implications for diverse stakeholders engaged in heritage conservation. Heritage conservation professionals necessitate specialised training programmes to acquire the requisite BIM skills and educational institutions and professional associations must prioritise BIM training to ensure conservation experts are well-equipped to leverage this technology (Yuan et al., 2022). Policymakers should consider developing supportive frameworks encompassing financial incentives, regulatory guidelines and public awareness campaigns to enhance BIM adoption in heritage conservation (Yuan et al., 2022). Technology providers should prioritise creating BIM tools tailored to the distinctive requirements of historic buildings, addressing interoperability issues and ensuring user-friendly and cost-effective solutions (Alshawabkeh, Baik and Miky, 2021).

Future research should build upon this investigation by acknowledging its constraints and exploring uncharted territories. Conducting longitudinal studies to monitor changes in BIM adoption over time among the same participant group would provide valuable insights into the long-term benefits and challenges (Shin and Kim, 2021). Cross-cultural comparative studies across different cultural and regulatory contexts can provide insights into how local factors influence BIM adoption and help identify best practices that can be adapted globally (Alshawabkeh, Baik and Miky, 2021). Further investigation is warranted to explore the integration of BIM with emerging technologies such as augmented reality (AR), virtual reality (VR) and IoT to enhance its capabilities and applications in heritage conservation (Yuan et al., 2022). Integrating BIM in preserving historic buildings can revolutionise the field by offering tools for precise documentation, effective management and

collaborative planning. By addressing the identified barriers and capitalising on the acknowledged benefits, stakeholders can profoundly transform heritage conservation practices. This study adds to the ongoing discourse and establishes a groundwork for future endeavours to incorporate digital technologies into preserving cultural heritage.

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