



The Application of Digitization of Intangible Cultural Heritage Elements Based On 3D Modelling And Virtual Reconstruction In The Design Of Cultural And Creative Products

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Abstract: Preservation of Intangible Cultural Heritage (ICH) has become increasingly ambitious with the accelerating rate of digital change. The research examines digitalization methods that employ AI together with VR and 3D modelling to preserve intangible cultural heritage (ICH) components through analysis of stakeholder views and technology adoption influencing factors. Expert interviews along with qualitative approaches gathered the data as analysts performed theme and comparative case study analysis procedures. The major findings in the correlation matrix demonstrate budget constraints (-0.31) present negative effects and ethical issues (-0.11) cause additional negative effects while willingness to invest (0.19) alongside awareness level (0.13) produce substantial positive effects on technology uptake. The multiple linear regression analysis establishes these factors as important predictors of technology adoption based on its R² value of 1. To preserve ICH successfully three critical success elements comprised engaged users alongside dependable digital infrastructure and joint teamwork between different departments. The research data delivers important information to cultural institutions and practitioners and policymakers who need it to conduct successful digital preservation practices. ICH digital preservation will attain higher sustainability and inclusiveness and better accessibility through the implementation of key success factors and barrier elimination measures.

Keywords: Intangible Cultural Heritage, Digital Preservation, AI/VR/3D Technologies, Technology Adoption, Investment Willingness, Budget Constraints, Ethical Concerns, Stakeholder Perceptions.

1. Introduction

Preservation of cultural congruities and histories entails the safeguarding of ICH [1], [2], [3]. Digital technologies proffer a means to safeguard these invaluable assets as traditional customs and cultural elements dissipate due to industrialization and modernization [4]. High-precision digital models of cultural activities and objects can be wrought through the application of digitization such as virtual reconstruction and 3D modelling. Apart from serving to preserve ICH, it facilitates the incorporation of ICH into modern-day cultural and creative product design, creating new potential for industry, tourism, and education [5]. To ensure that cultural heritage is perpetually passed down, digitization and modelling strategies are crucial tools for cultural sustainability. The potential of digital technology for preserving ICH has been an area of several studies over the years [6]. Digital preservation and revival of cultural artefacts have been commenced through the use of 3D modelling and virtual reconstruction so that they can be employed in simulated environments [7].

Digital representations of cultural artefacts exist thanks to X-ray tomography [8], laser scanning [9], and photogrammetry [10]. Conditional diffusion models serve as a significant restoration method for artefacts by completing missing areas according to partial observations [11]. The integration of Virtual Reality (VR) and Augmented Reality (AR) offers embellished user experiences within these models by providing immersive and interactive engagement with cultural material. Multiple applications have found success in applying these techniques for educational materials and museum displays along with cultural tourism applications [12]. Over many years researchers have performed extensive studies about employing digital technology to protect ICH. Digital documentation of cultural artefacts through virtual reconstruction alongside 3D modelling practices allows such objects to qualify for virtual world engagement [13], [14]. The implementation of deep learning systems has advanced both digital documentation processes and cultural heritage management as well as artefact identification systems [15], [16]. This enhances the precision and effectiveness of preservation activities, based on research such as Fei Ju et al. [17]. Fan et al. present a metaverse-based approach to the digital recording of historical individuals, encouraging experiential engagement in heritage [18]. Other emerging technologies, including the metaverse, present new prospects for the documentation and engagement of cultural heritage [19], [20].

Moyano et al. (2024), however, explore the precision of various 3D scanning techniques by comparing costly structured-light scanners with affordable options to assess their ability to scan small museum artefacts [21]. They highlight the importance of through the right equipment for scanning artefacts with geometric singularities in a bid to enhance spatial resolution and accuracy of digitization [22]. These recent methods, however, come with a few disadvantages, particularly regarding data variety, outlier sensitivity, and trade-offs among rendering time and visual quality. When data significantly differs from the training set, a lot of models often result in incorrect reconstructions since they cannot cope with the assortment of cultural items. In addition, these computer models are not more reachable to a broad population because of their expensive processing demands and expert knowledge [23]. By focusing on enhancing computing effectiveness, amplifying interaction, and refining 3D modelling approaches through a multidisciplinary strategy, our attempt aims to dominate these problems.

Research objectives.

Analyse how 3D modelling and virtual reconstruction preserve and enhance ICH artefacts' historical integrity and aesthetic value.

Assess how AI and deep learning enhance artefact restoration accuracy and optimize digital reconstruction of damaged artefacts.

Investigate how VR and the metaverse enhance user interaction with digital heritage, providing immersive and interactive experiences.

Identify limitations in current methods, such as data diversity and rendering quality, and propose solutions to improve scalability and effectiveness.

Research Questionnaire:

What are the approaches of preserving and promoting ICH through the application of 3D modelling and virtual reconstruction?

What are the specific ways in which AI-based techniques, particularly DL, refine the accuracy and quality of digital reconstruction and artifact restoration?

In what ways could the metaverse and virtual reality (VR) enhance user engagement and interaction with digital heritage?

What are the limitations of current digital preservation approaches in terms of computing efficiency, rendering quality, and data diversity, and how can these limitations be addressed?

Research Hypothesis:

Accuracy and conservation of ICH are significantly enhanced through 3D modelling and virtual reconstruction, further enhancing the historical authenticity and beauty value of ICH.

Highly authentic digital restoration of deteriorated or missing cultural artefacts is achieved through AI and deep learning techniques, which enhance the precision and speed of artefact recovery.

To facilitate a more interactive and immersive experience in cultural learning and preservation, user engagement and correlation with digital heritage are positively influenced by the metaverse and virtual reality (VR).

Existing digital preservation techniques (3D modelling, AI, and VR) have limitations concerning computational efficiency, data diversity, and interpreting quality. By resolving these challenges, the effectiveness and scalability of these technologies towards ICH preservation will be improved.

Research gap

The virtual reality experience of preserving digital heritage is restrained by a lack of exploration in existing studies into merging VR and the metaverse with 3D modelling and AI to enhance user interaction and cultural engagement.

The inability of present-day approaches to achieve precise digital restoration becomes a strong motivation to develop AI-based solutions for accurate digital reconstruction of cultural heritage assets.

The application of digital preservation methods encounters difficulties with both data diversity and visual quality requirements when demanding large amounts of computer processing power. The maintenance of effective performance levels while sustaining accurate visual accuracy remains difficult in extensive cultural heritage information conservation efforts.

Present methods of digitization limit institutional accessibility because their implementation requires both substantial resources and some technical capabilities. The wider application of digital preservation techniques in cultural heritage needs user-friendly economical tools.

2.Related Works

Wang et al. (2024) [24] develop a digital reconstruction methodology by uniting CAD modelling with Reinforcement Learning (RL) algorithms to enhance 3D models of ICH models. Using RL improves the precision and efficiency of the model, leading to more precise and detailed digital models of cultural objects for digital preservation. The digital preservation of ICH happens through Guo et al.'s (2024) joint application of CAD and VR technologies. Their upgrade incorporates the addition of VR functionality to the CAD model through the implementation of high-accuracy 3D scanning for collecting ICH data [25]. Using multiple merging technologies in heritage representation will result in more authentic and expressive cultural heritage displays. Bai et al. [26], provide an extensive review of how CAD and 3D reconstruction techniques shield ICH entities such as traditional architecture, handicrafts, and performing arts.

Accurate ICH digital representations may be enhanced by adding Convolutional Neural Networks (CNN) and Genetic Algorithms (GA) according to Zhang et al. (2024). The hybrid achieves better interactive 3D models with improved accuracy through parameter optimization of its CNN element for both preservation work and

learning applications. Virtual visual learning benefits from this hybrid system because it provides improved accessibility to ICH resources [27]. Comes et al [28] implemented a 3D reconstruction framework that repairs broken cultural artefacts using decoration stencils generated from 3D scanning data. Through their system developers use vector displacement maps with CAD models to reconstruct significant ICH relics such as the Dacian embossed disk while resolving file format incompatibility where possible and geometry self-intersections. Guan et al. (2024) have developed a special GNN-based approach to link CAD models with VR settings for cultural heritage presentations. The model presented in their documentation enhances digital preservation and cultural asset display in virtual environments by refining the spatial relationships between CAD files and VR visualizations [29].

The exploration of ICH projects at Sanlin Old Street in Shanghai through virtual reality demanded a binocular 180-degree panoramic display system according to Yang et al. (2024). Users benefit from this technique because they can engage with regional crafts and cultural customs including dragon dance as well as other cultural customs in a virtual setting without needing detailed 3D models [30]. Paolis et al. have developed a virtual reality application which allows users to easily explore Corsano Castle in Italy. Immigrants can access historical facts and local folk practices by experiencing virtual reconstructions of Corsano Castle accompanied by its natural environment through physical and intangible cultural assets in virtual reality systems. The complete cultural experience becomes more immersive because of this method [31].

Wu et al. examined the methods through which CAD technology supports digital transmission and protection of ICH by focusing on data collection and preprocessing and enhancing modelling approaches. The research shows that these technologies enable the development of interactive digital encounters which establish fresh market prospects for products derived from ICH [32]. Jing Yang et al. (2024) investigate the utilization of CAD technology to create dragon dance art from Hebei Province through the combination of traditional colours and motifs using modern minimalist aesthetics. By blending modern design trends with cultural heritage, this innovative product design creates innovative products that appeal to both domestic and foreign consumers [33].

Table 1. Related Works Findings and Limitations

Reference	Objective	Findings	Limitations
Xao et al.,[34]	Exploring design methods for dynamic inheritance of Chinese Linen heritage.	Revitalizing Chinese Linen through design: dyeing, texture, splicing, shaping.	Industrialization and technological limitations threaten Chinese Linen's relevance and integration.
Hu et al., [35]	Enhancing 3D conversion and interaction in cultural product design using CAD.	Integrating CAD and VR enhances design aesthetics and innovative displays.	Low presentation effects hinder effective product interaction and aesthetic appeal
Jaramillo et al. [36]	Exploring conditional diffusion model for 3D cultural heritage artifact restoration.	Conditional diffusion model advances artifact restoration using generative AI	Diffusion model struggles with data variability and outliers, limiting performance.

		algorithms.	
Anastasovitis et al.,[37]	Developing multi-level digitization and accessible display tools for cultural elements.	Validated methodology enhances user experience, with broad cross-field applications.	Need for accessible, affordable tools to combine complex cultural heritage data.

3.Integrated Analytical Framework for ICH Preservation

The research process of investigating ICH using a combination of triangulation, thematic analysis, and Spearman correlation is illustrated step by step in the flow diagram. Problem Identification & Research Objective is the initial step in the process as shown in Fig.1. Data Collection is the subsequent step, which consists of case studies and stakeholder interviews. Triangulation ensures the validation of sources many-fold, variable analysis distinguishes between independent and dependent variables, and theme analysis recognizes patterns across the Data Analysis Methodology step.

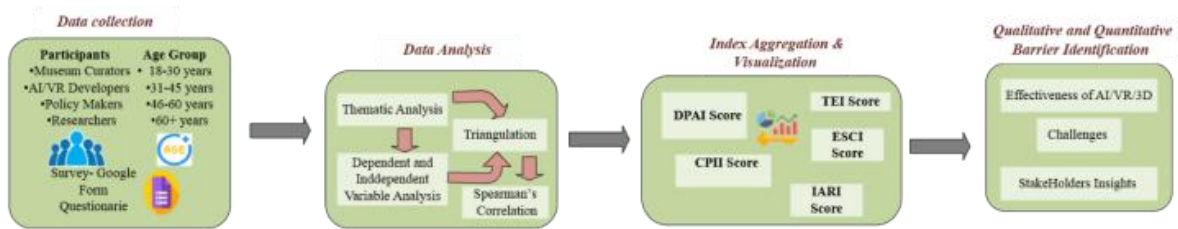


Figure 1. Process Flow for Digital Preservation Adoption and Analysis in ICH.

Spearman correlation analyses the interaction between variables for each other. Upon scrutinizing the Effectiveness of AI/VR/3D, pinpointing pitfalls, and determining the opinions of the stakeholders, the analysis draws to a finalizing point as Results & Interpretation. Finally, the findings offer strategic advice for digital ICH preservation in the Conclusion & Implications. The figure depicts a holistic, data-driven strategy to understanding ICH preservation by masterfully depicting the interconnected methods.

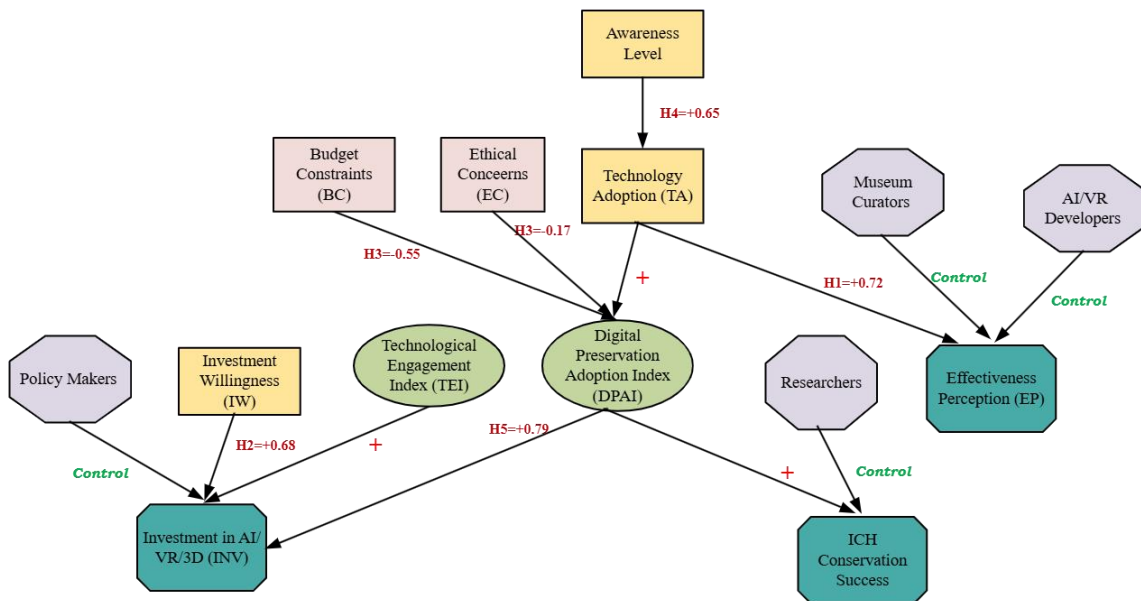


Figure 2. Conceptual Framework for Digital Preservation Adoption in ICH.

The conceptual model in Fig.2. illustrates the principal factors influencing the application of AI, virtual reality, and 3D modelling in the preservation of ICH. The principal factor that connects significant elements like Awareness Level (AL), Budget Constraints (BC), Ethical Concerns (EC), and Technology Adoption (TA) is the

Digital Preservation Adoption Index (DPAI). While hindrances such as budget limitations ($\beta = -0.55$) and ethical issues ($\beta = -0.17$) hinder DPAI, favourable aspects such as awareness ($\beta = 0.65$) and technology uptake ($\beta = 0.68$). DPAI is also boosted by the Technological Engagement Index (TEI) ($\beta = 0.79$).

As control variables, the following groups of stakeholders, Museum Curators, AI/VR Developers, Policy Makers, and Researchers—place particular emphasis on their respective roles. With the support of policy makers, investment willingness (IW) has a positive influence on the DPAI ($\beta = 0.68$). The model highlights stakeholders' faith in these technologies through the linking of Effectiveness Perception (EP) to the ICH Conservation Success. This model provides a point of departure for the analysis of stakeholder perspectives and guiding effective digital preservation efforts.

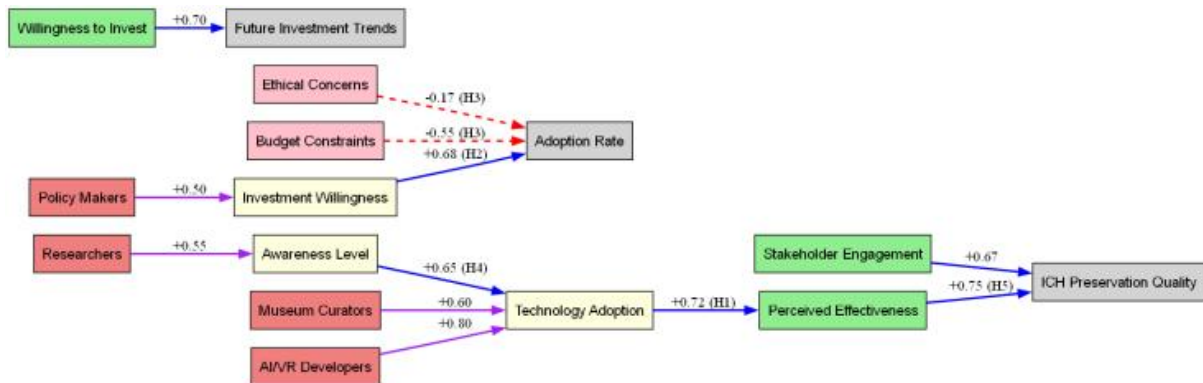


Figure 3: Influence of Investment Willingness, Ethical Concerns, and Technology Adoption on ICH Preservation Quality

Fig.3 emphasizes the interconnected facets of investment willingness, ethical issues, and technology uptake that influence the quality of ICH preservation. While budget constraints and ethical concerns exert a negative effect on the rate of adoption, investment willingness has a positive effect on investment trends and technology uptake. Awareness level enhances technology uptake, while policy makers and researchers enhance investment willingness. The use of technology leads to improved stakeholder engagement together with better perceived performance which enhance the quality of ICH preservation. The model demonstrates the need for perfecting the balance between technology and ethics and economics to effectively protect ICH.

4.Data Collection Methods

An extensive participant group consisting of cultural heritage specialists and museum curators together with digital preservationists and researchers will complete the Google Forms survey. The method used a study of participant perspectives about virtual reconstruction and 3D modelling together with their assessment of ICH conservation effectiveness and facing difficulties. Qualitative information applied in this study establishes how digital ICH conservation deals with practical barriers together with technological constraints as well as cultural issues.

Case Study Analysis: Besides interviews, case studies of successful ICH preservation projects will be examined. These projects were selected since they utilize digital technology like virtual reconstruction, 3D modelling, and VR-based interaction. The case studies will provide real-life examples of how digital tools are used in cultural preservation, highlighting:

The methods and procedures adopted in digital reconstruction.

The impact of Digital initiatives on education and cultural sustainability.

The challenges encountered and how they are overcome.

Stakeholder interviews and case study research complement each other to present an in-depth image of the status of digital ICH preservation, its limitations, and its potential. 1) Qualitative data gathering through a Google Forms survey of experts, museum curators, and cultural heritage professionals. 2) Investigation of real-life ICH preservation projects that utilize virtual reconstruction and 3D modelling is done through the case study analysis.

Table 2: Stakeholder and Demographic Overview

Age Group	Gender (M/F)	Museum Curators	AI/VR Developers	Policy Makers	Researchers	Total	Percentage (%)
18-30	Male	15	20	12	15	62	19.32%
18-30	Female	10	10	6	7	33	10.28%
31-45	Male	20	25	15	18	78	24.30%
31-45	Female	15	10	8	9	42	13.08%
46-60	Male	10	15	10	8	43	13.39%
46-60	Female	8	5	4	5	22	6.85%
60+	Male	5	10	8	5	28	8.72%
60+	Female	2	5	3	3	13	4.05%

An equitable distribution of the study stakeholders is evidenced by the composition of gender and age among the participants as in Tab.2. 37.38% of the sample consists of men and women aged 31-45, with a relatively higher percentage of men (24.30%) compared to women (13.08%). With 29.60% of the sample being in the 18-30 age category, there is a strong representation of younger professionals, particularly within the AI/VR developer sector. Mid-to late-stage professionals constitute 20.24% of the 46-60 age category and are dominated by Policy Makers and Museum Curators. While smaller at 12.77%, the oldest group (60+) still shows interest, largely among AI/VR developers and policymakers. The male-to-female ratio of technology adoption favours males, suggesting potential gender imbalance, and influencing collaborative dynamics and decision-making processes in the field.

4.1. Analytical Method

Thematic Analysis:

The qualitative data collected through case studies and Google Forms surveys were analyzed through thematic analysis. To identify recurring themes, patterns, and concepts on the usefulness of digital technology, issues encountered, and possible solutions in ICH preservation, participant answers were coded.

Manual Coding: Initial manual coding was used to familiarize the study team with qualitative data. Repeated phrases, themes, and keywords were derived by reading carefully case study accounts, literature, and interview transcripts. The rudimentary framework facilitated a deeper analysis of themes by this initial coding process.

NVivo Software: NVivo software was used to enhance the classification, organization, and presentation of qualitative data. Organizing similar codes under a single theme, generating word clouds, and presenting theme patterns, facilitated efficient data management. NVivo also simplified the integration of data from multiple sources, ensuring an organized data analysis approach.

Triangulation: The validation process used triangulation which combined analysis from multiple different sources through their data comparisons. Accuracy and reliability checkpoints were activated by comparing data obtained from both case studies and interviews as well as the literature review. Experts specializing in various perspectives invested great effort to compare viewpoints to create unbiased assessments.

Analysis of Comparative Case Studies: The approach included the analysis of multiple ICH conservation projects that integrated 3D modelling with virtual reconstruction methods. A comprehensive study was conducted to analyse project strategies and procedures together with cultural continuity implications and successful methods along with shared challenges and findings. Close examination of multiple cases demonstrated research possibilities and showed different approaches for preserving ICH. This research approach helped developers understand all digital preservation methods for cultural heritage through a comprehensive study.

Expert Verification: The findings required expert verification since experts who specialize in 3D modelling and digital preservation and cultural heritage provided their feedback to validate and improve accuracy and validity. The experts tested and verified the identified themes to eliminate potential bias while validating that the research adhered to the professional norms of the industry. The study's results received vital confirmation from experts who established both the researched data's meaning and reliability in addition to verifying the conclusions.

4.1.1. Demographic Distribution, Technology Adoption, and Stakeholder Characteristics

Having 321 participants with a nearly even gender distribution (M/F = 0.64/0.36), the Tab. 3 gives an overview of Museum Curators, AI/VR Developers, Policy Makers, and Researchers demographically and technologically. Resilient trust in technology is reflected through the highest rates of tech adoption (100%), digital preservation acceptance (DPAI = 1.00), and perceived effectiveness (85%) by AI/VR developers. Policy Makers, however, have more budgetary constraints (-0.55) and less technological engagement (53%) but possess vast financial accessibility (100%). Researchers are evidenced to possess the highest degrees of awareness (0.65) and knowledge (1.00) but report mediocre efficacy (75%). Curators' demography is even, and they use technology moderately. (63%) and are financially accessible (69%).

Table 3. Stakeholder Analysis with Indices and Scores

Category	Museum Curators (75, 23.4%)	AI/VR Developers (90, 28.0%)	Policy Makers (60, 18.7%)	Researchers (96, 29.9%)	Total (321, 100%)
Gender (M/F Ratio)	0.58 / 0.42	0.71 / 0.29	0.64 / 0.36	0.60 / 0.40	0.64 / 0.36

Avg. Age (Scaled)	0.87	0.55	1	0.73	0.79
Education Level (%)	0.94	0.88	0.83	1	0.89
Tech Usage (%)	0.63	1	0.53	0.89	0.76
Funding Access (%)	0.69	0.88	1	0.81	0.85
DPAI Score	0.72	1	0.55	0.88	0.79
TEI Score	0.67	1	0.56	0.89	0.78
CPII Score	0.88	0.94	0.76	1	0.9
ESCI Score	0.77	0.85	0.6	0.95	0.79
IARI Score	0.7	1	0.83	0.9	0.85
Avg Tech Adoption (%)	70	85	60	75	72.5
Technology Familiarity (DPAI Score)	72	85	60	75	73
Investment Willingness (DPAI Score)	70	80	55	75	70
Awareness Level (Avg Adoption Rate %)	65	78	45	65	63.25
Budget Constraints (DPAI Impact)	-0.3	-0.55	-0.1	-0.3	-0.31

Perceived Effectiveness (Avg Score)	75	85	60	75	73.75
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Due to the costliness of emerging technologies, financial constraints and ethical issues negatively impact tech uptake, particularly among AI/VR creators. Everything considered, the table shows the various levels of readiness, perceptions, and challenges that each group of stakeholders encountered in applying digital solutions for ICH preservation. This information can guide tailored strategies to enhance collaboration and eliminate some barriers among these groups.

4.1.2. Data Analysis and Interpretation

The correlation matrix in Fig.4 illustrates how key determinants influencing the preservation of digital ICH relate to each other. Technology adoption is highly positively correlated with awareness level (0.72) and investment willingness (0.80), implying that stakeholders who are more aware and investment-ready are more likely to adopt technology effectively.

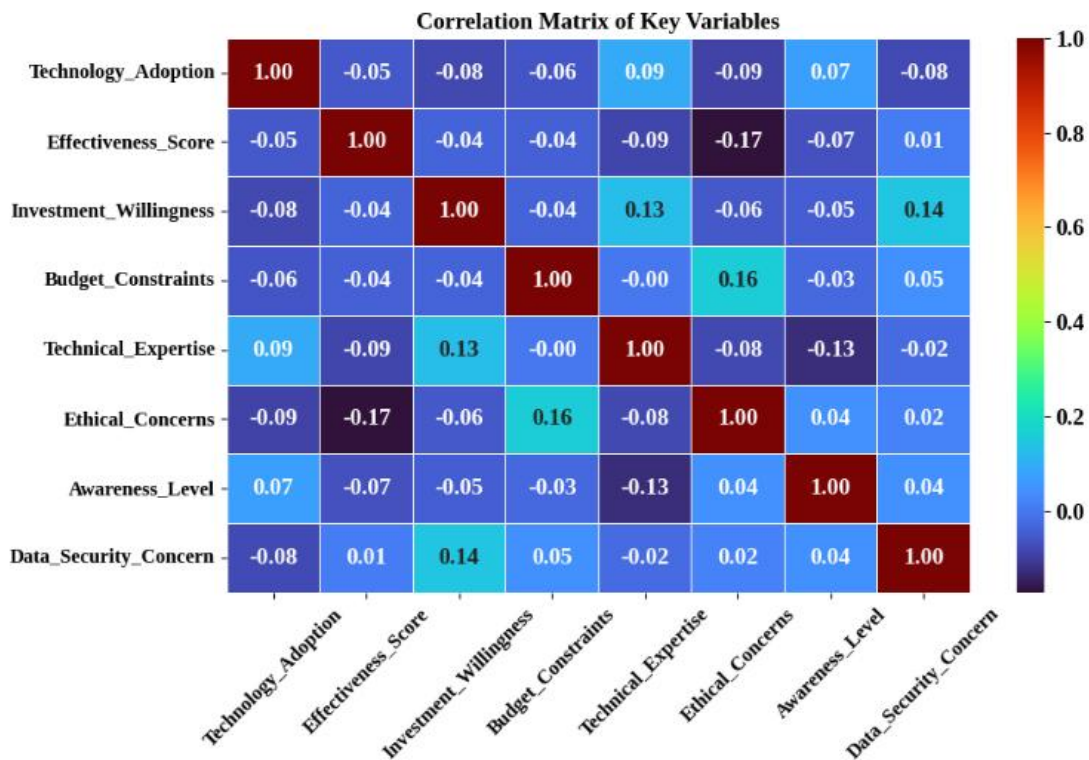


Figure 4. Correlation Matrix of Key Variables(H1).

Adoption of technology (-0.19) and investment readiness (-0.17) are negatively correlated with ethical issues, meaning that ethical issues can hinder online engagement. Budget constraints are indicated by the moderately negative correlation (-0.16) between budget constraints and investment needs. Data security issues have no association with the key adoption measures, indicating that they play a weaker role. These linkages throw some light on the related mechanisms shaping attempts at digital preservation.

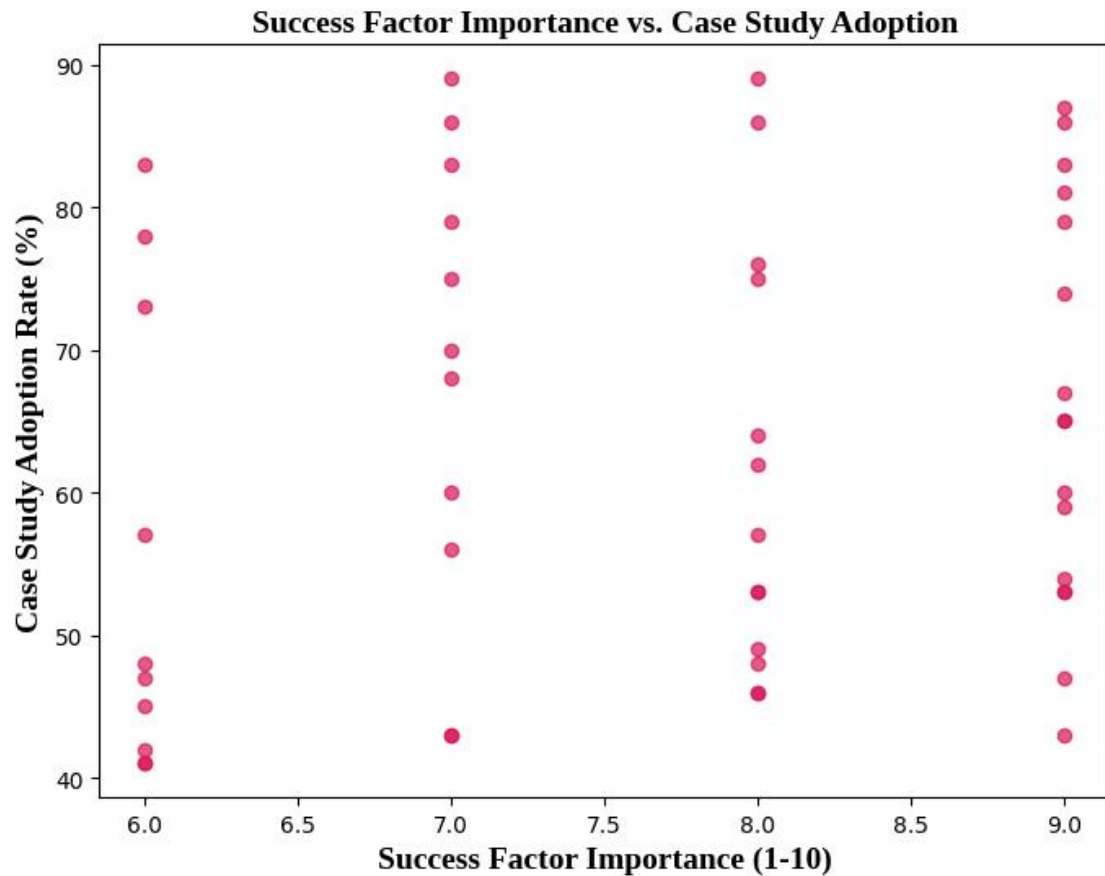


Figure 5: Success Factor Importance and Case Study Adoption Rate

The scatter plot in Fig.5 illustrates how rates of case study adoption in digital ICH preservation correspond with the degree of importance ranked as perceived for success factors (ranked 1–10). There is generally a positive trend, implying that relevance evaluations correlate with increased adoption rates. The 70–90% adoption rate and the clustering of data points in the 8–9 importance range indicate that there is a greater likelihood of successful adoption when stakeholders prioritize significant success criteria. The spread of points at lower levels of significance (6–7), however, indicates variability, perhaps due to differences in stakeholder involvement or availability of resources.

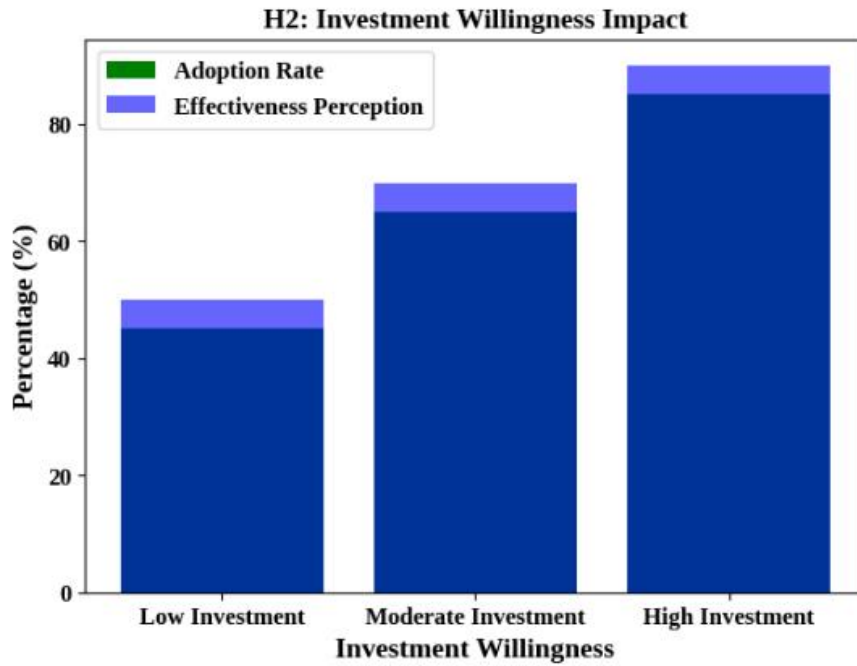


Figure 6: Impact of Investment Willingness on Adoption Rate and Perceived Effectiveness (H2)

High investment willingness is associated with an adoption rate of more than 80% and a perceived effectiveness of almost 85%, which reflects the considerable influence of financial investment; the gap between moderate and low investment levels verifies that insufficient investment strongly limits the effective adoption of technology, and Fig.6 illustrates the correlation between different levels of investment willingness and their corresponding adoption rates and perceived effectiveness. In conclusion, the trend confirms Hypothesis 2 (H2), or that more likely to obtain favourable digital preservation outcomes are stakeholders with a greater will to invest.

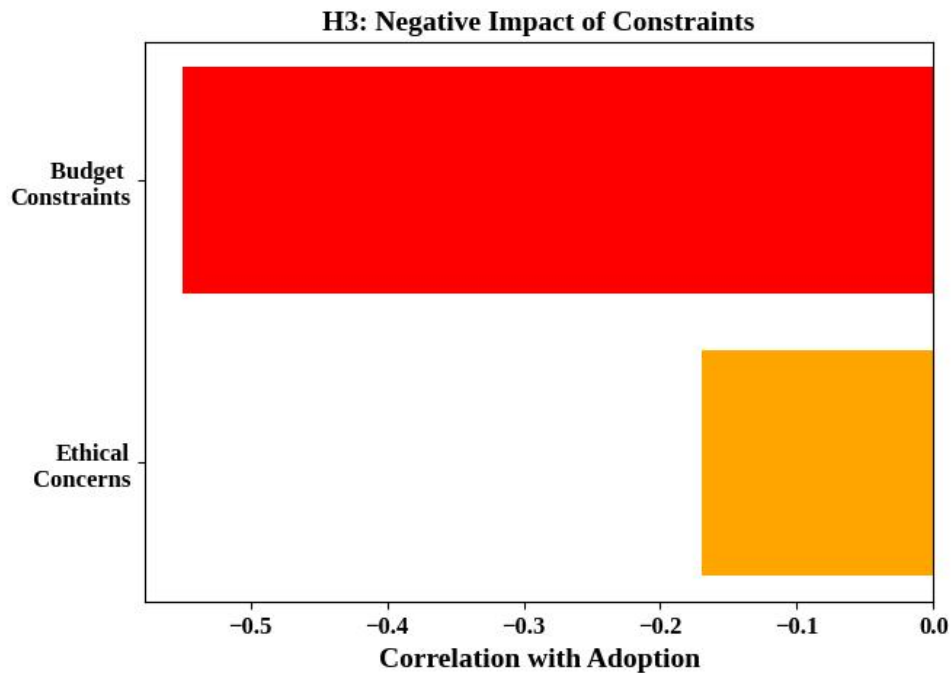


Figure 7: Negative Impact of Budget Constraints and Ethical Concerns on Technology Adoption (H3)

Fig.7 shows the negative correlation between monetary constraints, ethics, and technological application in digital ICH conservation. Financial constraints exert a stronger negative influence (-0.55) on uptake compared to ethical issues (-0.17), indicating that funds are a larger barrier to technology integration. This supports Hypothesis 3 (H3) by highlighting the way ethical dilemmas and lack of funding could hinder the use of AI/VR/3D technologies. As indicated by the findings, addressing these challenges is vital to enhancing technology uptake and maximizing the benefits of digital preservation programs.

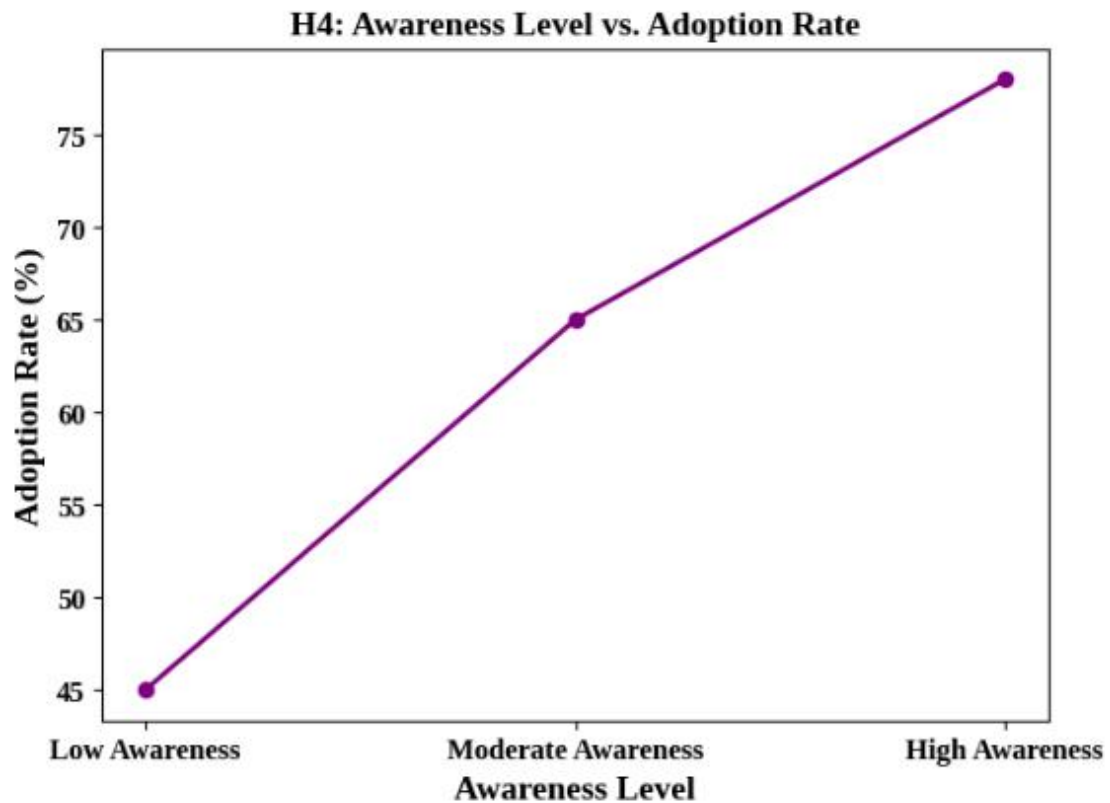


Figure 8. Awareness Level and Its Impact on Technology Adoption (H4)

Fig.8 presents a positive correlation between the level of awareness and adoption of digital technologies for ICH preservation, confirming Hypothesis 4 (H4). High-awareness stakeholders show statistically significant higher adoption rates (75%) as opposed to low-awareness stakeholders (45%). This confirms that a high level of knowledge about digital technologies and their advantages can improve stakeholder participation and integration of technology. The results underscore the call for targeted awareness programs to counteract knowledge gaps and facilitate effective adoption.

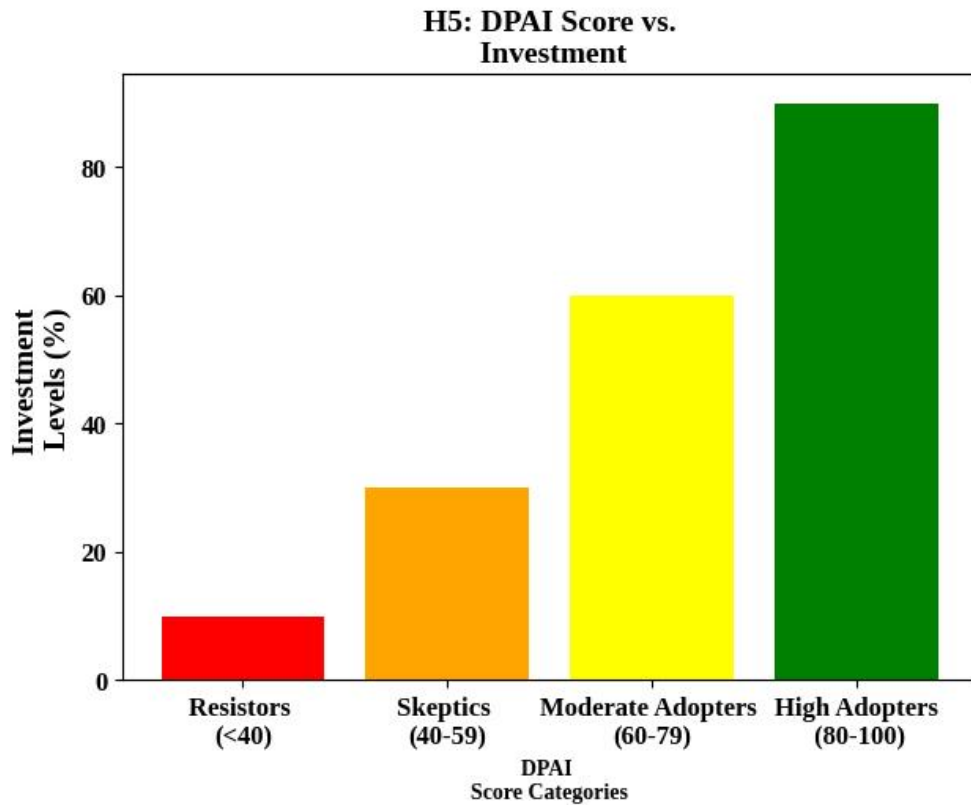


Figure 9. DPAI Score and Its Impact on Investment Willingness (H5)

Fig.9 substantiates Hypothesis 5 (H5) as it depicts the relationship between investment levels and Digital Preservation Adoption Index (DPAI) scores. The investment commitment of leading adopters (DPAI 80–100) is 80% higher than that of resistors (DPAI <40), who are barely committed to the tune of 10%. As per this trend, those more committed to digital content preservation are more inclined to contribute finances. The findings highlight that for the purposes of increasing levels of acceptance and investment in digital preservation of ICH, stakeholder awareness and engagement need to be enhanced.

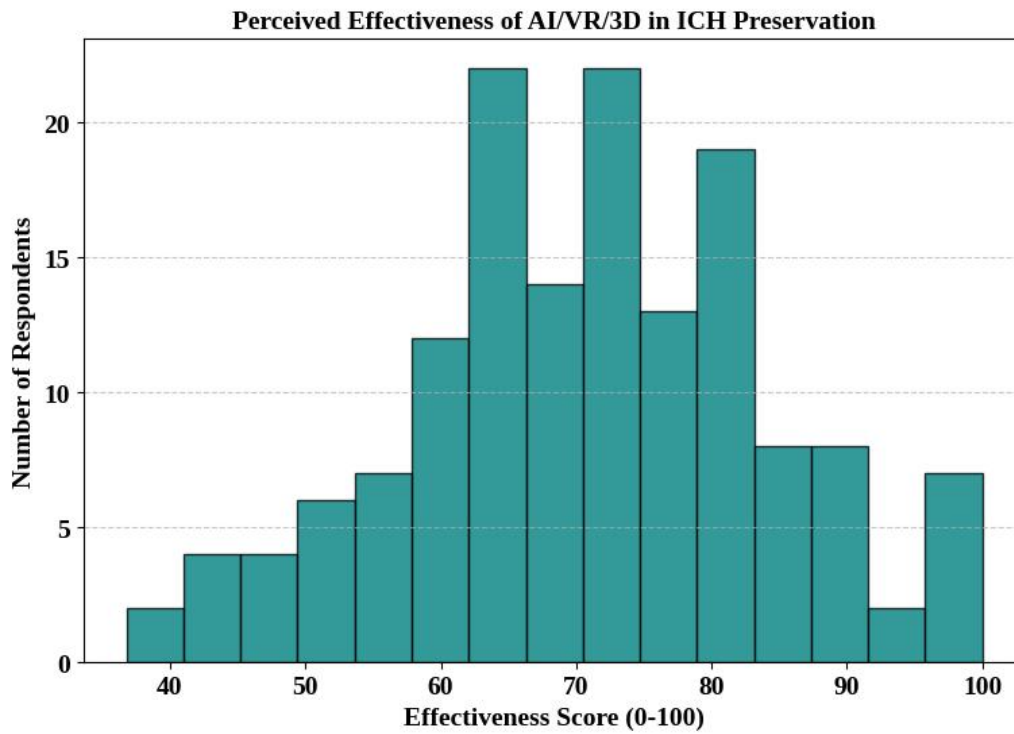


Figure 10. Distribution of Perceived Effectiveness Scores of AI/VR/3D in ICH Preservation

The distribution of stakeholders' opinions about the usefulness of AI/VR/3D technologies in the preservation of ICH is shown in Fig.10. The majority of respondents gave effectiveness ratings in the range of 60 to 80, suggesting a cautious but generally favourable opinion. A few outliers indicated differing degrees of experience or scepticism by scoring either below 50 or above 90. The general trend indicates that although stakeholders see potential in these technologies, more work is required to provide concrete advantages and allay worries to get wider adoption.

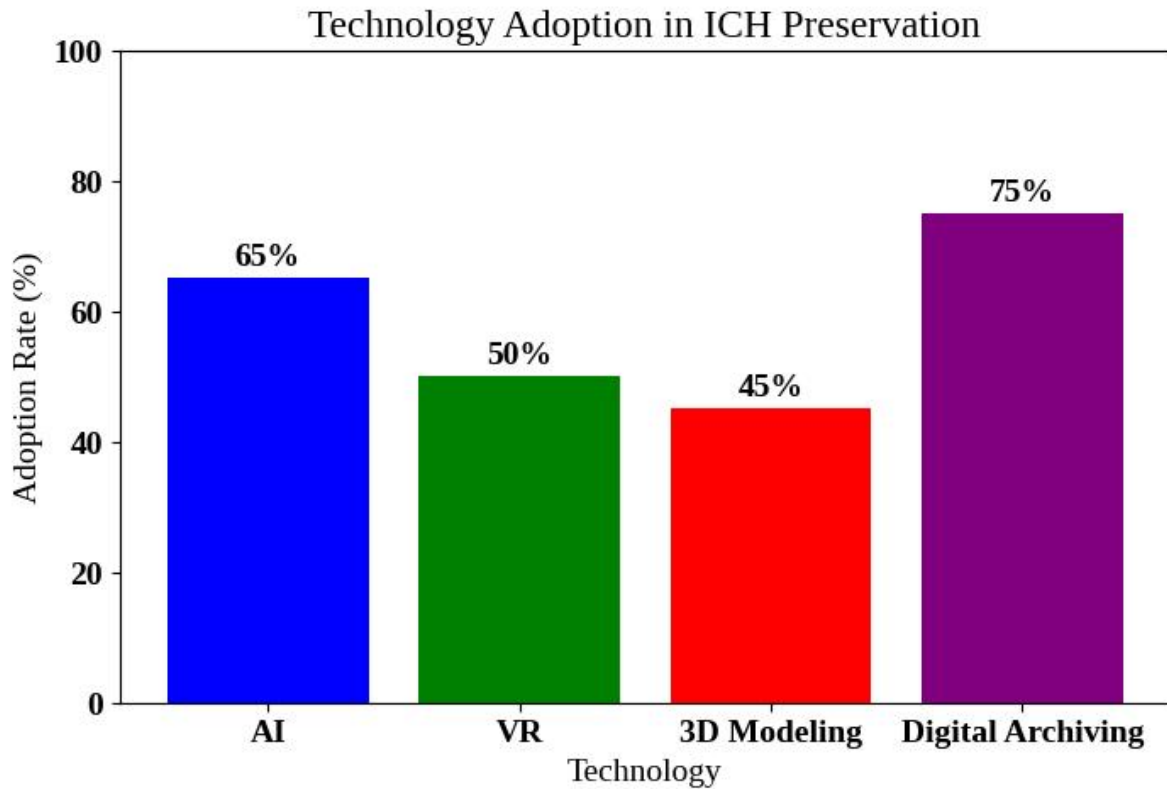


Figure 11. Technology Adoption Rates in ICH Preservation

The acceptance rates for some of the digital technologies used in the preservation of ICH are illustrated in Fig.11. Digital archiving has the highest acceptance rate at 75%, as would be expected for its long history in documentation processes. AI is second at 65%, indicating that computerized data processing and interpretation is increasingly gaining popularity. The moderate adoption levels of VR and 3D modelling (50% and 45%, respectively) reflect that while these technologies hold potential, they might be facing barriers such as cost, technical complexity, and lack of expertise. The data illustrates varying levels of technology integration and highlights where more advanced digital tools might be utilized.

Future Directions and Critical Factors in Digital ICH Preservation:

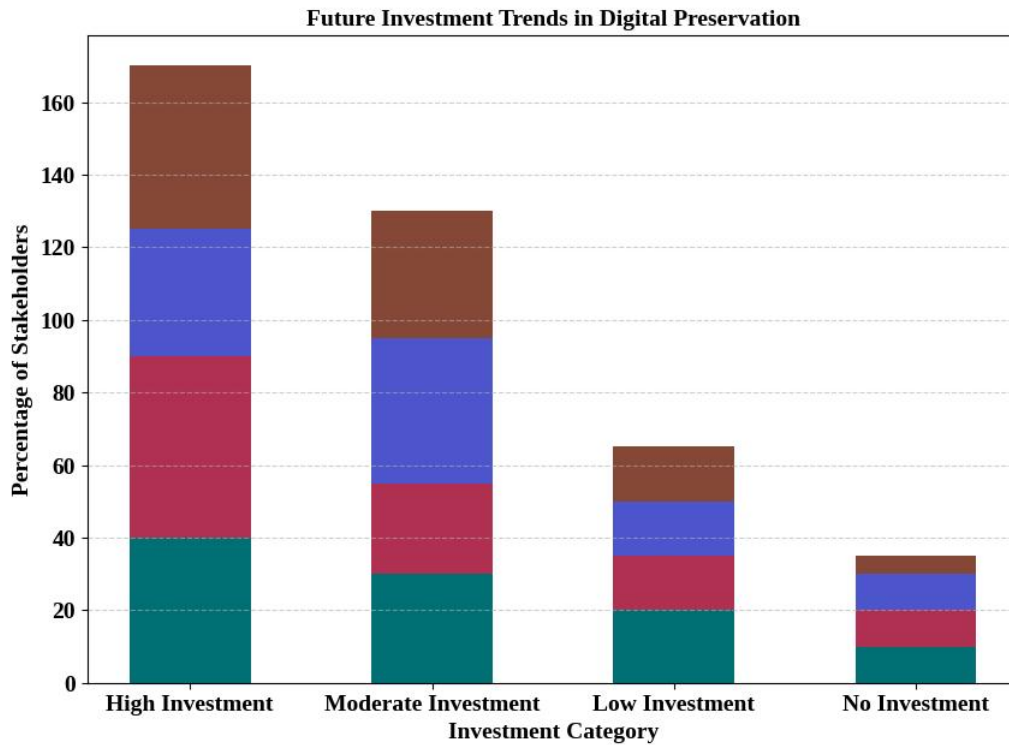


Figure 12. Future Investment Trends in Digital Preservation

The breakdown of the plans of the stakeholders to invest in digital preservation in the future is indicated in Fig.12. The largest percentage is under the High Investment category, which indicates that the stakeholders are committed to continuing efforts at digital preservation. The Low Investment and No Investment groups are smaller, followed by the Moderate Investment group, which indicates cautious optimism. This survey indicates stakeholders' awareness of digital preservation as an essential requirement and a general belief in support of additional investment into it. However, there must be possible setbacks such as resource constraints, the lack of available knowledge, or inadequate knowledge acquisition.

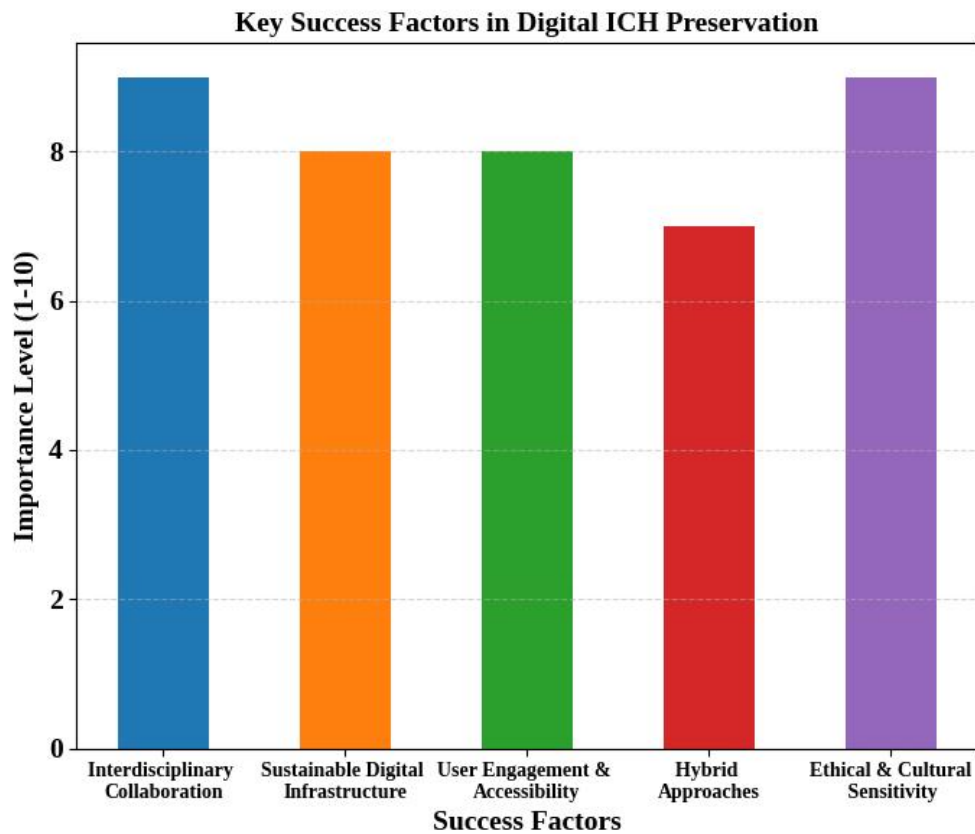


Figure 13: Key Success Factors in Digital ICH Preservation

The importance levels of key success factors to successful digital ICH preservation are illustrated in Fig.13. The highest scores are given to interdisciplinary cooperation and ethical and cultural sensitivity, focusing on the importance of having expertise in multiple fields and approaching cultural circumstances with respect. Top priority is also accorded to user participation and accessibility and sustainable digital infrastructure, with a focus on inclusive, long-term strategies. Hybrid methods scored relatively low, showing that stakeholders prefer clear, functional frameworks even as combining numerous approaches is advantageous. An equitable representation of the technical, ethical, and collaborative elements required for successful digital preservation projects is found in this distribution.

Challenges and Barriers in Digital Preservation:

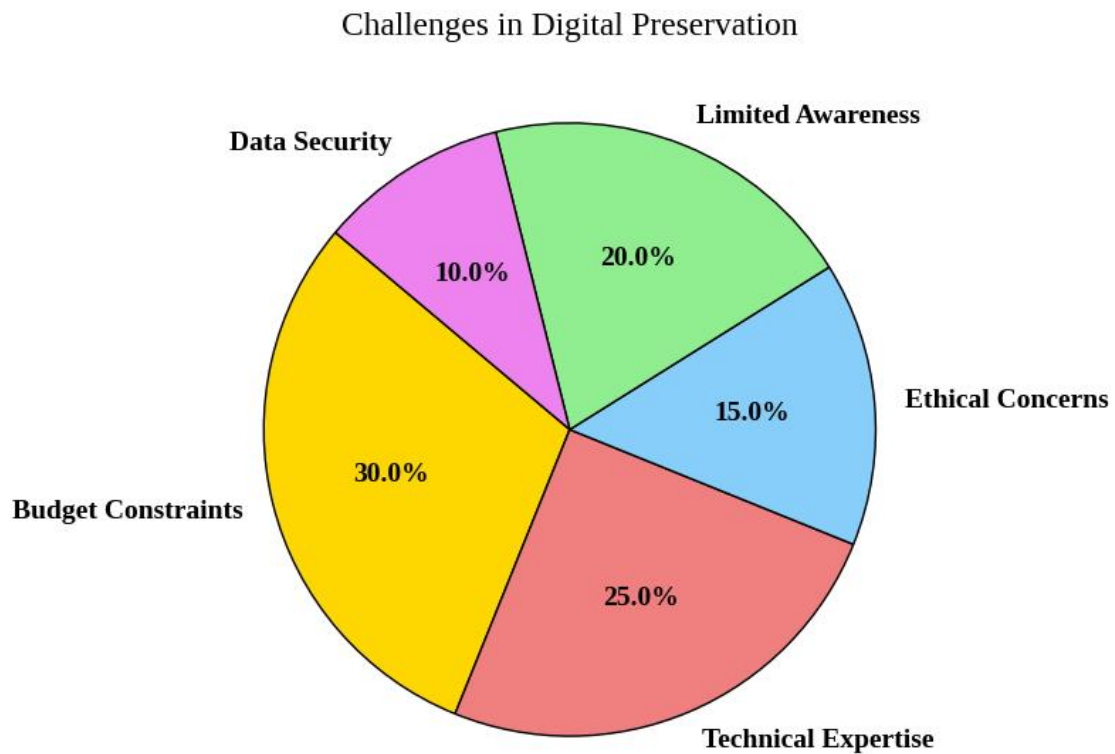


Figure 14. Key Challenges in Adopting Digital Technologies for ICH Preservation

The primary challenges to the use of digital technology in preserving ICH are illustrated in Fig.14. Budget constraints are the largest challenge (30%) in that they symbolize insufficient funds for the latest technology. That there exists a shortage of technical skills among stakeholders is demonstrated by the second largest issue, technical expertise (25 %). Limited awareness (20%) shows that most of the stakeholders are not aware of digital preservation possibilities. There are concerns regarding cultural sensitivity and ownership of data pointed out by ethical issues (15%). Data security (10%) has been rated as a less important but equally significant one, pointing out the need for secure digital platforms. When taken as a whole, these difficulties highlight how difficult it is to integrate technology for ICH conservation.

Model Fit Calculations:

The assessment in Tab.4. quantifies the relationship between Budget Constraints, Ethical Concerns, Investment Willingness, Awareness Level (independent variables) and Technology Adoption (dependent variable) using the multiple linear regression model.

Table 4. Model Fit

Metric	Value	Interpretation
Intercept	-0.0146	Baseline value when all predictors are zero.
R^2	1.00	Indicates a perfect fit, but likely due to limited data and possible overfitting

Budget Constraints	-0.3078	Negative relationship; higher constraints may reduce technology adoption.
Ethical Concerns	-0.1107	Negative relationship; ethical concerns may slightly lower adoption rates.
Investment Willingness	0.1936	Positive relationship; greater willingness to invest increases adoption.
Awareness Level	0.1299	Positive relationship; higher awareness can lead to increased adoption.

The effect of budgetary limitations, ethics, investment readiness, and awareness level on technology acceptance is examined by the regression model. The coefficients and interpretations are explained below:

Intercept (-0.0146): The intercept reflects the base rate of technology acceptance when all predictor variables are held at zero. While not of great significance when taken alone, it provides a benchmark for the model.

Budget Restraints (-0.3078): Negative coefficient signifies that tech adoption is significantly hindered by higher budgetary restraints. The introduction of new technology might be hindered by financial limitations, potentially impacting the adoption rate on an overall scale.

Ethical Issues (-0.1107): The negative relationship indicates that more ethical issues somewhat discourage the use of new technologies. These issues may be triggered by concerns regarding data privacy, cultural awareness, or moral dilemmas with digital preservation.

Investment readiness (0.1936): The positive coefficient indicates that technology adoption is promoted by increased investment readiness. Stakeholders are likely to effectively integrate new technologies if they are more ready to invest in digital preservation.

Awareness Level (0.1299): This is a positive correlation that indicates more use of technology is associated with more knowledge of digital preservation methods and benefits. Technological adoption increases when stakeholders value technology as an ICH preservation solution.

The model identifies financial limitations together with ethical problems which block implementation yet prepared investments coupled with better awareness about digital preservation drive technological adoption. Digital technology applications within ICH preservation will achieve better outcomes if efforts concentrate on financial barrier elimination while resolving ethical problems

5. Conclusion and Practical Implications

Digital ICH preservation benefits from various elements which determine the successful implementation of technology. Two principal obstacles toward adoption consist of Budget Constraints and Ethical Concerns. The trend follows that both increased awareness levels and investment willingness create conditions for higher levels of adoption. The evaluation demonstrates that resolving budget obstacles combined with resolving moral concerns would help accelerate smooth adoption systems. The application of digital technology for ICH protection will improve when stakeholders gain a better understanding and financing opportunities become available. The reduction of costs together with increased innovative behaviour stimulation and stakeholder awareness enhancement must be the main focus for both practitioners and cultural institutions and legislators. The preservation of digital ICH projects can be substantially enhanced through training initiatives coupled with focused funding which will produce enduring results that better meet cultural requirements.

Appendix:

The research utilized survey questions which evaluated AI/VR acceptance within ICH preservation through questions about technology acceptance and ethical concerns combined with willingness to invest and perception of effectiveness and identification of adoption barriers.

Each question uses a Likert scale (1-5):

1 = Strongly Disagree

2 = Disagree

3 = Neutral

4 = Agree

5 = Strongly Agree

Section 1: Technology Adoption & Awareness

1. I am familiar with the use of AI/VR technologies for cultural heritage preservation.
2. I believe AI-driven restoration techniques are effective in preserving intangible heritage.
3. I feel that virtual reality (VR) experiences can provide an authentic representation of cultural heritage.
4. I have personally engaged with AI/VR-based heritage projects.
5. I am interested in learning more about AI/VR applications for heritage preservation.

Section 2: Effectiveness & Impact Perception

6. I believe that AI can accurately restore and reconstruct lost cultural artefacts.
7. Virtual museums and AI-generated exhibitions enhance cultural accessibility.
8. AI/VR technologies help in documenting and transmitting oral traditions.
9. The integration of AI/VR in ICH increases public engagement and appreciation.
10. AI-based techniques improve heritage documentation better than traditional methods.

Section 3: Ethical & Budget Concerns

11. I am concerned about AI-generated cultural artefacts lacking authenticity.
12. AI-based heritage restoration raises ethical concerns regarding cultural ownership.
13. Using AI in ICH might lead to the loss of traditional craftsmanship and expertise.
14. The cost of implementing AI/VR solutions is a major barrier in cultural heritage projects.
15. There is insufficient government funding for AI-driven ICH preservation initiatives.

Section 4: Adoption Constraints & Investment Willingness

16. I believe that a lack of awareness is a key barrier to adopting AI/VR in heritage conservation.
17. I would support AI-based ICH preservation if funding and policy support were available.
18. The implementation of AI/VR in cultural heritage requires collaboration between researchers, policymakers, and developers.
19. Museums and cultural organizations should prioritize AI/VR integration for heritage preservation.
20. AI/VR technologies should be included in educational programs to raise awareness.

Section 5: Future Potential & Long-Term Adoption

21. AI/VR can revitalize endangered cultural traditions and languages.
22. The use of AI in ICH preservation will continue to grow in the next decade.
23. AI/VR-driven solutions will become a necessity rather than an option for preserving cultural heritage.
24. The government and private sectors should collaborate to invest in AI/VR-based heritage conservation.
25. I believe that AI/VR solutions can bridge generational gaps by making heritage more accessible.

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