

Integration of digital technology in conservation of traditional Balinese architecture: Strategic model innovation towards cultural sustainability

Ni Made Emmi Nutrisia Dewi^{1*}, Ngakan Ketut Acwin Dwijendra²,
I Kadek Pranajaya¹, Muhammad Febrian Rachmadhan Amri³,
Dewa Gede Adi Dharma Sucipta¹

¹Master of Design, Bali Institute of Design and Business (IDB Bali),
Denpasar, Bali, Indonesia

²Faculty of Engineering, Udayana University, Denpasar, Bali, Indonesia

³Study Program of Digital Business, Bali Institute of Design and Business (IDB Bali),
Denpasar, Bali, In Jl. Tukad Batanghari No.29, Panjer, Kec. Denpasar, Indonesia



ARTICLE INFO	ABSTRACT
<i>Article history:</i> Received September 04, 2025 Received in revised form Jan. 21, 2026 Accepted April 13, 2026 Available online June 01, 2026 <i>Keywords:</i> Architecture Conservation Digital technology Strategy model Traditional balinese *Corresponding author: Ni Made Emmi Nutrisia Dewi Master of Design, Bali Institute of Design and Business (IDB Bali), Denpasar, Bali, Indonesia Email: emminutrisia@idbbali.ac.id ORCID: https://orcid.org/0000-0001-6561-4183	Balinese traditional architecture constitutes a significant cultural legacy enriched with philosophical, societal, and ecological meanings; however, its continuity is increasingly challenged by the pressures of modernization, rapid urban expansion, and the declining transmission of indigenous knowledge across generations. This study investigates the function of integrating digital technologies as a conservation strategy aimed at reinforcing long-term cultural sustainability. A qualitative-descriptive approach is adopted through comprehensive literature review, on-site observation, and case-study examination of the digitalization processes applied to traditional architectural structures. The findings indicate that digital recording techniques (3D scanning, photogrammetry) together with immersive educational visualization (augmented reality/AR, virtual reality/VR) significantly improve the precision of heritage documentation, generate opportunities within the creative economy, support cultural learning initiatives, and enhance the involvement of local communities. Nevertheless, several major constraints remain, including limited digital literacy among stakeholders, inadequate technological infrastructure, cultural hesitation toward technological intervention, and the absence of coherent and integrative policy frameworks. Based on these findings, a strategic framework identified as the "Digital-Integrated Cultural Sustainability (DICS)" model is formulated, combining advanced digital applications with indigenous cultural principles to achieve sustainable preservation. This research ultimately demonstrates that digital technology should not be regarded merely as a technical instrument, but rather as an innovative and strategic mechanism for safeguarding the tangible and intangible cultural values of Bali. It is expected that these outcomes may provide practical guidance for the formulation of digital-oriented conservation policies and implementation strategies within other regions possessing rich cultural heritage. properly, and there are gaps in the connection between units.



Introduction

Traditional Balinese architecture represents an essential component of the cultural landscape that embodies the philosophy of *Tri Hita Karana*, which emphasizes harmony among human beings, the natural environment, and the divine. The presence of this architectural tradition functions not merely as a physical manifestation of built form, but also as a representation of the cultural and spiritual identity of Balinese society. Nevertheless, the accelerating processes of modernization and urban development have generated considerable pressure on the continuity of this architectural heritage. The documentation of traditional architectural knowledge is becoming increasingly limited and unsystematic, thereby threatening the sustainability of the cultural principles embedded within it (Sudana, Suryadana, and Bayupati 2020).

Empirical observations indicate that conventional conservation practices remain restricted in scope and have not yet comprehensively addressed contemporary challenges. For instance, the development of a web-based Balinese Traditional House Information System derived from the *Asta Kosala-Kosali* principles has contributed to conservation initiatives; however, it remains insufficient in responding to the broader need for integrated technological implementation (Mebanua, Amijaya, and Noviandri 2022). This situation therefore raises several critical questions: to what extent can digital technologies enhance the precision of documentation and the effectiveness of conservation efforts related to traditional Balinese architecture? Furthermore, how can the participation of local communities and the application of collaborative governance contribute to sustaining digitally oriented conservation practices? conservation?

What barriers are encountered, and which implementation strategies are most appropriate for realizing digital conservation practices? Within this framework, digital technologies such as 3D scanning, photogrammetry, augmented reality (AR), and virtual reality (VR) provide significant opportunities for documenting, reconstructing, and visualizing traditional buildings with a high degree of accuracy. Such technologies not only facilitate the preservation of physical structures, but also generate

opportunities for the growth of the creative economy, the promotion of culture-based tourism, and educational engagement for younger generations (Karatzas et al. 2025; Sthapit and Panthi 2024). Consequently, the integration of digital technology has the potential to establish a new paradigm of conservation that is participatory, adaptive, and sustainable. The objective of this research is therefore to formulate the Digital-Integrated Cultural Sustainability (DICS) strategic model as a conservation framework grounded in digital technology, to validate its implementation through participatory observation and focus group discussions, and to propose policy recommendations together with community empowerment strategies.

This research is expected to offer both conceptual and practical contributions toward the development of cultural preservation strategies that are compatible with the digital era, while simultaneously strengthening Bali's role as a cultural heritage center capable of adapting to technological transformation. The novelty of this study lies in the integration of digital technology with indigenous cultural values through the DICS framework. In contrast to earlier studies that predominantly emphasized technical documentation, this research positions digital technology as an innovative strategic approach for safeguarding the physical and cultural values of Bali in a sustainable manner.

Methods

This study adopts a qualitative research approach based on an interpretive paradigm and ethnographic methodology in order to gain an in-depth understanding of the integration of digital technology in the conservation of traditional Balinese architecture. The ethnographic approach was selected because it is particularly suitable for exploring cultural values, perceptions, and conservation practices that exist within society through the researcher's direct engagement in the social and cultural environment. Consequently, the research does not merely describe observable phenomena, but also interprets the meanings embedded within conservation practices that incorporate digital technology. Research data were obtained from contemporary sources through field observation, in-depth interviews,

and focus group discussions. The study location was purposively selected at representative traditional Balinese structures, including temples and traditional residential compounds within the Denpasar region and its surrounding areas, ensuring that the sample adequately reflected the contextual characteristics of the research problems and objects. Informants involved in the research consisted of traditional leaders, architects, academics, creative economy practitioners, and heritage site managers, all of whom were selected based on their direct engagement with cultural conservation initiatives and the application of digital technology.

Data analysis was conducted through thematic analysis consisting of several stages: initial coding to identify analytical categories, thematic grouping based on relationships among categories, and the identification of principal themes aligned with the research focus. These themes include documentation accuracy, AR/VR-based educational visualization and cultural promotion, opportunities for creative economic development and community empowerment, implementation challenges and potential solutions, as well as the formulation of the DICS model. The validity of the research findings was ensured through source triangulation by integrating literature review, observation, interviews, and focus group discussions, as well as through member checking with informants. The final outcome of the study is the formulation of the Digital-Integrated Cultural Sustainability (DICS) strategic model, which can be implemented within conservation practices of traditional Balinese architecture in a sustainable, inclusive, and locally grounded manner.

Results and discussion

The research question concerning the extent to which digital technology can improve the accuracy of documentation and the effectiveness of conservation of traditional Balinese architecture is addressed through preliminary findings demonstrating that the integration of digital technologies represents an innovative and highly relevant approach in the era of globalization. The application of digital tools and techniques, including 3D modeling, laser scanning, augmented reality (AR), and virtual reality (VR), introduces new possibilities for

documenting, restoring, and preserving traditional Balinese structures that embody profound cultural and spiritual significance. Through the utilization of technologies such as photogrammetry, 3D modeling, and Building Information Modeling (BIM), traditional buildings can be digitally recorded and preserved without diminishing their historical or cultural value (Carelia and Purwanto 2023). These findings indicate that conservation processes previously constrained by conventional methodologies can now be conducted with greater precision, efficiency, and long-term sustainability through the use of digital technologies. In addition to maintaining the physical preservation of architectural structures, the integration of digital technology also enhances public understanding and appreciation of Bali's cultural heritage, which is rich in symbolism and philosophical meaning. Moreover, the findings reveal that digital technology provides opportunities to introduce traditional Balinese architecture to a broader global audience, linking local cultural expressions with international networks while simultaneously encouraging the expansion of a culture-based creative economy.

Increasing documentation accuracy through digital technology

The application of 3D scanning technology (laser scanning) and photogrammetry has been demonstrated to significantly enhance the accuracy of documentation related to the physical characteristics of traditional Balinese buildings. These two techniques complement one another in producing precise digital models that support the documentation, restoration, and management of historic structures (Alshawabkeh, Baik, and Miky 2021). Visual data that are processed into three-dimensional models enable detailed and interactive virtual reconstructions, thereby strengthening the understanding of architectural configurations while also providing opportunities for sustainable digital preservation (Sarwito, Kesia, and Vania 2024). Figure 1 presents a three-dimensional model of a temple complex generated through photogrammetry, illustrating the spatial configuration, relationships among architectural elements, and their surrounding landscape context.



Figure 1. Illustration of taking regional images using photogrammetry

Figure 2 illustrates the application of photogrammetry in the conservation of traditional Balinese architecture, enabling precise documentation of specific architectural components, such as *pelinggih* elements.

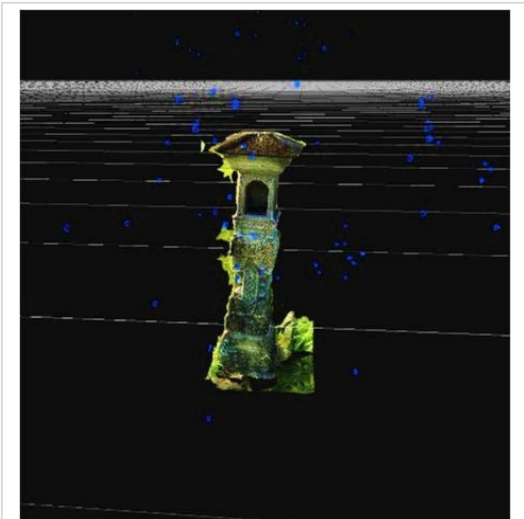


Figure 2. Illustration of capturing details of pelinggih objects using photogrammetry

The photogrammetry process in the conservation of Balinese architectural heritage consists of five principal stages: planning, image data acquisition, data processing, 3D model generation, and visualization or utilization. These stages are illustrated in figures 3–7, which demonstrate the systematic workflow from the

initial documentation stage to the final output of digital models. The high level of accuracy achieved through these processes also supports rescue operations, restoration initiatives, and reconstruction activities, while serving as an important reference for planning conservation funding and project management (Liu and Mamat 2024).



Figure 3. Example of planning and preparation stages for temple area objects



Figure 4. Example of image data collection stages using UAV/high resolution camera on temple area objects

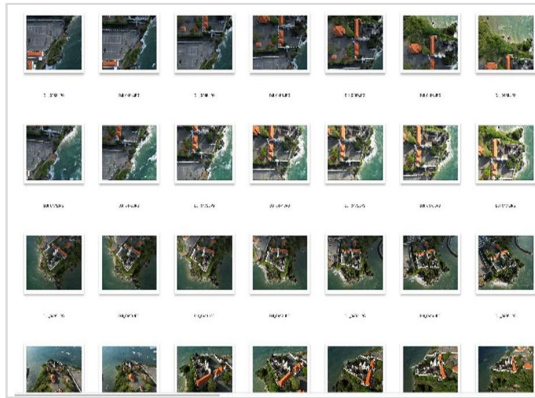


Figure 5. Example of Photogrammetric Data Processing Stages for Objects in the Temple Area

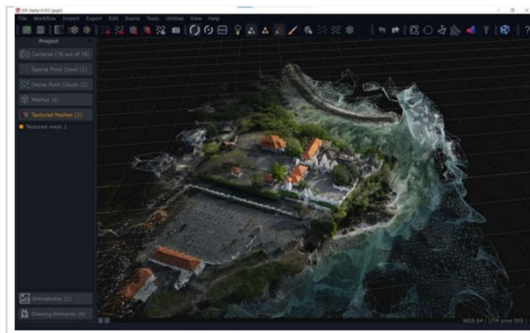


Figure 6. Example of stages for creating advanced 3D models for objects in the temple area



Figure 7. Example of Visualization and Integration Stages to BIM/Digital Archive in the Temple Area

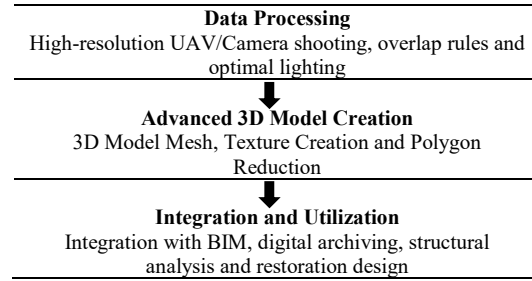
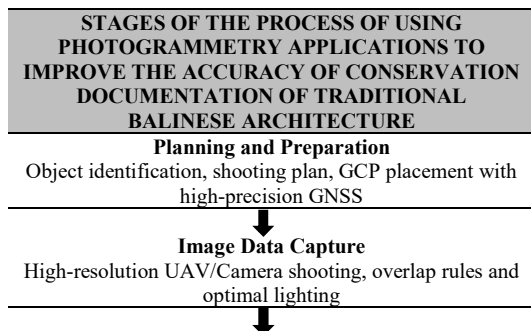


Figure 8. Diagram illustrating the process of photogrammetry application for improving the accuracy of conservation documentation of traditional Balinese architecture

Educational visualization and cultural promotion through Augmented Reality (AR) and Virtual Reality (VR) in Balinese traditional buildings

Augmented reality (AR) and virtual reality (VR) technologies play a crucial role in communicating the cultural significance of Balinese architecture through immersive and interactive experiences. The application of AR and VR allows younger generations and tourists to explore traditional architecture without requiring physical presence at heritage sites, while simultaneously supporting historical preservation efforts and promoting cultural awareness (Purwanto 2024; Rahardjo, Purwanto, and Ardianto 2024; Harrison, Rose, and Sterling 2025; Abukarki 2025; Setyawati and Triediantoro 2022).



Figure 9. Example of one of the 3D modeling of Balinese Traditional architectural buildings that are conservation objects



Figure 10. VR Space design using Sketchup

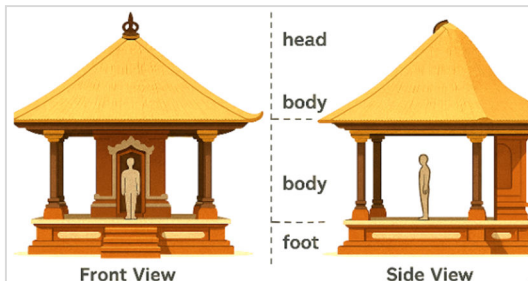
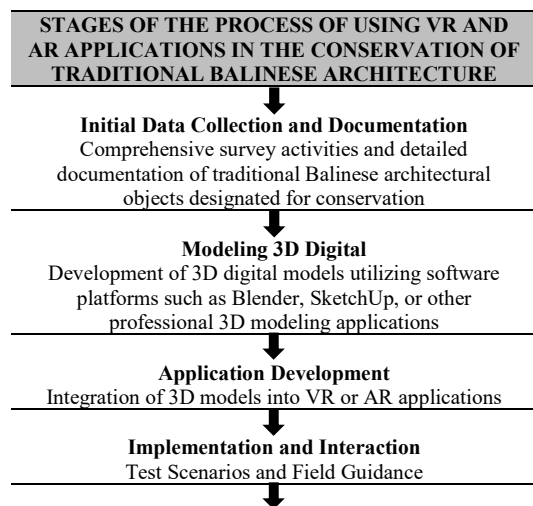


Figure 11. Example of VR in building proportions creation using Sketchup



Figure 12. Examples of VR in Building Layout Modeling on using SketchUp



Dissemination and Public Education Virtual Exhibition and AR Tourism

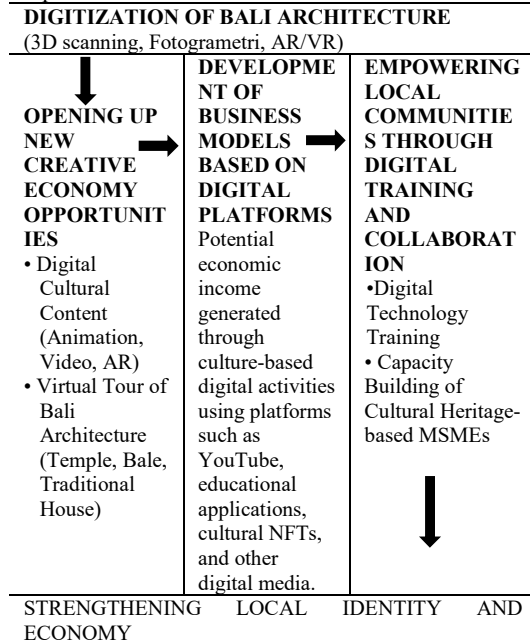
Figure 13. Diagram of the process of using VR and AR applications for the Conservation of Balinese Traditional architecture

The implementation process of AR and VR technologies encompasses several stages, including visual and textual data acquisition, three-dimensional modeling, application development, and phases of interaction and public dissemination. These stages are illustrated in figures 10–13 and further explained in the accompanying table (Boboc et al. 2022; Ibiş and Çakici Alp 2024). Through the application of 3D modeling and interactive simulation environments, AR and VR technologies not only enhance public learning and educational engagement but also introduce digital conservation strategies that remain responsive to social and historical contexts (Ma et al. 2025).

Creative economy opportunities and community empowerment

The integration of digital technologies such as VR, AR, and photogrammetry within the conservation of Balinese architecture does not solely support cultural preservation, but also creates opportunities for the development of the creative economy through digital content production, virtual heritage tours, and the reconstruction of historic architectural forms that enrich the educational experiences of younger generations (Pratowo 2022). Empirical studies conducted in Penglipuran Village demonstrate that the implementation of Building Information Modeling (BIM) and Historic Building Information Modeling (HBIM) is capable of providing semantic data rooted in customary traditions, generating accurate architectural documentation, and facilitating effective interdisciplinary collaboration for sustainable conservation practices (Suhari et al. 2022; Siewczyński and Jan Szot 2025; Di Stefano et al. 2020; Mutaqi, Salura, and Lake 2025).

Table 1. Positive Impact of Providing Creative Economy Opportunities and Community Empowerment



Implementation challenges and solutions: literacy, infrastructure, and regulation

The main challenges in the application of digital technology in Balinese cultural conservation include low digital literacy, limited infrastructure, and the absence of supportive regulations (Welly Ayu Apriani, Amiluhur Soeroso, and Jussac Maulana Masjhoer 2025).

Table 2. Implementation challenges and solutions: literacy, infrastructure, and regulation

Specification	Challenge	Solution
Low Digital Literacy	Limited training opportunities and inadequate understanding of technological tools	Community training & workshop programs and Collaboration with educational institutions
Limited Technology Infrastructure	Slow/unavailable internet and Lack of digital documentation tools	Procurement of tools from government/CSR support and strengthening village-based digital networks
Regulations Have Not Supported	Absence of digital conservation policies and insufficient cross-agency collaboration in	IT-based conservation policy formulation and Cross-sectoral team formation

initiative development
Integrated, Participatory, and Sustainable Digitalization Implementation

Model of digital technology integration strategy in the conservation of Balinese traditional architecture

The conservation strategy model proposed in this study is formulated through the Digital-Integrated Cultural Sustainability (DICS) approach, which integrates precise digital documentation, virtual cultural engagement, community capacity-building programs, and collaborative governance mechanisms. The role of digital technologies in architecture, particularly BIM and HBIM systems, has demonstrated significant effectiveness in strengthening the preservation and adaptive reuse of historic structures while maintaining their cultural significance within contemporary landscapes (Andy Satria et al. 2024; Poltak and Peter Ardianto 2024; Dharmatanna 2025).

Table 3. Four main pillars in the strategy model with the "Digital-Integrated Cultural Sustainability (DICS) Approach

Digital-Integrated Cultural Sustainability (DICS)		
Main Pillars	Method	Benefits
Digital Documentation and Mapping (DDM)	Utilizing photogrammetry, 3D laser scanning, and drones	Generation of spatially detailed digital databases of traditional architecture serving as references for conservation
Virtual Cultural Engagement (VCE)	Using Virtual Reality (VR), Augmented Reality (AR), and interactive virtual tours	Introduction of cultural values to younger generations and global audiences
Community-Centered Digital Training (CCDT)	Involving indigenous village communities in digital technology training	Ensuring knowledge transfer and strengthening local participation in conservation
Integrated Governance and Collaboration Platform (IGCP)	Building a cross-disciplinary digital collaboration system (architects, academics, government, community, creative industries)	Supporting integrated and sustainable conservation planning

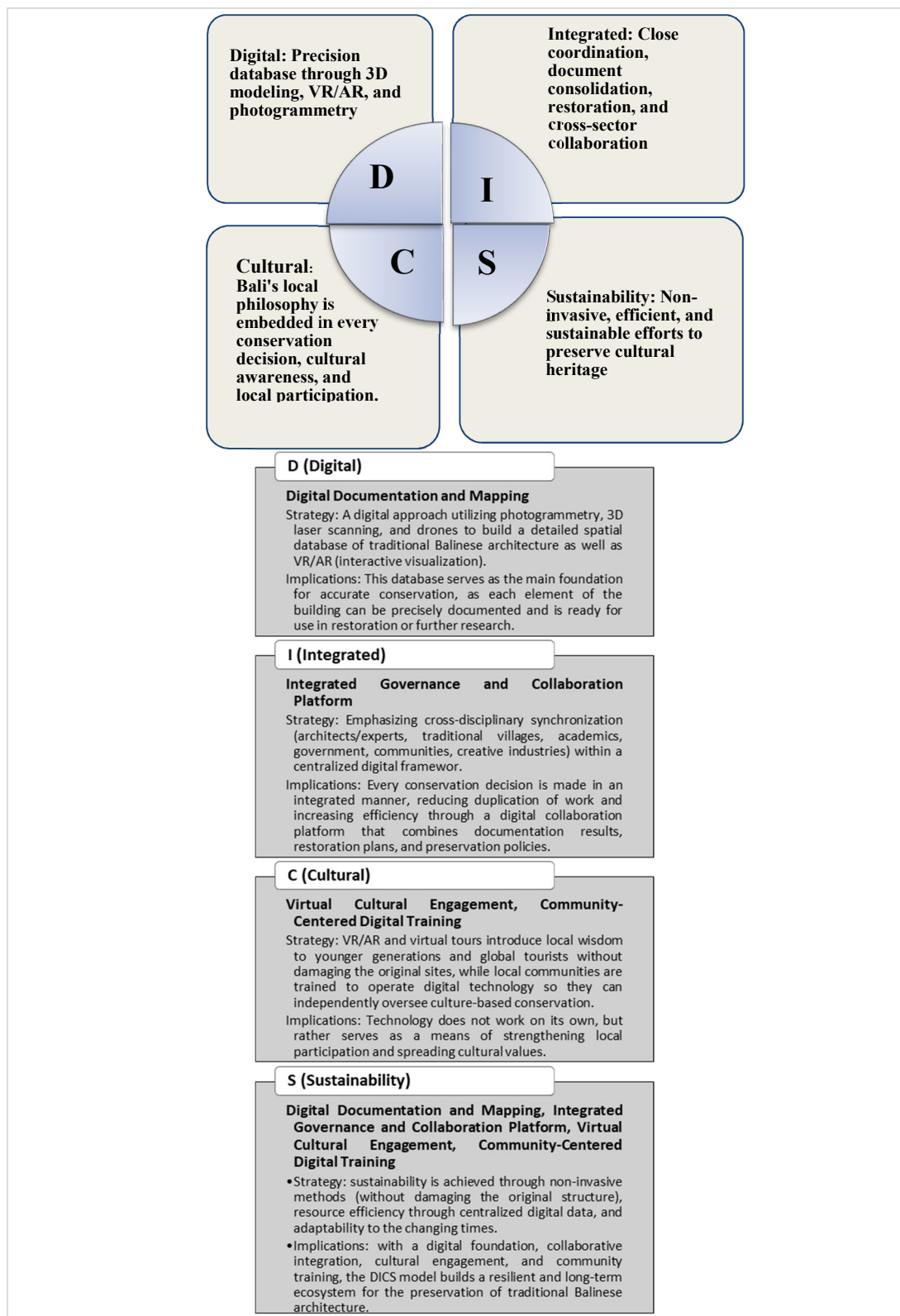


Figure 14. Diagram of the relationship between the model with the Digital-Integrated Cultural Sustainability (DICS) Approach and the four main pillars

The novelty of the DICS model lies in the simultaneous integration of high-precision digital documentation, cross-generational knowledge transfer, and collaborative engagement among multiple stakeholders. The innovative characteristics and targeted outputs associated with each digital platform are illustrated in tables 4–5 (Redyantanu and Otto 2025; Sapay et al. 2025).

Table 4. Novelty of strategy model with a "Digital-Integrated Cultural Sustainability" (DICS) approach

Aspect	Model DICS (Digital-Integrated Cultural Sustainability)	Novelty Contribution
Technological Approach	Comprehensive integration of photogrammetry, 3D scanning, VR, and AR	Development of a high-precision digital database for conserving traditional architecture
Conservation Focus	Inclusion of cultural narratives and traditional dimensions in digital formats	Conservation based on intangible heritage, not just physical
Stakeholder Involvement	Multi-stakeholder collaboration (indigenous villages, academics, creative industries, government, etc.)	Establishment of an inclusive and sustainable conservation ecosystem

Aspect	Model DICS (Digital-Integrated Cultural Sustainability)	Novelty Contribution
Implementation Strategy	Integrated in one unified strategic model	Provision of a clear direction for replication and continuous development
External/Yield	Interactive databases, 3D models, digital maps, and public education platforms	Expansion of public access, enhancement of awareness, and strengthening of conservation policies
Sustainability	Adaptable and up-to-date structured models	Ensuring the sustainability of cultural conservation across generations

Table 5. Output targets in the integration of digital technology in the application of strategic models with the "Digital-Integrated Cultural sustainability

	Platform Digital			
	Photogrammetry	3D Scanning	Virtual Reality (VR)	Augmented Reality (AR)
Function	Visual documentation of traditional building details	High-precision architectural modeling	Interactive simulations for education and planning	Visualization of cultural information at original locations and cultural promotion
Related Parties	Academics, local communities	Government, academics	Academics, creative industries	Government, community, and tourists
Strategy in DICS	Image-based precision documentation	Precision digital mapping and archiving	Cultural engagement through simulation	Enhancement of cultural experiences within real environments
Output/Outcome Targets	Accurate visual database for conservation	Precise restoration design and minimal errors	Public education and cultural awareness	Interactive and participatory cultural tourism

The integration of all digital platforms through interconnected systems and collaborative cooperation among relevant stakeholders to implement cross-sector governance strategies will ultimately establish a resilient and sustainable ecosystem for the conservation of traditional Balinese architecture.

The relationship between the DICS model and its four principal pillars is illustrated in figure 15, which highlights the integration of digital

documentation, cultural engagement, community training, and collaborative governance structures.

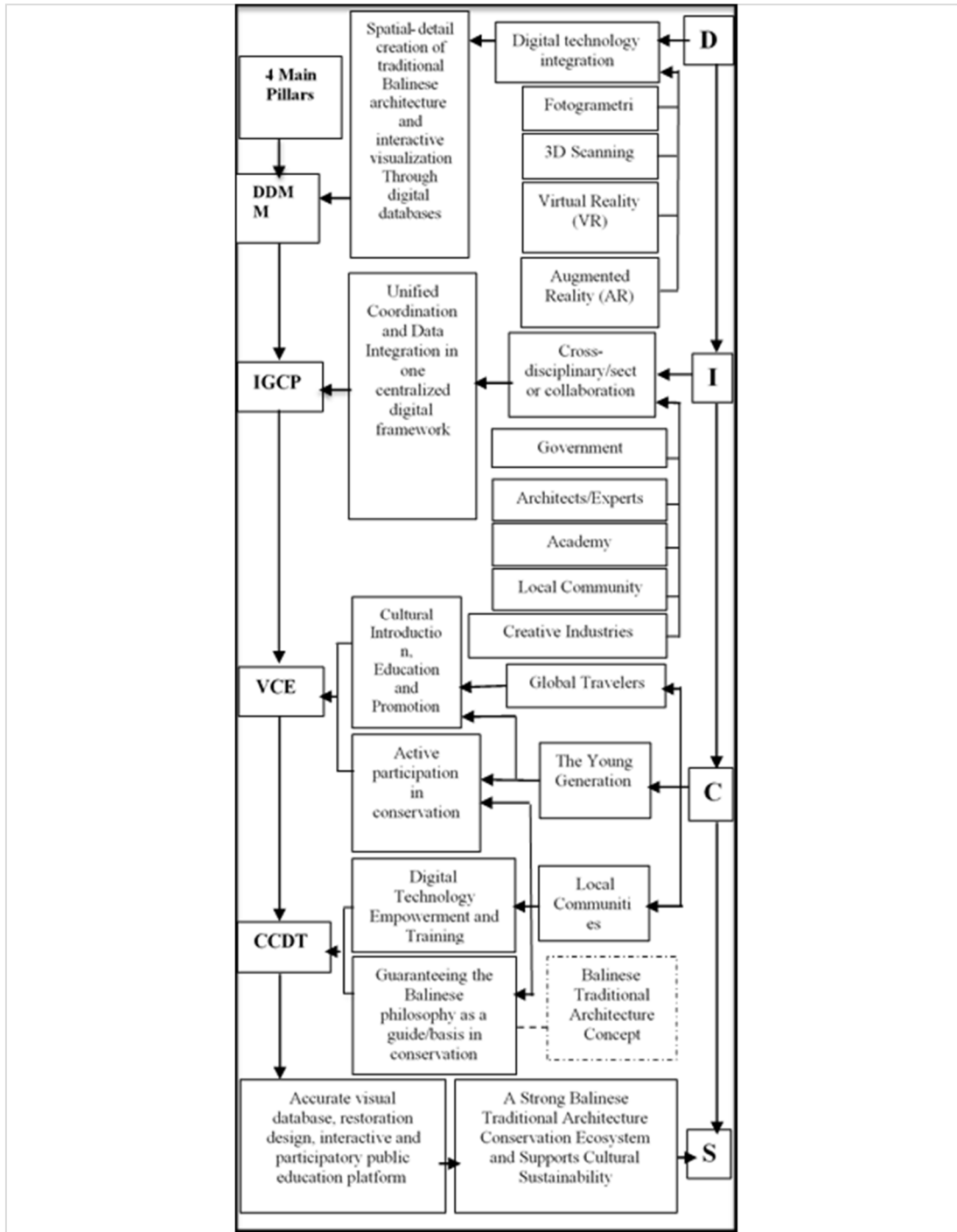


Figure 15. Summary diagram of the strategy model framework with the "Digital-Integrated Cultural Sustainability (DICS) approach

Conclusions

This research originates from the recognition that conventional methods for conserving traditional Balinese architecture remain limited in their capacity to document spatial characteristics with high precision or effectively communicate cultural meanings. Accordingly, the objective of this study was to formulate the Digital-Integrated Cultural Sustainability (DICS) approach as a digital technology-based conservation framework that is responsive to local contexts.

The findings demonstrate that technologies such as photogrammetry, 3D laser scanning, and drone-based documentation are capable of generating precise architectural records suitable for long-term restoration and digital archiving, while AR and VR technologies strengthen educational functions and cultural promotion through immersive and interactive experiences. Furthermore, the integration of digital technology creates opportunities for the development of the creative economy and the empowerment of indigenous village communities through digital training initiatives, although challenges related to literacy, infrastructure, and regulatory frameworks remain.

In conclusion, the DICS model formulated in this study integrates high-precision digital documentation, collaborative governance mechanisms, and cultural engagement through virtual media platforms. The principal contribution of this research lies in the development of an integrated strategic framework that aligns with the research problems and objectives while supporting the long-term sustainability of Balinese cultural heritage conservation.

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Author(s) contribution

Ni Made Emmi Nutrisia Dewi contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

Ngakan Ketut Acwin Dwijendra contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

I Kadek Pranajaya contribute to methodology, supervision, and validation.

Muhammad Febrian Rachmadhan Amri contribute to methodology, supervision, and validation.

Dewa Gede Adi Dharma Sucipta contribute to methodology, supervision, and validation.

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