Digital Twins as Governance Infrastructures in UNESCO Low-density Landscapes

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Abstract: Low-density regions often host culturally significant heritage assets with high social, symbolic, and economic value, but yet these resources remain underused because of weak coordination, limited visibility, and institutional fragmentation. This study addresses to that problem by conceptualizing the economy of forgetfulness as a governance condition in which dispersed heritage gradually loses salience in policy agendas and public investments due to persistent visibility deficits. It argues that digital twins should be understood not merely as a technical tool for documentation or monitoring, but as a strategic governance infrastructure that can reactivate dormant heritage and improve policy action in territorially fragmented settings. The study develops a theory-building comparative framework that traces how digital visibility can translate into governance outcomes through a sequential process, while showing that the economy of forgetfulness moderates the all process. To ground this argument, it uses UNESCO-listed cases - Douro Valley, Genoa, Sintra, and Pompeii - illustratively rather than as empirical tests, highlighting differences in institutional density, coordination capacity, and digital readiness. Selective reference is made to high-visibility contexts such as Notre-Dame to explore transferability, adaptation, and scaling without assuming direct replication. Where baseline visibility is low and neglect is high, digital interventions are expected to exert stronger effects on awareness, suggesting particularly high policy value in peripheral regions. These cases illustrate how digital twins' applications may reduce decision latency, uncover latent coordination potential, and support more effective governance across territorial contexts. Because the cases are illustrative rather than empirical, they clarify framework plausibility and transferability under adaptation rather than replication. The study's policy contributions are threefold: it reframes digital twins as a heritage activation infrastructure; it proposes an operationalizable moderated visibility-awareness mechanism expandable to full sequential paths; and it positions the economy of forgetfulness as a policy-shaping condition for territorial cohesion, development, and governance in marginalized regions.

Keywords: Digital twins, Heritage governance, Low-density regions, Economy of forgetfulness, Institutional logics, UNESCO

1. Introduction

Low-density regions (LDRs), as defined in Portugal by Portaria 208/2017, combine demographic sparsity with institutional fragmentation. They often contain culturally significant heritage assets with high symbolic, social, and economic value, yet these assets remain underutilized because they are weakly connected to coordination mechanisms, policy attention, and digital infrastructures that can support collective action (Mourão, 2020; Sánchez-Carreira, Reis Mourão and Blanco-Varela, 2023). This is not simply a problem of scarcity, but a governance failure in which heritage value exists without corresponding institutional mobilization.

We conceptualize this condition as an economy of forgetfulness: a governance dynamic in which dispersed heritage progressively loses salience in policy agendas and collective investment because of persistent visibility deficits (Mourão, 2020). In this paper, the concept serves as both a boundary condition and an explanatory lens for understanding why high-value heritage may remain institutionally invisible despite its cultural significance.

Within this context, digital twins (DTs) should be understood not merely as documentation or visualization tools, but as change infrastructures capable of enhancing visibility, supporting shared interpretation, and reducing informational frictions across fragmented actor networks (Chioni, Pezzica and Favargiotti, 2024; Mammone, Binetti and Massarelli, 2026). High-profile applications such as Notre-Dame show the technical potential of DTs for reconstruction and coordination, but they offer limited insight into how such affordances operate under conditions of institutional scarcity, lower visibility, and weaker governance capacity (Lister, Nash and Ledingham, 1951; Gagua et al., 2025). For that reason, analogies from high-capacity environments must be treated cautiously and adapted to the realities of LDRs.

Despite growing interest in digital heritage, the literature still lacks a clearly specified conceptual and comparative framework explaining how digital infrastructures shape governance dynamics across different institutional densities. This study addresses that gap through a theory-building, comparative, and theoretically

illustrative framework that conceptualizes DTs as change infrastructures. It proposes a sequential mechanism through which digital visibility increases stakeholder awareness, stimulates engagement, improves coordination, and gradually supports the institutionalization of innovation as a territorial capability.

Accordingly, the study is guided by two focused research questions:

RQ1: How do DT affordances influence the relationship between visibility, stakeholder awareness, and coordination in heritage governance?

RQ2: How does the economy of forgetfulness condition the effectiveness of digital visibility in LDR and institutionally fragmented contexts?

To illustrate and structure variation, the study adopts a comparative design based on UNESCO -listed cases - Douro Valley, Genoa, Sintra, and Pompeii - used as analytically structured examples rather than sources of causal inference. These cases allow the framework to be examined across different levels of institutional density, governance fragmentation, and digital readiness. Selective reference to high-visibility contexts such as Notre-Dame is used only to explore transferability across institutional settings, not to imply direct replication.

The study makes three contributions: it reframes DTs as governance infrastructures for heritage activation rather than as purely technical tools; it develops an operationalizable sequential mechanism linking digital visibility to institutional outcomes; it defines the economy of forgetfulness as a boundary condition shaping regional policy effectiveness, with implications for cohesion, territorial innovation, and development in marginalized regions.

2. Literature Review

This study is grounded in the premise that heritage governance is shaped not only by asset value, but also by the institutional logics that govern how value becomes visible, prioritized, and acted upon. In LDRs, heritage assets may possess strong symbolic, social, and economic significance, yet their activation is constrained by governance norms that privilege preservation over transformation and continuity over adaptation, intensified by demographic sparsity, administrative fragmentation, and limited fiscal capacity (Barney, 1991; Graham, Ashworth and Tunbridge, 2016; Mourão, 2020; Vale et al., 2024; Audretsch and Kariv, 2025). Within this context, the economy of forgetfulness can be understood as a governance-level mechanism of selective attention allocation: some heritage assets are not simply overlooked, but systematically deprioritized because their visibility, salience, and institutional support remain weak over time (Münch, Benz and Hartmann, 2022; Pedraza-Rodríguez et al., 2023; Sánchez-Carreira, Reis Mourão and Blanco-Varela, 2023). Forgetfulness is therefore an emergent property of governance systems under scarcity rather than an inherent attribute of the heritage asset itself.

Dynamic capabilities theory provides a complementary lens for explaining how digital infrastructures may alter this condition. It suggests that organizational and territorial performance depends on the capacity to sense, seize, and reconfigure resources in response to changing environments (Teece, Pisano and Shuen, 1997). Applied to heritage governance, this perspective implies that digital visibility alone is insufficient unless it can be converted into shared awareness, coordinated action, and routinized institutional adaptation. DTs can be read as governance infrastructures because they do not merely represent assets; they can also reorganize information flows, reduce informational friction, and support collective interpretation across fragmented actor networks (Thornton and Ocasio, 2008; Thornton, Ocasio and Lounsbury, 2012). The theoretical implication is that DTs matter most when they function as bridging infrastructures between visibility and governance action.

The literature on DTs has expanded rapidly, especially in relation to monitoring, simulation, documentation, and decision support for physical and cultural assets. Recent studies confirm the value of DTs for conservation, performance tracking, and operational management, particularly where spatial complexity and asset fragility require detailed digital representation (Shabani et al., 2022; Pletsch et al., 2026; Qian et al., 2026). However, this body of work remains predominantly artefact-centered, giving substantial attention to data quality, technical architecture, and system fidelity, but paying less attention to how digital systems interact with institutional logics, power relations, and attention allocation.

High-profile examples such as Notre-Dame demonstrate that DTs can support multi-actor coordination and recovery in resource-rich and highly visible settings, but such cases operate under conditions of stronger institutional capacity, greater policy attention, and denser coordination networks than those typically found in low-density territories (Gagua et al., 2025). For this reason, the transferability of those experiences to fragmented territorial contexts must be treated cautiously. What is needed is a conceptual shift from viewing

DTs as technical artifacts to understanding them as governance infrastructures that shape how visibility is translated into collective action.

Research on public innovation and institutional change helps explain why governance systems differ in their ability to absorb and use digital tools. From this perspective, innovation is not simply the introduction of a new technology, but a change in routines, coordination structures, and organizational capabilities (Teece, Pisano and Shuen, 1997). In low-density heritage territories, this matters because institutional fragmentation often weakens the channels through which information becomes action. Even when digital tools are present, their impact depends on whether they can be embedded in recurring governance practices that support cooperation across actors and scales.

This literature therefore clarifies the mechanism through which DTs may matter beyond documentation: if DT-generated visibility can strengthen awareness, then awareness may support engagement, and engagement may improve coordination and institutional learning. Yet this sequence remains underdeveloped in the heritage governance literature, particularly in settings marked by sparse institutional capacity and uneven digital readiness.

Studies of forgetfulness and selective neglect provide the final strand needed to explain why some heritage assets remain marginal despite their value. These works show that cultural assets can lose salience over time when they are repeatedly absent from decision agendas, investment cycles, and public narratives (Mourão, 2020; Sánchez-Carreira, Reis Mourão and Blanco-Varela, 2023). In this sense, neglect is not merely accidental; it becomes cumulative and structural, gradually reducing visibility and weakening the institutional conditions required for heritage activation. By combining the economy of forgetfulness with the notion of DTs as governance infrastructures, the study explains how visibility may become a trigger for awareness, coordination, and institutional change.

Taken together, these four strands clarify important parts of the problem, but none fully explains how digital visibility becomes governance action under conditions of institutional scarcity. Existing research remains fragmented between technical studies of DTs, value-based accounts of heritage, theories of institutional change, and analyses of neglect. What is still absent is a framework that links digital visibility, stakeholder awareness, coordination, and territorial innovation within the specific conditions of low-density heritage governance.

3. Methodology

This study adopts an abductive, theory-building, and comparative-illustrative approach to conceptualize DTs as governance infrastructures in low-density heritage regions (Whetten, 1989; Langley, 1999; Ketokivi and Mantere, 2021). Its purpose is not to estimate causal effects empirically, but to develop a conceptually coherent and operationally specifiable framework for understanding how digital visibility may translate into governance action under conditions of institutional scarcity. The study therefore follows a conceptual design grounded in iterative theory development rather than empirical hypothesis testing.

3.1 Research Design

The research design was built through the synthesis of fragmented literatures on heritage governance, DTs, public innovation, institutional logics, and the economy of forgetfulness. This integration was used to identify recurring explanatory gaps and to build a conceptual framework linking digital affordances to institutional outcomes. The resulting design is explicitly conceptual and comparative-illustrative: it uses evidence-informed vignettes to clarify plausibility and scope, but it does not claim statistical validation or causal identification. This approach is consistent with process-oriented theory building, where the goal is to generate a parsimonious and logically ordered explanation from multiple strands of prior work (Langley, 1999; Ketokivi and Mantere, 2021).

3.2 Model Development Through Abductive Comparison

The framework was developed through an abductive process of moving back and forth between theory and empirical illustration. First, the core constructs were identified and refined from the literature: digital visibility, awareness, engagement, coordination, innovation culture, and the economy of forgetfulness. Second, these constructs were compared across related conceptual domains to determine how they could be connected into a coherent explanatory sequence. Third, the resulting framework was checked against illustrative heritage cases to assess whether the proposed relationships were internally consistent and theoretically plausible. This process follows established logic in abductive and process research, in which theoretical refinement emerges

through repeated comparison between concepts, cases, and prior explanations regions (Whetten, 1989; Langley, 1999; Ketokivi and Mantere, 2021).

3.3 Comparative-illustrative Case Strategy

The study adopts UNESCO cases as illustrative vignettes rather than as units of causal inference. Their purpose is to clarify how the proposed DT mechanism may operate differently across governance contexts characterized by variation in institutional density, coordination capacity, digital readiness, and governance fragmentation. In this sense, the comparative strategy strengthens the conceptual argument by showing transferability through adaptation rather than replication of a flagship model.

Douro Valley is retained as the core transfer case because it combines low institutional density, territorial dispersion, fragmented governance, and emerging digital heritage initiatives. This makes it particularly suitable for examining how DTs may produce strong relative effects where baseline visibility and coordination are limited. Genoa and Sintra represent intermediate cases in which coordination capacity and digital readiness are more developed, but still uneven enough to test how the mechanism behaves under partial institutional support. Pompeii illustrates a high-value heritage setting with strong visibility but complex multi-level governance, where DTs are expected to support rather than initiate governance change. Notre-Dame is retained as a high-visibility benchmark, useful for understanding how DTs operate in a highly resourced and institutionally dense context, but with limited direct transferability to low-density territories.

To make this comparison explicit, Table 1 presents the cases as an illustrative analytical matrix for framework development.

Table 1: Comparative UNESCO cases as illustrative anchors for framework development

Case	Institutional density	Coordination capacity	Digital readiness	Forgetfulness level	Expected DT effect
Douro Valley	Low	Weak (multi-municipal)	Emerging	High	Strong (low baseline)
Genoa	Medium	Moderate	Moderate	Medium	Moderate
Sintra	Medium-High	Strong (national)	Advanced	Low-Medium	Incremental
Pompeii	High	Complex (multi-level)	High	Low	Supportive
Notre-Dame	Very High	Excellent	Very High	Very Low	Benchmark

The cases vary systematically across institutional density, coordination capacity, digital readiness, and forgetfulness level, allowing the framework to be interpreted across distinct territorial configurations. Douro Valley corresponds to low density, weak multi-municipal coordination, emerging digital readiness, and high forgetfulness, which implies a strong expected DT effect because even modest gains in visibility may overcome structural invisibility. Genoa is positioned at a medium level across the dimensions, suggesting a moderate DT effect. Sintra reflects medium-high institutional density with stronger coordination and advanced digital readiness, but lower forgetfulness, which implies more incremental effects. Pompeii combines high institutional density with complex multi-level governance and high digital readiness, so DTs are expected to function as supportive governance tools. Notre-Dame represents the benchmark case: very high institutional density, excellent coordination capacity, very high digital readiness, and very low forgetfulness, which implies a strong symbolic baseline but more limited interpretive value for low-density transfer settings.

This comparative logic sharpens the framework's scope and boundary conditions. Rather than assuming universal applicability, the study argues that DTs generate the strongest relative governance effects where forgetfulness is highest and baseline coordination capacity is lowest (Mourão, 2020; OECD, 2025c, 2025b, 2025a). The comparative design therefore stabilizes the framework conceptually while preserving its contextual sensitivity.

4. Results and Discussion

This study conceptualizes DTs as change infrastructures that reconfigure how heritage becomes visible, interpretable, and governable in low-density territorial settings, rather than as technical artefacts confined to documentation or simulation purposes (Thornton and Ocasio, 2008; Thornton, Ocasio and Lounsbury, 2012; Musiani et al., 2016; Bratton, 2019). DTs do not simply represent heritage assets; they alter the informational

conditions under which those assets enter governance attention and collective action. Their relevance in UNESCO low-density landscapes lies in their capacity to reduce informational asymmetries, make dispersed heritage legible, and counter the economy of forgetfulness that weakens policy salience and institutional responsiveness (Sánchez-Carreira, Reis Mourão and Blanco-Varela, 2023). Therefore figure 1 presents the conceptual framework captures as a sequential governance mechanism in which DT-enabled visibility is the first step, shared awareness the second, stakeholder engagement the third, cross-actor coordination the fourth, and the institutionalization of innovation culture the final outcome.

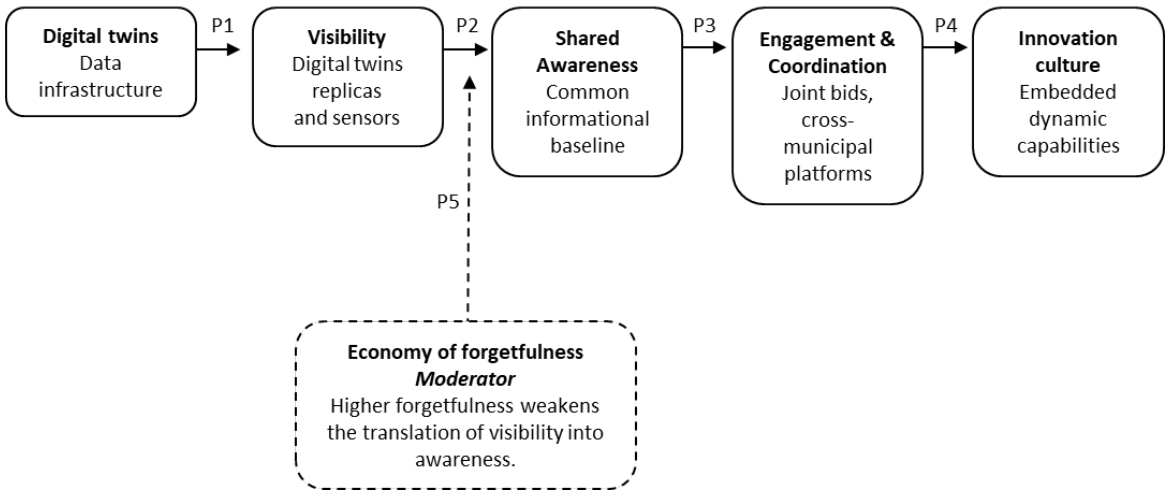


Figure 1: Conceptual framework

The framework is sequential, but not mechanically linear. The first transition is from DT to visibility: when heritage is digitally represented and cognitively accessible, it becomes more observable to relevant actors across institutional levels (Shabani et al., 2022). Visibility is thus a governance condition that makes neglected heritage cognitively present and politically available. Once visibility is established, it can be converted into shared awareness, understood as a common recognition among stakeholders that a given asset or territorial issue is relevant, legitimate, and worthy of collective attention (Pletsch et al., 2026). Shared awareness then provides the cognitive basis for engagement, because actors are more likely to participate when the object of action is jointly recognized as a common concern. In this sense, DTs function as bridging infrastructures that move heritage from digital legibility to collective governance capacity (Sicilia and Palazón, 2023; Teece, Pisano and Shuen, 1997).

4.1 Propositions and measurability

The framework advances five propositions and one boundary condition. All are derived from a common mechanism in which DTs first generate visibility, then enable shared awareness, and subsequently support governance coordination. The propositions are theoretically grounded and empirically tractable, allowing future research to examine the model through observable indicators. Their sequence is cumulative: each step depends on the prior one, but each can also be measured independently.

P1. *Higher levels of DT-enabled visibility are positively associated with stakeholder visibility.*

At the first stage, the DT makes heritage more visible through digital representation, platform access, spatial visualization, and repeated exposure. Visibility may be operationalized through platform reach, frequency of digital encounters, access intensity, content circulation, or stakeholder exposure to the DT environment (Shabani et al., 2022). The core claim is that DTs increase the likelihood that heritage assets will be noticed and cognitively registered by relevant actors, especially where baseline salience is weak.

P2. *Higher levels of visibility are positively associated with shared awareness among stakeholders.*

Once heritage becomes visible, it may be converted into shared awareness, understood as a common recognition of the asset's existence, relevance, and governance significance. Shared awareness may be measured through convergence in stakeholder perceptions, issue recognition, salience alignment, or evidence of a common interpretive frame across actors. Visibility alone is insufficient unless it produces intersubjective

recognition. In low-density heritage contexts, this step is critical because it transforms dispersed information into a shared cognitive basis for action (Pletsch et al., 2026).

P3. *Higher levels of shared awareness are positively associated with stakeholder engagement.*

Shared awareness creates the relational and normative conditions for participation by reducing uncertainty about relevance and legitimacy. Engagement may be operationalized through participation frequency, meeting attendance, response intensity, collaborative contributions, or involvement in governance processes. When stakeholders recognize a heritage issue as collectively meaningful, they are more likely to invest time, attention, and effort in addressing it (Sicilia and Palazón, 2023).

P4. *Higher levels of stakeholder engagement are positively associated with stronger cross-actor coordination.*

Engagement becomes governance-relevant when it is sustained enough to produce routine interaction, trust, and mutual adjustment. Coordination may be measured through inter-organizational collaboration, joint planning, shared data use, co-produced initiatives, or the regularity of collective decision-making practices. Repeated engagement lowers transaction costs and enables actors to align expectations across organizational boundaries (Teece, Pisano and Shuen, 1997; Warner and Wäger, 2019).

P5. *Higher levels of cross-actor coordination are positively associated with the institutionalization of territorial innovation culture.*

Sustained coordination can embed adaptive routines, collaborative norms, and problem-solving practices within the territorial system. Innovation culture may be operationalized through the frequency of adaptive initiatives, the persistence of experimentation, the routinization of collaborative governance, or the institutionalization of learning-oriented practices over time. Innovation culture is thus the product of repeated coordination that becomes normalized within governance structures (Teece, Pisano and Shuen, 1997).

Forgetfulness refers to low policy salience, weak institutional attention, and the cumulative neglect of heritage assets over time (Mourão, 2020; Sánchez-Carreira, Reis Mourão and Blanco-Varela, 2023). In contexts where heritage has been marginalized, a DT's visibility effect is likely to be stronger because it reintroduces the asset into cognitive and institutional space. By contrast, where baseline visibility is already high, the marginal effect of additional digital representation is likely to be more limited. This boundary condition explains why DTs may produce stronger governance returns in low-density regions than in more institutionally dense settings.

For empirical development, the model can be operationalized through distinct indicators at each stage. Visibility may be captured through access rates, digital reach, interaction intensity, or exposure metrics; shared awareness through salience convergence, perceived relevance, or aligned stakeholder framing; engagement through participation frequency, responsiveness, or involvement intensity; coordination through joint planning, shared projects, and data exchange; and innovation culture through the recurrence of adaptive or collaborative governance routines (Teece, Pisano and Shuen, 1997; Shabani et al., 2022; Pletsch et al., 2026). This specification preserves conceptual clarity while remaining open to future empirical testing.

4.2 Theoretical Contributions

This study advances theory in three interconnected ways. First, it reframes DTs as governance infrastructures rather than purely technical documentation tools, extending institutional logics to explain how digital systems reshape attention allocation and coordination in fragmented settings (Thornton, Ocasio and Lounsbury, 2012). This perspective positions DTs as institutional bridging mechanisms that convert visibility into governable resources (Shabani et al., 2022).

Second, the sequential mechanism from visibility to innovation culture provides a structured explanation of how digital interventions become institutional change. By integrating dynamic capabilities theory, the model shows how awareness creates the cognitive conditions for engagement, how engagement lowers coordination costs, and how sustained coordination embeds adaptive routines within territorial governance systems (Teece, Pisano and Shuen, 1997; Warner and Wäger, 2019). This addresses a gap in both digital heritage and public innovation literatures, where the micro-processes of institutional activation remain underdeveloped.

Third, the economy of forgetfulness is positioned as a measurable boundary condition that amplifies the governance effects of digital visibility. In contexts of cumulative neglect, even modest digital interventions generate disproportionate salience because they operate against a low baseline of institutional attention (Mourão, 2020; Sánchez-Carreira, Reis Mourão and Blanco-Varela, 2023). This contribution integrates selective

neglect research with digital infrastructure theory, offering a novel explanation for why the same technical intervention may produce divergent governance outcomes across territories.

4.3 Practical Implications

The framework carries direct implications for heritage policy design in resource-constrained settings. Low-density territories should prioritize interoperable, modular digital architectures over monolithic flagship replicas, focusing on lightweight platforms that reduce transaction costs across fragmented municipalities (Audretsch and Kariv, 2025; Lopes et al., 2025). Three priorities emerge from the model: modular architecture enables scalable deployment through common data environments and sensor-to-decision pipelines supporting cross-municipal coordination without heavy upfront investment; routine building transforms DTs from one-off projects into recurring governance practices by embedding insights into regular coordination cycles (Warner and Wäger, 2019); capacity alignment ensures digital visibility translates to impact via foundational connectivity, staff competencies, institutional trust, and pre-existing cooperation - without which technical sophistication fails (Silva et al., 2024).

5. Conclusions

This study proposes a novel conceptual interpretation of DTs as governance infrastructures for heritage activation in LDRs, rather than as purely technical tools for documentation or monitoring. Its main contribution is to explain how digital visibility may be translated into shared awareness, stakeholder engagement, coordination, and, ultimately, a territorial culture of innovation under conditions of institutional fragmentation and selective neglect.

The study remains explicitly conceptual and comparative-illustrative in scope. Accordingly, its contribution is theoretical: it offers a relevant and operationally specifiable framework for understanding governance dynamics in marginalized heritage territories, but it does not provide empirical testing, causal verification, or statistical generalization.

A second contribution is the introduction of the economy of forgetfulness as a pertinent boundary condition that helps explain why the same digital intervention may generate different governance effects across places. This point strengthens the study's originality because it connects digital heritage, institutional theory, and territorial governance in a way that remains underdeveloped in the current literature.

The conclusions should therefore remain objective and proportionate to the design of the study. The framework suggests analytical plausibility, not empirical confirmation, and the illustrative cases support conceptual transferability rather than explanatory proof.

Future research should test the proposed model empirically across multiple low-density heritage contexts. In this respect, Hayes (2018) should be cited only as a methodological direction for future work, particularly for the development of a structural equation model or other moderated-mediation strategy capable of evaluating the sequential relationships proposed here, and not as support for the present study's conclusions.

Such research could specify visibility, awareness, engagement, coordination, and innovation culture as latent constructs, while examining forgetfulness as a moderator shaping the strength of the visibility–awareness relationship. This would allow the model to move from conceptual novelty to empirical validation without overstating what the current study demonstrates.

Additional work may also explore longitudinal and comparative designs, including non-UNESCO low-density territories, in order to assess scalability, contextual variation, and policy relevance beyond the cases discussed here

Ethics Declaration: Not Applicable.

AI Declaration: AI tools were used to support the orthographic and grammatical revision in academic English writing.

Consent for Publication: Not Applicable.

Availability of Data and Material: Not Applicable.

Competing Interests: The authors declare that they have no competing interests.

Funding: This work is funded by national funds through FCT - Fundação para a Ciência e a Tecnologia, I.P., under the Programme Contract UID/05105/2025. https://doi.org/10.54499/UID/05105/2025.

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