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Global multi-level mapping of visual heritage practice: Visual evaluation and management of cultural heritage

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ABSTRACT

Visual experience is a primary channel through which the values of tangible cultural heritage are perceived and governed, making visual evaluation and management central to conservation and to Sustainable Development Goal (SDG) 11.4. However, practice remains fragmented across scales, and many statutory toolkits lag behind advances in geographic information systems (GIS)-based visibility analysis, 3D visualization, remote sensing, and perception-based evidence. We compile, code, and cross-analyze a multi-level corpus spanning 26 international instruments, 293 national items from 112 countries, and 867 World Heritage properties. Using a four-dimensional framework (values, typology, visual-evaluation methods, and visual-management strategies), we apply k-medoids clustering with multidimensional scaling (MDS) at the national level, mask-aware association mapping at the property level, and cross-level diagnostics. Across levels, practice converges on a technical-spatial regime. At the property level, GIS-based viewshed and visual sensitivity analysis, verified visuals and 3D visualization techniques, and GIS-based spatial-historical analysis form a near-universal methodological core and are most frequently translated into zoning and spatial regulation and height or massing controls. Participatory and perception- or experience-based methods remain sporadic. Value framings are dominated by Historic, Social and Political, and Aesthetic emphases, while Ecological and Scientific are comparatively marginal. Cross-level coherence is strongest where governance frameworks are mature, and portfolios are coherent; it weakens where portfolios are heterogeneous or in federated or lower-capacity settings. National portfolios cluster into four method-strategy regimes that explain characteristic object-method-strategy sequences. In response, we outline operational bridges including tiered standards for visibility and 3D evidence, deployable perception protocols, participation modules linked to Heritage Impact Assessment (HIA) or Visual Impact Assessment (VIA) triggers, and auditable communication packages. These are organized within a Global Peer Network aligned to portfolio archetypes and method-strategy regimes. The study contributes a reusable global dataset and map of visual-heritage practice and an integration framework that supports more transparent, comparable, and context-sensitive decisions across levels.

1. Introduction

Tangible cultural heritage comprises *monuments, groups of buildings,* and *sites.*[1] Their significance spans historical, artistic, scientific, and social dimensions, and in some contexts, ecological considerations (Pereira Roders, 2007). Significance is anchored in material fabric and associated practices, but it is also communicated and regulated through visual experience, which shapes how communities and authorities perceive heritage values and guides conservation and planning decisions (Deghati Najd et al., 2015). Assessing the visual environment and potential visual impacts, and translating that evidence into management measures, is central to safeguarding tangible cultural heritage and

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[1] **UNESCO. 1972.** *Convention Concerning the Protection of the World Cultural and Natural Heritage.* https://whc.unesco.org/en/guidelines

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sustaining its use (Jerpåsen and Larsen, 2011; Peng et al., 2025). This lack of cross-level, comparable evidence is particularly critical in light of Sustainable Development Goal (SDG) 11.4,[2] which calls for strengthening efforts to protect and safeguard the world's cultural and natural heritage. By providing a global, multi-level overview of how visual evidence is produced and translated into management actions, this study offers an evidence base to support that international mandate.

Although new techniques, such as various metrics developed for perception studies and spatial analyses grounded in geographic science, have been applied to identify the visual characteristics of such heritage and to assess potential impacts (Cao et al., 2026; Gao et al., 2025; Zhao et al., 2025), the global state of practice has yet to be systematically synthesized. Approaches to visual evaluation and management vary across governance traditions, capacity, and heritage type (Nijhuis et al., 2011b; Teller and Bond, 2002). In the absence of a global overview, cross-jurisdictional learning is constrained, evidence-based updates proceed slowly, and the emergence of a transferable reference framework is hindered. This study addresses these gaps by mapping visual evaluation and management approaches across countries and World Heritage properties to provide an evidence-based foundation for improving practice and policy.

1.1. Visual practice for cultural heritage

Visual experience refers to how people and institutions perceive and interpret a heritage place through its visual environment, including the place's visually perceivable attributes and setting, and how this perception shapes the appreciation of significance and informs governance decisions (Council of Europe, 2000; ICOMOS, 2005). We use "visual experience" as an overarching term encompassing related notions, such as views, and the management objective, often framed as visual integrity (UNESCO, 2025).

In practice, this linkage between perception and decision-making is addressed through two connected stages of work on heritage visual environments. The first is visual evaluation, which identifies and characterises visual attributes and conditions linked to significance and produces verifiable evidence, including key viewpoints and sequences, viewsheds and skyline profiles, and sensitivity analyses related to massing, height, setbacks, materials, and lighting (Artese et al., 2017; Liu and Nijhuis, 2020; Peng et al., 2025). The second is visual management, which leverages that evidence through law, policy, spatial controls, and project conditions. It also establishes a loop of monitoring, review, and update, ensuring that visual objectives remain on track (Janssen et al., 2017; Jenkins, 2018).

These activities are typically organized across *governance*, *planning*, and *design* levels. *Governance* addresses "*why*" and "*what*" by stating the visual attributes and objectives tied to significance, embedding visual evidence in legislation, policy, and impact assessment protocols such as Heritage Impact Assessment (HIA) and Visual Impact Assessment (VIA), and defines triggers, reporting responsibilities, and monitoring expectations (Patiwael et al., 2019). *Planning* addresses "*where*" and "*how much*" by turning evidence into maps and rules that allocate protection and capacity across the property, buffer, and wider setting, while aligning with other policy levels (Kalman and Létourneau, 2020; Veldpaus, 2015). *Design* addresses "*how*" by testing proposals from specified viewpoints against visual objectives, applying the mitigation sequence of avoid, reduce, and compensate, and conditioning materials and lighting. Compliance is checked during and after construction through repeatable visual reviews.

Seen through this stage-and-level lens, the ways evidence is produced, translated into controls, and carried through to projects can vary across jurisdictions and heritage types (Patiwael et al., 2019). Single cases can be instructive, but what works well in one context may not be applicable in another.

1.2. Visual practice across international, national, and property levels

This subsection shifts from the functional to the institutional levels that organize practice and shape outcomes. International guidance sets the overall orientation by linking authenticity and integrity to location and setting, and by clarifying the types of visual conditions that warrant protection (Alberts and Hazen, 2010; Wang et al., 2015). It signals what counts as credible evidence without prescribing a single template. At the national level, systems translate that orientation into legal and procedural baselines. They indicate when visual evidence is required, what minimum standards it should meet, and how such evidence informs approvals and monitoring. The emphasis is on consistent expectations rather than uniform instruments (Fairclough and Møller, 2008; Jerpåsen and Larsen, 2011). At the property level, management plans and HIA procedures apply those baselines to specific places. They specify where and how visual objectives are tested, how choices are documented, and how outcomes are checked during delivery and operation (Ashrafi et al., 2021; Lopes et al., 2019). Here, statements of intent become project-specific decisions and verifiable records.

Implementation varies across regions and institutions, underscoring the need for a comparable global database and a shared vocabulary to document approaches at the national and property levels. This need follows directly from the multi-level structure described above. International guidance articulates the orientation, national systems translate that orientation into baselines and procedural triggers, and property-level instruments apply those baselines in project decisions and records. Therefore, researchers and practitioners should pay particular attention to how this chain holds together in practice: how significance and setting are framed, what is treated as credible visual evidence, when evidence is required, and how authorities carry it out through approvals, conditions, monitoring, and updates (UNESCO, 2025; UNESCO et al., 2022). These elements determine whether visual objectives remain defensible and auditable, and whether practices can be compared meaningfully across countries and sites despite different legal cultures and administrative capacities.

1.3. Research gaps and objectives

Building on the discussion above, two research gaps emerge. First, there is no systematic global evidence showing how visual evaluation and visual management are specified and implemented across international, national, and property scales, which limits comparison and constrains options for improvement. Second, many policies and toolkits lag behind advances in analytical and visualization techniques; as a result, innovations remain project-based rather than routinized through governance rules, planning instruments, and design-stage procedures.

In response to these gaps, the paper pursues three objectives: (a) compile, code, and map visual evaluation and visual management approaches across heritage scales and types applied to international instruments, national policies, and property-based plans; (b) diagnose strengths, weaknesses, and the alignment between context and method, identifying practices suitable for transfer and areas that warrant enhancement; and (c) curate a global reference network and outline practical routes for introducing newer analytical and visualization techniques into routine governance, planning, and design levels.

This cross-level mapping draws on a corpus spanning 26 international instruments, 293 national items from 112 countries, and 867 World Heritage properties. The corpus incorporates principal texts from UNESCO,[3] including the Convention and the Operational Guidelines,

[2] **United Nations. 2015.** *Transforming our world: the 2030 Agenda for Sustainable Development.* https://sdgs.un.org/2030agenda

[3] **UNESCO.** *World Heritage Centre documents database.* https://whc.unesco.org/en/documents/

and from ICOMOS,[4] including key charters and doctrinal papers. Using a single, consistent analytic structure across these materials enables like-for-like comparison across international, national, and property systems, which prior work has often struggled to achieve when studies remain single-scale, case-based, or method-specific. On this basis, the paper offers three contributions: a reusable global dataset and mapped evidence base of visual evaluation and management approaches for benchmarking and peer learning; a replicable workflow for comparing national practice regimes and diagnosing cross-level coherence between international orientation, national baselines, and property-level implementation; and an integration framework that links newer analytical and visualization techniques to routine governance, planning, and design procedures while maintaining transparency and standards.

Beyond these contributions, the analysis reveals systematic patterns. Methods and strategies cluster across governance levels, and participatory and perceptual approaches remain underrepresented across all three scales. Together, these findings provide a replicable evidence base for strengthening guidance, informing policy reform, and promoting more coherent and harmonized visual practice within heritage governance systems.

2. Methods

To map the current landscape of visual practice in cultural heritage and to provide a practical lever for global method upgrading, this study develops an integrated mapping framework spanning three levels: international, national, and property. The workflow includes four steps: (a) document collection and screening, (b) data processing by coding, (c) multi-level analysis, and (d) cross-level analysis. To conduct cross-level mapping, both coding and analysis are organized around the exact four dimensions at every level. These dimensions are property scale and typology, heritage values, visual evaluation methods, and visual management strategies. The first two constitute content, capturing decision-makers' priorities and focal concerns. The latter two constitute practice, capturing how visual conditions and effects are evidenced and addressed through instruments, procedures, and controls. Within and across levels, this structure supports pattern synthesis (including clustering and co-occurrence mapping) and alignment diagnostics between international orientation, national baselines, and property-level implementation. This consistency enables like-for-like comparison across levels (Fig. 1).

2.1. Document collection and screening

For each level, we adopted a comprehensive but clearly bounded mechanism for collecting and screening research documents. Retrieval was completed on October 17, 2025. For documents with multiple versions, we kept the latest consolidated version and collapsed duplicate language. We recorded access dates for each item. We acquired all national instruments and World Heritage property documents in their official languages. We then translated them into English using AI-assisted translation, with manual checks for key terms. Since the analysis focuses on structural content rather than linguistic nuance, this procedure ensures cross-linguistic comparability while retaining the originals for verification.

(a) International level: International charters, guidelines, and regulations, widely accepted and frequently cited normative texts, provide a shared language and minimum consensus for value assessment and management practice; accordingly, they serve as the top-level reference and logical starting point for this study's comparative analysis. Selected documents had to be both broadly applicable and targeted, and authoritative. Inclusion required three conditions: first, international scope rather than regional limitation; second, explicit heritage-related visual content covering evaluation and/or management, operationalized through concrete provisions such as procedures, indicators, thresholds, or evidentiary requirements; third, demonstrated institutional authority by at least one of the following: formal adoption by an intergovernmental organization's assembly or committee; publication by a World Heritage treaty-system advisory body with routine citation by the World Heritage Committee or Secretariat; or issuance by an international professional federation or society with clear cross-national uptake, for example citation in national standards or by major funders. We excluded drafts, consultative texts, region-specific guidance, and documents lacking operational provisions. Applying these criteria yielded a final set of 26 documents, primarily from UNESCO,[5] ICOMOS,[6] IFLA, TICCIH, and ICCROM **(Appendix A1)**.

(b) National level: Records were retrieved from UNESCO's *Database of National Cultural Heritage Laws* and from official government repositories.[7] Items were eligible if they explicitly regulated or evaluated the visual environment, for example, views, skylines, settings, view corridors, panoramas, buffer zones, advertising or signage, and lighting or glare. After de-duplication, the corpus contains 293 items across 112 countries **(Appendix A2)**.

(c) Property level: The corpus comprises World Heritage cultural and mixed properties whose Periodic Reporting and approved management plans include references to visual evaluation or visual-environment management.[8] This screening yielded 867 properties from 153 countries **(Appendix A3)**.

2.2. Data processing by coding

At the data-processing stage, the primary method was coding. Throughout the coding process, consistency was maintained across four dimensions (property scales and types, heritage value, visual evaluation method, and visual management strategy) to support consistent interfaces for subsequent cross-level analysis. Because the purpose and precision requirements differed between levels, coding proceeded in two stages:

(a) At the international level, we aimed to develop the four-dimensional codebook and controlled vocabulary that would anchor later analyses. We used an exploratory-guided procedure with open coding, iterative consolidation, and consensus meetings. Because categories were being defined and refined, inter-coder coefficients were not computed at this stage; quality control relied on side-by-side calibration and a documented audit trail (Cascio et al., 2019). For example, recurrent references in UNESCO and ICOMOS texts to “setting,” “key views,” and “visual intrusion” were consolidated into stable terms and category definitions, which later allowed consistent coding of evaluation evidence and management intent in national and property documents.

(b) At the national and property levels, coding followed the finalized international codebook with low degrees of freedom and higher precision requirements. We adopted a single-coder workflow with stratified dual coding of 10% of items (Burla et al., 2008). Inter-coder agreement was assessed using Cohen's κ, with a target threshold of 0.70. Disagreements triggered short calibration sessions and codebook clarifications, followed by corrections to affected records (Rau and Shih, 2021). For the dimensions of heritage value and heritage typology, coding strictly followed the international level categories without modification. For visual evaluation methods and visual management strategies, when cases could not be clearly classified, coders discussed them jointly; if consensus could not be reached, a new subcategory was

[4] **ICOMOS.** *Charters and doctrinal texts.* https://www.icomos.org/charters-and-doctrinal-texts/

[5] **UNESCO.** *World Heritage Centre documents.*

[6] **ICOMOS.** *Charters and doctrinal texts.*

[7] **UNESCO.** *UNESCO Database of National Cultural Heritage Laws.* https://www.unesco.org/en/cultnatlaws?hub=169342

[8] **UNESCO.** *World Heritage List.* https://whc.unesco.org/en/list/

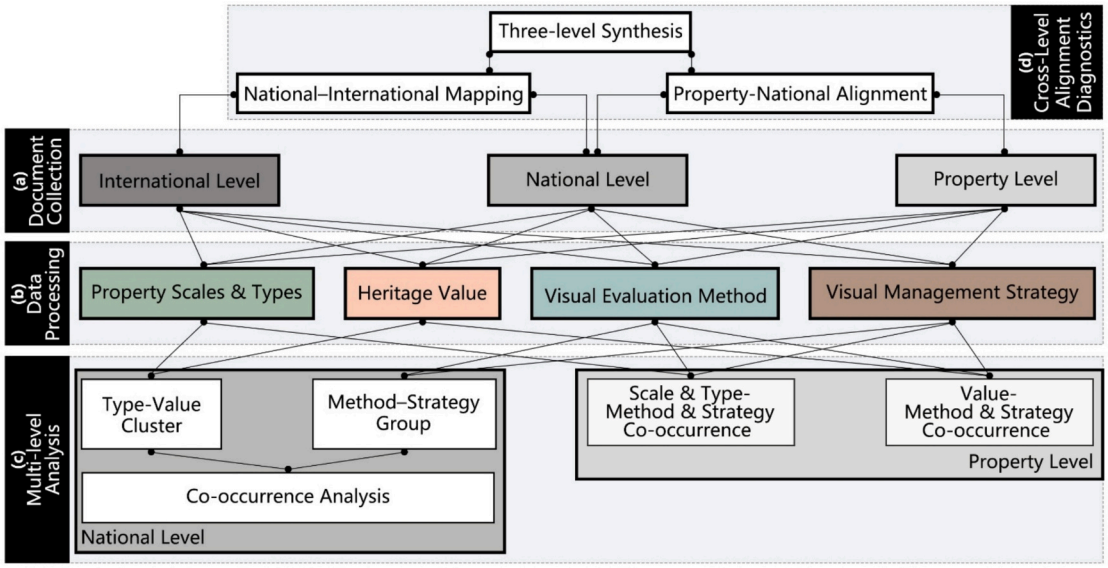

Fig. 1. Integrated mapping framework for visual evaluation and management of cultural heritage, applied at international, national, and property levels: (a) document collection and screening, (b) data processing by coding, (c) multi-level analysis, including clustering and association mapping using mask-aware co-occurrence matrices, and (d) cross-level analysis, quantifying alignment as international-national level divergence and national-property level consistency on a five-level scale, and integrating results through a three-level synthesis.

added with a clear definition and citation, and the codebook was updated accordingly **(Appendix A5-A8)**. In provisions that combined evidence and action, we coded the evidence component under visual-evaluation methods and the action component under visual-management strategies. This includes cases where a viewshed or sensitivity analysis is required to justify height caps and setback rules.

2.3. Multi-level analysis

Before undertaking the integrated analysis, we first analyzed each level separately. For the international level, the principal output is the organized synthesis of codes, namely the four-dimensional vocabulary and its code lists. The national and property levels then use distinct but complementary analytical approaches, described below.

At the national level, we compile country-level profiles from the coded results. The analysis proceeds in three parts. First, we identify each nation's thematic focus by grouping countries with similar mixes of heritage-object types and value orientations evidenced in national texts. Second, we characterize national tendencies in visual practice by grouping countries based on their combined profiles of visual management strategies and visual evaluation methods. Third, we test whether these two typologies align by relating focus groups to practice groups and assessing their correspondence. To do so, we quantify how different two countries' code profiles are using a set-overlap distance (Jaccard distance) computed on binary presence/absence data that ignores inapplicable entries (mask-aware binary data), and then average these distances with equal weights across code families to avoid dominance by higher-dimensional blocks. Countries are then clustered around representative cases using k-medoids (PAM), with the number of clusters K guided by average silhouette width, bootstrap stability, and parsimony or interpretability. Similarity relationships are visualized using metric multidimensional scaling (MDS), and the resulting types are mapped to show geographic distribution and cross-mapped against selected features to highlight characteristic patterns (Arbelaitz et al., 2013; Li, 2005; Schubert and Rousseeuw, 2019; Williams, 2000).

At the property level, we focus on association structures rather than clustering. Specifically, mask-aware co-occurrence matrices relate: property types to visual evaluation methods and to management strategies; scale to methods and to strategies; value classes to methods and to strategies; and UNESCO regions to methods and to strategies. For each matrix, edges represent row-standardized conditional proportions computed on the observation mask. Links with conditional proportions below 0.05 are suppressed to reduce visual noise. Regional summaries are reported as raw counts and as rates per 100 properties, using the number of properties in the region as the denominator (Riehmann et al., 2005).

2.4. Cross-level alignment diagnostics

The purpose of the cross-level analysis is to establish coherent links among the international, national, and property levels through the shared four-dimensional framework. This connects the semantic foundations defined by international guidance, the policy expressions at the national level, and the practical applications observed at the property level. By aligning these levels within one structure, the study shows how concepts, policies, and practices interact across levels. In essence, this cross-level analysis checks how much each country's profile diverges from the global pattern and how each property's profile aligns with its national pattern, translating complex comparisons into a simple five-level scale for ease of interpretation. In detail, divergence and consistency are evaluated separately within each dimension to preserve comparability and diagnostic clarity. Each dimension has its own classification criteria, yet all outputs are expressed on a five-level scale to allow visual comparison and integration. Operationally, the detailed classification indicators for each dimension are reported in the results.

(a) International-national mapping: For each country, divergence is computed within each dimension by comparing mask-aware presence vectors with the international baseline using Jaccard dissimilarity, then standardizing scores on a 0–1 scale. Lower values indicate closer alignment with the international pattern; higher values indicate greater differentiation. Continuous scores are discretized into five divergence levels from very low to very high. Maps display where national frameworks adopt, reinterpret, or omit elements of the international vocabulary, revealing patterns of conceptual and procedural translation.

(b) National-property alignment: For each World Heritage property, consistency with its national profile is assessed across the exact four dimensions. Similarity is calculated from mask-aware presence or frequency-normalized vectors and converted to a five-level consistency

scale, ranging from highly consistent to non-overlap. Results are mapped geographically, with regional summaries reported as counts and as rates to ensure comparability across regions.

The resulting multi-scale maps form the analytical interface linking all three levels. They support the identification of gaps, including global gaps in visual-heritage practice and cross-level gaps between international guidance, national regulation, and property implementation. Recognizing these gaps enables targeted capacity building and policy refinement. From the perspective of international charters and guidelines, the mapping provides a replicable pathway for technical updating that minimizes policy-adjustment costs while strengthening global coherence in visual-heritage management.

3. Results

This section reports the main cross-level patterns revealed by the mapping. Across countries and World Heritage properties, practice converges on a predominantly technical and spatial regime, while participatory and perception-based approaches remain sporadic across all three scales. Cross-level coherence varies across governance contexts, with more substantial alignment in some regimes and weaker national-property coupling in others. The subsections below detail these patterns at international, national, and property levels and then summarize the cross-level diagnostics.

3.1. Results for the international level

The coding results have been organized into four dimensions accordingly:

(a) Property scales and types: Consistent with legally binding international conventions, non-binding UNESCO policy instruments and recommendations, and international charters and doctrinal principles by expert bodies, we retain three property scales and multi-label property types of 13 categories. The detailed definitions are reported in the table (Fig. 2).

(b) Heritage value: Core charters emphasize aesthetic, historic, and scientific values, and extend to social, economic, ecological, and political considerations. Coding (verbatim) rendered as: *(i) Aesthetic*, *(ii) Ecological*, *(iii) Economic*, *(iv) Historic*, *(v) Political*, *(vi) Scientific*, *(vii) Social*, *(viii) Age*. For World Heritage properties, inscription criteria are recorded as Outstanding Universal Value (OUV) proxies. Closely related classes may be merged during analysis, but labels remain unchanged (Table 1).

(c) Visual evaluation method: International guidance documents outline numerous visual evaluation and visualization techniques. For classification, we summarized these into six method families (Table 2).

(d) Visual management strategy: Protection of visual qualities is achieved through a range of planning and management measures. We categorized seven such strategy types (Table 3).

3.2. Analysis results for the national level

At the national level, the most frequently represented property types are *Historic buildings and ensembles*, *Cultural landscapes, parks and gardens*, and *Urban, rural settlements/ Historic towns and villages*. In terms of value framings, *Historic & Age* and *Aesthetic* are more prominent, whereas *Ecological & Scientific* and *Social & Political & Economic* are comparatively marginal. National materials place greater weight on *Design/planning-concept-based visual analysis* (*M6*), *Participatory evaluation and multi-criteria evaluation frameworks* (*M5*), and *GIS-based spatial-*

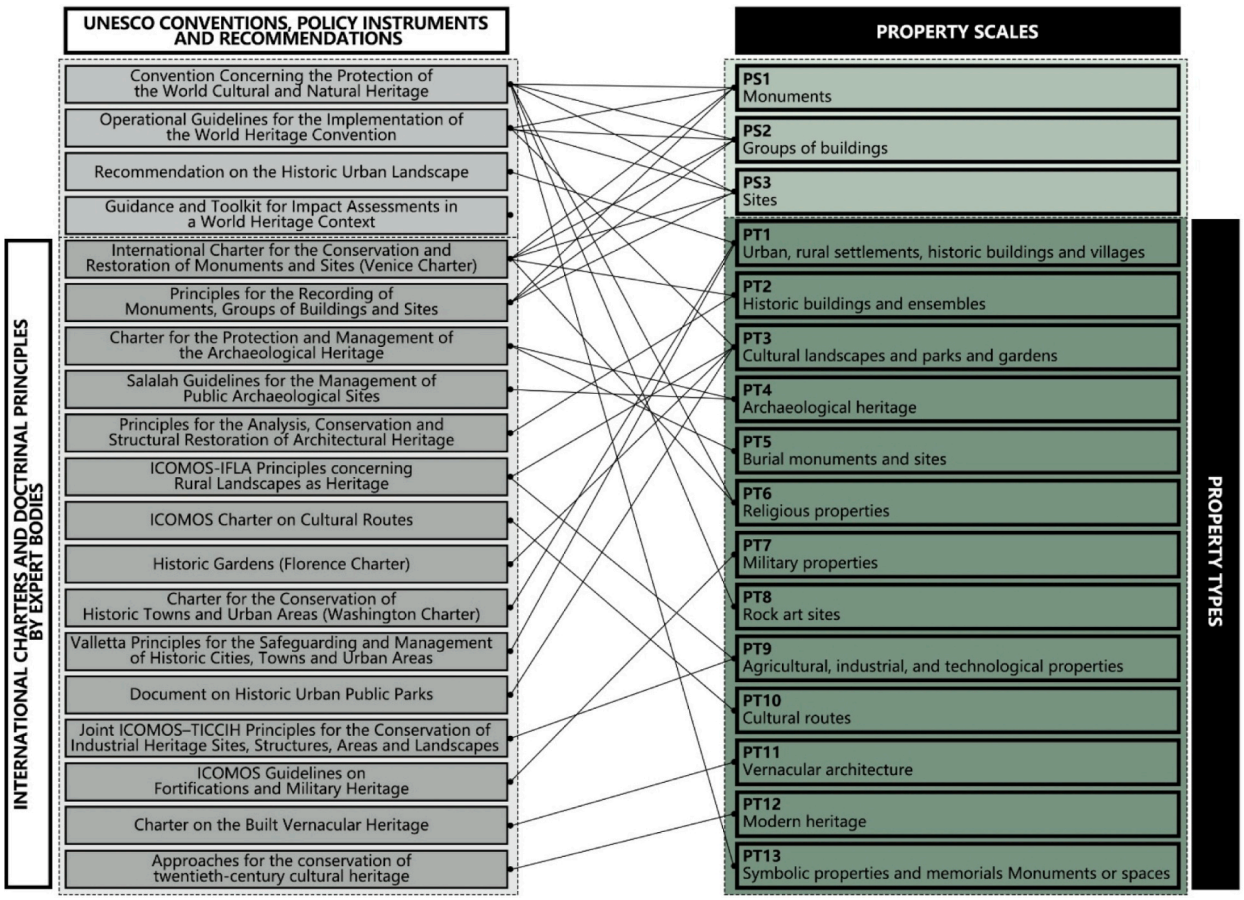

Fig. 2. International classification of property scales and types (definitions can be found in **Appendix A4**).

Table 1
International classification of heritage value (Internationally endorsed instruments can be found in **Appendix A1**).

Index	Heritage value	Definition	Internationally endorsed instruments
V1	Aesthetic	The sensory and perceptual qualities of a place contribute to its recognized beauty and legibility.	2, 8, 9, 19
V2	Ecological	The significance of ecological processes, ecosystem integrity, and biodiversity patterns sustained by the place.	1, 2, 14
V3	Economic	The capacity of heritage to support sustainable livelihoods and equitable local benefits while reinforcing conservation goals.	3, 16, 17, 18
V4	Historic	Evidential and representational value as a witness to cultural traditions, typological developments, and significant phases of human history.	1, 2, 9, 10
V5	Political	Associative value arising from direct or tangible links to events, ideas, belief systems, or commemorative narratives shaping public memory and identity.	2, 21
V6	Scientific	Informational potential for knowledge production, enabling research and evidence-based conservation.	2, 11, 10, 13
V7	Social	Community-based significance grounded in identity, practice, attachment, and well-being, often expressed through participation and shared stewardship.	3, 21, 17, 18
V8	Age	The time-depth discernible in the material fabric and the respect for accumulated contributions from different periods.	9, 7

Table 2
International classification of visual evaluation method (Internationally endorsed instruments can be found in **Appendix A1**).

Index	Visual evaluation method	Definition & Scope	Internationally endorsed instruments
M1	Perception- and experience-based assessment	Assessment grounded in perception, experience, and cognitive responses (e.g., surveys, interviews, perception mapping)	2, 3, 7, 21
M2	GIS-based viewshed and visual sensitivity analysis	Quantitative modeling of visibility and exposure using GIS and terrain/ building data to define visual sensitivity zones or metrics.	5, 8, 21
M3	Verified visuals and 3D visualization techniques	Use of accurate visual representation (AVR), realistic rendering, virtual reality (VR)/augmented reality (AR), or 3D scenario visualization for visual impact communication and verification.	5, 10
M4	GIS-based spatial, historical analysis	Integrated GIS analysis combining spatial-historical landscape interpretation with the establishment of visual baselines and metrics (terrain/cover typologies, skyline, view corridors, sensitivity thresholds).	3, 8, 10, 21
M5	Participatory evaluation and multi-criteria evaluation frameworks	Integration of multiple criteria and stakeholder inputs through participatory workshop tools to synthesize visual evaluation outcomes for decision-making.	3, 5, 6
M6	Design/planning-concept-based visual analysis	Design/planning-concept-based analysis of visual qualities (form/figure-ground, frontage, massing composition, scale, walkability, imageability), producing design/planning-oriented recommendations.	2, 20, 21

historical analysis (*M4*), especially view-corridor and skyline assessments used to support zoning and development control. In contrast, visual management relies heavily on spatial controls, while participatory measures and perception studies remain limited. As specified in Methods, any apparent coverage gaps (e.g., Japan) reflect our restriction to UNESCO-recognized official sources to ensure cross-country comparability (Fig. 3).

3.2.1. Clustering by value-type: national-level substantive focus

Combinations of property types and heritage values capture each country's substantive priorities, and the clustering reveals clear contrasts and overall trends (Fig. 4).

Cluster-1 (C1, Settlement Architecture Landscape Core, $n = 47$): The largest and most stable cluster, structured around *Urban, rural settlements/ Historic towns and villages*, *Historic buildings and ensembles*, and *Cultural landscapes, parks and gardens*, with *Aesthetic* and *Ecological & Scientific* values. A typical member is from South Africa.

Cluster 2 (C2, Insular Religion and Archaeology Blend, n = 4): This cluster concentrates on *Archaeological heritage*, *Burial monuments and sites*, *Historic buildings and ensembles*, and *Religious properties*, combining *Aesthetic*, *Historic & Age*, and *Social & Political & Economic* values. A typical example is Samoa.

Cluster 3 (C3, History Centric Balanced Portfolio, $n = 42$): Value profile is dominated by *Historic & Age* significance, with no dominant object class. A typical case is Vietnam.

Cluster 4 (C4, Religion Burial Military Archaeology, $n = 1$): A singleton cluster (UK) combining *Religious properties* and *Burial monuments and sites* with strong *Military properties* and *Archaeological heritage* components, alongside *Urban, rural settlements/ Historic towns and villages*. Values emphasize *Social & Political & Economic*, and *Ecological & Scientific* dimensions.

Cluster 5 (C5, Rock Art and Technological Heritage, n = 1): Another singleton (Peru), focused on *Rock-art sites*, *Agricultural, industrial and technological properties*, *Cultural routes*, *Archaeological heritage*, and *Urban, rural settlements/ Historic towns and villages*, with *Social & Political & Economic*, *Ecological & Scientific*, and *Aesthetic* values emphases.

Cluster 6 (C6, Integrated Settlement Landscape, $n = 15$): Includes *Urban, rural settlements/ Historic towns and villages*, *Archaeological heritage*, *Cultural routes*, *Cultural landscapes, parks and gardens*, *Agricultural, industrial, and technological properties*, with strong *Social & Political & Economic*, and *Ecological & Scientific* values. A typical case is Turkey.

Cluster 7 (C7, Rock Art Specialization, $n = 2$): Concentrated in *Rock-art sites* with *Social & Political & Economic*, *Ecological & Scientific*, and *Aesthetic* emphases. A typical member is Jordan.

Across clusters, recurring associations are led by *Historic & Age* values and anchored in a common type backbone comprising *Urban, rural settlements/ Historic towns and villages*, *Historic buildings and ensembles*, and *Cultural landscapes, parks and gardens*, onto which cluster-specific value-type combinations are layered. C1 combines this

Table 3
International classification of visual management strategy (Internationally endorsed instruments can be found in **Appendix A1**).

Index	Visual management strategy (dominance level)	Definition & Scope	Internationally endorsed instruments
S1	Protection of the visual qualities of cultural heritage	An overarching commitment or policy objective to protect the visual qualities/character of cultural heritage, even when specific instruments are not detailed.	1, 2, 3, 7
S2	Regulatory and institutional protection of visual integrity	Statutory frameworks, institutions, and procedural mechanisms combined with indicator-based monitoring/ reporting that safeguard the visual integrity of heritage.	1, 2, 6, 10
S3	Visual interpretation and public engagement	Stakeholders and public participation in recognizing, interpreting, and communicating visual values of heritage, fostering shared understanding and stewardship.	3, 6
Index	**Visual management strategies (planning level)**	**Definition & Scope**	**References**
S4	Development control via visual/heritage impact assessment	Project-level control using Visual/Heritage Impact Assessment to inform approval conditions, mitigation, or refusal.	2, 5
S5	Visual protection via zoning and spatial regulation	City/regional-scale visual protection delivered through zoning, land-use controls, buffer zones, and mapped view corridors or protection areas.	2, 3, 20
Index	**Visual management strategies (Design level)**	**Definition & Scope**	**References**
S6	Height, massing, form, and material control regulation	Establish design/build-level controls on height, setbacks, massing, façade articulation, color, and materials to ensure visual compatibility with heritage.	2, 7, 9, 20, 21
S7	Visual integration in architectural and landscape design	Design- and site-level analysis ensuring coherent visual relationships between new interventions, built forms, and the surrounding heritage landscape (e.g., skyline harmony, enclosure, sequence, and viewpoint composition).	3, 2, 5, 8

backbone with strong *Aesthetic* and *Ecological & Scientific* emphases; C3 adds a *Historic & Age*-led balance; and C6 incorporates *Cultural routes* and *Agricultural, industrial, and technological properties* with high *Social & Political & Economic* scores. C2 and C4 emphasize *Religious properties, Burial monuments and sites*, *Military properties*, and *Archaeological heritage*, while C5 and C7 specialize in *Rock-art sites* and *Agricultural, industrial, and technological properties* with mixed *Aesthetic*, *Ecological & Scientific*, and *Social & Political & Economic* emphases. Geographically, C1 and C3 represent baseline patterns across Africa, Latin America, and Asia; C6 concentrates in Europe and the Mediterranean; C2 and C7 correspond to island and small-state portfolios; and C4 and C5 are outlier single-nation types.

Thus, despite apparent variety in heritage portfolios, countries tend to follow a limited set of recurring value-type combinations, often shaped by regional governance and cultural legacies. This suggests a globally patterned structure in how heritage values and property types are prioritized.

3.2.2. Clustering by method-strategy: national configurations of visual practice

Binary indicators of methods and strategies capture each country's configuration of visual practice. Clustering these yields four method-strategy groups (G1-G4) that capture contrasting dominant profiles, although separations are only weak to moderate (Fig. 5). This indicates that the four regimes are not sharply bounded categories. Instead, they represent dominant tendencies in national method-strategy portfolios, and some countries show overlapping characteristics across adjacent groups. A country may therefore align primarily with one regime while selectively adopting tools that are more typical of another.

Group 1 (G1, Evidence Integrated, $n = 12$): A full-stack regime combining advanced analytical methods with strict visual control. On the method side, it features strong use of *GIS-based viewshed and visual sensitivity analysis* (*M2*), *Verified visuals and 3D visualization techniques* (*M3*), and *GIS-based spatial-historical analysis* (*M4*). On the strategy side, it shows strong use of *Height, massing, form, and material control regulation* (*S6*) and *Visual integration in architectural and landscape design* (*S7*). Cluster means are near universal for *Protection of the visual qualities of cultural heritage* (*S1*), *Regulatory and institutional protection of visual integrity* (*S2*), *Development control* via *visual/heritage impact assessment* (*S4*), and *Visual protection* via *zoning and spatial regulation* (*S5*), indicating a comprehensively instrumented toolkit. In contrast, *Perception- and experience-based assessment* (*M1*) and *Visual interpretation and public engagement* (*S3*) are comparatively lighter. Typical members include Italy, Portugal, and the Netherlands.

Group 2 (G2, Policy Oriented, $n = 24$): A procedural group with strong normative framing but minimal technical implementation. Policy tools and regulatory references are present in *M5*, *S1*, *S2*, and *S4*, but spatial modeling and visualization techniques such as *M2*, *M3*, *M4*, and *S6* are nearly absent. Typical members include Vietnam, Finland, and Nepal.

Group 3 (G3, Regulatory Baseline, $n = 58$): The dominant group, characterized by broad reliance on standard planning instruments such as M4 and *M6*, and regulatory strategies including *S2*, S4, *S5*, and *S6*. Advanced analytics, particularly M2, *M3*, and strategy *S3*, are rarely used. This group spans countries across all continents and income levels, including Ireland, Peru, and Senegal.

Group 4 (G4, Entry Level, $n = 18$): A minimalist group with near universal *S1* plus moderate *M6* and *S5*. Most other levers sit below baseline, with the most significant deficits in *M4*, *M5*, *S2*, *S4*, *S7*; *M2*, *M3*, *S3* are near zero. The group suggests capacity, mandate, or implementation constraints. Typical members include Timor-Leste, Belarus, and Uganda.

Each group's typical pattern reflects institutional maturity and portfolio complexity. Most countries (*G2*, *G3*, and *G4*) rely on a narrow set of widely used methods (notably *M4* and *M6*) and near-universal baseline controls (*S1*, *S2*, *S4*, *S5*, and *S6*), whereas the more demanding analytics (*M2*, *M3*) and selective strategies (*S3*, *S7*) are concentrated predominantly in *G1*. *G2* primarily focuses on policy and procedural framing, with little technical follow-through, while *G4* operates with a minimalist *S1* and *S5* portfolio. Geographically, G1 is dominated by small- to medium-sized, mostly European countries with relatively mature planning and heritage institutions, G2 and G4 include many low- and middle-income, small-island or landlocked states where

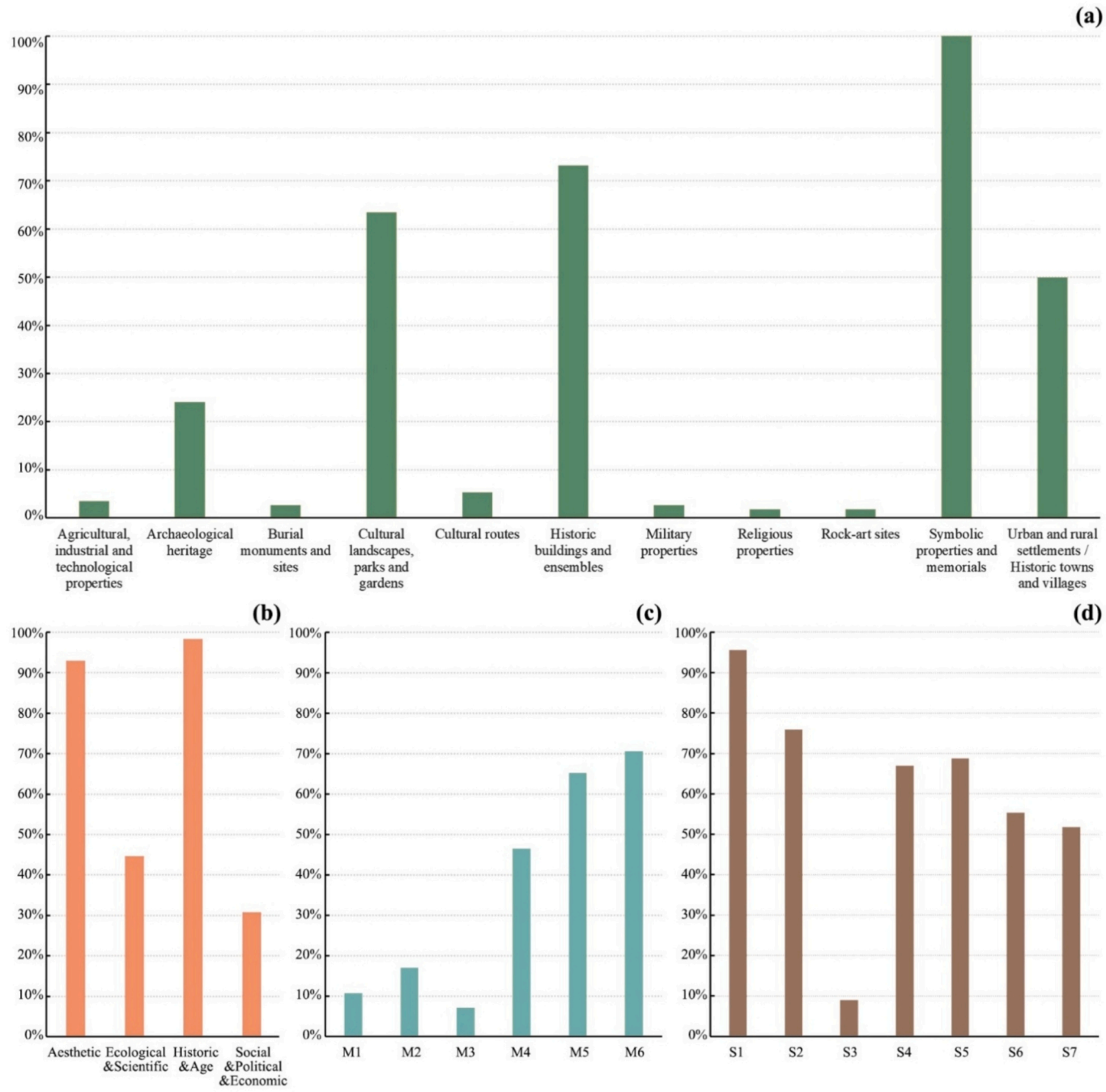

Fig. 3. Summary of national level coding analysis: (a) proportion of countries by property types; (b) proportion of countries by heritage value; (c) proportion of countries by visual evaluation method; (d) proportion of countries by visual management strategy (details can be found in **Appendix A5**).

capacity and resource constraints are more visible, and the regulatory-baseline G3 is spread across all continents and income groups, cutting across diverse urban, rural, coastal and inland settings.

This suggests that most countries employ a baseline suite of visual planning tools, but only those with stronger institutional frameworks and technical capacity can operationalize advanced methods such as spatial analytics and integrative design. These findings underscore a structural bottleneck: while recognition of visual integrity is widespread, the tools needed to manage it systematically remain concentrated in a limited set of national systems.

3.2.3. Co-occurrence between national type-value and method-strategy regimes

The overlay of type-value clusters (C1-C7) and method-strategy groups (G1-G4) reveals a strongly patterned field. At the system level, most countries (C1, C3) cluster together with the integrated *Urban, rural settlements/ Historic towns and villages, Cultural landscapes, parks and gardens* of C6, converging on G3 Regulatory Baseline. A much smaller subset, dominated by C1, C4, and C6 portfolios, operates the G1 Evidence Integrated regime, while G2 Policy Oriented and G4 Entry Level absorb more limited but distinctive shares of mainly C3, C2, and C7 countries (Fig. 6). This flow suggests that national type-value clusters translate predictably into method-strategy groups; clusters with broader or more complex types are more likely to adopt G1, while more

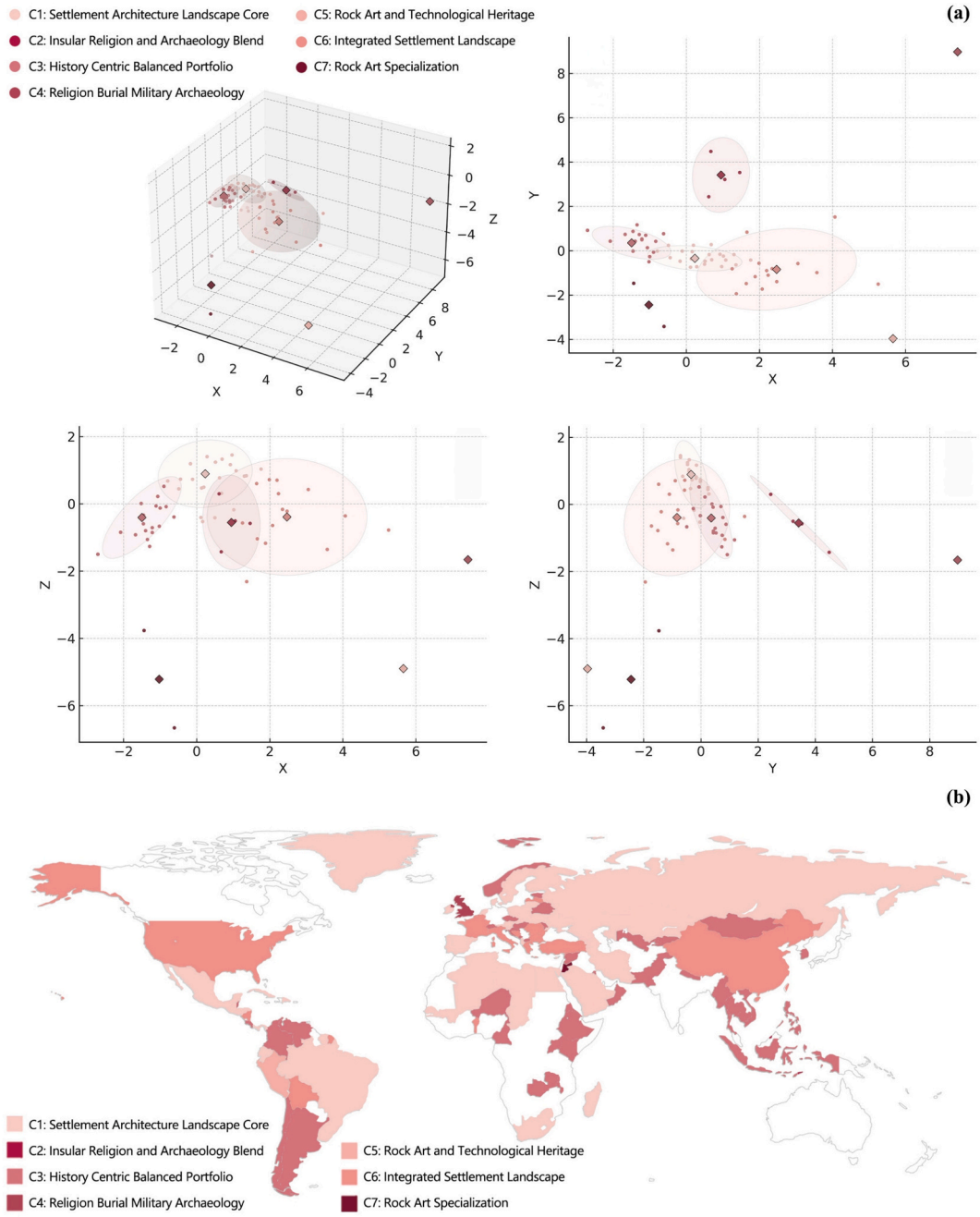

Fig. 4. National level clustering result by type-value: (a) 3D MDS representation of countries colored by clusters in value-type space; (b) global mapping of the seven clusters by country (details can be found in **Appendix A6**).

specialized or capacity-constrained countries align with G2 or G4.

Geographically, C1&G3 and C3&G3 combinations form a widely distributed backbone spanning much of Europe, parts of Latin America, and several rapidly urbanizing Asian economies. Evidence Integrated combinations (especially C1&G1 and C6&G1) are concentrated in European and Mediterranean states, whereas more specialized pairings such as C2&G3/4 and C7&G3/4 occur mainly in small island or coastal states and a few arid Middle Eastern settings.

These patterns highlight a persistent global asymmetry in the diffusion of visual evaluation methods and in the management strategies for cultural heritage. Innovation remains highly uneven, concentrated in a few advanced regimes, and largely absent across vast geographic regions.

3.3. Results of property-level analysis

At the property level, the analysis focuses on reading association structures among attributes, methods, and strategies rather than clustering countries. Coding results show a pronounced focus on *Urban, rural settlements/ Historic towns and villages,* and *Cultural landscapes, parks and gardens*, with smaller shares in *Religious properties*, *Historic buildings and ensembles*, *Archaeological heritage*, and *Agricultural, industrial and technological properties*. Value orientations are led by *Historic & Age* and *Social & Political*, with *Aesthetic* also strong and Ecological & Scientific comparatively sparse. Methods are highly technical-spatial: *GIS-based viewshed and visual sensitivity analysis* (*M2*), *Verified visuals and 3D visualization techniques* (*M3*), and *GIS-based spatial, historical analysis* (*M4*) are near-universal; *Public engagement and Perception- and experience-*

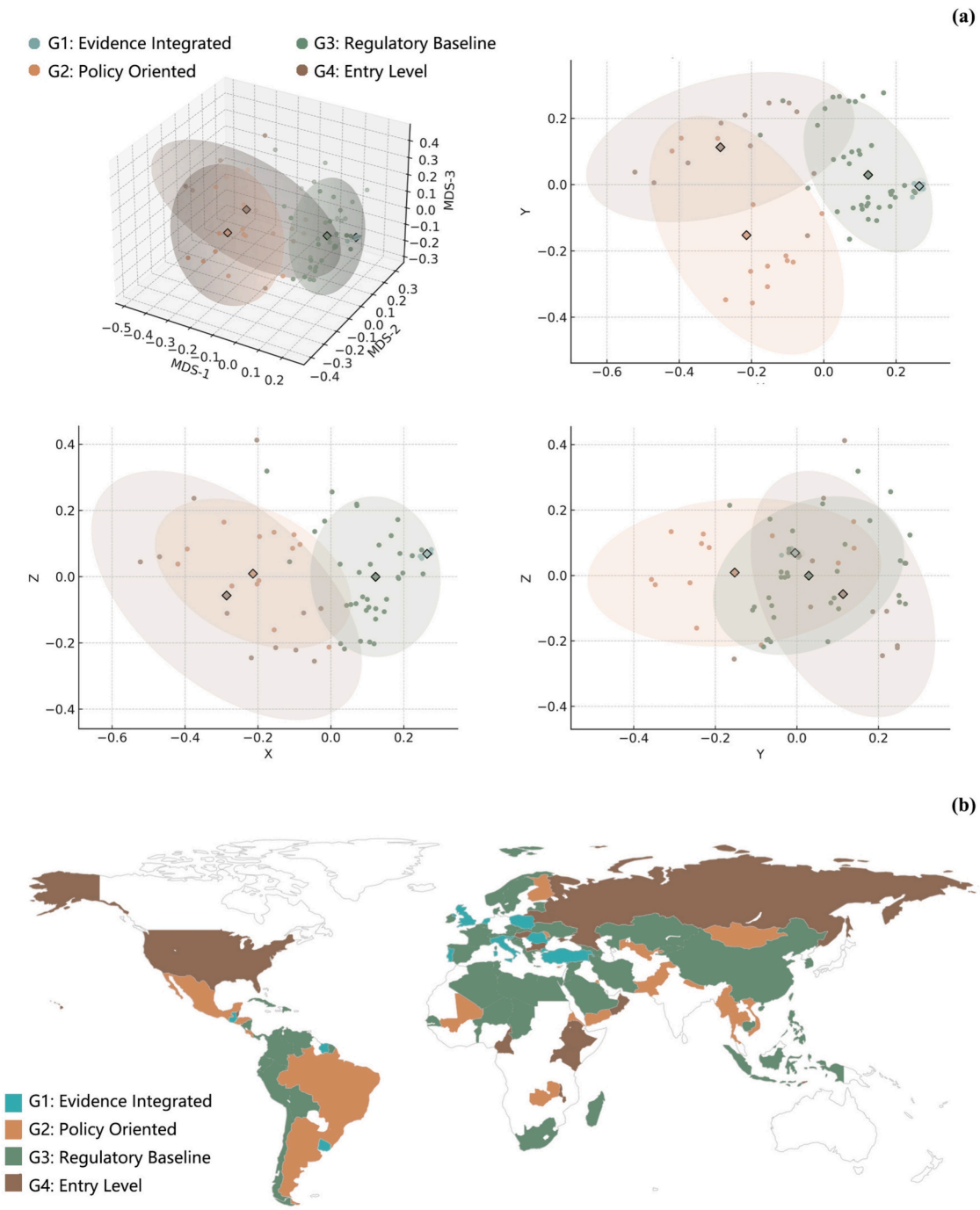

Fig. 5. National level clustering result by Method-Strategy: (a) 3D MDS representation of countries colored by clusters in method-strategy space; (b) global mapping of the four clusters by country (details can be found in **Appendix A7**).

based assessment (*M1*) are rare; *Participatory evaluation and multi-criteria evaluation frameworks* (*M5*) and *design/planning-concept-based visual analysis* (*M6*) occur at intermediate levels. Strategies concentrate on *visual zoning and spatial regulation* (*S5*) and *height, massing, form and material control regulation* (*S6*); *development control* via *visual/heritage impact assessment* (*S4*) is widespread but not universal; *architectural and landscape integration is moderate* (*S7*); *public engagement and visual interpretation* (*S3*) is limited. Apparent gaps reflect documentation: we count only practices explicitly recorded in official sources (Fig. 7).

3.3.1. *Property types and the selection of visual evaluation methods and management strategies*

On the visual evaluation methods side, selection is guided by a quantitative-spatial triad, *M2*, *M3,* and *M4*; *M6* appears at intermediate levels where technical outputs are translated into design or regulatory language, while *M1* and *M5* remain infrequent (Fig. 8a).

On the visual management strategy side, flows are dominated by *S5* and *S6*, both fed primarily by *Urban, rural settlements/ Historic towns and villages,* and secondarily by *Cultural landscapes, parks and gardens*. *S7* forms a clear secondary destination, especially for *Historic buildings and ensembles* and *Religious properties,* while *S4* and *S3* remain limited (Fig. 8b).

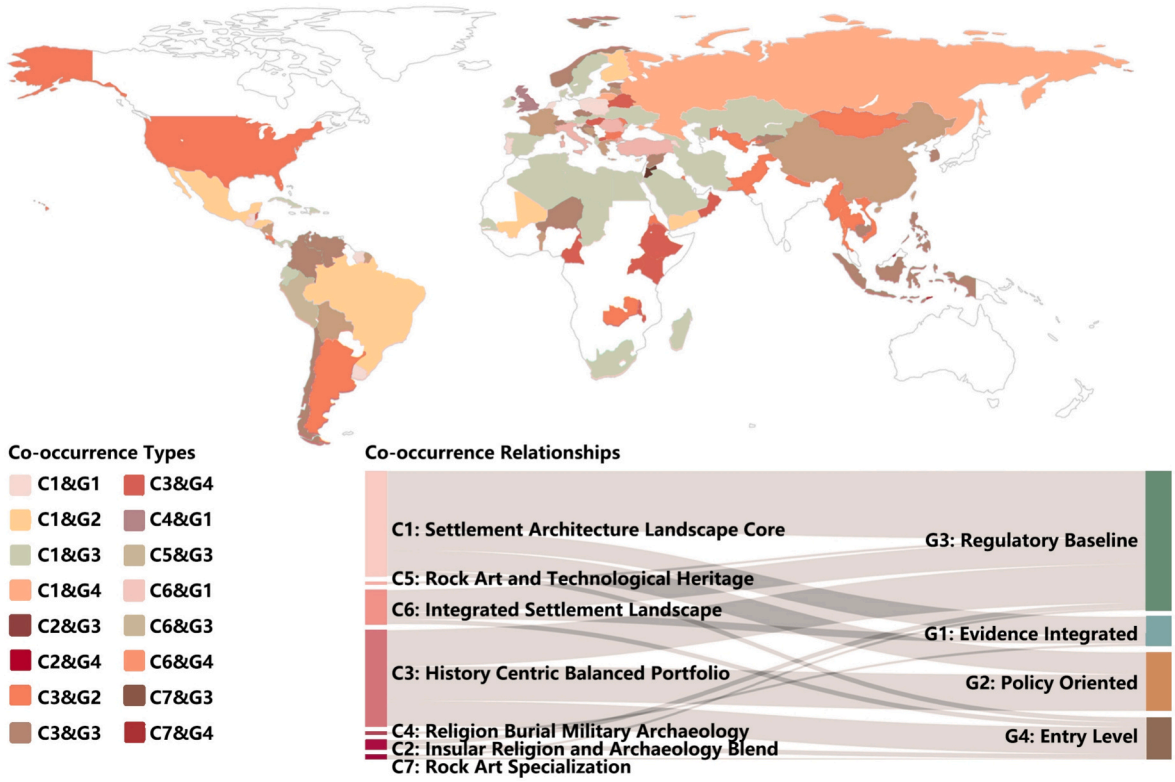

Fig. 6. Co-occurrence between national type-value and method-strategy regimes: (a) global mapping of co-occurrence types; (b) co-occurrence relationship between national type-value and method-strategy.

Linking objects, methods, and strategies reveals consistent sequences. *Urban, rural settlements/ Historic towns and villages,* and *Cultural landscapes, parks and gardens* most often combine *M2-M4* (with frequent *M3* supplements) and culminate in *S5* and *S6*. *Historic buildings and ensembles* and *Religious properties* show stronger transitions to *S7*, with auxiliary flows to *S5* and *S6*. *Archaeological heritage* typically pairs *M3* and *M4*, again translating mainly into *S6* and *S5*. Overall, *S4* appears only occasionally, and *S3* is rarely used, underscoring a structural tendency across property types to prioritize technical assessment and spatial regulation over participatory or interpretive approaches.

3.3.2. *Property scales and the selection of visual evaluation methods and management strategies*

Across property scales, both profiles are technical and spatial-control oriented. On the visual evaluation side (**Fig. 9Fig. 9a**), *M2*, *M3*, and *M4* form the core, with *M6* present at lower levels, while *M1* and *M5* remain marginal. On the visual management side (Fig. 9b), *S5* and *S6* dominate across all scales, followed by *S7*, whereas *S4* is modest and *S3* is minimal.

By scale, *Groups of buildings* are led by *M2* and *M4*, with substantial *M3*, and most often end in *S5* and *S6*, with *S7* as a secondary outlet and only limited flows to *S4* and *S3*. *Sites* combine *M4*, *M2*, and *M3* in more balanced proportions and most often culminate in *S6*, followed by *S5* and *S7*, with *S4* and *S3* present but thin. *Monuments* rely primarily on *M3* and *M4*, with smaller contributions from *M2* and only minor contributions from *M1*, *M5*, and *M6*, and most frequently end in *S7*, with thinner flows to *S5*, *S6*, *S4*, and *S3*.

Taken together, this configuration implies that, regardless of scale, heritage properties are predominantly evaluated through *M2-M4* that feed into *S5* and *S6*, while *S7*, *M1*, and participatory or impact-focused approaches (*M5, S3, S4*) remain consistently underrepresented.

3.3.3. *How property heritage values are safeguarded and put into practice*

The diagrams (Fig. 10) show that heritage values are routinely channelled through a technical-spatial assessment culture and then resolved in spatial control instruments. Across values, the dominant route runs from *M2*, often paired with *M3* and *M4*, to *S5* and to *S6*. *M6* enters when results must be translated into design or regulatory terms. *M1* and *M5* remain peripheral, which indicates a system that privileges measurable visibility and mappable context over experiential or deliberative evidence.

Preferences vary by value. *Historic & Age* values tend toward visibility mapping through *M2,* supported by *M4* and selective *M3*, coupled with spatial regulation via *S5* and *S6*. *Social & Political* values rely more on *M4*, with M2 where key sightlines matter, mainly managed through *S6*, with *S5* in support. *Aesthetic* values privilege *M3* alongside *M2* and target *M6*, and are typically handled through design-oriented responses in *S6* and *S7*, with zoning secondary. *Ecological & Scientific* values are lightly represented, assessed primarily through *M4* and dispersed across strategies with occasional project-level checks via *S4*.

Taken together, the evidence suggests that each value follows a characteristic assessment-management sequence: *Historic & Age* toward visibility mapping and spatial regulation, *Social & Political* toward spatial-historical mapping and form control, *Aesthetic* toward verified visuals and integration-oriented design, and *Ecological & Scientific* toward landscape mapping with diffuse management outcomes. The systematic underuse of *M1* and *M5*, alongside the marginal role of *S3*, reveals a persistent bias toward technical objectivity and regulatory control, and a corresponding gap in experiential and participatory safeguards.

3.4. *Cross-level alignment diagnostics*

This section examines cross-level patterns across international, national, and property levels to show how visual evaluation and management practices move between them. Using harmonized category sets, we apply three overlays: *(i) national-property consistency,* property-level coverage of types, values, methods, and strategies relative to national

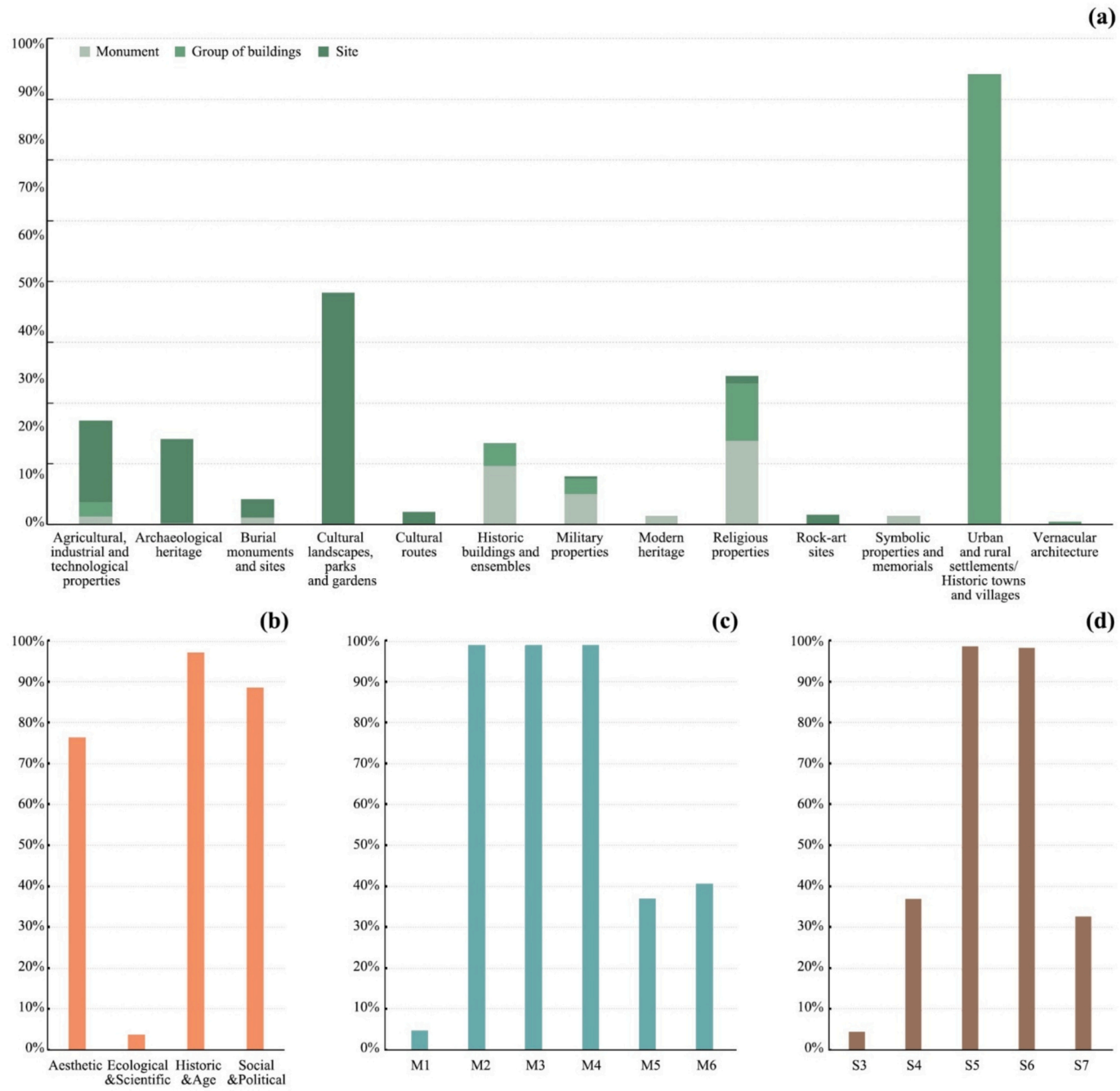

Fig. 7. Summary of property level coding analysis: (a) proportion of properties by property scales and types; (b) proportion of properties by heritage value; (c) proportion of properties by visual evaluation method; (d) proportion of properties by visual management strategy (details can be found in **Appendix A8**).

toolkits; *(ii) international–national overlay*, national coverage relative to the whole international sets; and *(iii) three-level synthesis*, which identifies recurrent cross-level configurations.

3.4.1. National-property consistency

At the national-property level, the profile is predominantly technical and spatial (Fig. 11c, d). *S5* and *S6* are recorded for virtually all properties. The methodological core is similarly universal; *M2*, *M3*, and *M4* occur at roughly 99% of properties. *S3* and *M1* are rare, while *M6* and *M5* are intermediate. Value tags (Fig. 11b) concentrate in the *Historic & Age* and the *Social & Political* registers, at approximately 98 and 89%, with *Aesthetic* also strong and *Ecological & Scientific* sparse, though somewhat more frequent in a few portfolios (China, Türkiye). Large Western European portfolios and China combine near-universal spatial controls with the complete technical toolkit and moderate uptake of *M6* and *M5*, typically 30 to 60% of properties, while explicit *S3* often remains minimal or absent (Italy, France, UK, China). Other settings maintain the technical core but adopt *S4* and *M5* less consistently.

These contrasts are consistent with variation in four interrelated factors: how responsibility and review are organized, the physical complexity of *Cultural landscapes, parks and gardens,* and *Urban, rural settlements/ Historic towns and villages*, long-standing administrative emphases, and the resources available for modeling, monitoring, and coordination. Clear lines of oversight support the standardization of technical and spatial instruments. Dense historic fabrics and complex topography increase the practical returns to visibility analysis and three-dimensional workflows, which therefore become default practices. Where protection cultures prioritize development control, spatial

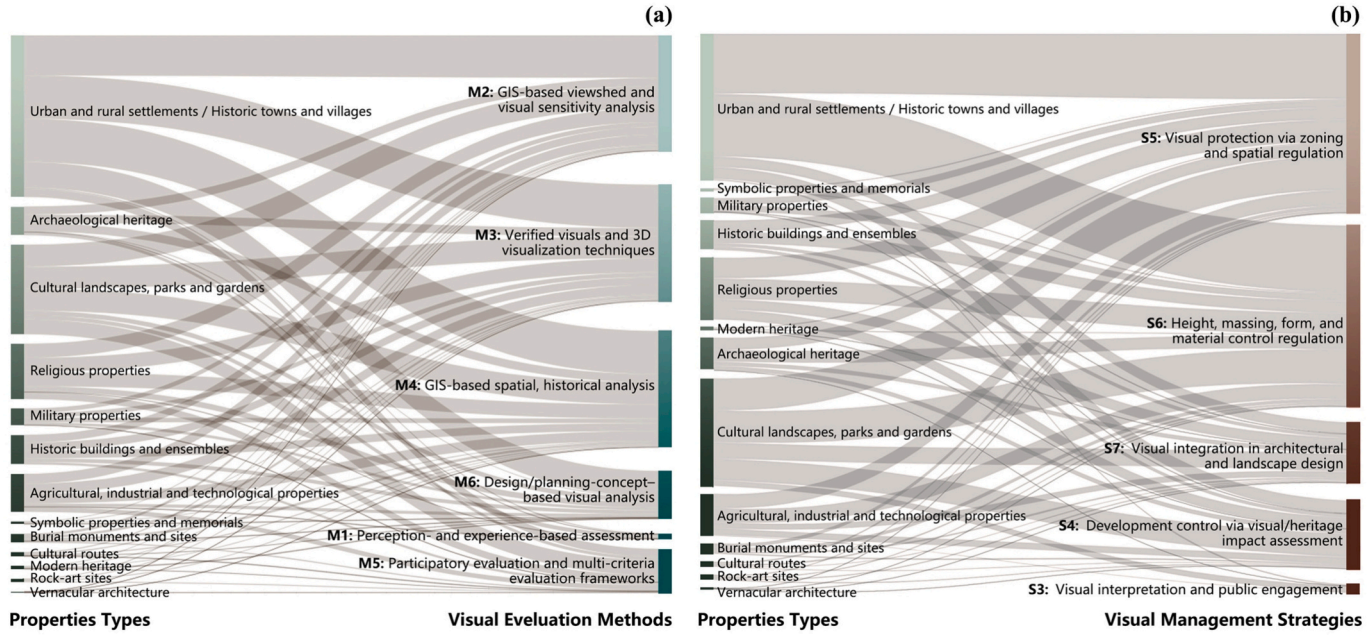

Fig. 8. Property types and the selection of visual evaluation methods and management strategies: (a) co-occurrence between property types and visual evaluation methods; (b) co-occurrence between property types and visual management strategies.

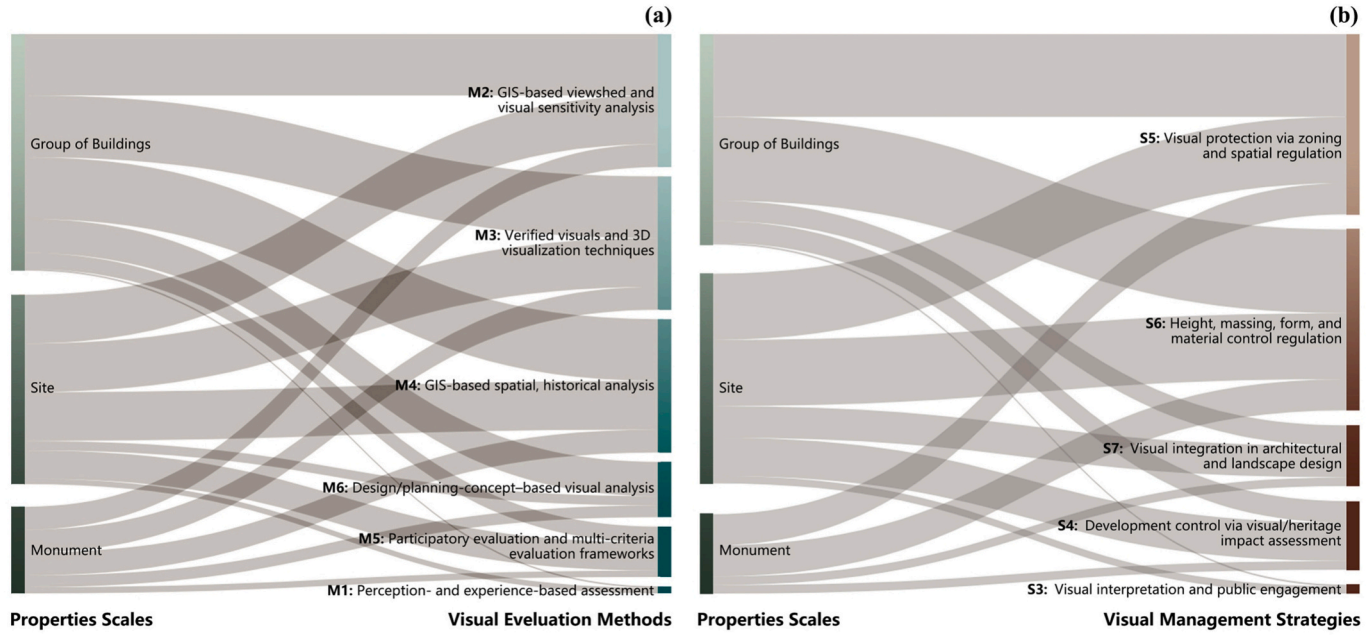

Fig. 9. Property scales and the selection of visual evaluation methods and management strategies**:** (a) co-occurrence between property scales and visual evaluation methods; (b) co-occurrence between property scales and visual management strategies.

regulation diffuses more readily than perception- or participation-based approaches. Where capacity is limited, agencies tend to concentrate on a minimal regulatory core and defer labor-intensive engagement.

Taken together, these patterns suggest that comprehensive use of the visual toolkit at the property level is most likely where governance structures and resources explicitly support advanced analytics, while most systems remain anchored in a narrower but robust technical-regulatory baseline.

3.4.2. International-national divergence

At the international-national level, maps show wide dispersion in heritage-type breadth (Fig. 12a). A small group of states approaches portfolio-wide representation, while many cluster in intermediate tiers, with the highest coverage more common in Europe. Value coverage is similarly stratified (Fig. 12b), with a small set attaining complete or near-complete articulation of all value classes and many stabilizing at three or four.

Method families and strategy sets display parallel geographies (Fig. 12c,d). They are most complete within a compact European-Mediterranean group, with a clear second tier just below the top band, while many national systems occupy middle- or low-coverage classes. Overall, the pattern is a structured gradient rather than a binary divide:

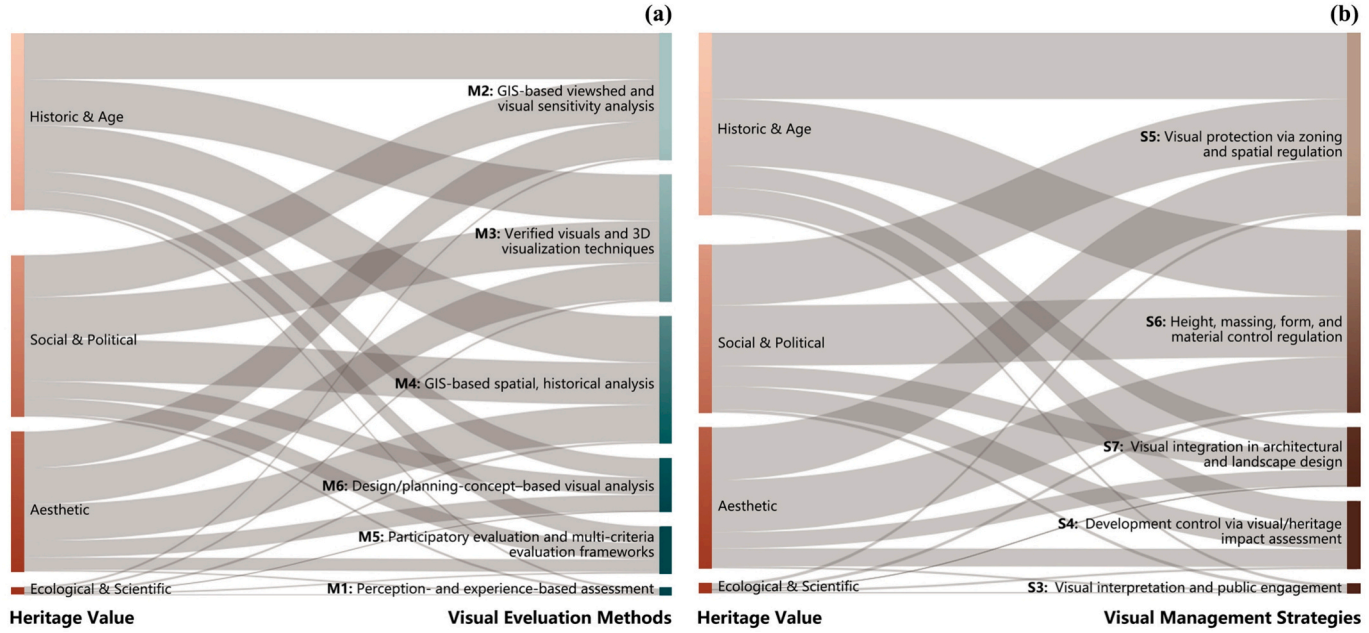

Fig. 10. How property heritage values are safeguarded and put into practice: (a) co-occurrence between property heritage values and visual evaluation methods; (b) co-occurrence between property heritage values and visual management strategies.

a small group achieves comprehensive coverage, a larger cohort is high but incomplete, and many remain in intermediate or low classes.

Variation across these classes aligns with four recurrent influences. Coordinated guidance and predictable review procedures help scale method families and strategy sets. Dense urban fabrics or complex relief make intensive spatial control both salient and cost-effective. Administrative traditions shape which dimensions mature first, for example, prioritizing development control before complete codification of value classes or method families. Resource endowments condition delivery, since sustained modeling and inter-agency coordination are required to populate method families and operationalize strategy sets at the national scale.

Taken together, these patterns imply that countries reaching the highest coverage tiers combine strong coordination, complex historic landscapes, planning-oriented administrative traditions, and sufficient technical capacity, while others naturally exhibit gaps in their national visual-heritage toolkits.

3.4.3. Three-level synthesis

Stacking the two overlays (Fig. 13), namely property-level coverage relative to national toolkits and national coverage relative to the international sets, yields a compact typology of recurrent cross-level configurations.

Near-complete national coverage of methods and strategies with high property-level correspondence, indicating limited attenuation from policy signal to practice and illustrating what fully integrated visual governance can look like in a small European-Mediterranean group. National frameworks do not enumerate all categories, yet instruments at the property level align closely with available domestic portfolios, producing moderate to high property-level coverage within a narrower rule set and demonstrating that strong transmission from policy to practice can occur even with only partially developed national toolkits. Broad strategy coverage and alignment between methods and values coexist with reduced cross-level specificity across diverse property types, as breadth in heritage types dilutes object-specific correspondence even in otherwise well-equipped regimes. Limited national coverage coincides with weak property alignment, often where responsibilities are delegated to sub-national instruments or delivery capacity is constrained, signaling fragmented or under-resourced visual governance.

Read across all three levels, these overlays reveal a coherent gradient. A small cluster attains comprehensive coverage across category sets and strong transmission to properties; a broader group achieves high but incomplete coverage with selective correspondence; and many systems stabilize in intermediate or low tiers with uneven uptake. Overall, this three-level pattern implies that only countries with predictable oversight, favorable landscape and settlement conditions, planning-oriented coordination, and sustained resources can translate national visual toolkits into routine property practice. In contrast, the coupling between international guidance, national codification, and on-site implementation remains partial or fragmented.

4. Discussion

This paper reveals both consolidation and gaps in visual heritage practice across governance tiers through multi-level mapping. While many systems converge on technically auditable, spatially oriented tools, participatory and perception-based components remain sporadic, and coherence varies across international guidance, national baselines, and site-level delivery. This study contributes a reusable dataset, a replicable multi-level workflow, and an integration framework that connects analytical techniques to routine governance procedures. The discussion interprets these patterns and their drivers, and outlines staged upgrading pathways to strengthen alignment, equity, and delivery.

4.1. Why these patterns occur: plausible structural drivers

Across countries and World Heritage properties, several consistent patterns emerge. Practice converges on a technical-spatial regime in which GIS-based analysis and visualization are most often translated into zoning instruments and height or massing controls. Public engagement and perception- or experience-based assessment remain scarce, while design-led analysis and participatory or multi-criteria approaches appear at intermediate frequencies. Value framings are dominated by *Historic & Age* and *Social & Political & Economic* emphases, with strong *Aesthetic* emphases and relatively sparse *Ecological & Scientific* articulation. Patterns of cross-level coherence also vary markedly

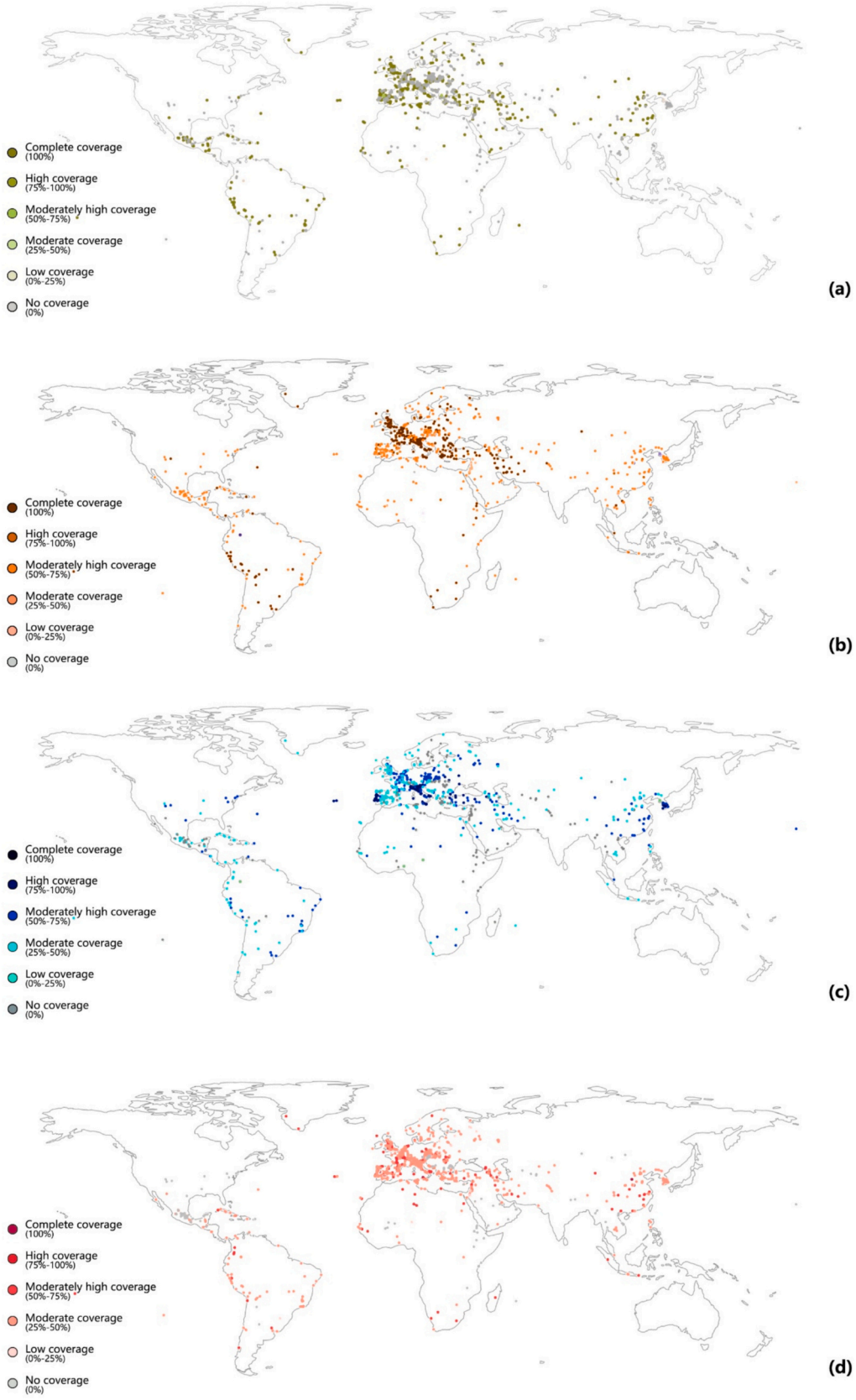

Fig. 11. National-property consistency cross-level alignment diagnostics: (a) property-level coverage of property type relative to national-level toolkits; (b) property-level coverage of heritage value relative to national-level toolkits; (c) property-level coverage of visual evaluation method relative to national-level toolkits; (d) property-level coverage of visual management strategy relative to national-level toolkits.

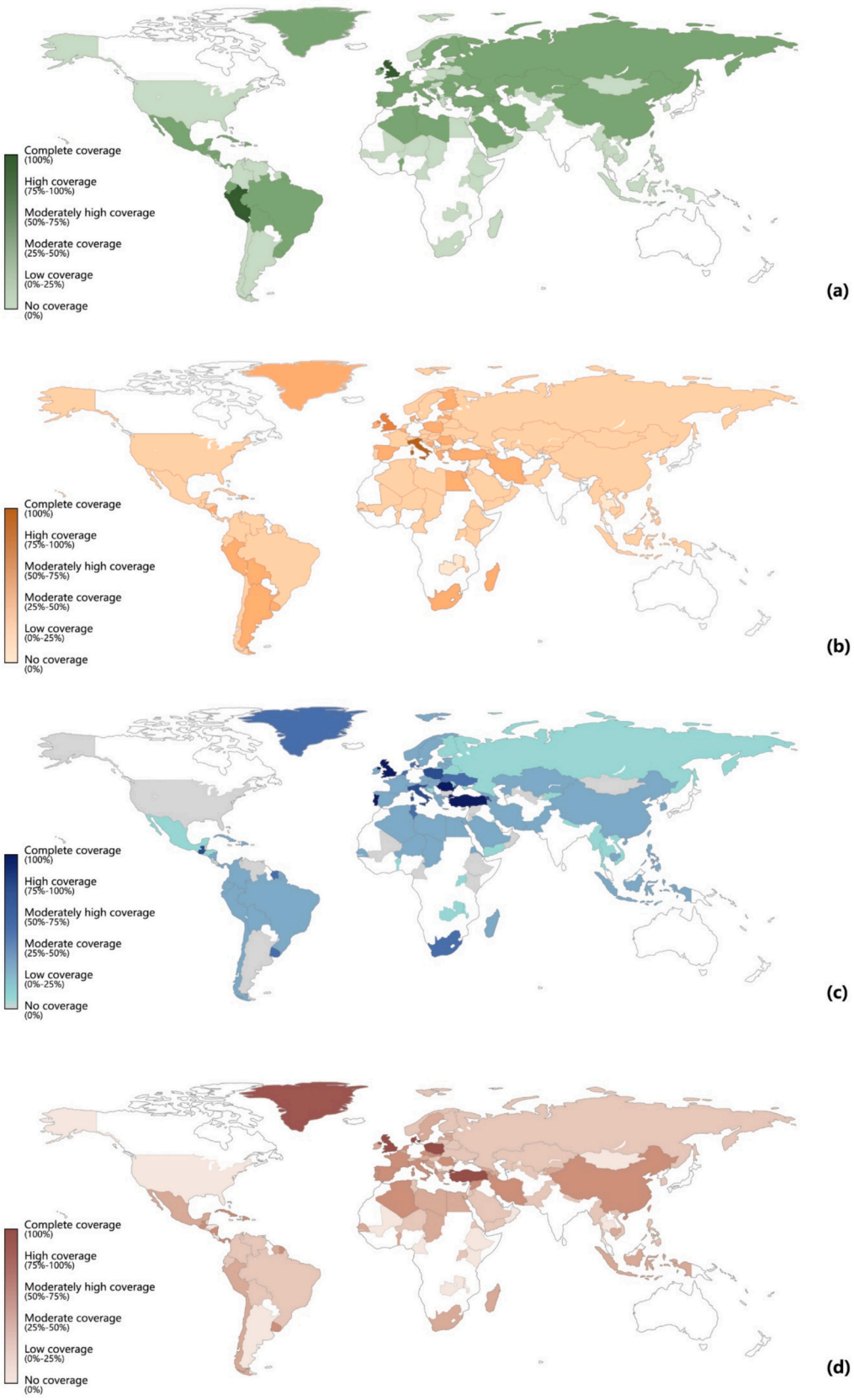

Fig. 12. International-national divergence cross-level alignment diagnostics: (a) national-level coverage of property type relative to international-level toolkits; (b) national-level coverage of heritage value relative to international-level toolkits; (c) national-level coverage of visual evaluation method relative to international-level toolkits; (d) national-level coverage of visual management strategy relative to international-level toolkits.

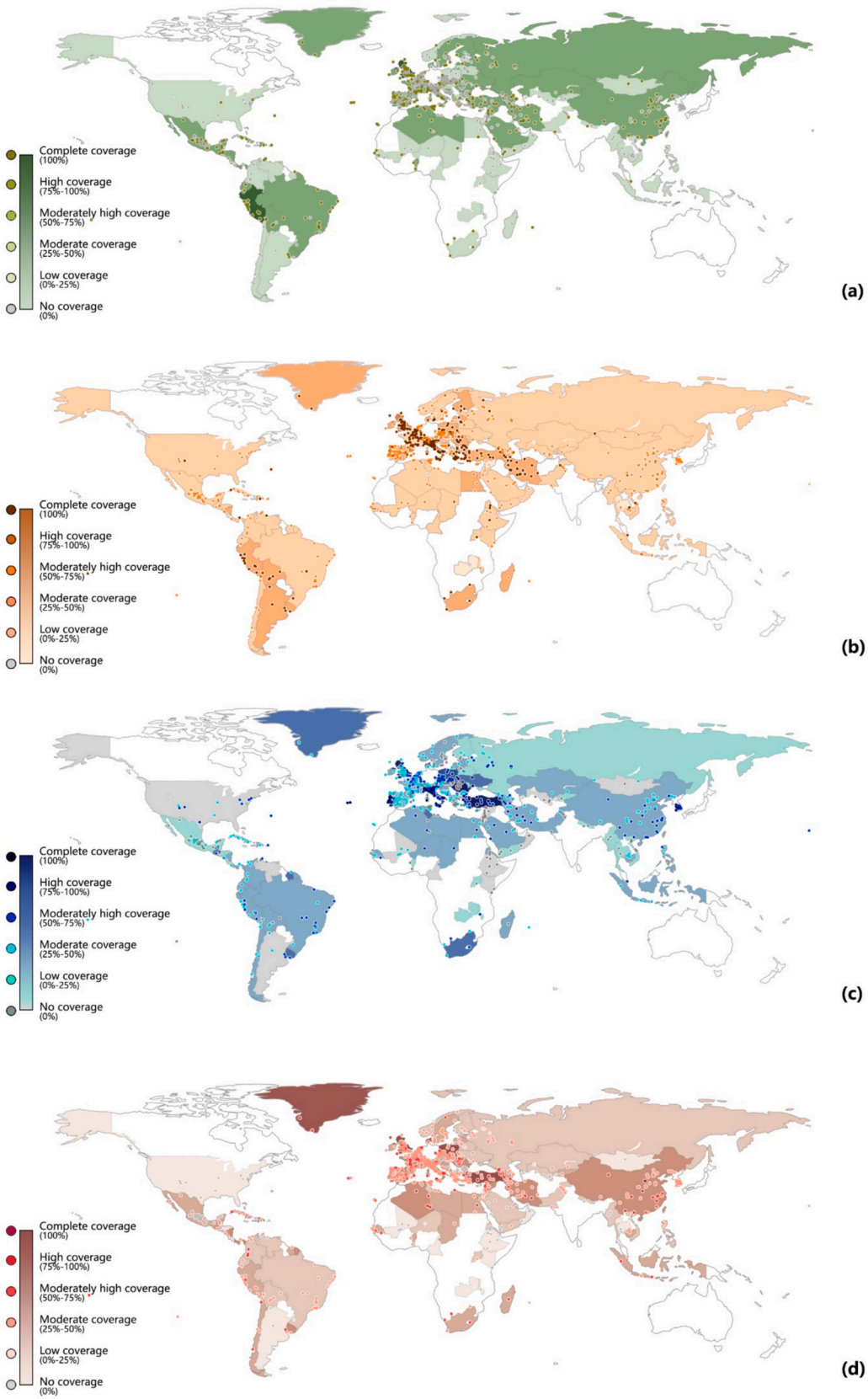

Fig. 13. Three-level synthesis cross-level alignment diagnostics: (a) three-level synthesis of property type coverage; (b) three-level synthesis of heritage value coverage; (c) three-level synthesis of visual evaluation method coverage; (d) three-level synthesis of visual management strategy coverage.

across governance contexts.

This convergence is not only interpretive; it is directly visible in our coded results at both the property and national levels. In the property corpus, *GIS-based viewshed and visual sensitivity analysis* (*M2*), *verified visuals and 3D visualization techniques* (*M3*), and *GIS-based spatial-historical analysis* (*M4*) form a near-universal methodological core and are most consistently coupled with *zoning and spatial regulation* (*S5*) and *height or massing controls* (*S6*). These recurring sequences across property scales and types suggest that technical evidence is routinely operationalized through spatially explicit rules rather than through deliberative, perception-based, or experience-based safeguards. At the national level, the dominance of the "regulatory baseline" regime further indicates that many countries have institutionalized this translation by embedding spatial mapping and visibility-oriented evidence within statutory planning controls. At the same time, only a smaller "evidence-integrated" group mainstreams the full *M2-M4* stack alongside stronger design integration and broader evidence portfolios.

This interpretation is consistent with the increasing use of remote sensing and cloud-based geospatial workflows in heritage monitoring and management, including at the global scale for cultural World Heritage properties (Guo et al., 2023). As spatial evidence becomes more standardized and auditable, it is also easier to translate into regulatory instruments, including mapped zones, corridors, and buffers, as well as enforceable height or massing controls. This helps explain why the convergence identified in our dataset takes a predominantly technical-spatial form. Against this backdrop, three interlocking drivers plausibly explain why this configuration persists and why cross-level coherence varies across governance settings:

First, political and institutional design is evidenced by the contrast between unitary planning regimes that codify comprehensive analytic and regulatory toolkits and devolved or federal arrangements where policy signals fragment (Cullingworth et al., 2006; Young, 2016). Western European and Mediterranean portfolios concentrate in the top or high tiers for national visual-method and strategy coverage, and site-level overlays show frequent matches at those tiers. In a federal context, several United States properties register zero site-level strategy coverage, consistent with heavier reliance on sub-national instruments and weaker standardization of participatory or interpretive components at the national-property interface.

Second, geography and settlement morphology raise the cost of standardization and shape the returns to technical evidence (Bianca, 2014; Gospodini, 2004; Peng et al., 2025). Dense historic fabrics and complex topographies coincide with more substantial alignment in value-method overlays and more frequent complete site-level matches (e.g., Andean and Italian cases). By contrast, extensive maritime or archipelagic settings more often show mid-tier site matches, reflecting a practical preference for general spatial instruments over repeated, fine-grained iterative testing (e.g., Papahānaumokuākea and Vegaøyan cases).

Third, economic capacity and implementation bandwidth shape regime maturity (Berg, 2017; Shipley and Kovacs, 2008). Western Europe and parts of the Mediterranean concentrate in high or complete tiers on the national maps for values and methods, and many of their properties register complete value-national matches in the site overlays. Capacity-constrained or higher-risk contexts show thinner national toolkits and patchier site-level uptake (e.g., Central America and South Asia).

Taken together, these drivers account for the observed spectrum from comprehensive and congruent regimes to fragmented country-property coupling and point toward interventions that complete fundamental visual baselines, better align instruments with protection needs, and progressively standardize analytical and verification tools where site-level safeguards remain weak (Patiwael et al., 2019). At the same time, they help explain why participatory and perception-based approaches remain sporadic and why this matters for equity and community engagement, including who is represented in visual experience when regulatory decisions are anchored mainly in technical evidence and spatial controls.

4.2. Gaps and bridges between scholarship and practice

Practice typically follows a documentation and visibility sequence that leads to rule-setting through corridors, height envelopes, and buffer controls. Multi-criteria evaluation is used selectively. Perception inputs are infrequent and only weakly correlated with spatial indicators. Portfolios commonly emphasize iconic sites and corridors, while everyday or peripheral landscapes and diachronic changes are underrepresented. Evidence packages are auditable for geometry but rarely specify uncertainty, audience stratification, or transferability, which constrains comparability across sites (Leung et al., 2015).

Recent scholarship converges on an integrative, modular, and cross-scalar paradigm that links perceptual and behavioral evidence with spatial indicators (Daniel, 2001; Liu and Nijhuis, 2020), broadens representation beyond emblematic sites toward ordinary and large-area landscapes (Gobster et al., 2019; Nijhuis et al., 2011a), and articulates traceable protocols, input standards, and uncertainty handling from analysis through regulation.

There are three principal gaps:

(a) **Interface gap:** Practice rarely couples eye-level experience, such as surveys or attention traces, with the GIS and 3D indicators used in control instruments. Scholarship calls for perception-aware spatial indicators that are calibrated and validated against field or immersive evidence (Dramstad et al., 2006; Weitkamp et al., 2014).

(b) **Representation gap:** Current portfolios underrepresent everyday and large-area landscapes. Research urges typological diversification and multi-scalar designs that translate micro-level experience into territorial rules (Ginzarly et al., 2024; Mosler, 2019).

(c) **Application gap:** Practice packages evidence for audit but lacks shared modules for input standards, accurate visual representation (AVR) or level-of-detail conformance, audience stratification, and explicit uncertainty propagation from analysis to thresholds and scenarios. The literature emphasizes precisely this operational level (Cardenas and Halman, 2016; Leung et al., 2015; Palmer, 2019).

4.3. Building a global peer network for visual-heritage practice

We propose a two-track strategy that builds on our cross-level findings while aligning with state-of-the-art guidance (Ashrafi et al., 2021; Teller and Bond, 2002).

Track A: Peer complementarity among countries and sites with similar heritage types and value orientations.

Our mappings show recurrent method-object pairings. Some countries and sites have already adopted measures that partially bridge the interface and application gaps, for example, integrating perception modules into visibility control and reporting uncertainty alongside indicators. These pioneers can serve as mentors for peer sites with the same type and value profile that have not yet adopted such measures.

Establish Peer Learning Constellations organized by heritage type, value orientation, and governance maturity. Within each constellation, designate mentor sites that already demonstrate perception-spatial coupling, uncertainty reporting, and cross-scale synthesis, and learner sites with similar attributes but missing modules. Run like-for-like transfers in which the mentor's validated modules, including sampling frames, indicator formation, validation checks, and decision rules, are replicated in the learner's context. Adopt a progression from Basic to Enhanced to Advanced evidence standards for inputs, AVR or level-of-detail compliance, quality assurance logs, and reproducibility packages, so that capability tiers can differ without sacrificing comparability.

Because heterogeneity is minimized within a constellation, adoption costs decrease and external validity increases. Gaps close fastest when practice already contains elements of the integrative paradigm but lacks standardized packaging.

Track B: Targeted infusion where no peer possesses the missing capability.

When a constellation reveals capability blanks shared by all peers, such as the absence of immersive validation or the lack of uncertainty propagation into thresholds, introduce new visual evaluation methods and visual management strategies drawn from recent research modules to seed the missing functionality.

(a) Visual evaluation methods: ***(i)*** Perception-spatial coupling that links eye-level traces, including surveys, gaze or attention, and 360-degree imagery, to visibility and composition metrics to produce perception-aware indicators with effect sizes and confidence ranges (Peng et al., 2025; Zhang et al., 2024). ***(ii)*** Immersive validation through virtual reality (VR) and augmented reality (AR) with route- and viewpoint-matched trials and ecological validity checks against in-situ responses, stratified by audience groups such as residents, heritage communities, visitors, and experts (Grêt-Regamey and Fagerholm, 2024; Lovett et al., 2015). ***(iii)*** Augmentation with user-generated content and machine learning to extract public sentiment and attention cues and align them with GIS layers, complementing expert judgments (Foroughi et al., 2023; Tieskens et al., 2018). ***(iv)*** Uncertainty accounting through protocols that quantify model-to-field discrepancies and carry uncertainty envelopes into scenarios and regulatory thresholds (Leung et al., 2015). ***(v)*** Cross-scale synthesis that translates micro-level indicators such as enclosure, skyline integrity, and corridor continuity into territorial sensitivity maps and families of rules (González Del Campo, 2017; Zhou et al., 2023).

Visual management strategies: ***(i)*** Evidence-to-rule templates that map validated indicators to view-corridor controls, skyline envelopes, and buffer zoning, with two tracks of decision gates, namely complex compliance and multi-criteria optimization within compliant sets (Ferretti and Comino, 2015; Jato-Espino et al., 2022). ***(ii)*** Audience-sensitive decision weights and procedures that record, explain, review, and escalate when preferences conflict with heritage baselines (Glucker et al., 2013; O'Faircheallaigh, 2010). ***(iii)*** Reproducible communication packages that include interactive viewers, open data bundles, and versioned decision logs to strengthen auditability and public legitimacy (Fagerholm et al., 2021; Wu et al., 2010).

Track C: A global network to sustain convergence.

Tracks A and B come together in a Global Visual Heritage Network, a practice-research consortium that institutionalizes mutual learning among heritage sites and managing authorities while continuously incorporating frontier findings from academia. The network curates a Module Library that implements the integrative framework's building blocks, including Spatial-Perceptual Coupling, Multi-perspective Evaluation, Cross-scale Synthesis, Evidence-Decision Integration, and Digital Documentation and Reconstruction, each supported by input standards, validation checklists, and uncertainty reporting formats. It maintains a Case Commons organized by heritage type and value orientation that documents mentor-to-learner transfers, with before-and-after indicators and policy outcomes. It also operates a Standards Track that version-controls the Basic, Enhanced, and Advanced evidence tiers, including AVR or level-of-detail conformance, sampling stratification, quality assurance and quality control, and audit trails, allowing jurisdictions to climb capability ladders without losing comparability.

By leveraging peer complementarity where it already exists and introducing targeted methods and strategies where capabilities are absent, the proposed approach closes the interface, representation, and application gaps while remaining aligned with governance requirements for integrity, authenticity, and traceability.

4.4. Implications for policy, practice, and research

Taken together, the analyses and strategies outlined above suggest broader implications for policy, practice, and research. Importantly, the global dataset, typologies, and multi-level integration framework can be used to benchmark current practice, diagnose gaps, and sequence realistic upgrades across governance tiers.

At the policy level, the findings provide a replicable basis for updating visual-heritage guidance and aligning national rules with delivery on the ground. National heritage agencies can use the typology to determine whether their approach resembles an entry-level or a more advanced regime and then prioritize targeted improvements. For example, agencies can introduce clearer VIA/HIA screening triggers for development in sensitive settings, specify minimum evidence packages (e.g., viewpoint selection logic, baseline mapping, and auditable visibility analysis), and invest in routine GIS-based viewshed or visual sensitivity analysis when capacity is limited. In more mature contexts, policymakers may consider formalizing currently underused modules, such as structured participation, perception-based evidence, and uncertainty reporting, to ensure decisions are not driven solely by spatial controls. Standardizing these elements would improve cross-tier coherence and strengthen protection of visual integrity across jurisdictions (Ashrafi et al., 2021; Teller and Bond, 2002). At the international level, UNESCO/ICOMOS and related advisory bodies can incorporate typologies into training and guidance updates and promote regime-appropriate next steps rather than one-size-fits-all recommendations.

At the practice level, the framework supports stronger Visual Impact Assessments (VIA) and more inclusive Heritage Impact Assessments (HIA) by serving as a scoping and quality assurance checklist. Practitioners, including impact assessment professionals, site managers, and design teams, can use it to assemble fit-for-purpose evidence packages. For example, they can pair GIS-based visibility outputs with verified visualizations and, where social or associative values are prominent, add lightweight perception and stakeholder modules to test whether modelled impacts align with experienced effects. Implementing reproducible communication packages, such as versioned 3D models, shareable data bundles when feasible, and decision logs that record assumptions and uncertainties, can further improve transparency and public trust (Daniel, 2001; Weitkamp et al., 2014).

For research, priorities include developing perceptual and social metrics that are feasible to integrate into routine planning and IA workflows and evaluating how participatory initiatives and governance models affect the adoption and effectiveness of more integrated visual toolkits (Cullingworth et al., 2006; Young, 2016).

In sum, the study provides a scalable foundation for harmonizing visual evaluation and management practices, strengthening capacity through targeted upgrading pathways, and supporting more inclusive and evidence-based heritage governance.

4.5. Limitations

This study prioritizes comparability over exhaustiveness. As a result, several heritage-rich countries are not represented at the national level (e.g., Japan, Germany), because eligible, consolidated national instruments with explicit visual provisions could not be retrieved under our inclusion criteria. Language and coding introduce residual error despite AI-assisted translation and reliability checks. The international codebook and mask-aware binary indicators register adoption rather than intensity, quality, or enforcement, and clustering choices may shift boundaries at the margin. The corpus is a time-bound snapshot (retrieved on October 17, 2025) and may miss recent reforms. Signals for GIS/3D/visibility depend on heterogeneous data and reporting standards, limiting cross-jurisdiction comparability. Scope is restricted to WH cultural/mixed properties and official sources, so sub-national ordinances, grey literature, and project reports are underrepresented. Future work should broaden sources (especially sub-national), add

graded quality/effectiveness metrics, and standardize uncertainty reporting.

5. Conclusion

This study assembled and cross-analyzed a global, multi-level corpus of visual evaluation and visual management practices for tangible cultural heritage, spanning international instruments, national policies, and World Heritage property documents. It provides a benchmarkable evidence base and a transferable integration framework for upgrading visual heritage practice across levels. Empirically, the findings indicate a worldwide emphasis on technical and spatial approaches. Viewshed and visual-sensitivity analysis, 3D visualization, and spatial planning controls are most consistently used to safeguard visibility and landscape character, whereas participatory and perception-based methods remain sporadic and underutilized. Differences also track governance capacity: mature systems managing complex historic landscapes tend to exhibit more balanced method and strategy portfolios, while capacity-constrained or federated contexts rely on baseline measures. For impact assessment and heritage governance, the evidence base and integration framework support auditing current practice, prioritizing feasible upgrades, and improving transparency and consistency across tiers. Structured peer exchange and tiered toolkits can help routinize transferable innovations rather than leaving them as isolated projects, thereby strengthening HIA and VIA decision-making to be more context-sensitive and adaptive. By standardizing comparable evidence and promoting context-sensitive visual management, these findings support the SDG 11.4 agenda by strengthening institutions' capacity to safeguard cultural and natural heritage amid ongoing change.

Data statement

The source corpus and official access links are documented in Section 2.1 and **Appendix A1-A3**. The complete coding framework and full coded results are provided in the Supplementary Material (**Appendix A4-A8**), allowing for the replication of the analyses reported in Sections 2–4. The dataset and codebook are available from the corresponding author upon reasonable request. Third-party source documents are not redistributed due to copyright and access restrictions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eiar.2026.108404.

Data availability

Data will be made available on request.

References

Alberts, H.C., Hazen, H.D., 2010. Maintaining authenticity and integrity at cultural world heritage sites. Geogr. Rev. 100 (1), 56–73.

Arbelaitz, O., Gurrutxaga, I., Muguerza, J., Pérez, J.M., Perona, I., 2013. An extensive comparative study of cluster validity indices. Pattern Recogn. 46 (1), 243–256. https://doi.org/10.1016/j.patcog.2012.07.021.

Artese, M.T., Ciocca, G., Gagliardi, I., 2017. Evaluating perceptual visual attributes in social and cultural heritage web sites. J. Cult. Herit. 26, 91–100. https://doi.org/10.1016/j.culher.2017.02.009.

Ashrafi, B., Kloos, M., Neugebauer, C., 2021. Heritage impact assessment, beyond an assessment tool: a comparative analysis of urban development impact on visual integrity in four UNESCO world heritage properties. J. Cult. Herit. 47, 199–207. https://doi.org/10.1016/j.culher.2020.08.002.

Berg, S.K., 2017. Cultural heritage as a resource for property development. Hist. Environ.: Policy Prac. 8 (4), 304–322. https://doi.org/10.1080/17567505.2017.1399582.

Bianca, S., 2014. Morphology as the study of City form and layering. In: Reconnecting the City, pp. 85–111. https://doi.org/10.1002/9781118383940.ch3.

Burla, L., Knierim, B., Barth, J., Liewald, K., Duetz, M., Abel, T., 2008. From text to codings: intercoder reliability assessment in qualitative content analysis. Nurs. Res. 57 (2), 113–117. https://doi.org/10.1097/01.NNR.0000313482.33917.7d.

Cao, Z., Mao, Y., Zhang, X., Huang, L., Mustafa, M., Mohd Hafizal, M.I., 2026. Are we reusing heritage safely? Stakeholder perceptions and safety priorities in the adaptive reuse of Chinese architectural heritage. Environ. Impact Assess. Rev. 118, 108257. https://doi.org/10.1016/j.eiar.2025.108257.

Cardenas, I.C., Halman, J.I.M., 2016. Coping with uncertainty in environmental impact assessments: open techniques. Environ. Impact Assess. Rev. 60, 24–39. https://doi.org/10.1016/j.eiar.2016.02.006.

Cascio, M.A., Lee, E., Vaudrin, N., Freedman, D.A., 2019. A team-based approach to open coding: considerations for creating intercoder consensus. Field Methods 31 (2), 116–130. https://doi.org/10.1177/1525822X19838237.

Council of Europe, 2000. European Landscape Convention. https://rm.coe.int/16807b6bc7.

Cullingworth, B., Davoudi, S., Webb, D., Vigar, G., Pendlebury, J., Townshend, T., Gkartzios, M., Hart, T., Nadin, V., 2006. Town and Country Planning in the UK. Routledge. https://doi.org/10.4324/9781003292906.

Daniel, T.C., 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. Landsc. Urban Plan. 54 (1), 267–281. https://doi.org/10.1016/S0169-2046(01)00141-4.

Deghati Najd, M., Ismail, N.A., Maulan, S., Mohd Yunos, M.Y., Dabbagh Niya, M., 2015. Visual preference dimensions of historic urban areas: the determinants for urban heritage conservation. Habitat Int. 49, 115–125. https://doi.org/10.1016/j.habitatint.2015.05.003.

Dramstad, W.E., Tveit, M.S., Fjellstad, W.J., Fry, G.L.A., 2006. Relationships between visual landscape preferences and map-based indicators of landscape structure. Landsc. Urban Plan. 78 (4), 465–474. https://doi.org/10.1016/j.landurbplan.2005.12.006.

Fagerholm, N., Raymond, C.M., Olafsson, A.S., Brown, G., Rinne, T., Hasanzadeh, K., Broberg, A., Kyttä, M., 2021. A methodological framework for analysis of participatory mapping data in research, planning, and management. Int. J. Geogr. Inf. Sci. 35 (9), 1848–1875. https://doi.org/10.1080/13658816.2020.1869747.

Fairclough, G., Møller, P., 2008. Landscape as Heritage-the Management and Protection of Landscape in Europe, A Summary by the Action COST A27 "LANDMARKS". Geographica Bernensia.

Ferretti, V., Comino, E., 2015. An integrated framework to assess complex cultural and natural heritage systems with multi-attribute value theory. J. Cult. Herit. 16 (5), 688–697. https://doi.org/10.1016/j.culher.2015.01.007.

Foroughi, M., de Andrade, B., Pereira Roders, A., 2023. Capturing public voices: the role of social media in heritage management. Habitat Int. 142, 102934. https://doi.org/10.1016/j.habitatint.2023.102934.

Gao, X., Wang, H., Zhao, J., Wang, Y., Li, C., Gong, C., 2025. Visual comfort impact assessment for walking spaces of urban historic district in China based on semantic segmentation algorithm. Environ. Impact Assess. Rev. 114, 107917. https://doi.org/10.1016/j.eiar.2025.107917.

Ginzarly, M., El Khoury, R., Srour, F.J., 2024. Public space and everyday heritage: an inquiry into children's and adults' perception. City Cult. Soc. 38, 100594. https://doi.org/10.1016/j.ccs.2024.100594.

Glucker, A.N., Driessen, P.P.J., Kolhoff, A., Runhaar, H.A.C., 2013. Public participation in environmental impact assessment: why, who and how? Environ. Impact Assess. Rev. 43, 104–111. https://doi.org/10.1016/j.eiar.2013.06.003.

Gobster, P.H., Ribe, R.G., Palmer, J.F., 2019. Themes and trends in visual assessment research: introduction to the landscape and urban planning special collection on the visual assessment of landscapes. Landsc. Urban Plan. 191, 103635. https://doi.org/10.1016/j.landurbplan.2019.103635.

González Del Campo, A., 2017. Mapping environmental sensitivity: a systematic online approach to support environmental assessment and planning. Environ. Impact Assess. Rev. 66, 86–98. https://doi.org/10.1016/j.eiar.2017.06.010.

Gospodini, A., 2004. Urban morphology and place identity in European cities: built heritage and innovative design. J. Urban Des. 9 (2), 225–248. https://doi.org/10.1080/1357480042000227834.

Grêt-Regamey, A., Fagerholm, N., 2024. Key factors to enhance efficacy of 3D digital environments for transformative landscape and urban planning. Landsc. Urban Plan. 244, 104978. https://doi.org/10.1016/j.landurbplan.2023.104978.

Guo, H., Chen, F., Tang, Y., Ding, Y., Chen, M., Zhou, W., Zhu, M., Gao, S., Yang, R., Zheng, W., Fang, C., Lin, H., Roders, A.P., Cigna, F., Tapete, D., Xu, B., 2023. Progress toward the sustainable development of world cultural heritage sites facing land-cover changes. Innovation 4 (5). https://doi.org/10.1016/j.xinn.2023.100496.

ICOMOS, 2005. Xi'an Declaration on the Conservation of the Setting of Heritage Structures, Sites and Areas. https://www.icomos.org/images/DOCUMENTS/Charters/xian-declaration.pdf.

Janssen, J., Luiten, E., Renes, H., Stegmeijer, E., 2017. Heritage as sector, factor and vector: conceptualizing the shifting relationship between heritage management and spatial planning. Eur. Plan. Stud. 25 (9), 1654–1672. https://doi.org/10.1080/09654313.2017.1329410.

Jato-Espino, D., Martín-Rodríguez, Á., Martínez-Corral, A., Sañudo-Fontaneda, L.A., 2022. Multi-expert multi-criteria decision analysis model to support the conservation

of paramount elements in industrial facilities. Herit. Sci. 10 (1), 68. https://doi.org/10.1186/s40494-022-00712-7.
Jenkins, V., 2018. Protecting the natural and cultural heritage of local landscapes: finding substance in law and legal decision making. Land Use Policy 73, 73–83. https://doi.org/10.1016/j.landusepol.2017.12.056.
Jerpåsen, G.B., Larsen, K.C., 2011. Visual impact of wind farms on cultural heritage: a Norwegian case study. Environ. Impact Assess. Rev. 31 (3), 206–215. https://doi.org/10.1016/j.eiar.2010.12.005.
Kalman, H., Létourneau, M.R., 2020. Heritage Planning: Principles and Process. Routledge.
Leung, W., Noble, B., Gunn, J., Jaeger, J.A.G., 2015. A review of uncertainty research in impact assessment. Environ. Impact Assess. Rev. 50, 116–123. https://doi.org/10.1016/j.eiar.2014.09.005.
Li, T., 2005. A general model for clustering binary data. In: Proceedings of the Eleventh ACM SIGKDD International Conference on Knowledge Discovery in Data Mining, Chicago, Illinois, USA.
Liu, M., Nijhuis, S., 2020. Mapping landscape spaces: methods for understanding spatial-visual characteristics in landscape design. Environ. Impact Assess. Rev. 82, 106376. https://doi.org/10.1016/j.eiar.2020.106376.
Lopes, A.S., Macedo, D.V., Brito, A.Y.S., Furtado, V., 2019. Assessment of urban cultural-heritage protection zones using a co-visibility-analysis tool. Comput. Environ. Urban. Syst. 76, 139–149. https://doi.org/10.1016/j.compenvurbsys.2019.04.009.
Lovett, A., Appleton, K., Warren-Kretzschmar, B., Von Haaren, C., 2015. Using 3D visualization methods in landscape planning: an evaluation of options and practical issues. Landsc. Urban Plan. 142, 85–94. https://doi.org/10.1016/j.landurbplan.2015.02.021.
Mosler, S., 2019. Everyday heritage concept as an approach to place-making process in the urban landscape. J. Urban Des. 24 (5), 778–793. https://doi.org/10.1080/13574809.2019.1568187.
Nijhuis, S., van Lammeren, R., Antrop, M., 2011a. Exploring visual landscapes: introduction. Res. Urban. Ser. 2, 15–39. https://doi.org/10.7480/rius.2.205.
Nijhuis, S., Van Lammeren, R., van der Hoeven, F., 2011b. Exploring the Visual Landscape: Advances in Physiognomic Landscape Research in the Netherlands, Vol. 2. TU Delft.
O'Faircheallaigh, C., 2010. Public participation and environmental impact assessment: purposes, implications, and lessons for public policy making. Environ. Impact Assess. Rev. 30 (1), 19–27. https://doi.org/10.1016/j.eiar.2009.05.001.
Palmer, J.F., 2019. The contribution of a GIS-based landscape assessment model to a scientifically rigorous approach to visual impact assessment. Landsc. Urban Plan. 189, 80–90. https://doi.org/10.1016/j.landurbplan.2019.03.005.
Patiwael, P.R., Groote, P., Vanclay, F., 2019. Improving heritage impact assessment: an analytical critique of the ICOMOS guidelines. Int. J. Herit. Stud. 25 (4), 333–347. https://doi.org/10.1080/13527258.2018.1477057.
Peng, Y., Nijhuis, S., Geng, M., Yu, Y., 2025. Enhancing visual attribute comprehension of urban heritage landscapes using combined GIS-based visual analysis methods: West Lake as a case study. Environ. Impact Assess. Rev. 115, 108032. https://doi.org/10.1016/j.eiar.2025.108032.
Pereira Roders, A.R., 2007. Re-Architecture: Lifespan Rehabilitation of Built Heritage-Scapus. PhD thesis. Technische Universiteit Eindhoven, Eindhoven, the Netherlands.
Rau, G., Shih, Y.-S., 2021. Evaluation of Cohen's kappa and other measures of inter-rater agreement for genre analysis and other nominal data. J. Engl. Acad. Purp. 53, 101026. https://doi.org/10.1016/j.jeap.2021.101026.
Riehmann, P., Hanfler, M., Froehlich, B., 2005. Interactive Sankey diagrams. In: IEEE Symposium on Information Visualization, 2005. INFOVIS 2005., Minneapolis, USA.
Schubert, E., Rousseeuw, P.J., 2019. Faster k-medoids clustering: Improving the PAM, CLARA, and CLARANS algorithms. In: Similarity Search and Applications (SISAP 2019), Vol. 11807. Springer, pp. 171–187. https://doi.org/10.1007/978-3-030-32047-8_16.
Shipley, R., Kovacs, J.F., 2008. Good governance principles for the cultural heritage sector: lessons from international experience. Corp. Gov. 8 (2), 214–228. https://doi.org/10.1108/14720700810863823.
Teller, J., Bond, A., 2002. Review of present European environmental policies and legislation involving cultural heritage. Environ. Impact Assess. Rev. 22 (6), 611–632. https://doi.org/10.1016/S0195-9255(02)00009-4.
Tieskens, K.F., Van Zanten, B.T., Schulp, C.J.E., Verburg, P.H., 2018. Aesthetic appreciation of the cultural landscape through social media: an analysis of revealed preference in the Dutch river landscape. Landsc. Urban Plan. 177, 128–137. https://doi.org/10.1016/j.landurbplan.2018.05.002.
UNESCO, 2025. Operational guidelines for the implementation of the world heritage convention (WHC.25/01). U. W. H. Centre. https://whc.unesco.org/document/222376.
UNESCO, ICCROM, ICOMOS, & IUCN, 2022. Guidance and Toolkit for Impact Assessments in a World Heritage Context. https://www.iccrom.org/sites/default/files/publications/2022-07/en_0_ia_guidance_world_heritage_iccrom_2022_web_0.pdf.
Veldpaus, L., 2015. Historic Urban Landscapes: Framing the Integration of Urban and Heritage Planning in Multilevel Governance. PhD thesis. Technische Universiteit Eindhoven, Eindhoven, the Netherlands.
Wang, Y., Huang, S., Kim, A.K., 2015. Toward a framework integrating authenticity and integrity in heritage tourism. J. Sustain. Tour. 23 (10), 1468–1481.
Weitkamp, G., Lammeren, R.v., Bregt, A., 2014. Validation of isovist variables as predictors of perceived landscape openness. Landsc. Urban Plan. 125, 140–145. https://doi.org/10.1016/j.landurbplan.2014.02.021.
Williams, C.K.I., 2000. On a connection between kernel PCA and metric multidimensional scaling. In: Leen, T.K., Dietterich, T.G., Tresp, V. (Eds.), Advances in Neural Information Processing Systems, Vol. 13. MIT Press, pp. 675–681.
Wu, H., He, Z., Gong, J., 2010. A virtual globe-based 3D visualization and interactive framework for public participation in urban planning processes. Comput. Environ. Urban. Syst. 34 (4), 291–298. https://doi.org/10.1016/j.compenvurbsys.2009.12.001.
Young, G., 2016. The Routledge Research Companion to Planning and Culture. Routledge. https://doi.org/10.4324/9781315613390.
Zhang, H., Andrade, B., Wang, X., Aburabee, I., Yuan, S., 2024. A study of spatial cognition in the rural heritage based on VR 3D eye-tracking experiments. Herit. Sci. 12 (1), 141. https://doi.org/10.1186/s40494-024-01264-8.
Zhao, J., Han, C., Wu, Y., Xu, C., Huang, X., Qi, X., Qi, Y., Gao, L., 2025. A deep learning-based study on visual quality assessment of commercial renovation of Chinese traditional building facades. Environ. Impact Assess. Rev. 113, 107862. https://doi.org/10.1016/j.eiar.2025.107862.
Zhou, L., Zhao, Y., Yang, X., He, J., Wang, H., 2023. Identification of important terraced visual landscapes based on a sensitivity-subjectivity preference matrix for agricultural cultural heritage in the southwestern China. Ecol. Indic. 154, 110573. https://doi.org/10.1016/j.ecolind.2023.110573.