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Strong on Diagnosis, Weak on Delivery: A Structured Assessment of Urban Nature-based Solutions Frameworks

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Abstract

Nature-based Solutions (NbS) are increasingly promoted as essential instruments for urban climate adaptation, biodiversity recovery, and sustainable development. Yet their implementation remains slow and insufficiently monitored. Frameworks, including standards, guidelines, tools, and indicator sets, are meant to bridge the gap between NbS ambition and practice, but it is unclear how comprehensively they support cities across the full range of operational tasks. We conducted a structured qualitative content analysis, with dual-reviewer coding, of 30 NbS frameworks relevant to urban contexts. Each framework was assessed across six operational dimensions: baseline assessment and ecological performance; planning and design; implementation; financing and funding mechanisms; monitoring and evaluation; and impacts and

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co-benefits. We also evaluated the presence of practical "how-to" guidance and classified each framework into one of four functional archetypes: Integrator, Designer, Financier, or Monitor. Results revealed a structural imbalance: approximately two-thirds of frameworks provided guidance on baseline assessment and planning, while only 36.7% addressed implementation, the lowest of any dimension. Gaps in operational guidance, financing, and monitoring co-occurred systematically, consistent with shared structural causes rooted in disciplinary biases. Only five frameworks achieved consistently high coverage across all functional dimensions. The archetype typology offers practitioners a navigation tool for assembling complementary resources matched to their functional dimensions and governance context. Policy implications include requiring comprehensive planning that addresses both diagnostic and delivery dimensions as a condition of NbS funding. These also include embedding comprehensive monitoring and verification requirements and investing in cross-disciplinary institutional capacity to support scaled implementation.

Keywords: urban planning; urban resilience; implementation frameworks; monitoring and evaluation; framework assessment; policy integration

1. Introduction

Urban areas are at the center of global sustainability transitions. By 2050, nearly 70% of the world's population will reside in cities, placing growing stress on ecosystems, infrastructure, and public health [1]. As climate change accelerates the frequency and severity of urban heat events, flooding, and ecological degradation, Nature-based Solutions (NbS) have emerged as interventions capable of simultaneously addressing environmental, social, and economic

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challenges. NbS can contribute to urban resilience by mitigating flood risk and heat waves [2,3], enhancing biodiversity [4], and strengthening social well-being and cohesion [5].

The relevance of NbS has been further reinforced by their formal integration into major international policy frameworks, including the EU Nature Restoration Law, the IPCC Sixth Assessment Report, and the Kunming–Montreal Global Biodiversity Framework [6]. This mainstreaming signals a movement beyond conservation-centered perspectives toward viewing NbS as essential instruments for climate adaptation, biodiversity recovery, and sustainable development [7,8]. However, NbS uptake has highlighted a growing disconnection between conceptual ambitions and operational implementation, particularly in urban contexts where land-use conflicts, equity considerations, and competing planning priorities are most acute [9,10]. Despite widespread ambition and enthusiasm, the implementation of urban NbS remains slow, inconsistent, and insufficiently monitored [8,11]. This persistent "implementation gap" underscores the need for coherent approaches that address the full range of operational dimensions required to move NbS from concept to delivery, including its planning, financing, governance, and evaluation.

Frameworks for NbS, whether standards, guidelines, tools, or indicator sets, play a central role in bridging this implementation gap [12]. They provide a structured foundation for linking ecological processes to planning and policy decisions, aiding effectiveness, equitability and accountability in NbS interventions. Frameworks set common terminology and criteria, facilitating comparability across projects and preventing ambiguity or misinterpretation of the NbS concept, including risks of greenwashing or maladaptation [13,14]. They support informed decision-making by clarifying trade-offs, cost–benefit relationships, and the suitability of different interventions across distinct spatial scales and urban contexts [15]. Critically, urban

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NbS require collaboration among diverse actors, including planners, engineers, architects, ecologists, economists, community groups, and local governments. Frameworks can help reconcile these different actors, knowledge systems and institutional cultures, offering shared guidance for co-design, implementation, and long-term stewardship [9].

However, the support that frameworks and tools provide is markedly uneven across the operational dimensions of NbS practice. For scoping and problem characterization, practitioners can draw on well-established approaches such as the IUCN Global Standard for NbS [15], the EKLIPSE framework [16], and structured planning methods [8], alongside ecosystem service and co-benefit assessment tools such as InVEST [17] and ESTIMAP [18]. Coverage thins considerably for construction and early-establishment of NbS, where guidance on quality assurance, baseline data collection, and performance benchmarking is critical for informing long-term monitoring and operation [19]. Gaps deepen further at the monitoring and adaptive management phases, where feedback from ecological outcomes should inform iterative design improvements and replication decisions, yet few tools are explicitly structured to link monitoring outputs to management triggers or investment decisions [20,21]. NbS research more broadly tends to focus on design rather than the quantification of performance, particularly in relation to climate adaptation outcomes [22].

These gaps carry consequences that extend far beyond project-level performance. Monitoring practices for NbS remain fragmented, with standards and indicators varying across carbon, biodiversity, and ecosystem service domains [23]. A systematic map of 252 studies on coastal NbS found that long-term performance was rarely evaluated, that most studies spanned fewer than five years, and that social and economic metrics were rarely included [24], a pattern consistent with the broader literature on NbS monitoring deficits. At the same time, cities are

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increasingly expected to report NbS outcomes in climate adaptation plans, national climate commitments, biodiversity strategies, and SDG reporting [25]. This requires interoperable metrics that translate ecosystem extent, condition, and service flows into policy-relevant terms, which ecosystem accounting standards such as the SEEA-EA are designed to provide [26]. Disclosure frameworks such as the Taskforce on Nature-related Financial Disclosures (TNFD) are also creating demand for nature-related data comparable to climate-related metrics [27,28]. Without such evidence, the long-term performance and societal benefits of NbS remain difficult to demonstrate, undermining investor confidence and constraining the prospects for scaling.

Monitoring is not the only dimension where guidance falls short. Financing urban NbS requires navigating complex arrangements across public budgets, private investment, and innovative mechanisms such as blended finance and green bonds, yet few frameworks provide actionable guidance on how to structure, access, or sequence these instruments [29]. Similarly, the transition from design to physical implementation, involving procurement, construction management, institutional coordination, and stakeholder engagement during execution, remains one of the least systematically addressed aspects of NbS practice. Annual NbS investment must rise to an estimated USD 674 billion by 2050 to meet combined global climate, biodiversity, and land-restoration targets [30], yet many existing frameworks offer limited operational guidance on financing mechanisms or implementation pathways, leaving practitioners without the tools needed to mobilize capital at that scale [31].

Despite the proliferation of NbS frameworks over the past decade, guidance remains fragmented and inconsistently evaluated. Existing frameworks differ widely in purpose, structure, and scope, ranging from high-level verification standards such as the IUCN Global Standard to operational design guidelines, ecosystem service assessment tools, and monitoring indicator sets. While this

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diversity offers contextual flexibility, it also generates confusion for practitioners who must navigate overlapping, incomplete, or mutually inconsistent guidance. Prior reviews have examined specific subsets of this literature, such as principles for designing NbS impact evaluation frameworks [32], urban co-benefit assessment approaches [16], and the integration of green infrastructure, ecosystem services, and NbS concepts [33], but to date no study has systematically compared the full spectrum of frameworks with an explicit focus on their applicability to urban implementation contexts. Critically, there remains limited understanding of how these frameworks translate into practice, what tools they recommend and for which aspects, and where the most consequential gaps persist for decision-making, governance, and monitoring.

This paper examines how well the existing guidance landscape equips cities to close this implementation gap. We present a comprehensive structured assessment of NbS frameworks, with a specific focus on urban implementation across the full range of operational dimensions. We synthesize and compare existing NbS frameworks, examining their application scale, target audience and coverage across operational dimensions (e.g., design and planning, financing, monitoring & evaluation); identify areas of convergence, divergence, and missing guidance, with particular attention to the balance between diagnostic dimensions (baseline assessment, planning and design) and delivery dimensions (implementation, financing, monitoring and evaluation); and propose pathways for strengthening coherence, accountability, and effectiveness across NbS frameworks, supporting their integration into urban planning, policy, investment, and monitoring systems at scale.

By synthesizing insights across standards, guidelines, tools, and indicator sets, this study offers a consolidated analytical foundation for advancing the next generation of urban NbS frameworks,

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one that addresses the full spectrum of operational dimensions, is evidence-grounded, and calibrated to the governance and accountability demands of contemporary urban NbS practice.

2. Methods

2.1 Framework identification and selection

For the purposes of this study, a *framework* was defined as a structured and systematic architecture designed to guide the planning, implementation, evaluation, or governance of NbS (adapted from Wickenberg et al. [12]). Frameworks were distinguished from standalone tools by their broader conceptual coherence and integrative scope. Whereas individual tools typically address a discrete analytical function, frameworks consolidate multiple components, such as guiding principles, indicators, lifecycle guidance, decision-support elements, and governance or financing considerations, within a unified structure intended to standardize practice, enable replication, and support cross-case comparison.

Frameworks were identified through a review of both peer-reviewed and grey literature, complemented by snowballing (following references cited in documents and suggestions from regional experts in land use planning, urban ecology, and NbS governance). We also performed targeted searches of resources produced by international organizations, academic institutions, urban and regional planning bodies, multilateral agencies, development banks, city networks, and non-governmental organizations. The search strategy was designed to ensure broad representation of the ways in which NbS are currently conceptualized, operationalized, and evaluated across governance levels and geographic contexts. The review included conceptual and operational frameworks, standards, guidance documents, indicator sets, policy instruments, and decision-support platforms relevant to the planning, implementation, financing, monitoring, and

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evaluation of NbS. Documented case studies were also screened to identify frameworks applied in practice across diverse socio-ecological and institutional settings.

Document identification followed a structured inventory approach, not a systematic literature review. The search spanned peer-reviewed and grey literature, multiple institutional types, and diverse geographic contexts. Inclusion criteria required that a document: (i) explicitly address NbS or closely related concepts such as Natural Solutions (the role of protected areas in combating climate change), Ecosystem-based Adaptation (EbA), Ecosystem-based Disaster Risk Reduction (EcoDRR), Green Infrastructure (for economic growth and investments, in the urban context), Natural Infrastructure (for sustainable Integrated Water Resource Management), and Holistic or Regenerative Landscape management [34]; (ii) provide structured guidance, criteria, indicators, or procedural steps; and (iii) be applicable to planning, implementation, evaluation, governance, or financing.

All documents meeting the three inclusion criteria were retained, without additional filtering. Both research-driven and practitioner-oriented frameworks were included to ensure representation of scientific, policy, and implementation perspectives. While exhaustive coverage of every NbS-relevant document was neither feasible nor the goal, the search strategy was constructed to capture the range of frameworks currently shaping practice.

2.2. Analytical Approach

Each framework, regardless of format (e.g., standard, guidance document, or indicator set), was treated as a single unit of analysis. Identified frameworks were distributed among the coding team such that each framework was independently assessed by two reviewers. Reviewers were assigned frameworks to balance workload while ensuring that no framework was evaluated by a

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single coder. Following independent assessment, all coding was compared across reviewer pairs. Where discrepancies arose, these were brought to the full coding team for discussion, and final codes were determined by consensus. This deliberative approach was preferred over a statistical reliability metric because the coding protocol combined categorical judgments with interpretive assessments of guidance quality, where disagreements often reflected genuine ambiguity in the source material rather than coder error, making consensus-based resolution more appropriate than reconciliation through numerical thresholds.

2.3. Coding Protocol

A standardized coding protocol was developed to compare document characteristics, conceptual framing, and operational guidance across documents (S1 Table). Using this protocol, a structured qualitative content analysis was conducted to identify areas of convergence, divergence, and omission, synthesized as key findings. The analysis followed a predefined protocol that combined closed-ended categorical coding with qualitative synthesis.

2.3.1. Institutional Origin and NbS conceptualization

For each framework, we recorded the authoring or publishing entities, such as multilateral and United Nations (UN) bodies, development banks, national governments, city networks, NGOs, academic institutions, EU-funded consortia, and other multi-stakeholder initiatives (e.g., CityAdapt, SELVAR). Stated objectives were extracted verbatim and used as the primary analytical anchor. Subsequent evaluation of scope, emphasis, and limitations was grounded in these explicitly articulated purposes rather than inferred interpretations. Definitions of NbS were extracted and systematically compared with the IUCN definition to assess conceptual alignment

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or divergence. The embedded conceptual framing such as resilience, biodiversity, climate adaptation, or urban planning, was documented.

2.3.2. Spatial scale and target audience

Spatial and governance scales explicitly identified in each framework, such as building, neighborhood, city, regional, national and global, were recorded. Where scale was not addressed, it was coded as "not specified". The presence of NbS typologies was documented, including whether frameworks categorized interventions by ecosystem type, hazard type, or functional mechanism.

Urban relevance was assessed using a three-point categorical scale. Frameworks were coded as *Low* when urban contexts were referenced only superficially or implicitly; *Medium* when urban applications were explicitly addressed through examples or guidance; and *High* when the framework was intentionally designed for urban settings or when urban NbS constituted a central focus. Classification was based exclusively on the stated scope, framing, and illustrative content of each document.

Target audiences were coded as explicitly stated by the authors; where inferred, this was clearly noted. Audiences were subsequently grouped into three clusters: (i) policy and norm-setting actors; (ii) municipal and practitioner-oriented actors; and (iii) knowledge and evidence providers. Geographic applicability was recorded based solely on the stated scope of each framework.

2.3.3 Practical guidance across operational dimensions of NbS

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Each framework was evaluated across six operational dimensions of NbS: (i) baseline assessment and ecological performance; (ii) planning and design; (iii) implementation; (iv) financing and funding mechanisms; (v) monitoring and evaluation; and (vi) impacts and co-benefits. These dimensions draw on established project cycle frameworks [35] but are framed as operational domains rather than sequential phases, reflecting the reality that activities, such as financing, monitoring, and stakeholder engagement, operate concurrently and iteratively throughout the project [36]. The frameworks were also reviewed on another dimension: whether they provide additional "how to" guidance on the practical application of the framework. This approach echoes the work of Sarabi et al. [9], who classified key enablers into financial, institutional, and knowledge-based dimensions.

Each framework was coded using a three-point scale across all six operational dimensions and the "how to" dimension: *Yes* when structured methods or explicit guidance were provided; *Limited* when structured methods or explicit guidance were mentioned without sufficient methodological detail; and *No* when structured methods or explicit guidance were not substantively addressed. To characterize the overall directional orientation of each framework, two composite scores (*Diagnosis Strength* and *Delivery Strength*) were derived from the dimension-level ratings and used to position frameworks along a diagnostic–delivery continuum (S1 Fig and S2 Table).

2.4 Framework archetype classification

Following this process, the frameworks were clustered according to similarities and differences leading to the identification of four archetypes: *Integrator, Designer, Financier,* and *Monitor* (the archetypes typology is considered part of the findings, so the characteristics of each

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252 archetype are explained in the results section). Classification followed explicit decision rules
253 based on the dimension-level ratings. Integrators required overall "how-to" guidance and
254 comprehensive (Yes/High) guidance on at least four of the six dimensions, including Financing.
255 Financiers required comprehensive guidance on Financing but not on Planning and Design or
256 Implementation. Designers required comprehensive guidance on both Baseline Assessment and
257 Planning and Design but not on Financing. Monitors required comprehensive guidance on both
258 Monitoring and Evaluation and Impacts and Co-benefits but not on Financing. Frameworks
259 meeting none of these criteria were retained as Unclassified, and frameworks meeting the criteria
260 for both the Designer and Monitor archetypes (n = 3) were assigned according to the primary
261 purpose stated in their objectives. Thus, we ensured that classification reflects primary
262 specialization rather than overall comprehensiveness. The four-archetype typology was
263 developed inductively from the results of the analysis of the frameworks and scoring. In addition,
264 the inductively generated archetype typology was compared to hierarchical clustering and
265 showed substantial agreement (Adjusted Rand Index = 0.69; S2 Fig; [37]).

266 The rationale of the inductive archetypes rests on three key considerations. First, the six
267 operational dimensions were grouped into two functional clusters: diagnostic dimensions are
268 concerned with understanding the problem and designing the solution (Baseline and Ecological
269 Performance; Planning and Design), and delivery dimensions are concerned with delivery,
270 accountability, and resource mobilization (Implementation; Financing and Funding; Monitoring
271 and Evaluation; Impacts and Co-benefits). Second, within the delivery cluster, Financing and
272 M&E represent distinct practitioner functions, with the former addressing capital mobilization
273 and financial structuring and the latter addressing performance measurement and adaptive
274 management, and were therefore treated as separate specialization dimensions. Third, the

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diagnostic dimensions operate as a coherent functional unit, drawing on a shared body of ecological, spatial, and planning methods that are distinct from the competencies required in delivery dimensions. An overview of the analysis process, including the dimensions, archetypes and key findings is illustrated in Fig 1. The 4 archetypes and the key findings are further examined in the following section.

3. Results

Our analysis identified 30 NbS frameworks, revealing substantial variation in scope, structure, and operational emphasis. The findings reveal that frameworks continue to be characterized by incomplete coverage across one or more of the six operational dimensions and limited provision of practical guidance for local governments and practitioners. While the frameworks vary considerably in terms of urban relevance, application scale, and target audiences (further discussed in section 3.1), they revealed an emphasis on geographic specificity, a tendency towards thematic narrowness, and an overall lack of guidance on specific dimensions (Fig 1). Additional information on how these characteristics overlapped across the various frameworks is presented in S3 Table.

The results are presented in two sub-sections: section 3.1 presents the spatial and governance scales addressed by frameworks and section 3.2 explains the Archetypes and how they reflect coverage across operational dimensions of NbS. Together, these findings provide an overview of the current landscape of NbS frameworks highlighting differences in thematic coverage, decision-support functions, and level of operational guidance.

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Fig 1. Overview of the analytical process. Frameworks were evaluated across six operational dimensions and overall "how to" guidance, leading to four emerging archetypes and six key findings.

3.1. Spatial and Governance Scale

The scale of application for which frameworks provide guidance varied considerably across the 30 documents reviewed. The city scale was the most frequently addressed, appearing in 27 frameworks (90%), followed by the regional (14 frameworks, 47%) and neighborhood scales (13 frameworks, 43%). Coverage diminishes sharply at both ends of the spatial spectrum: building-level guidance appeared in only 5 frameworks (17%), and only 2 frameworks (7%) explicitly addressed the global scale (Fig 2A). Regarding intended audience, 29 of the 30 frameworks (97%) target local governments. Policymakers and practitioners are also common targets of the frameworks, each addressed by 27 frameworks (90%). Private entities and national governments appear less frequently, referenced in 16 (53%) and 15 (50%) of the frameworks, respectively (Fig 2B).

Fig 2. Spatial scale of application and target audiences of the reviewed NbS frameworks. (A) Spatial scales at which each framework provides guidance. (B) Target audiences explicitly identified by each framework. Dark green cells indicate that a scale or audience is addressed; light blue cells indicate that it is not. The Scope column indicates each framework's geographic focus.

3.2. Archetypes reflecting coverage across the operational dimensions

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The review of 30 frameworks reveals considerable variation in how thoroughly current guidelines and standards support the adoption of NbS across cities. Coverage across the six operational dimensions and overall "how-to" guidance differed substantially (Fig 3). Impacts and Co-benefits was the most consistently covered dimension, with 21 frameworks (70.0%) providing Yes/High guidance, and only 4 (13.3%) offering Limited/Medium and 5 (16.7%) No/Low coverage. Among the two diagnostic dimensions, Baseline and Ecological Performance and Planning and Design of Solutions, coverage was also relatively strong, with 19 (63.3%) and 18 frameworks (60.0%) respectively providing Yes/High guidance. Both dimensions showed modest No/Low counts (2 and 3 frameworks, respectively), suggesting that most frameworks adequately support stakeholders in assessing ecological conditions and selecting appropriate NbS types prior to implementation. Coverage drops for implementation, financing, and monitoring and evaluation. Implementation of Solutions was the weakest of all six dimensions, with only 11 frameworks (36.7%) rated Yes/High, 13 (43.3%) rated Limited/Medium, and 6 (20.0%) rated No/Low, the highest Limited/Medium count of any dimension, signaling widespread fragmentation in implementation guidance rather than outright absence. Financing and Funding Mechanisms and Monitoring and Evaluation (M&E) showed only marginally higher coverage, with 14 (46.7%) and 13 (43.3%) frameworks providing Yes/High guidance, respectively. Notably, No/Low counts were highest for M&E (8 frameworks, 26.7%) and Financing (6 frameworks, 20.0%), reflecting that a substantial proportion of frameworks entirely omit guidance on long-term financial sustainability and performance tracking. Overall “how-to” guidance was provided by 21 frameworks (70.0%), was limited in 5 (16.7%) and absent in 4 (13.3%). Only five frameworks were rated Yes/High on all six dimensions; the remaining 25 provided limited or no guidance on at least one dimension.

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Fig 3. Comprehensiveness of guidance across operational dimensions. Number of frameworks (n = 30) rated Yes/High, Limited/Medium, or No/Low for each of the six operational dimensions and for overall "how-to" guidance.

The distribution of coverage across operational dimensions and the presence of 'how-to' guidelines further revealed four archetypes (*Integrators*, *Designers*, *Financiers*, *Monitors*), reflecting different priorities, governance approaches, and spatial scales.

Integrators demonstrate both breadth and depth, combining comprehensive guidance on diagnostic and delivery dimensions. A framework was classified as an *Integrator* if overall "how-to" guidance was present and at least four of the six dimensions were represented through comprehensive guidance, including Financing, the delivery dimension that most clearly separated comprehensive from specialized frameworks. This group includes 9 frameworks developed by different stakeholders, ranging from the IUCN Global Standard for NbS and national or regional frameworks such as the ADB's to outputs of funded research projects, such as the Connecting Nature Framework.

Designers specialize in the diagnostic aspects of the NbS operational dimensions, providing guidance on baseline assessment, ecological design, and planning, with limited support for financing, implementation, and monitoring. Five frameworks were grouped under the Designer archetype due to their emphasis on offering guidelines to assess ecological conditions and on providing support for the preparations before the implementation of an urban NbS. These frameworks provided comprehensive advice on both the Baseline Assessment and Ecological Performance and the Planning and Design dimensions, but were limited in terms of Financing guidelines, being classified as Limited or below in this dimension.

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Financiers specialize in the economic dimensions of NbS, including funding sources, investment instruments, and cost-benefit analysis. While only four frameworks were grouped under this archetype, the focus on the financial aspects of NbS makes this a unique type of document. Developed by organizations, such as the United Nations Environment Programme (UNEP) and ICLEI - Local Governments for Sustainability, these frameworks offered comprehensive guidance on Financing but limited or no guidance on the Planning and Design and Implementation dimensions.

Monitors specialize in performance measurement, impact evaluation, indicator development, and adaptive management. Led by various stakeholders representing government and practice, the frameworks under this archetype are particularly relevant for the study of NbS in the long term, allowing for the examination of their benefits, informing adaptive management and providing lessons to improve future practices. The six frameworks classified as *Monitors*, however, reveal that debates about financing NbS are still detached from discussions about monitoring and evaluation of their benefits since they provided valuable guidance on both Impacts and Co-benefits and the Monitoring and Evaluation dimensions, while none was rated Yes/High on Financing.

Frameworks meeting the criteria for both the *Integrator* and one of the specialized groups (*Designers, Financiers* or *Monitors*) were assigned to the *Integrator category*, reflecting that Integrators may include specialized depth in one or more dimensions while still demonstrating overall breadth.

Six frameworks did not share sufficient characteristics with any archetype to justify a distinct additional category and are therefore retained as *Unclassified.* This group includes both

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advocacy-oriented documents that do not intend to provide direct operational guidance (such as the Playbook for Urban Biodiversity, [38]) and frameworks with highly uneven coverage profiles across dimensions. The complete list of frameworks and their assigned archetypes is presented in Table 1.

Table 1. Complete list of frameworks and their assigned archetype reflecting coverage across six operational dimensions: (i) baseline assessment and ecological performance (BA); (ii) planning and design (PD); (iii) implementation (IM); (iv) financing and funding mechanisms (FF); (v) monitoring and evaluation (ME); and (vi) impacts and co-benefits (IC); and "How-to". Y = Yes/High, L = Limited/Medium, N = No/Low

NbS Framework		**Operational Dimensions**						**How to**
		Diagnostic		**Delivery**				
Name	**Organization**	**BA**	**PD**	**IM**	**FF**	**ME**	**IC**	
Integrator Archetype								
ADB: Practitioner's Guide [39]	Asian Development Bank (ADB)	Y	Y	Y	Y	L	Y	Y
Connecting Nature Framework [40]	Connecting Nature Framework - EU Horizon 2020	Y	Y	Y	Y	Y	Y	Y
GBC: Principles for NbS [41]	UK Green Building Council (GBC)	Y	Y	L	Y	Y	Y	Y
IUCN Global Standards for NbS [15]	International Union for Conservation of Nature (IUCN)	Y	Y	Y	Y	Y	Y	Y

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NbS Framework		Operational Dimensions						How to
		Diagnostic		Delivery				
Name	**Organization**	**BA**	**PD**	**IM**	**FF**	**ME**	**IC**	
NbS for Climate Resilient Cities [42]	United Nations Environment Program (UNEP)	Y	Y	Y	Y	Y	Y	Y
ROAM [43]	IUCN	Y	Y	L	Y	N	Y	Y
ThinkNature NbS Handbook [44]	European Union (EU) Research consortia	L	Y	Y	Y	L	Y	Y
World Bank Guidelines NbS [45]	World Bank	Y	Y	Y	Y	Y	Y	Y
Dept of Interior NbS Roadmap [46]	U.S. Department of Interior	Y	Y	Y	Y	Y	Y	Y
Designer Archetype								
CBD Guidelines to Climate Resilience [47]	CBD	Y	Y	Y	L	Y	Y	Y
NbS for Reducing Disaster Risks [48]	Wetlands International National Institute of Disaster Management, New Delhi	Y	Y	Y	L	L	L	Y

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NbS Framework		Operational Dimensions						How to
		Diagnostic		Delivery				
Name	**Organization**	**BA**	**PD**	**IM**	**FF**	**ME**	**IC**	
Nature Positive Cities [49]	World Economic Forum	Y	Y	L	L	N	L	Y
UN Habitat NbS Climate Resilience [50]	UN Habitat	Y	Y	L	N	N	Y	Y
Making Nature's City [51]	San Francisco Estuary Institute	Y	Y	L	N	N	N	Y
Financier Archetype								
ICLEI Guide Financing Biodiversity [29]	ICLEI	L	L	N	Y	N	N	Y
NbS in Latin America and the Caribbean [52]	InterAmerican Development Bank	N	N	N	Y	L	Y	L
UNEP State of Finance for Nature in Cities [28]	UNEP	L	N	N	Y	L	Y	Y
ENSURE [53]	CEEW (Council on Energy, Environment and Water)	Y	L	L	Y	L	Y	N
Monitor Archetype								

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NbS Framework		**Operational Dimensions**						**How to**
		Diagnostic		**Delivery**				
Name	**Organization**	**BA**	**PD**	**IM**	**FF**	**ME**	**IC**	
10 Protocols NbS [54]	CityAdapt	L	Y	Y	L	Y	Y	L
Berlin Pact [55]	ICLEI	L	L	L	L	Y	Y	L
C40 Finance [56]	C40 Cities Finance Facility and SELVAR	Y	Y	L	L	Y	Y	Y
EC NbS Handbook for Practitioners [57]	European Commission	Y	Y	N	N	Y	Y	Y
EKLIPSE Expert Working Group [16]	EU Research consortia	Y	L	L	N	Y	Y	Y
Urban Nature Indexes (UNI) [58]	IUCN	Y	L	N	N	Y	Y	Y
Unclassified								
Dryland NbS Informal Settlements [59]	ICLEI Africa	N	N	N	N	N	N	L
NbS Resource Guide 2.0 [60]	The White House (USA)	L	L	L	L	L	N	N
Playbook for Urban Biodiversity [38]	Melbourne Centre for Cities	L	Y	L	L	N	N	N

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NbS Framework		Operational Dimensions						How to
		Diagnostic		Delivery				
Name	Organization	BA	PD	IM	FF	ME	IC	
U-20 NbS Framework [61]	U-20 Nature-based Urban Solutions Taskforce	L	L	L	L	L	L	Y
UNaLab Introducing NbS [62]	Urban Nature Lab (Funding from EU Horizon 2020)	Y	L	Y	Y	L	L	L
UNEP Smart Sustainable Resilient Cities [63]	UNEP	L	L	L	L	N	Y	N

A comprehensive analysis of all frameworks according to the six operational dimensions using the diagnostic and delivery strength scoring described in section 2.3.3 is provided in S1 Fig and S2 Table.

4. Discussion

Our assessment of 30 NbS frameworks shows that the guidance available to cities is broad in aspiration but structurally uneven, with substantial resources supporting the diagnostic dimensions of NbS projects but persistent deficits at the delivery dimensions. This means that documents providing guidance on implementation, financing, and monitoring are still scarce.

The distribution of archetypes across the 30 frameworks (9 Integrators, 5 Designers, 4 Financiers, 6 Monitors, and 6 Unclassified) reveals a notable imbalance between where guidance

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is most needed and where it is most available. Below, we interpret these findings in the context of the current NbS literature and propose pathways toward a more coherent and accountable guidance architecture.

4.1 Geographic Specificity

In 10 frameworks (33.3%), guidance was anchored to particular regional, national, or ecosystem conditions. These documents offer valuable insights for implementers working in similar contexts, but geographic specificity can restrict the transferability of knowledge to other settings [31]. Half of them also offered limited operational guidance, suggesting that context-specific frameworks would benefit from a section of transferable, actionable guidance.

Among the Unclassified frameworks, specificity had different implications. The NbS Resource Guide 2.0 [60] and the U-20 NbS Framework [61] provide limited guidance across all dimensions, offering breadth with limited depth and little grounding in specific examples. At the other extreme, the Dryland NbS for Informal Settlements framework [59] contributes knowledge on an underrepresented context [64], relevant given growing interest in NbS in historically marginalized settings [50], but its limited guidance makes it closer to an advocacy document than an operational guide. Clearer guidance in such frameworks would reduce the "framework fatigue" practitioners report when navigating overlapping, incomplete, or inconsistent guidance [9].

Recommendation: Context-adaptive design. Geographic specificity reflects a tension between the contextual grounding that gives frameworks credibility and the transferability that gives them reach. Future frameworks can address this tension through explicit context-adaptation

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approaches, structured processes through which users assess local conditions and adjust guidance accordingly, rather than prescribing universally applicable solutions.

4.2 Absence of Guidance on Funding Pathways

Clear discussion of financing and funding strategies was absent in 8 frameworks (26.7%), even in some that nominally address the topic, revealing a disconnect between diagnostic content and actionable pathways to public, private, or innovative financing. This gap frequently co-occurred with a lack of operational guidance: 62% of frameworks exhibiting one also exhibited the other.

Dedicated resources are also scarce. Financiers are the least represented archetype, with only four examples: the ICLEI Guide to Biodiversity Financing for Cities and Regions, NbS in LAC, the UNEP State of Finance for Nature in Cities, and ENSURE [28,29,52,53]. Moreover, all four offer limited guidance on planning and design; the ICLEI Guide, for instance, provides only limited advice on baseline and planning dimensions, and NbS in LAC addresses neither [29,52]. Practitioners who turn to Financier frameworks will therefore find little help in linking financial instruments to ecologically grounded project design, risking financially viable but ecologically suboptimal interventions.

Cities that cannot access actionable financial guidance, whether investment cases, risk assessment methodologies, blended finance models, or cost-benefit frameworks, are less likely to mainstream NbS, because investors require evidence of return on investment, risk reduction, or measurable co-benefits to justify capital allocation. The result is a vicious cycle: insufficient monitoring data weakens the case for investment, while insufficient investment limits the resources available for monitoring and implementation.

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Recommendation: Engaging finance and governance actors. Frameworks must expand their communicative reach to include private investors, national policymakers, and development finance institutions. Future financial guidance for NbS should be embedded within or explicitly linked to frameworks that also address baseline assessment and design, ensuring that investment instruments are grounded in ecologically sound project specifications.

4.3 Lack of Operational and Practical Guidance

In 7 frameworks (23.3%), the lack of operational and practical guidance was one of the most pressing constraints on adoption. These frameworks articulate principles or document case studies without replicable implementation steps, and "how to" guidance was generally less common for the delivery dimensions.

Diagnostic dimensions are covered far more often than implementation (36.7%, the lowest of any dimension), financing (46.7%), or monitoring and evaluation (43.3%), and only five frameworks (16.7%) provide consistent guidance across all operational dimensions. We interpret this recurrence as a structural challenge for the field. Many frameworks are rooted in ecology, conservation science, and spatial planning, disciplines that bring deep expertise to problem diagnosis and solution design but have historically engaged less with procurement, contract management, institutional coordination, financial structuring, and adaptive management. The result is a guidance ecosystem that reproduces disciplinary silos: it equips cities to identify what to do but offers comparatively little support for how to fund, build, and verify NbS interventions.

This finding corroborates earlier observations by Seddon et al. [65] on NbS standards that lack integration between biophysical and socio-economic criteria, and extends them by showing that the imbalance is structural rather than merely thematic. The absence of implementation support

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and of financial pathways are manifestations of a shared deficit: institutional and economic perspectives are often missing simultaneously, limiting the ability of frameworks to guide delivery decisions. Closing this gap requires engagement with disciplines and professional practices underrepresented in the NbS framework landscape, including project management, public procurement, construction management, and institutional coordination.

Recommendation: Closing the delivery gap. The systematic study of methods to promote the adoption and integration of evidence-based practices into routine settings offers a potentially valuable but largely untapped body of knowledge for NbS practitioners. Frameworks that provide comprehensive implementation guidance, notably the ADB Practitioner's Guide, the Connecting Nature Framework, the World Bank Guidelines, and the CBD Guidelines (a Designer framework) [39,40,45,47], show that diagnostic strength need not preclude strong delivery guidance. They share explicit attention to the institutional and procedural realities of project delivery, often incorporating step-by-step guidance, worked examples, and practitioner-oriented toolkits, and can serve as models for structured guidance on sequencing, stakeholder coordination, risk management, and adaptive decision-making during execution.

4.4 Gaps in M&E Indicators and Guidance for Assessing co-benefits

Gaps in monitoring, evaluation, and indicators were observed in 7 frameworks (23.3%), which do not yet provide clear guidance on how implementers can evaluate the benefits and co-benefits of implemented NbS. In these frameworks measurement strategies are absent, underspecified, or there are limited mentions to strategies for assessing co-benefits.

Five frameworks provided comprehensive guidance across all operational dimensions and therefore connect monitoring and co-benefit assessment to the other dimensions: the Connecting

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Nature Framework, the IUCN Global Standard for NbS, the World Bank Guidelines, the UNEP NbS for Climate-Resilient Cities, and the U.S. Department of Interior NbS Roadmap [15,40,42,45,46]. All are Integrators developed by large multilateral or governmental bodies or research consortia with cross-disciplinary mandates and substantial resources for stakeholder consultation, suggesting that their comprehensiveness reflects institutional capacity as well as ambition. Among the remaining Integrators, the Restoration Opportunities Assessment Methodology, for example, provides structured diagnostic guidance but less support for delivery and even less for monitoring and evaluation [43].

Fewer than half of the frameworks (43.3%) substantively address monitoring and evaluation, even as commitments under the Paris Agreement, the Kunming–Montreal Global Biodiversity Framework, and the Sustainable Development Goals increasingly require cities to demonstrate measurable NbS outcomes rather than merely plan for them [14,66]. Monitoring guidance thus remains concentrated in a small number of specialized frameworks rather than embedded as standard practice.

Even the six Monitor frameworks, which offer strong guidance on monitoring and evaluation and on impacts and co-benefits, cover the other dimensions unevenly. C40 Finance, the EC NbS Handbook for Practitioners, the EKLIPSE framework, and the Urban Nature Indexes [16,56–58] provide comprehensive baseline guidance, but none offers comprehensive financing guidance, and the EC Handbook and the Urban Nature Indexes offer none on implementation. Frameworks that specialize in monitoring are thus not necessarily equipped to guide the implementation and financing that generate the outcomes they measure, and risk producing evaluations that reflect execution failures rather than the inherent potential of NbS interventions.

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Coverage of impacts and co-benefits, the highest of any dimension (70.0%), appears oriented predominantly toward identifying what NbS could deliver rather than verifying what they have delivered. This asymmetry perpetuates the uncertainty about actual NbS performance that Chausson et al. [67] identified as a fundamental barrier to building the evidence base for NbS effectiveness. The credibility of NbS as a policy instrument ultimately depends on demonstrated, not projected, outcomes.

Recommendation: Communicable monitoring, reporting, and verification. Bridging monitoring and the other dimensions requires shared, communicable indicator sets that enable cross-city comparison and cumulative evidence building. Alignment with established accounting frameworks such as the SEEA-EA [26] offers a globally recognized structure for linking ecosystem condition and service flows to economic and policy metrics. Because indicator sets that are too rigid risk excluding locally relevant outcomes while those that are too flexible undermine comparability, a tiered approach, with a core set of mandatory indicators supplemented by context-specific optional indicators, may offer the most productive compromise. The Urban Nature Indexes illustrate one model for structuring indicator-based assessment [58].

4.5 Unclear Advice on Community Participation

Seven frameworks (23.3%) provided unclear guidance on community participation and governance, acknowledging stakeholder engagement, co-production, and cross-departmental coordination without structured guidance. Moreover, 43% of the frameworks lacking information on monitoring and evaluation also fell short on community participation and financing (S3

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Table), reinforcing the observation that frameworks overlooking one delivery dimension tend to overlook others.

Limited guidance on community participation is a well-known challenge in the field, and practices sensitive to local priorities, values, and aspirations are particularly important for NbS to achieve their full potential in historically marginalized contexts [68]. Structured advice is still missing for critical steps: how to identify key stakeholder groups, how to engage them in co-designing NbS, and how to involve them in implementation and long-term maintenance.

Without such guidance, even well-designed NbS projects risk stalling at the point of delivery [69], and guidance on aligning community values with broader biodiversity, climate adaptation, and urban development goals is a critical step towards mainstreaming NbS within urban policies [70].

Designer frameworks illustrate this gap. Making Nature's City, Nature Positive Cities, and UN-Habitat's NbS Climate Resilience [49–51] provide valuable advice on diagnostic dimensions but limited information on how communities can participate in the implementation, financing, or assessment of NbS. Frameworks that do not speak to the decision-making logics of communities, investors, developers, and national policymakers are less likely to help cities move beyond grant-dependent pilot projects.

Recommendation: Investing in participatory approaches and institutional capacity. The lack of frameworks that holistically integrate participation, finance, project management, and governance mirrors a broader capacity gap within the institutions responsible for NbS delivery. Policymakers can address this by investing in training that builds competencies at the intersection of the social sciences, ecology, urban planning, public finance, and project

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552 management, and by accounting for community participation in government policy and budget
553 allocations. Frameworks themselves can play a catalytic role by guiding community-oriented
554 design and implementation practices.

555 **4.6 Thematic Narrowness**

556 Thematic narrowness was observed in 7 frameworks (23.3%), reflecting a tendency for
557 frameworks to provide in-depth specialized advice on one or a few of the dimensions at a time.
558 These frameworks had limited scope and, therefore, were intended to provide guidance
559 exclusively to a particular operational dimension, ecosystem or urban setting, such as financing,
560 forest landscapes, biodiversity indices, or informal settlements.

561 Thematic narrowness overlapped with geographic specificity in two frameworks (S3 Table),
562 indicating deliberate targeting of a specific set of stakeholders and a well-defined domain,
563 although these frameworks did not provide structured operational guidance, cover M&E, or
564 examine scalability strategies. Such frameworks appear designed with intentional focus rather
565 than exhibiting the uneven coverage typical of frameworks attempting broader scope: a
566 framework that sets out to address only financing is not less relevant for omitting
567 implementation.

568 Nearly all frameworks target local governments (97%) and practitioners (90%), whereas only
569 about half address private entities or national governments (53% and 50%, respectively), the
570 actors more likely to seek advice on overarching financing, design, and assessment strategies.
571 Current guidance therefore favors local implementers.

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The nine Integrator frameworks can serve as comprehensive starting points from which practitioners deepen their guidance using specialized frameworks. From this perspective, thematic narrowness is valuable: frameworks can be used as modular components assembled according to context, rather than consolidated into a single but likely more generic document. This allows municipal actors to combine local specificity with well-established generic guidance, and to engage with the resources, regulatory conditions, and investment instruments that originate beyond the municipal level and may be tied to frameworks adopted by funders and national governments.

Recommendation: Interoperability over consolidation. The diversity of NbS frameworks is not inherently problematic; the challenge lies in navigating that diversity of themes covered effectively. Rather than advocating for a single meta-framework, which would risk sacrificing the contextual specificity that gives individual frameworks their value, we propose that the archetype typology developed in this study can serve as a practical navigation tool. By classifying frameworks according to their functional specialization, practitioners can identify which combination of resources best suits their needs, balancing specificity and interoperability. A city entering the design phase might draw on a *Designer* framework such as Nature Positive Cities for ecological and spatial guidance, then turn to a *Financier* framework like the ICLEI Guide when developing its investment case, and a *Monitor* framework such as EKLIPSE when establishing its evaluation protocol.

4.7 Policy implications

The structural gaps documented in this study carry direct implications for policymakers at multiple governance levels.

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Supporting coverage of each operational dimension in NbS funding and policy instruments. Because many frameworks simultaneously lack advice on implementation, financing, and monitoring, funders, including national governments, development banks, and multilateral agencies, should encourage NbS proposals to demonstrate not only diagnostic soundness (ecological baseline assessment and design rationale) but also delivery readiness, including financing pathways, implementation plans, and monitoring protocols. Precedents exist: the World Bank's project cycle mandates appraisal, implementation planning, and monitoring and evaluation as conditions of financing [71], and the IUCN Global Standard for NbS functions in part as a funder-facing accountability tool that links ecological criteria to project verification [15]. Such requirements would create demand for more operationally complete frameworks and reduce the risk of funded projects stalling where diagnostic work ends and delivery begins.

Embedding monitoring into policy. The disconnect between financing and monitoring is a governance gap as well as a technical one. Policymakers should consider requiring monitoring protocols as a central component of NbS policy instruments, analogous to the reporting requirements for greenhouse gas inventories under the Paris Agreement, and aligning them with accounting structures such as the SEEA-EA to reduce duplication, enable cross-jurisdictional comparison, and strengthen the evidence base that underpins continued political and financial commitment to NbS.

Addressing trade-offs and synergies in decision-making. Current frameworks overwhelmingly emphasize the co-benefits of NbS but rarely provide structured guidance for evaluating trade-offs among outcomes, for example, tensions between flood mitigation and biodiversity conservation, or between urban greening and housing affordability. Policymakers should ensure that NbS planning processes include explicit mechanisms for identifying,

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evaluating, and communicating trade-offs, not only synergies. Without such mechanisms, NbS risk being adopted on the basis of optimistic benefit projections that do not reflect the distributional consequences experienced by different communities. This is particularly important in contexts where NbS may intersect with equity concerns, such as green gentrification or uneven access to urban nature.

Bridging governance levels. The finding that only about half of city-focused frameworks address national governments or private entities as audiences reflects a broader governance challenge: urban NbS implementation depends on enabling conditions that are distributed across jurisdictional levels. National policymakers can support urban NbS by establishing regulatory frameworks, fiscal instruments, and intergovernmental coordination mechanisms that create a supportive operating environment for municipal action. City networks and multilateral platforms can facilitate horizontal learning and peer exchange, helping cities navigate the fragmented guidance landscape and identify framework combinations suited to their context.

4.8 Limitations

Several limitations should be noted when interpreting the findings of this study. First, frameworks employing adjacent but less common or region-specific terminology, such as low-impact development or water-sensitive design, may have been missed even where their content overlaps substantively with NbS guidance. The boundaries of NbS as a concept remain contested, and alternative framings may offer relevant guidance which are not captured in this review.

Second, the archetype classification is an author-derived analytical construct designed as a diagnostic tool rather than a definitive categorization. The classification criteria depend on

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threshold choices (e.g., requiring a *Financier* to emphasize financing and lack comprehensive guidance on planning and implementation) that, if adjusted, could shift individual frameworks between categories. Frameworks that fall near the boundaries between archetypes or that exhibit highly uneven profiles may be particularly sensitive to such threshold effects.

Third, this review assesses the content and stated scope of frameworks but does not evaluate their uptake or effectiveness in practice. A framework that provides comprehensive guidance on implementation may not be widely adopted, and one that is widely adopted may not lead to better outcomes on the ground. Whether coverage across functional dimensions translates into improved NbS delivery remains an empirical question beyond the scope of this analysis, and one that warrants dedicated investigation as the framework landscape continues to evolve.

5. Conclusions

This study assessed 30 NbS frameworks to evaluate the coherence and completeness of the guidance available to cities seeking to implement nature-based solutions. The findings reveal a fundamental structural imbalance: the diagnostic dimensions of NbS are well served by existing frameworks, while the delivery dimensions remain substantially under-resourced. Only a small subset of *Integrator* frameworks, developed mainly by large multilateral or governmental institutions, provides comprehensive coverage across operational dimensions, indicating that end-to-end support is rare and concentrated among well-resourced organizations.

The analysis also demonstrates that these weaknesses are not isolated but cluster systematically, with operational guidance, financing, and monitoring deficits frequently co-occurring within the same frameworks. These findings suggest that the root causes are structural, reflecting

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disciplinary biases and institutional mandates, rather than incidental oversights that could be addressed through piecemeal additions.

The archetype typology developed here offers both a diagnostic tool and a practical navigation aid for practitioners. Rather than searching for a single framework that addresses all needs, users can assemble complementary resources matched to their operational needs and their specific governance context, using *Integrator* frameworks as comprehensive entry points supplemented by specialized *Designer*, *Financier*, or *Monitor* frameworks where deeper guidance is required.

Moving forward, the most pressing priorities for the NbS framework landscape are threefold: closing the delivery gap by integrating implementation science and project management methodologies into NbS guidance; establishing communicable but flexible monitoring and verification protocols aligned with global accounting frameworks; and expanding the communicative reach of frameworks to engage private investors, national policymakers, and development finance institutions as active audiences. The next generation of urban NbS frameworks must be co-produced not only by professionals of a few disciplines and organizations but with finance professionals, public administrators, and the communities implementing, maintaining and co-habitating with nature in cities.

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Supporting information

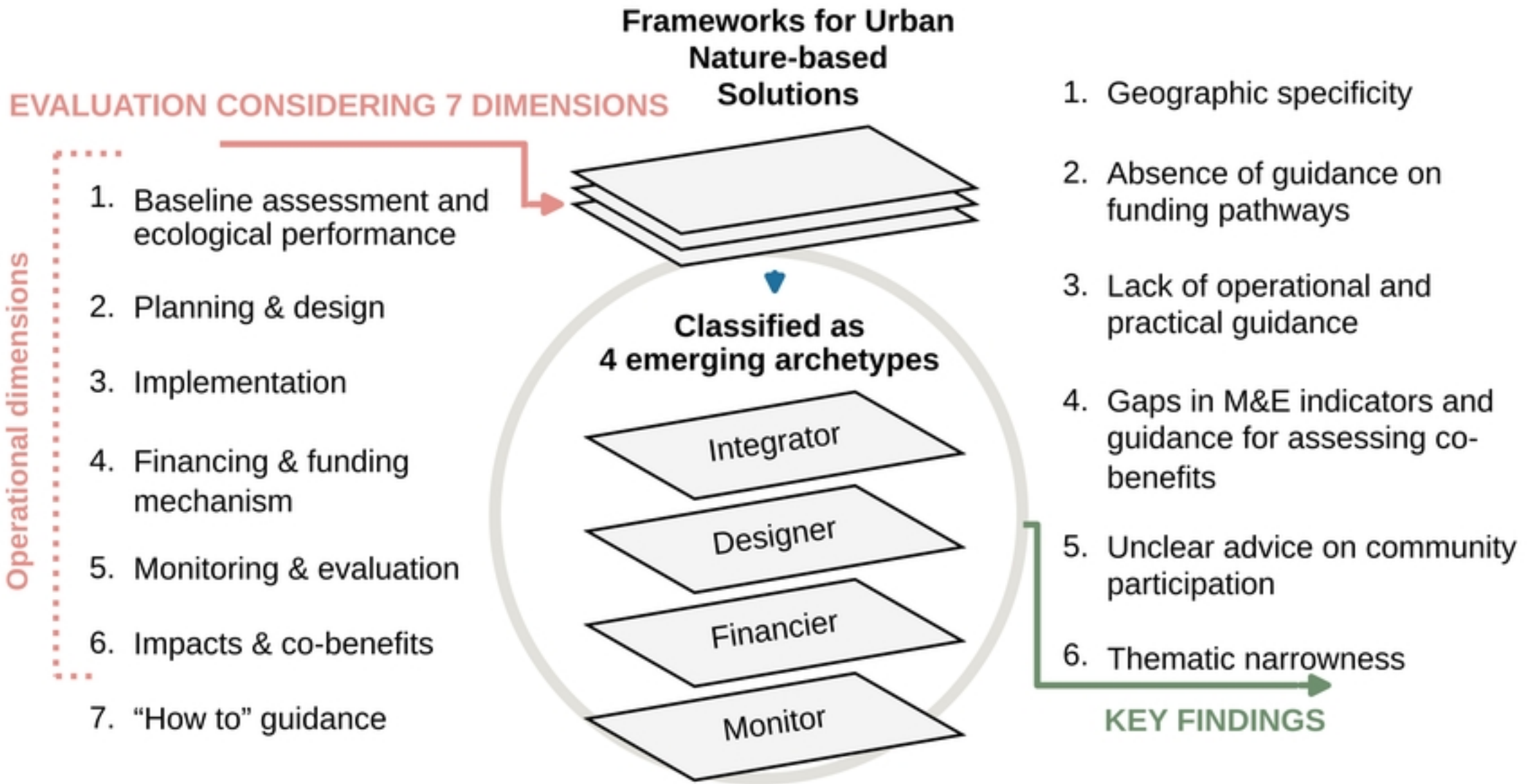
S1 Table. Coding protocol and variable dictionary. Standardized coding parameters, variable definitions, and categorical scoring criteria used in the qualitative content analysis.

S1 Fig. Continuum of NbS framework functional orientations. Diagnosis Strength and Delivery Strength composite scores across the assessed frameworks.

S2 Table. Detailed scoring matrix across the 30 NbS frameworks. Dimension-level ratings (BA, PD, IM, FF, ME, IC, how-to) and diagnostic and delivery composite scores for each framework.

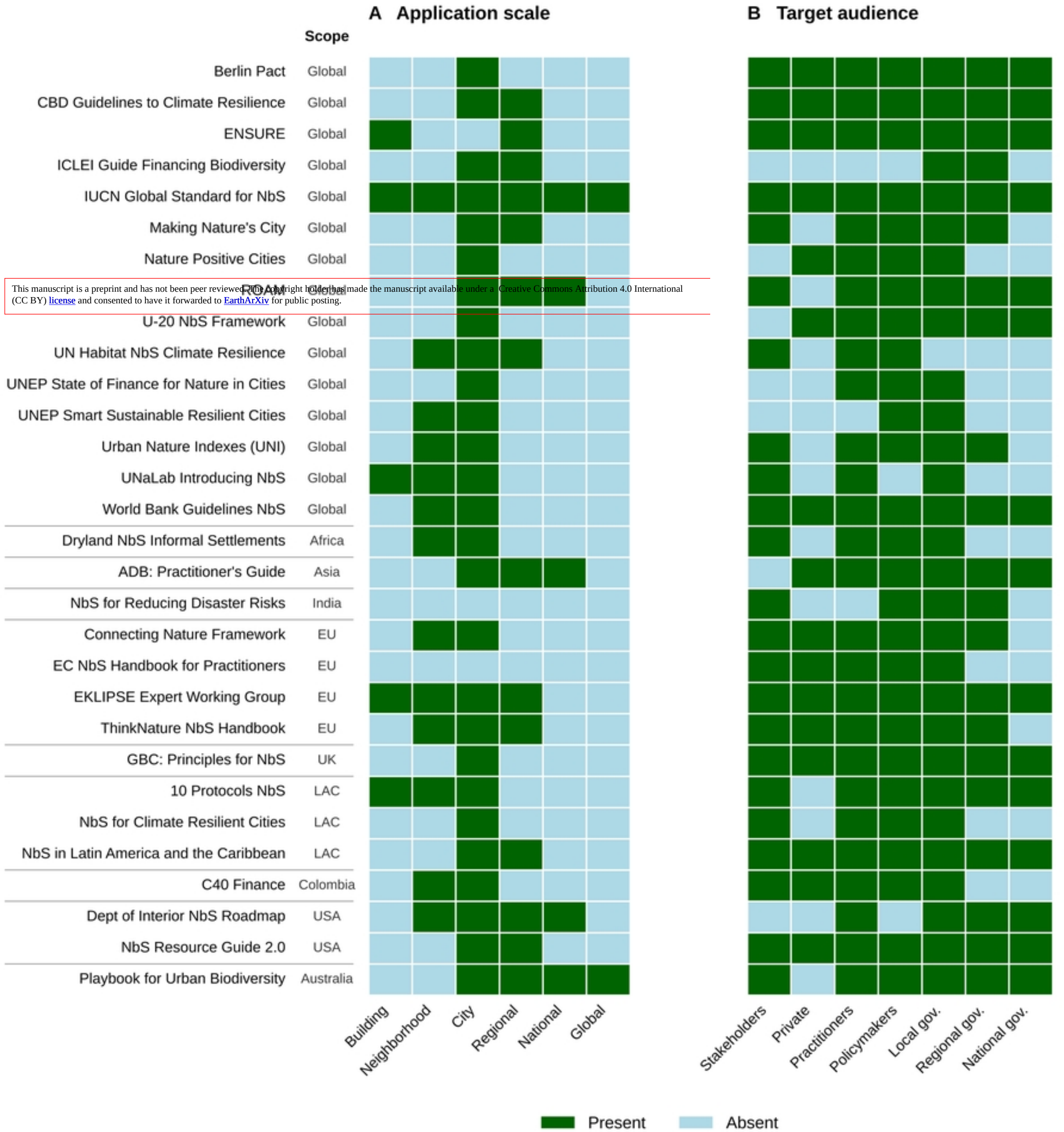
S2 Fig. Hierarchical clustering agreement. Comparison of the inductive archetype typology with hierarchical clustering (Adjusted Rand Index).

S3 Table. Overlap matrix of framework attributes and operational gaps. Cross-cutting framework characteristics, geographic specificity, thematic focus, and guidance gaps.

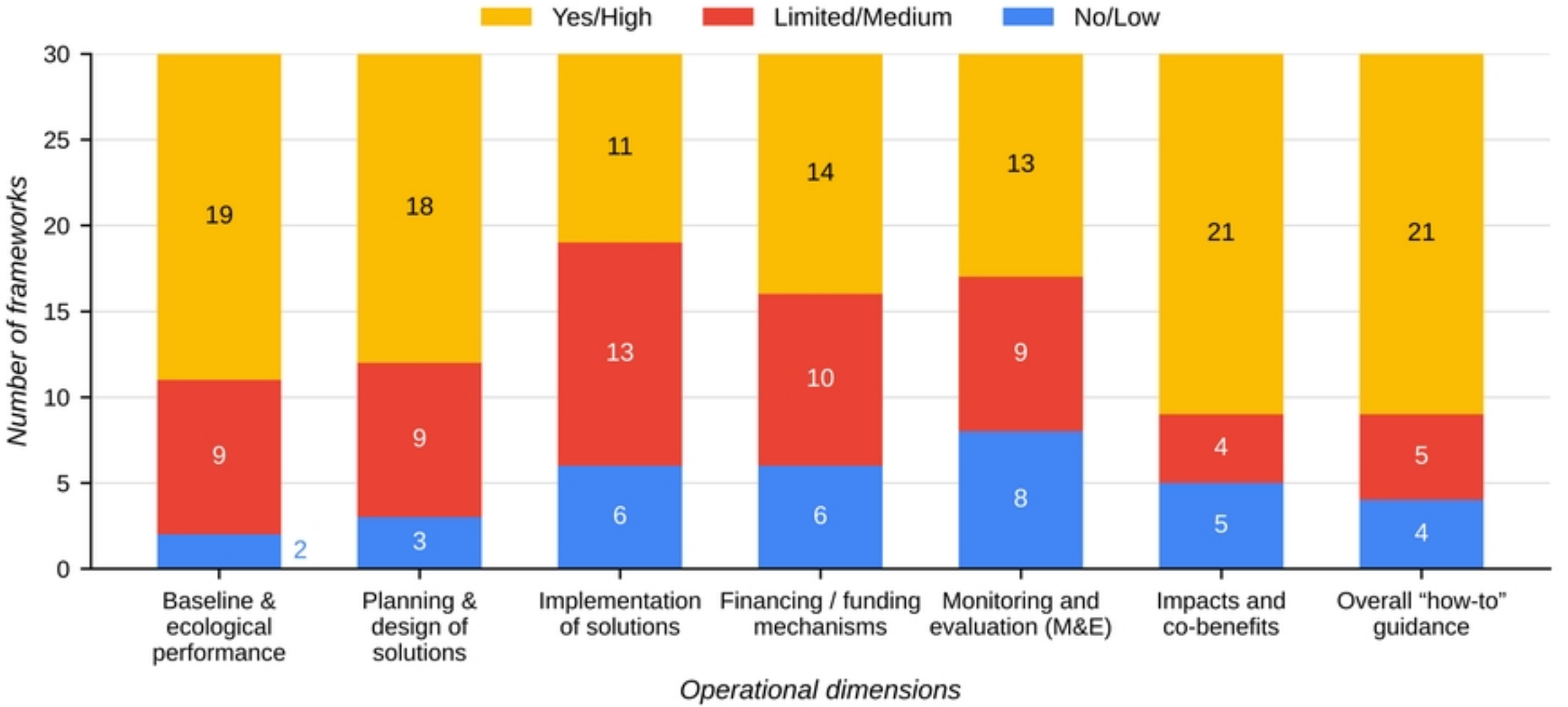

Frameworks for Urban Nature-based Solutions
EVALUATION CONSIDERING 7 DIMENSIONS
Operational dimensions
1. Baseline assessment and ecological performance
2. Planning & design
3. Implementation
4. Financing & funding mechanism
5. Monitoring & evaluation
6. Impacts & co-benefits
7. "How to" guidance
Classified as 4 emerging archetypes
Integrator
Designer
Financier
Monitor
1. Geographic specificity
2. Absence of guidance on funding pathways
3. Lack of operational and practical guidance
4. Gaps in M&E indicators and guidance for assessing co-benefits
5. Unclear advice on community participation
6. Thematic narrowness
KEY FINDINGS

Figure

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Figure


Yes/High
Limited/Medium
No/Low
Number of frameworks
30
25
20
15
10
5
0
19
9
2
18
9
3
11
13
6
14
10
6
13
9
8
21
4
5
21
5
4
Baseline & ecological performance
Planning & design of solutions
Implementation of solutions
Financing / funding mechanisms
Monitoring and evaluation (M&E)
Impacts and co-benefits
Overall "how-to" guidance
Operational dimensions

Figure