frontiers in Blockchain

TYPE Original Research
PUBLISHED 04 November 2026
DOI 10.3389/fbloc.2026.1961818

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OPEN ACCESS

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RECEIVED 08 August 2026
REVISED 15 October 2026
ACCEPTED 17 October 2026
PUBLISHED 04 November 2026

CITATION
Bennett K (2026) Operationalising the impact-finance protocol: institutional architecture and the role of DLT in digital sustainable finance.
Front. Blockchain 9:1961818.
doi: 10.3389/fbloc.2026.1961818

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Operationalising the impact-finance protocol: institutional architecture and the role of DLT in digital sustainable finance

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Sustainable, impact and development finance increasingly rely on digital systems to measure and manage real-world social and environmental performance. Yet impact information is still used primarily for reporting and retrospective assessment, rather than as an operational input into financial decision-making. This creates a persistent gap between what financial systems know about real-world outcomes and how capital is actually allocated, released or constrained. This study examines how that gap might be addressed through the Impact-Finance Protocol (IFP), an institutional architecture designed to connect trusted real-world information with financial execution. Building on the conceptual IFP proposed in earlier work, the study evaluates how the protocol behaves when operationalised under real implementation conditions. A comparative Design Science approach was used, combining an initial reference implementation with a longitudinal programme of implementation across multiple institutional, governance and technical contexts. The protocol, rather than any individual organisation, technology or project, was treated as the unit of analysis. Implementation evidence was systematically reconstructed through evidence validation, qualitative coding, implementation-episode reconstruction, comparative analysis and Design Knowledge synthesis. The findings show that the core responsibilities for structuring evidence and verifying its meaning remain comparatively stable across different implementation contexts. By contrast, connecting verified information to financial action requires more extensive governance, institutional authority and operational coordination than the original architecture anticipated. Practical implementation also depends on cross-cutting capabilities such as legal identity, compliance, financial accounts, payment rails and coordination across recurring and overlapping implementation processes. Community participation emerges as an operational capability, while system-level Assessment remains comparatively immature and requires further implementation and evaluation. Where distributed ledger technology (DLT) mechanisms were used, they supported selective integrity, coordination and governed execution, but remained context-dependent rather than necessary architectural components; off-chain verification, institutional authority and governance remained fundamental to financial activation. The study contributes implementation-derived Design Knowledge and transferable Design Principles for digital sustainable finance. It shows that enabling trusted impact information to influence financial decisions requires not only reliable data

and verification, but an institutional architecture capable of governing how information becomes actionable financial value across diverse real-world settings.

KEYWORDS

design science research, development finance, digital sustainable finance, impact finance, impact-finance protocol, institutional architecture, participatory action design research, regenerative finance

1 Introduction

Despite sustained growth in sustainable, impact and development finance, capital allocation remains weakly coupled to verifiable social and ecological performance. Financial instruments increasingly incorporate sustainability objectives, yet the information used to assess performance remains predominantly retrospective, self-reported and weakly connected to financial decision-making (Attridge and Engen, 2019; Bennett, 2026b; 2026d; Busch et al., 2021). The problem is therefore not simply whether impact can be measured, but whether trusted impact information can become operational within financial systems: informing allocation, payment, incentive, governance and other financial decisions while preserving provenance, accountability and institutional legitimacy. This challenge is particularly significant in development finance, where capital must often operate across fragmented institutional, technical and governance environments (Bennett, 2026b; 2026c).

Recent advances in digital infrastructure, distributed systems and trusted data environments have created new opportunities to integrate impact information more directly into financial decision-making (Hoven, In & Puschmann, 2026). However, implementation research suggests that technical capability does not translate automatically into institutional use (Venable, Pries-Heje & Baskerville, 2016). Organisational blockchain implementation has been shown to depend on experimentation, contextual adaptation and the mitigation of implementation constraints (Du et al., 2019), while research in financial services identifies governance, decision rights, control and accountability as persistent concerns in distributed infrastructures (Zachariadis, Hileman & Scott, 2019). More recent empirical evidence similarly links blockchain implementation in financial institutions to technological readiness, organisational governance and regulatory support (Alsmadi and Al-Smadi, 2026). At the boundary between digital infrastructure and real-world information, research on blockchain oracles further demonstrates that on-chain integrity does not itself establish the reliability of off-chain inputs, including in accounting and ESG-reporting applications (Caldarelli, 2025).

These strands collectively indicate that trustworthy digital finance depends on more than technical functionality, but they tend to examine technology implementation, governance or data integration as distinct problems. Comparatively limited empirical research has examined how verification, institutional authority, governance, financial execution and operational readiness interact within an integrated architecture over time. Architectural coherence alone does not guarantee executability. Without systematic implementation and evaluation, even well-designed frameworks risk remaining aspirational.

The present study addresses this gap through comparative Design Science evaluation of the Impact-Finance Protocol (IFP), an institutional architecture developed in earlier work to connect verified impact information with financial execution (Bennett, 2026a). Rather than treating organisations, technologies or implementation environments as comparative cases, the IFP provides the analytical constant. A bounded reference implementation reconstructed from its project documentation and implementation artefacts is compared with a longitudinal implementation journey spanning materially different institutional, governance and technical conditions to examine which protocol responsibilities remain stable, which require refinement or extension, and which remain context dependent.

The study therefore shifts from conceptual specification to comparative operationalisation. Using a Participatory Action Design Research (PADRE)-informed reconstruction, implementation evidence is traced through phenomena and implementation episodes to comparative architectural findings and Design Knowledge (Bilandzic and Venable, 2011; Haj-Bolouri, Bernhardsson & Rossi, 2016; Sein et al., 2011). Development outcomes, organisational performance, technology performance, adoption and scalability are not evaluated; these boundaries are specified further in Section 2.2.2.

The central research question guiding this study is: *How does operationalising the Impact-Finance Protocol across contrasting institutional, governance and technical environments refine understanding of the institutional architecture required for digital sustainable finance?*

By addressing this question, the study contributes an implementation-derived refinement of the IFP and identifies stable, context-dependent and emergent Design Knowledge concerning the institutional conditions required to translate trusted real-world information into governed financial action. The resulting evaluation distinguishes comparatively mature execution responsibilities from adaptive capabilities that remain emergent or provisional, providing an empirically bounded architecture for digital sustainable finance.

2 Research design and methods

2.1 Research context

This study forms part of a broader doctoral research programme examining how impact information can become operational within financial systems. Earlier stages identified limitations in prevailing impact-measurement and capital-allocation arrangements and developed the conceptual IFP as a six-function institutional architecture linking Data, Logic, Value, Governance, Community and Assessment (Hevner et al., 2004; Sein et al., 2011).

The present study moves from conceptual specification to comparative evaluation. It draws on a bounded reference

implementation (EE1) reconstructed from its project documentation and implementation artefacts, and a longitudinal implementation reconstruction to examine how the architecture behaves under materially different institutional, governance, financial and technical conditions. The objective is not to evaluate the participating organisations or technologies, but to determine how implementation confirms, refines, extends, contextualises or challenges the responsibilities specified by the reference architecture (Gregor and Hevner, 2013; Venable, Pries-Heje & Baskerville, 2016).

2.2 Research design

2.2.1 Participatory action design research

This study adopts Participatory Action Design Research (PADRE), which combines participatory action research with Design Science Research to examine artefacts through iterative cycles of implementation, observation, reflection and refinement (Bilandzic and Venable, 2011; Haj-Bolouri, Bernhardsson & Rossi, 2016). PADRE is appropriate because the IFP is not evaluated as a static conceptual model but through its interaction with real institutional, technical and governance conditions, allowing implementation to expose assumptions, dependencies and architectural boundaries that may remain invisible at the level of specification.

PADRE is used here pragmatically rather than as an emancipatory or organisational-change methodology. Participatory activities and practitioner observation generated implementation evidence, while the analytical focus remained the protocol and the Design Knowledge produced through its operationalisation. The resulting implementation record was subsequently reconstructed and compared systematically, separating participation in implementation from the analytical process used to derive the findings reported here (McRobert, 2018).

This approach aligns with design-science traditions in information systems and infrastructure research, where artefacts are treated as hypotheses embodied in form. The IFP is not examined as a normative framework to be validated, but as an executable system whose assumptions, interfaces, and failure modes must be surfaced through use (Hevner et al., 2004; Sein et al., 2011). The implementation evidence generated through these iterative cycles subsequently forms the basis for a comparative Design Science evaluation through which implementation-derived Design Knowledge is reconstructed and protocol architecture refined.

2.2.1.1 Researcher positionality

The research was conducted by a practitioner–researcher with direct involvement in the design and instantiation of the protocol under study. This positionality provided privileged access to operational detail, decision processes and implementation artefacts, but also created risks of interpretive dependence, retrospective confirmation bias and over-attribution. The analytical reconstruction and comparative classifications reported in this study were undertaken by the author; no independent second-coder analysis or external audit of the complete classification set was conducted.

Several safeguards were therefore used to constrain interpretation. The protocol, rather than participating organisations or implementation outcomes, was treated as the analytical constant; implementation evidence was registered separately from subsequent analytical reconstruction; material claims were tested against provenance, temporal sequence and cross-source corroboration; ambiguous or contradictory evidence was retained rather than resolved through narrative smoothing; and comparative classifications preserved non-equivalence, challenges, unsupported propositions and explicit evidentiary boundaries. These procedures reduce, but do not eliminate, dependence on the practitioner–researcher's interpretation (McIntyre, 2008; Sein et al., 2011).

2.2.2 Scope boundaries

Consistent with this focus, the study does not evaluate development outcomes, organisational performance, adoption, scalability, or the effectiveness of particular technologies, platforms, governance models or financial instruments. The execution environments are treated as contrasting implementation contexts rather than comparative cases. The analytical concern is how the IFP's responsibilities behave under differing implementation conditions.

2.3 Comparative design science evaluation

2.3.1 Comparative evaluation design

The comparative evaluation used a reference-first design. EE1 provided a bounded reference implementation reconstructed from its project documentation and implementation artefacts, against which responsibilities exercised during the longitudinal implementation journey could be compared (Venable, Pries-Heje & Baskerville, 2016). The later environments were selected because they exposed the architecture to materially different institutional, governance, financial and technical conditions, allowing comparison of architectural stability, refinement, extension and contextual dependence.

Comparative findings were then used to refine the protocol architecture and derive implementation-based Design Knowledge. Figure 1 summarises this design.

2.3.2 IFP as the analytical constant

The intervention examined was the Impact-Finance Protocol (IFP), treated as an executable institutional architecture and the analytical constant across implementation environments. The protocol comprises six functional responsibilities: Data, which establishes evidence, context and provenance; Logic, which evaluates evidence against rules, thresholds and conditions; Value, which translates qualified states into financial action; Governance, which establishes authority, decision rights and accountability; Community, which incorporates situated participation and implementation context; and Assessment, which supports review, learning and adaptation. The

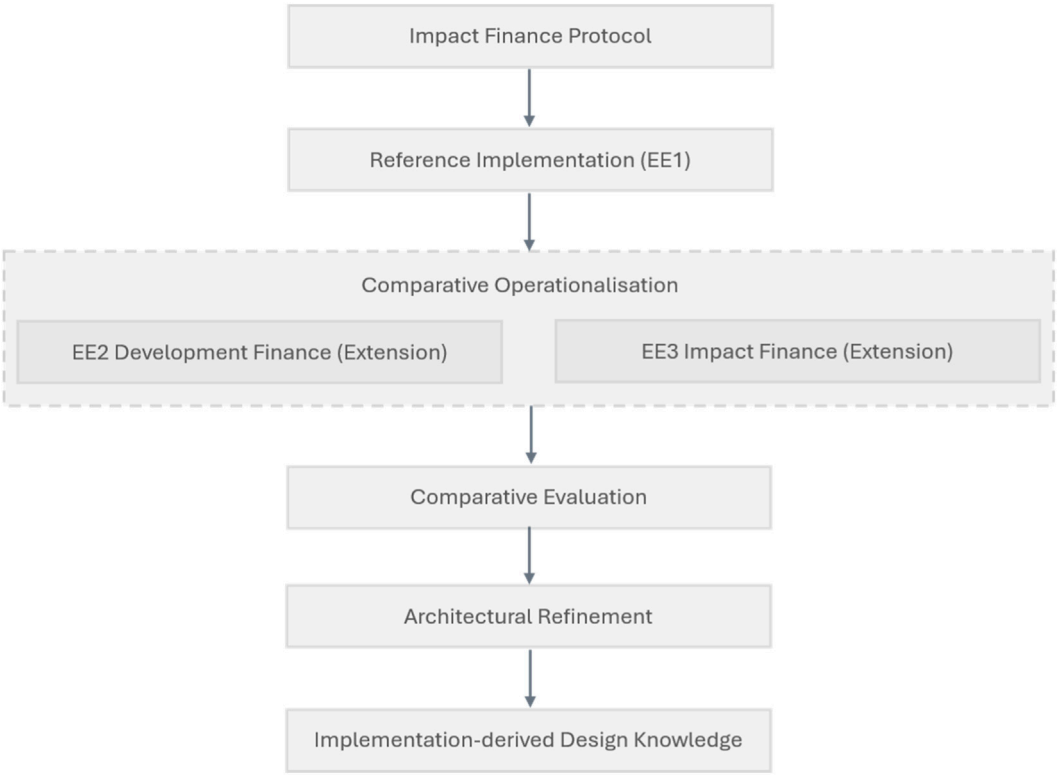


FIGURE 1
Comparative design science evaluation.

comparative evaluation examined how these responsibilities were instantiated under differing conditions rather than whether particular organisations, technologies or financial mechanisms performed successfully.

Evaluation focused on the inputs, processes, outputs, interfaces and failure modes associated with each function. Particular attention was given to Data–Logic–Value execution because these functions mediate the transition from evidence to financial action, while Governance, Community and Assessment provide authority, participation and adaptive capacity. The analysis examined whether these responsibilities could be instantiated coherently, whether interfaces between them functioned as intended, and where assumptions embedded in the architecture were exposed by operational conditions.

Within Data, the protocol accommodates multiple forms of impact information relevant to sustainable, impact and development finance, including quantitative environmental signals, service or outcome proxies, governance records, community narratives and contextual information supporting interpretation and institutional memory. Such information is treated as an input to protocol execution rather than as evidence of realised development outcomes.

Within Logic, validation and verification determine whether and under what conditions information can influence downstream financial execution. Verification effort is proportionate to the role of the information: evidence directly conditioning financial action is expected to satisfy appropriate validation or verification requirements, while contextual information may inform governance, learning and interpretation without requiring equivalent assurance.

For empirical evaluation, Value was interpreted broadly to include mobilisation, routing, allocation, payment, receipt and reporting. The study examined a bounded set of financial execution mechanisms sufficient to test whether financial workflows could be conditioned on verified non-financial information rather than comparing financial instruments or assessing their effectiveness. Evidence of protocol execution was therefore not treated as evidence of achieved development outcomes.

Across these functions, execution was evaluated through explicit transitions between states, including submission, validation or verification, dispute, resolution, execution and blockage, rather than assumed to proceed through discretionary judgement or *post hoc* interpretation. These transitions enabled empirical examination of readiness, incompleteness and failure as well as successful execution. The IFP was therefore treated as modular and context-agnostic at the level of functional responsibility, while remaining context-sensitive in how those responsibilities were instantiated.

2.3.3 Execution environments

Three execution environments were used to expose the IFP to contrasting implementation conditions (Venable, Pries-Heje & Baskerville, 2016). EE1 provided the bounded reference

TABLE 1 Comparative evaluation design and protocol operationalisation contexts.

	EE1	EE2	EE3
Comparative role	Reference implementation	Comparative operationalisation	Comparative operationalisation
Primary context	Sustainable finance	Development finance	Impact finance
Primary purpose	Enterprise verification and capital allocation	Community funding and transparency	Collective ownership and treasury governance
Data	●	○	○
Logic	●	○	○
Value	●	○	●
Governance	○	●	●
Community	○	●	●
Assessment	○	●	●

● Primary instantiation.
○ Secondary or indirect exercise.

TABLE 2 Empirical evidence base used for comparative protocol evaluation.

Evidence category	Artefact types	Purpose
Operational interactions	Meeting transcripts, email correspondence, messaging records	Document implementation decisions, coordination and iterative design
Design artefacts	Architecture diagrams, protocol specifications, working documents	Trace protocol evolution and architectural refinement
Technical artefacts	GitHub repositories, implementation documentation, system configurations	Document technical instantiation and execution logic
Governance artefacts	Decision records, governance documentation, agreements	Capture institutional arrangements and rule evolution
Reflective artefacts	Research notes, implementation reflections, presentation materials	Support interpretation, reconstruction and design knowledge synthesis

implementation, while EE2 and EE3 introduced materially different development-finance and decentralised/hybrid conditions. They were selected for analytical contrast rather than as independent comparative cases.

Table 1 maps the principal context and purpose of each environment against the six protocol functions. Differences in layer coverage are interpreted as evidence of where responsibilities were exercised, constrained or remained untested; absence of a mechanism in one environment is therefore not treated as disconfirmation of the underlying architectural responsibility.

Throughout the analysis, implementation-status terms are used distinctly. "Implemented" denotes a mechanism or process instantiated in practice; "tested" denotes deliberate examination of an implemented or configured mechanism; "demonstrated" indicates that the evidence supports the stated capability or finding, but does not by itself imply production deployment; "exploratory" denotes activity investigated or configured without completed implementation; and "proposed" denotes a mechanism or capability articulated but not empirically instantiated. "Operationalised" is used at the architectural level to describe translation of the IFP from conceptual specification into implementation settings, rather than as a claim that every component was fully implemented.

2.3.4 Empirical evidence base

The empirical corpus comprised implementation artefacts generated through routine project activity rather than material created retrospectively for this study. Consistent with the participatory action design research approach, evidence was generated as a by-product of implementation rather than through separately constructed research instruments (Bilandzic and Venable, 2011; Haj-Bolouri, Bernhardsson & Rossi, 2016; Sein et al., 2011). Sources included communications, meeting and workshop records, financial and administrative records, technical and platform documentation, governance artefacts, implementation materials and researcher reflections. Table 2 summarises the principal evidence classes and their analytical purpose.

The longitudinal corpus was registered before analytical coding. The Master Evidence Register contained 7,142 evidence items spanning the bounded implementation period. Evidence was first registered and validated for provenance, temporal location and recoverability before analytical relevance was assessed. Coding was then applied where a record contained observable implementation activity meeting at least one of the 43 defined Implementation Phenomena. Each phenomenon included an explicit definition and exclusion boundary, distinguishing implementation-relevant content from general discussion, routine

acknowledgement, purely social exchange or references without observable implementation activity. This produced 2,755 coded evidence units (38.6% of registered items) and 4,255 evidence–phenomenon assignments; the larger assignment count reflects multi-label coding where a single evidence unit instantiated more than one phenomenon. The analytical record also contained 2,682 linked artefact references and 7,852 explicit evidence relationships. Coding coverage therefore refers to the proportion of the registered corpus assigned to Implementation Phenomena, rather than to completeness of the underlying implementation record.

Evidence was analysed longitudinally using process tracing and cross-source corroboration (Bennett and Checkel, 2015). No single artefact was treated as sufficient where material claims depended on relationships among actors, decisions or events; instead, evidence was interpreted through temporal sequence, provenance and convergence across sources. This enabled reconstruction of implementation development over time while retaining uncertainty where the record was incomplete or ambiguous.

2.3.5 Analytical workflow

The analytical workflow converted the longitudinal evidence record into progressively higher-order analytical units while preserving traceability to source evidence (Figure 2). Evidence was first registered and validated for provenance, temporal location and recoverability before being organised into Implementation Phenomena representing observable patterns of activity.

Coded evidence was then reconstructed into Implementation Episodes (IEs): bounded periods in which identifiable objectives, actors, dependencies and protocol responsibilities interacted through implementation (Gregor and Hevner, 2013; Miles et al., 2022). Episodes were grouped around a common implementation objective and observable period of related activity, with boundaries identified through changes in objective, implementation state or activity, including commencement, closure, transition or reopening. Parallel and recurring activity was retained as separate or overlapping episodes where distinct trajectories were evident rather than being collapsed into a linear project chronology.

Each IE was subsequently compared with the canonical responsibilities and implementation characteristics reconstructed from EE1. *Confirmation* indicated support for an existing architectural responsibility without material change; *refinement* retained the responsibility but required greater specification of its conditions, boundaries or operation; *extension* added a responsibility, interface or capability beyond the reference architecture; *contextualisation* indicated that the underlying responsibility remained relevant while its implementation form varied materially with context; *challenge* identified an assumption, limitation or transfer boundary that could not be carried forward unchanged; and *new observation* identified a material condition or relationship not represented in EE1, with any architectural consequence determined during subsequent synthesis. Classifications were non-exclusive because an episode could bear different relationships to different reference loci or simultaneously support an underlying responsibility while refining or extending its operational form.

Ambiguous or incomplete evidence was not forced into definitive classification. Interpretations were assessed against provenance, temporal sequence, corroborating sources, alternative classifications and countervailing evidence. Non-equivalence was distinguished from contradiction: absence of a mechanism or implementation form in another environment was not treated as evidence against the underlying architectural responsibility. Where the record did not support a stronger interpretation, claims were bounded, evidentiary confidence reduced, propositions refined or replaced, or capabilities left unsupported.

Confidence ratings refer to evidentiary confidence within the reconstructed record, not external validity, transferability or causal effect. Ratings considered provenance and recoverability, directness and specificity of support, corroboration across records or sources, and completeness of the relevant temporal and implementation record. High confidence indicated clear, traceable and sufficiently corroborated support without material unresolved ambiguity;

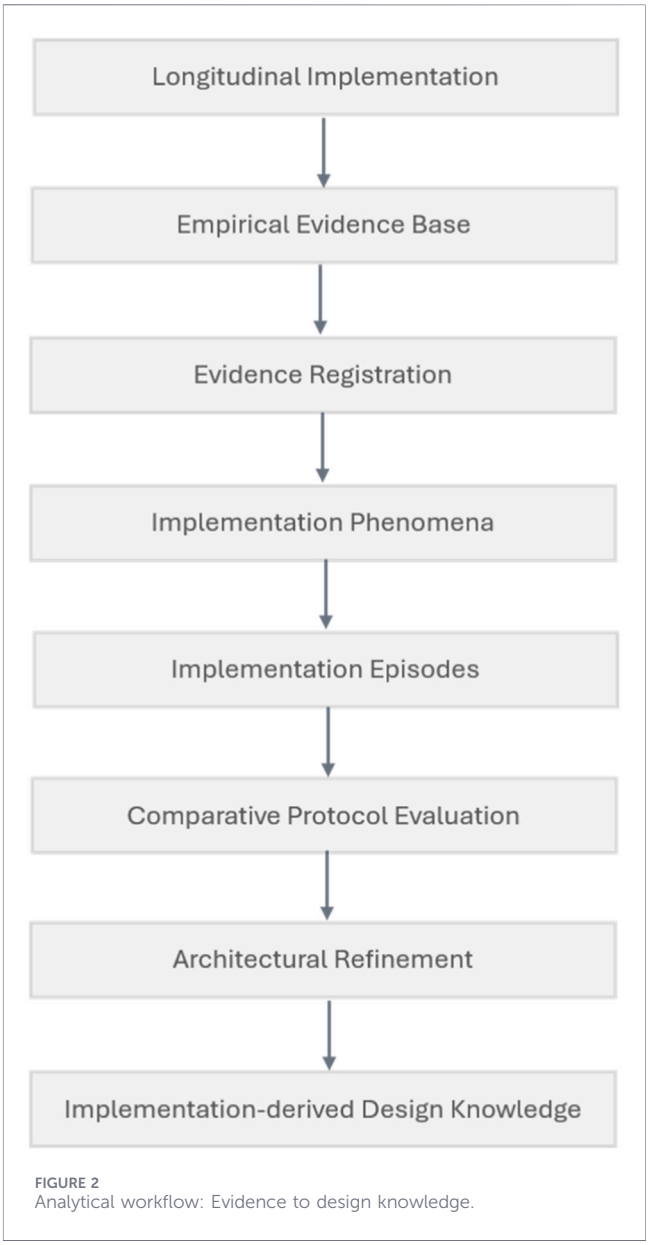


FIGURE 2
Analytical workflow: Evidence to design knowledge.

TABLE 3 Empirical foundations and comparative roles.

Empirical foundation	Timeframe	Evidence basis	Unit of analysis	Implementation maturity	Comparative role
EE1 reference reconstruction	Nov 2025–23 July 2026	Project documentation, GitHub history, technical artefacts, meeting records, architecture documentation and implementation evidence	Reference implementation (13 IEs)	Bounded implementation with strong support for data and logic, bounded logic–Value execution, and provisional governance, community and assessment	Establishes the implementation-derived reference architecture
Longitudinal comparative reconstruction	13 September 2022–30 July 2026	7,142 registered evidence items comprising WhatsApp communications, emails, meeting transcripts and linked implementation artefacts	Implementation episode (20 reconstructed episodes)	Multi-year, multi-context operationalisation across institutional, financial, community and technical strands	Evaluates architectural stability, refinement and context dependence beyond EE1

Complete reference and longitudinal implementation registers are provided in Supplementary Sections S1, S2.

Medium confidence indicated credible support subject to material incompleteness, limited corroboration or uncertainty concerning implementation state or timing; and Low confidence indicated sparse, partial or indirect support sufficient only for a bounded inference. The resulting comparative synthesis informed architectural refinement, derivation of Stable, Context-dependent and Emergent Design Knowledge, Design Principles and proposition reassessment (Gregor and Hevner, 2013; Venable et al., 2016). Complete registers and record-level analytical traceability are provided in Supplementary Sections S2-S6.

3 Findings

3.1 Empirical basis and reference position

The comparative evaluation rests on two empirically asymmetric but analytically complementary foundations. EE1 comprises a bounded reference implementation reconstructed across six phases and 13 episodes. The longitudinal reconstruction spans 13 September 2022 to 30 July 2026 and comprises 7,142 registered evidence items, 43 implementation phenomena and 20 IEs across four overlapping phases.

This asymmetry is analytically important. EE1 provides a comparatively mature architectural reference against which responsibilities could be identified, while the longitudinal reconstruction provides broader variation in institutional, governance, financial and technical conditions. The comparison therefore tests functional portability and architectural boundaries rather than equivalence between implementation environments. Table 3 summarises the empirical foundations and their comparative roles.

3.2 Reference implementation and baseline architecture

EE1 established the implementation-derived baseline against which the longitudinal operationalisation was subsequently evaluated. Conducted between November 2025 and 23 July 2026, the engagement was structured as an architecture-led reference proof of concept rather than a production deployment. Its purpose was to examine how heterogeneous electricity and emissions evidence could be ingested, reconciled, attributed and translated into auditable assertions capable of informing downstream institutional or financial workflows. Representative and synthetic data were used where real supplier data were unavailable.

3.2.1 Implementation trajectory

EE1 developed through six implementation phases comprising 13 episodes between November 2025 and July 2026. Rather than representing a linear build sequence, the phases progressively exposed the responsibilities required to translate evidence into governed financial action.

Phase 1: problem framing and contracting–established the initial architecture and clarified the need to maintain provenance, contextual evidence and verification logic as connected but distinguishable responsibilities.

Phase 2: requirements elaboration–extended this foundation through more explicit treatment of qualification, confidence and attribution, demonstrating that Logic operates relationally across evidence rather than through isolated record validation.

Phase 3: mobilisation and architectural exploration–exposed the importance of state and readiness. Incomplete, pending, unsupported and blocked conditions required explicit representation, while eligibility for financial action depended on more than the presence of verified evidence.

Phase 4: scope alignment and architectural re-baselining–strengthened the distinction between authority and execution. Governance determined who could authorise rules, thresholds and actions, while execution mechanisms remained separately configurable.

Phase 5: thin-slice implementation–tested portability across conventional and digitally enabled mechanisms. Functional responsibilities remained recognisable across implementations, although the mechanisms through which they were realised differed materially.

Phase 6: hardening, formalisation and handover–consolidated the bounded architecture and its remaining gaps. The

TABLE 4 EE1 reference architecture and evidentiary status.

Protocol function	EE1 implementation finding	Evidentiary status	Principal boundary
Data	Provenance-preserving evidence architecture linking source, context, transformation and assertion	High	No universal multi-capital ontology or broad cross-domain implementation
Logic	Relational, stateful and policy-governed verification incorporating attribution, confidence, incompleteness and temporal state	High	Specific confidence, attribution and conformance mechanisms remain domain-bound
Value	Finance-ready assertions, classifications, proofs and demonstrative workflow signals	Medium	No live payment, allocation, incentive issuance or financial integration
Governance	Rule authority, methodology ownership, access, evidence custody, versioning and conformance control	Medium	Mature institutional governance, dispute resolution and adaptive change were not implemented
Community	Actor plurality and differentiated evidence visibility	Conceptual	No distributed sensing, collective sensemaking or participatory protocol operation
Assessment	Claim-confidence and implementation-conformance antecedents	Conceptual	No ecosystem-purpose, multi-capital or longitudinal assessment

implementation established a traceable Data–Logic–Value pathway and supporting governance responsibilities but did not demonstrate production operation, complete automated eligibility, independent assurance acceptance or mature Community and Assessment functions.

The complete six-phase chronology and E1–E13 register are provided in Supplementary Section S1.

3.2.2 Reference architectural findings

EE1 provided strongest implementation support for Data, Logic and Value, with Governance partially exercised and Community and Assessment remaining less mature. Across the implementation, evidence provenance and context became inseparable from verification; Logic became relational and stateful; and Value required traceability from qualified evidence through financial action and subsequent proof. Governance established the need to distinguish decision authority from execution authority.

Eleven historical Design Principles were derived within EE1 from these implementation findings. They are retained as part of the reference implementation genealogy rather than treated as the final comparative Design Principles developed later in this study; the complete register is provided in Supplementary Section S1.

The evidentiary boundary remains material. EE1 did not demonstrate production deployment, live end-to-end institutional financial execution, independent assurance acceptance, mature Community operation or a completed Assessment-mediated adaptive cycle. Table 4 therefore reports function-level status within the bounded implementation rather than claims of complete protocol validation.

3.3 Longitudinal implementation trajectory

The longitudinal reconstruction identified 20 IEs across four overlapping phases. Unlike EE1, these episodes were not organised around deliberate development of a single architecture. They emerged through recurrent and parallel implementation activity spanning community funding, institutional establishment, financial routing, digital-platform experimentation, governance and reporting.

Phase 1: Early community implementation and funding practice. Initial episodes established recurring needs identification, beneficiary support, mobilisation, payment and reporting practices. Evidence and financial action were already linked, but through largely manual and relationship-dependent processes rather than formal protocol infrastructure.

Phase 2: Organisational and institutional establishment. Implementation expanded beyond individual funding events to legal identity, organisational authority, account establishment, compliance, partner readiness and recurring programme coordination. These episodes demonstrated that institutional readiness is not external to execution: it forms part of the conditions through which financial action becomes possible.

Phase 3: Digital and governance experimentation. Parallel experimentation introduced digital funding, treasury and governance mechanisms alongside conventional arrangements. Functional responsibilities remained recognisable across mechanisms, but implementation exposed differences in participation, authority, liquidity, usability and institutional compatibility. This phase therefore provided evidence of functional portability without establishing mechanism equivalence.

Phase 4: Financial routing, institutional transfer and recurrent operation. Later episodes combined recurring funding cycles with more complex transfer, account, reporting and route-selection requirements. Three constraints became particularly visible: funding timing, institutional transfer requirements, and platform or financial-route limitations. Responses included route substitution, workaround states, delayed execution and reopening of apparently completed episodes.

Across the four phases, implementation was therefore recurrent and overlapping rather than linear. The education-finance, school-development, platform-pilot, and proposal-and-reporting cycles repeatedly reopened as needs, evidence, funding or institutional conditions changed. School-energy and guarantee-related episodes remained exploratory and are not treated as completed

TABLE 5 Longitudinal implementation phases and episodes.

Phase	Period	Episodes	Principal implementation development
Phase 1: Community onboarding and institutional foundations	13 September 2022–27 August 2023	IE-001–IE-004	Community and platform onboarding, initial student support, foundation registration, organisational banking capacity and establishment of the primary-school project
Phase 2: Education-finance model formation and school establishment	23 November 2023–4 November 2024	IE-004–IE-006	Definition and operation of the sixty-six-student scholarship model, 2024 funding and disbursement, recurring reporting and school-development routines
Phase 3: Recurring education operations and platform-pilot preparation	20 November 2024–30 December 2025	IE-004; IE-007–IE-010	2025 scholarship cycle, ecosystemic-finance use-case framing, pilot mobilisation, platform coordination and impact-token deployment
Phase 4: Parallel pilots, institutional rails and evidence workflows	9 December 2025–30 July 2026	IE-011–IE-020	School growth, 2026 scholarships, tokenomics, demonstrations, DAF transfer, local-currency testing, family-office routing, institutional-account onboarding, allocation and reporting, plus exploratory energy and guarantee extensions

A complete register of the twenty IEs, including episode boundaries, dates, objectives, supporting phenomena, evidence counts, relationships, PADRE, responsibilities, status and evidentiary boundaries, is provided in the Supplementary Section S2.

implementations. Table 5 summarises the longitudinal phases; the complete IE register and recurring-cycle analysis are provided in Supplementary Section S2.

3.4 Comparative reconstruction against the reference architecture

Comparative reconstruction examined how the twenty IEs identified through the longitudinal reconstruction confirmed, refined, extended or challenged the implementation-derived reference architecture established through EE1. Rather than comparing organisations, technologies or implementation outcomes, the analysis treated the protocol itself as the analytical constant, using the reference architecture as the basis against which subsequent operationalisation could be evaluated. Each implementation episode was systematically compared against twenty-nine canonical reference loci reconstructed from the EE1 implementation, allowing stable functional responsibilities to be distinguished from context-dependent adaptations and genuinely emergent architectural characteristics.

Comparison identified sixteen confirmations, twelve refinements, seventeen extensions, eighteen contextualisations, three challenges and eleven new observations across the twenty IEs. These classifications were not mutually exclusive. Individual IEs frequently contributed multiple comparative relationships, reflecting the interconnected nature of institutional, technical and financial implementation. Comparative confidence was assessed as high for fifteen IEs, medium for four, and low for one. Importantly, challenges denote exposed assumptions, implementation boundaries or transfer limitations rather than architectural failure. Collectively, the comparative reconstruction supports the structural coherence of the protocol across substantially different implementation settings while undergoing important refinement through operational practice. Table 6 summarises the episode-level comparative relationships and their principal architectural implications and boundaries.

3.4.1 Confirmed architectural responsibilities

The strongest confirmations concerned responsibilities rather than mechanisms. Evidence, context and provenance remained linked; verification operated relationally rather than at record level; incomplete and blocked conditions required explicit representation; temporal state mattered; and authority remained distinguishable from execution. These responsibilities were portable across conventional, decentralised and hybrid mechanisms, although functional portability did not establish mechanism equivalence.

3.4.2 Refined and extended architectural responsibilities

Operationalisation refined the conditions surrounding execution. Beneficiary eligibility, allocation priorities, legal identity, account and partner readiness, financial-route selection, deadlines, and recurrent or reopening lifecycles became explicit architectural concerns. Confidence, attribution and qualification mechanisms were also shown to be domain specific rather than universal.

The principal extensions occurred in Value and Governance. Value expanded beyond finance-ready assertions to encompass mobilisation, routing, payment, disbursement, allocation, receipt, proof and reporting. Governance expanded to include legal and organisational authority, compliance, account control, participation, collective decision-making, allocation priorities and accountability. Community supplied situated needs, context, progress evidence and feedback, but did not demonstrate representative protocol governance or a complete adaptive cycle.

3.4.3 Contextualisations, challenges and new observations

Several EE1 mechanisms–including its confidence model, emissions attribution, renewable treatment, selective anchoring, fail-closed access and conformance mechanisms–were not

TABLE 6 Episode-level comparative synthesis.

Comparative relationship	Count	Principal architectural implication	Principal boundary
Confirmation	16	Core functional responsibilities remained stable across implementation contexts	Portability does not imply implementation equivalence
Refinement	12	Institutional readiness and operational coordination required additional architectural specification	Domain-specific implementation remained necessary
Extension	17	Value and governance expanded substantially beyond EE1	Extensions remain bounded by observed contexts
Contextualisation	18	Several mechanisms proved implementation-specific rather than universal	Context should configure mechanisms, not responsibilities
Challenge	3	Exposed assumptions and transfer boundaries requiring explicit qualification	Challenges denote limits of demonstrated transferability rather than architectural failure
New observation	11	Institutional enablement, lifecycle coordination and recurrent implementation emerged through comparison	Requires further validation beyond current implementation contexts

A complete episode-level comparative matrix, including all implementation episode–reference architecture comparisons, classification rationale, confidence assessments and supporting phenomenon and Evidence IDs, is provided in the Supplementary Section S3.

reproduced as universal forms. Their absence represents non-equivalence or lack of comparative testing rather than disconfirmation. More consequentially, Value emerged as reciprocal rather than terminal: rail, account, compliance, liquidity, timing and usability constraints fed back into Data, Logic and Governance. Implementation also proved recurrent, parallel and path dependent, with closure frequently periodic or provisional.

3.5 Refined protocol architecture

Comparative evaluation retained all six PADRE functions but materially refined their operational responsibilities and relative maturity. Data, Logic, Value and Governance received high-confidence implementation support, although Logic, Value and Governance remained context dependent in important respects. Community was emerging at medium confidence, while Assessment remained provisional and low confidence. Figure 3 presents the resulting architecture and Table 7 summarises function-level comparative status. A complete component-level architecture register, including all twenty-nine canonical reference loci, comparative classifications, confidence assessments, episode support and Evidence-ID traceability, is provided in the Supplementary Section S4.

3.5.1 Data

Confirmed and refined; High confidence. Data comprises provenance-linked contextual evidence, including beneficiary and operating context, identity and compliance documentation, receipts, media, institutional records and readiness inputs. Implementation confirmed the need to preserve evidence relationships and temporal state. No universal multi-capital data model was demonstrated.

3.5.2 Logic

Confirmed, refined and context dependent; High confidence. Logic operates relationally and statefully across eligibility, allocation, authority, route, period and readiness conditions. Confidence, attribution and threshold mechanisms are configurable to domain and purpose rather than universal protocol forms.

3.5.3 Value

Extended and context dependent; High confidence. Value encompasses mobilisation, execution, allocation, proof and reporting. Financial rails, accounts, compliance, liquidity, timing and usability constrain execution and feed reciprocally into other protocol functions. Deterministic automatic triggering was not demonstrated.

3.5.4 Governance

Extended, refined and context dependent; High confidence. Governance encompasses legal and organisational authority, compliance, accounts, roles, participation, proposals, voting, allocation and accountability. DAO or voting mechanisms represent possible implementations rather than universal architectural requirements.

3.5.5 Community

Extended but emerging; Medium confidence. Community contributed situated needs, local context, implementation coordination, progress evidence and usability feedback. The evidence did not demonstrate sustained mutual credit, community currency, representative protocol governance or community-led rule change.

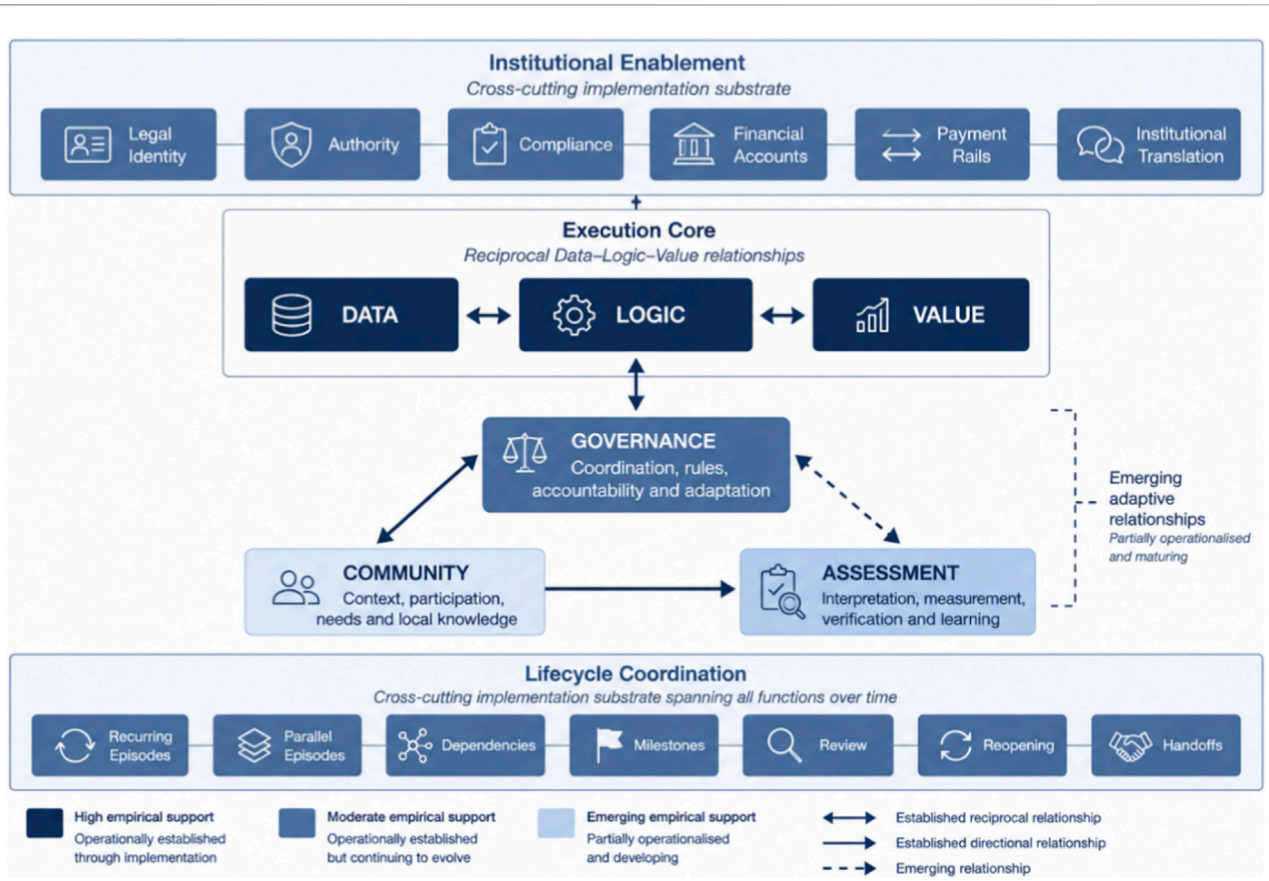


FIGURE 3
Refined IFP architecture emerging from comparative design science evaluation.

TABLE 7 **Comparative status of the six protocol functions.**

Protocol function	Comparative status	Principal refinement	Confidence	Evidentiary boundary
Data	Confirmed and refined	Provenance expanded to include institutional readiness, identity and contextual evidence	High	No universal multi-capital data model demonstrated
Logic	Confirmed, refined and context-dependent	Relational, stateful evaluation incorporating eligibility, authority, allocation, readiness and timing	High	Confidence, attribution and thresholds remain domain-specific
Value	Extended and context-dependent	Expanded from finance-ready assertions to mobilisation, execution, allocation, proof and reporting	High	No deterministic automatic triggering demonstrated
Governance	Extended, refined and context-dependent	Expanded into institutional authority, compliance, participation and accountability	High	Governance mechanisms remain implementation-specific
Community	Extended but emerging	Situated needs, implementation coordination, local evidence and usability feedback	Medium	No representative protocol governance or community-led rule change demonstrated
Assessment	Emerging and strongly context-dependent	Integrity review, progress review, donor reporting and post-implementation reflection	Low	No mature ecosystem-purpose or multi-capital assessment demonstrated

TABLE 8 Summary of implementation-derived design knowledge.

Design Knowledge class	Core knowledge contribution	Confidence range	Principal boundary
Stable design knowledge	Durable responsibilities concerning evidence-to-action lineage, relational and stateful logic, authority–execution separation, temporal lifecycle, actor relationships and accountable financial action	Predominantly high	Does not establish universal mechanisms or a complete adaptive cycle
Context-dependent design knowledge	Configurable mechanisms for confidence, attribution, financial routing, governance, evidence custody, sequencing, community participation and assessment	High to medium	Mechanisms vary with domain, institution, regulation, infrastructure and participant capability
Emergent design knowledge	Longitudinally visible conditions concerning institutional readiness, reciprocal financial feedback, path-dependent capability, recurrent episodes, route plurality, translation, community intelligence and provisional closure	High to medium	Requires validation beyond the present implementation settings

3.5.6 Assessment

Emerging and strongly context dependent; Low confidence. Observed antecedents comprised integrity and progress review, post-test reflection, donor reporting and accountability. Mature multi-capital accounts, interdependency mapping, ecosystem-purpose Assessment and Assessment-mediated recalibration were not demonstrated.

3.5.7 Cross-cutting implementation substrates

Two cross-cutting implementation substrates operate across the six functions without constituting additional PADRE layers.

Institutional Enablement comprises legal identity, organisational authority, compliance, financial accounts, payment rails, participant capability and institution-facing translation. These capabilities function as endogenous conditions of protocol execution rather than external implementation context.

Lifecycle Coordination captures the recurrent and overlapping nature of implementation: dependencies, milestones, workaround states, review, temporary closure, reopening and handoffs. It is therefore an architectural property of operationalisation rather than merely a project-management activity.

Collectively, the findings indicate that the six-function architecture remains conceptually stable while becoming operationally richer. Figure 3 represents the reciprocal Data–Logic–Value execution core, asymmetric maturity of the adaptive functions and the two cross-cutting substrates; Table 7 reports the comparative status and evidentiary boundary of each protocol function.

3.6 Implementation-derived design knowledge

Comparative synthesis produced 27 implementation-derived Design Knowledge statements, organised into nine Stable, nine Context-dependent and nine Emergent items. The classes distinguish responsibilities that remained durable across implementation conditions from mechanisms requiring configuration and insights that became visible only through longitudinal operationalisation (Gregor and Hevner, 2013). Table 8 summarises the three classes; complete statements, confidence assessments, boundaries and traceability are provided in Supplementary Section S5.

3.6.1 Stable design Knowledge

Stable Design Knowledge (SDK) concerns responsibilities that remained durable across implementation conditions. These include maintaining evidence-to-action lineage; relational and readiness-based Logic; explicit representation of incomplete and blocked states; separation of authority from execution; portability of functional responsibilities across mechanisms; preservation of temporal lifecycle; treatment of actor relationships and evidence visibility as architectural inputs; traceability through financial action and accountability; and separation of execution from adaptation pathways. Collectively, these findings describe the comparatively stable responsibilities of the architecture without prescribing how each must be implemented.

3.6.2 Context-dependent design knowledge

Context-dependent Design Knowledge (CDK) identifies dimensions that require configuration to institutional, domain or technical conditions. These include confidence and eligibility representation; attribution and allocation methodology; ledger or token roles; financial routing and institutional readiness; governance mechanisms; evidence form, custody and disclosure; sequencing and completion; community participation and local value circulation; and Assessment and feedback architecture. Their context dependence limits claims that any single EE1 mechanism represents a universal protocol form.

3.6.3 Emergent design knowledge

Emergent Design Knowledge (EDK) captures insights visible primarily through longitudinal implementation: institutional readiness as endogenous to execution; bidirectional feedback from financial mechanisms; path-dependent capability accumulation; recurrent and parallel episodes; route plurality as

resilience; institution-facing translation; community-supplied implementation intelligence; evidence–governance–allocation–reporting loops; and provisional closure. These findings extend the architecture from a set of functional responsibilities toward an account of how those responsibilities evolve through implementation.

3.7 Transferable design principles and proposition status

The final stage of synthesis translated the refined architecture and Design Knowledge into twelve transferable Design Principles (Gregor and Hevner, 2013; Venable, Pries-Heje & Baskerville, 2016). These principles were derived after the comparative evaluation and are distinct from the eleven historical Design Principles reconstructed from EE1. The historical principles explain how the reference architecture emerged; the comparative principles prescribe how future implementations of this class of institutional architecture should be designed and evaluated.

3.7.1 Transferable design Principles

Twelve comparative Design Principles (DPs) were derived from the refined architecture and Design Knowledge synthesis. They are analytically distinct from the eleven historical EE1 principles and are organised into four families reflecting different dimensions of protocol operationalisation. Transferability refers to their intended relevance to future implementations within the stated application contexts, rather than demonstrated universal generalisability.

1. Provenance, readiness and governed transformation (DP-01–DP-03) concerns the integrity of the evidence-to-action pathway. These principles require implementations to preserve auditable lineage through financial execution and reporting, represent evidence and pathway readiness explicitly, and ensure that material transformations of evidence into claims, classifications or allocations are transparent and appropriately authorised.
2. Authority, portability and mechanism configuration (DP-04–DP-07) concerns how stable protocol responsibilities are instantiated across differing institutional and technical environments. These principles separate legitimate authority from execution, preserve functional responsibilities while allowing mechanisms to vary, treat financial rails as bidirectionally coupled to the wider architecture, and support route plurality without sacrificing governance or traceability.
3. Institutional enablement, lifecycle coordination and community evidence (DP-08–DP-10) addresses implementation conditions that became visible through longitudinal operationalisation. These principles treat institutional and participant readiness as an explicit implementation responsibility, require recurrent and parallel implementation processes to be coordinated over time, and recognise community-generated context as governed implementation evidence rather than as an external or purely consultative input.
4. Governed financial activation and maturity-sensitive evaluation (DP-11–DP-12) concerns the conditions under which the architecture can legitimately act and the claims that can subsequently be made about its performance. These principles require financial action to occur only when both evidentiary and execution pathways are ready and require evaluation claims to remain proportionate to demonstrated artefact and implementation maturity.

The principles also differ in the scope of their contribution. Table 9 distinguishes three contribution categories: IFP-specific architectural principles; implementation-derived principles; and broader institutional, financial or Design Science principles empirically reinforced through the study. These categories are not mutually exclusive, but identify the principal basis of each principle's contribution and avoid treating all twelve as equally novel or equally specific to the IFP.

Complete rationale, scope, confidence and traceability from the comparative findings and Design Knowledge are provided in Supplementary Section S6.

3.7.2 Refined protocol propositions

Comparative synthesis also reassessed the ten reconstructed protocol propositions (Gregor and Hevner, 2013; Venable, Pries-Heje & Baskerville, 2016). One was confirmed, one extended, five refined, one replaced and two remained unsupported within the present evidence base. RP-07 was confirmed, while RP-02 was extended; RP-01, RP-03, RP-05, RP-08 and RP-10 were refined; RP-04 was replaced; and RP-06 and RP-09 remained unsupported.

Three results are particularly consequential. First, deterministic triggering was replaced by governed, readiness-dependent activation, reflecting the demonstrated influence of authority, compliance, accounts, routes and other execution conditions. Second, cross-scale multi-capital aggregation remained unsupported. Third, the proposed adaptive closed loop was refined but not confirmed because mature Assessment-mediated recalibration was not demonstrated. Unsupported propositions should therefore be interpreted as capabilities not established within the present evidence base rather than rejected theoretical possibilities.

Comparative support was not assumed. An architectural responsibility or proposition was treated as stable only where it remained supported across different implementation contexts without material contradictory evidence. Where the evidence showed that a proposition did not hold in practice, or that its specified form conflicted with observed implementation, it could be weakened, replaced or removed. By contrast, where a capability had not been implemented or the evidence was insufficiently mature, it was classified as unsupported rather than disconfirmed. No core IFP function met the threshold for removal in this study. However, RP-04 was replaced because deterministic financial triggering was inconsistent with observed execution conditions, while RP-06 and RP-09 remained unsupported because the capabilities they proposed were not demonstrated.

Complete proposition statements, assessments, confidence and traceability are provided in Supplementary Section S6.

TABLE 9 Transferable design principles.

ID	Condensed principle	Evidentiary Confidence	Primary application context	Contribution category
DP-01	Preserve auditable evidence-to-action lineage through execution, proof and reporting	High	Consequential evidence-to-action and financial execution	IFP-specific architectural principle
DP-02	Represent evidence, institutional and pathway readiness as explicit execution states	High	Multi-party and conditional execution environments	IFP-specific architectural principle
DP-03	Externalise and authorise material transformation methods	High	Evidence-to-claim transformation and allocation decisions	IFP-specific architectural principle
DP-04	Separate legitimate authority from execution at consequential boundaries	High	Multi-actor institutional decision and execution systems	Broader principle empirically reinforced
DP-05	Stabilise functional responsibilities while allowing contextual mechanisms to vary	High	Cross-platform and cross-jurisdiction implementations	IFP-specific architectural principle
DP-06	Treat financial rails as bidirectionally coupled adapters	High	Implementations using external financial, token or payment rails	Implementation-derived principle
DP-07	Support governed route plurality without breaking traceability	Medium	Cross-border or infrastructure-constrained payment environments	Implementation-derived principle
DP-08	Make institutional and participant readiness an explicit workstream	High	Multi-organisation and regulated implementation settings	Broader principle empirically reinforced
DP-09	Govern recurrent and parallel IEs explicitly	High	Longitudinal or multi-strand implementation programmes	Broader principle empirically reinforced
DP-10	Use community-generated context as governed implementation evidence	Medium	Community-linked or beneficiary-facing implementations	Implementation-derived principle
DP-11	Activate financial action only when evidence and execution pathways are both ready	High	Outcome-linked financial allocations, transfers or automated workflows	Broader principle empirically reinforced
DP-12	Match evaluation claims to artefact maturity and preserve unresolved boundaries	High	Design science evaluation, replication and conformance assessment	Broader principle empirically reinforced

4 Discussion

Comparative operationalisation produced three principal findings that frame the Discussion. First, the six-function IFP remained analytically coherent across materially different implementation conditions, but functional portability did not imply mechanism equivalence. Second, financial execution emerged as governed and readiness dependent rather than deterministic, with Institutional Enablement and Lifecycle Coordination operating across the architecture. Third, the execution pathway matured more strongly than the adaptive pathway: Data, Logic, Value and Governance received comparatively strong support, while Community remained emerging and Assessment provisional.

4.1 Implementation as design science evaluation

The findings reinforce a central Design Science proposition: implementation does more than test whether an artefact functions; it exposes assumptions, interfaces and boundary conditions that conceptual specification alone cannot reveal (Gregor and Hevner, 2013; Hevner et al., 2004; Sein et al., 2011). EE1 established a bounded architecture, but longitudinal operationalisation revealed additional institutional, financial and temporal dependencies that changed how several responsibilities had to be understood.

Methodologically, the study also demonstrates the value of reconstructing implementation before evaluating it. Separating evidence registration, phenomenon identification, IE reconstruction and comparative synthesis reduced dependence on retrospective practitioner narrative while preserving traceability from implementation evidence to higher-order Design Knowledge. This is particularly relevant to longitudinal Design Science research in which the artefact and its implementation context evolve together.

4.2 Stability of responsibilities and variability of mechanisms

A central finding is that functional responsibilities were more portable than the mechanisms through which they were instantiated. Across the reference implementation and the longitudinal journey, the need to preserve evidence provenance, evaluate relationships, represent readiness and blocked states, distinguish authority from execution and retain temporal lineage remained comparatively stable. By contrast, confidence models,

attribution methods, governance arrangements, financial routes, tokens, accounts, disclosure practices and community-participation mechanisms varied substantially.

This distinction refines the original claim that the protocol is technology agnostic. Technology agnosticism should not be interpreted to mean that technologies, financial rails or governance forms are interchangeable without consequence. Different mechanisms impose different requirements concerning legal status, identity, custody, liquidity, fees, timing, privacy, accessibility and institutional acceptance. These differences can alter the evidence required, the states represented within Logic and the authorities that must be exercised through Governance.

The architecture is therefore best understood as preserving stable responsibilities while allowing contextual mechanisms to vary within governed boundaries. This is more precise than treating technologies or instruments as passive adapters. An adapter may be technically replaceable, but a substantive change in legal meaning, evidentiary semantics, authority or risk may require reconfiguration–or even extension–of the underlying implementation.

This has important implications for cross-domain transfer. The reference implementation's factorised confidence model, emissions attribution, renewable-instrument handling, selective anchoring and conformance procedures remain legitimate implementations of the architecture, but they are not universal forms. Likewise, scholarship eligibility, donor restrictions, account onboarding and platform voting are context-specific manifestations of broader responsibilities. Transferability therefore resides primarily in the architecture's functional and semantic boundaries, not in the replication of any one implementation mechanism.

4.3 From deterministic triggering to governed financial activation

The most consequential architectural refinement concerns the relationship between verified information and financial action. The original conceptual framing implied a relatively directional sequence in which trusted evidence passes through Logic and conditions Value. The empirical findings support that sequence only in qualified form.

Verified information proved necessary but insufficient for financial execution. Across the longitudinal implementation journey, action also depended upon legal identity, account status, compliance, liquidity, route availability, timing, fees, institutional approval, withdrawal capacity and practical usability. These conditions were not peripheral operational details. They determined whether a verified or eligible claim could be acted upon, through which pathway, at what time and under whose authority.

Financial activation is therefore better represented as governed and readiness-dependent rather than automatically triggered. This does not weaken the ambition to connect trusted impact information with financial execution. Instead, it makes that connection institutionally credible. Where financial action has legal, fiduciary, distributional or operational consequences, execution should occur only when both the evidentiary claim and the selected execution pathway satisfy explicit Governance and readiness conditions.

The findings also show that Value is not a passive terminal function. Once a financial mechanism or route is selected, its constraints feed back into the rest of the architecture. A route may require additional identity documentation, introduce timing delays, limit currencies, alter reporting requirements or necessitate a different account structure. Value therefore affects Data requirements, Logic states and Governance arrangements.

The resulting execution core is reciprocal:

Data informs Logic; Logic conditions Value; Value-pathway constraints feed back into Data, Logic and Governance.

This reciprocal relationship is particularly important for digital sustainable finance because programmable execution is often represented as though validated data can be translated directly into automated transactions (Auzepy et al., 2023; Bennett, 2026c; Hoven, In & Puschmann, 2026). The present findings indicate that such a model is defensible only where institutional readiness and authority have already been established and represented. Automation does not remove governance; it embeds prior governance decisions into execution.

4.4 Institutional enablement and lifecycle coordination

Institutional enablement emerged as one of the most important contributions of the longitudinal comparison. Identity, authority, compliance, accounts, participant capability and institution-facing translation were initially easy to treat as external prerequisites to protocol execution. The evidence instead showed that these capabilities are endogenous conditions of operability.

The longitudinal journey could not have progressed to account onboarding, donor-advised-fund transfers, family-office routing or evidence reporting without earlier foundation registration, tax documentation, organisational relationships, payment experience and beneficiary coordination. Institutional readiness accumulated path-dependently. Later implementation possibilities were shaped by capabilities developed through prior episodes rather than created anew at the moment of technical deployment.

This finding challenges a common tendency to separate "the protocol" from the institutional work required to make it usable. A technically complete architecture may remain non-operational when participants lack legitimate authority, appropriate accounts, compliance readiness, shared understanding or the capacity to engage with institutional counterparties. Institutional enablement should therefore be treated as a cross-cutting deployment substrate rather than as an external implementation condition.

Lifecycle coordination emerged in parallel. Neither the reference implementation nor the longitudinal journey followed a simple sequence from design to implementation and closure. Episodes overlapped, reopened and proceeded at different speeds. Financial cycles generated new reporting and funding requirements; evidence production informed subsequent allocation; route constraints triggered substitutions; and individual episodes could close while the wider implementation system remained active.

Operationalisation should therefore be understood as recurrent and multi-strand. This differs from conventional project logic, in which implementation is assumed to culminate in a terminal handover. In impact-linked and development-finance settings,

TABLE 10 Empirical status and architectural role of DLT-Related mechanisms.

DLT-related mechanism	Empirical status	Role in implementation	Architectural dependence on DLT
Selective anchoring of qualifying assertions	Implemented and tested within the bounded EE1 thin slice	Provided independent integrity evidence and potential claim portability after off-chain verification	Optional/context-dependent The underlying requirements for verification, provenance and evidence custody remain without anchoring
Token- and ledger-based participation and governance mechanisms	Observed in longitudinal implementation	Supported participation, proposals, voting, treasury and governance processes	Optional/context-dependent. Governance responsibilities remain necessary, but can be implemented through non-DLT mechanisms
Ledger- or token-mediated disbursement and value transfer	Observed in longitudinal implementation, with maturity varying by episode	Supported or proposed treasury, disbursement and value-transfer pathways	Optional/context-dependent. Financial execution remains subject to institutional authority, compliance, account, liquidity and route readiness regardless of rail
Proposed tokenised incentive or value-flow mechanisms	Proposed or exploratory rather than established as a general implementation requirement	Provided potential mechanisms for incentive and value-flow configuration	Not architecturally required The IFP specifies the relevant value and governance responsibilities rather than a required token mechanism

payment, evidence, review, reporting and renewed mobilisation are often cyclical. Lifecycle coordination must preserve dependencies, state, responsibility and traceability across those cycles.

The two substrates are related. Institutional enablement makes participation and execution possible; lifecycle coordination sustains those capabilities across recurrent and parallel activity. Neither constitutes an additional IFP function because both operate across Data, Logic, Value, Governance, Community and Assessment. Their significance lies in explaining why architecture that appears complete at the functional level may still fail to become institutionally usable.

4.5 Trust, verification and the role of blockchain

The findings support the earlier discussion's central insight that trust in digital sustainable finance is an institutional property rather than a feature supplied by any single technology (Bennett, 2025a; 2025b; 2025c; 2026c; Hoven, In & Puschmann, 2026). However, the completed analysis permits that claim to be stated more precisely.

Trustworthy action depended upon an inspectable lineage connecting source evidence, contextual relationships, governed transformation methods, readiness states, authorised decisions, financial execution, proof and subsequent reporting. Cryptographic anchoring or distributed records may strengthen integrity within this lineage, but they do not establish whether heterogeneous real-world evidence is valid, complete, appropriately attributed or authorised for use.

The reference implementation demonstrated a bounded role for blockchain through selective anchoring of qualifying assertions after off-chain verification. The longitudinal journey documented additional observed and proposed roles for tokens, treasuries, proposals, voting and value-transfer mechanisms at varying levels of implementation maturity. Across these settings, however, blockchain remained one mechanism within a broader institutional architecture. This finding is consistent with research showing that distributed infrastructures retain material governance, control and institutional-readiness requirements (Alsmadi and Al-Smadi, 2026; Benedict and Gill, 2022; Zachariadis, Hileman & Scott, 2019), while extending that literature by locating those requirements within an end-to-end architecture linking off-chain evidence, verification and governed financial execution.

This suggests a responsible boundary for Blockchain for Good applications. Distributed infrastructure can preserve integrity, coordinate participation or execute governed decisions, but it should not be treated as a substitute for evidence quality, legitimate authority, appropriate disclosure, institutional readiness or accountability. Indeed, immutable execution may amplify rather than resolve deficiencies when the underlying evidence, methodology or authority is weak (Bennett, 2025a; 2025b; 2025c; 2026c; Hoven, In & Puschmann, 2026).

To make this boundary explicit, Table 10 distinguishes the DLT-related mechanisms encountered in the empirical record, their implementation status, the architectural purpose they served and whether the underlying IFP responsibility depends upon DLT.

Substituting conventional infrastructure would therefore remove particular ledger-specific mechanisms rather than the underlying architectural responsibilities. Verification, provenance, institutional authority, governance, execution readiness and accountability would remain necessary; their implementation mechanisms would change. DLT is consequently neither constitutive of the IFP nor a prerequisite for its operation, but a configurable mechanism where its integrity, coordination or execution properties create value.

The contribution to blockchain-enabled sustainable finance is therefore not a claim that blockchain produces trust. It is a specification of where blockchain and related digital mechanisms can legitimately operate within a wider evidence-to-action

architecture. Off-chain verification establishes the basis of the claim; Governance authorises the conditions of action; financial and ledger mechanisms support integrity or execution; and reporting preserves accountability after the transaction.

4.6 Execution and adaptation remain distinct capabilities

The original Discussion proposed complementary execution and adaptive-learning cycles. That distinction remains useful but requires material qualification (Bennett, 2026a).

The study provides substantial evidence for the execution pathway connecting Data, Logic, Governance and Value. It also identifies antecedents of institutional adaptation, including community-supplied needs, progress evidence, reporting, integrity review and recurrent redesign. It does not, however, demonstrate a complete Community–Assessment–Governance adaptive cycle.

Community became empirically visible as situated implementation intelligence. Participants supplied local needs, constraints, progress information and usability feedback that affected coordination and allocation. This is more than passive participation, but it is not equivalent to representative governance or community-led protocol change.

Assessment remained less mature. Integrity review, post-test reflection, donor reporting and accountability processes generated learning, but these activities did not amount to ecosystem-purpose Assessment, multi-capital evaluation or systematic recalibration of Governance. Consequently, the adaptive pathway remains a refined architectural proposition supported by antecedents rather than a fully operationalised capability.

This distinction protects the paper from overstating regenerative functionality. A system may support evidence-informed financial execution without yet demonstrating that it can assess broader ecosystem progress or adapt capital allocation in response to multi-capital outcomes. The present architecture supports conditions for governed learning, but mature adaptive finance remains a future research object.

4.7 Implications for digital sustainable finance

The findings suggest that the central infrastructure challenge in digital sustainable finance is not simply producing more non-financial information or creating more programmable financial products. It is constructing a reliable institutional pathway through which evidence becomes actionable without losing provenance, context, authority or accountability (Bennett, 2026b; 2026c; Hoven, In & Puschmann, 2026).

This has several practical implications.

First, evidence systems should be designed around consequential decisions rather than disclosure alone. The required evidentiary standard depends upon what the information is expected to influence. Contextual information may support learning or interpretation, whereas information conditioning payments or allocations requires more explicit provenance, authority, confidence and readiness controls.

Second, financial-system designers should represent blocked, incomplete and pending states explicitly. Real implementation rarely moves cleanly from verification to execution. Systems that conceal uncertainty or force binary decisions risk turning operational incompleteness into false confidence.

Third, institution-facing integration should be treated as a design responsibility. Organisations require claims, proofs and workflow states that are intelligible within their own governance, compliance, assurance and decision processes. Technical interoperability is insufficient when outputs are not institutionally comprehensible or usable (Gregor and Hevner, 2013; Gregor et al., 2020).

Fourth, multiple financial routes may increase resilience where they remain separately governed and traceable. Route substitution can help navigate infrastructure constraints, but it should not obscure changes in cost, authority, custody, timing or risk (Venable et al., 2016).

Finally, implementation claims should remain maturity sensitive. A reference proof of concept can establish architectural ancestry and interface viability without demonstrating production-scale performance, institutional acceptance or realised outcomes. Similarly, recurring reporting and community input can establish adaptive antecedents without proving a mature regenerative financial system.

Taken together, these findings imply different priorities for institutional and policy actors. Financial institutions incorporating sustainability or impact information into lending, investment, payment, allocation or incentive workflows should treat verified information as one input to a governed decision process, with explicit controls over authority, readiness, execution state and subsequent accountability. For policymakers and standards setters, the findings suggest that requirements for trustworthy digital sustainable finance should extend beyond data quality and technical interoperability to include provenance, methodological authority, institutional readiness and the governance of consequential action. DLT or other technical mechanisms may support these requirements, but should not themselves be treated as evidence of institutional legitimacy or decision readiness.

4.8 Contributions

The study makes four related contributions.

Empirically, it provides an episode-level comparative reconstruction linking a bounded reference implementation with a multi-year operationalisation journey. This creates a richer basis for evaluating institutional architecture than either a single technical implementation or an unstructured collection of implementation narratives.

Theoretically and architecturally, the study advances the conceptual IFP into an empirically bounded account of institutional evidence-to-action. It shows that financial activation is not a terminal response to verified information but a reciprocal and governed process in which execution constraints feed back into Data, Logic and Governance; institutional readiness is endogenous to operability; and technical mechanisms can vary while underlying functional responsibilities remain comparatively stable. The resulting contribution shifts attention from whether impact information can be digitised to how evidence, authority,

readiness, execution and accountability must be coordinated for that information to influence consequential financial action.

Methodologically, the staged progression from evidence registration through phenomena, episodes, comparative classifications and Design Knowledge provides a traceable method for reconstructing longitudinal Design Science implementation. It explicitly retains non-equivalence, confidence and unresolved boundaries rather than resolving them through retrospective narrative coherence.

With regard to Design Knowledge, the separation of stable, context-dependent and emergent knowledge clarifies what may transfer across settings, what must remain configurable and what requires further validation. The twelve comparative Design Principles translate those findings into guidance for future implementations while preserving the boundaries of the evidence.

For Blockchain for Good research, these contributions clarify the institutional boundary between off-chain evidence, verification logic, selective ledger or token mechanisms and governed financial action. The resulting architecture treats blockchain as a context-dependent integrity, coordination or execution capability rather than as a substitute for real-world verification.

4.9 Limitations and future research

Several limitations bound the findings. First, the empirical foundations are asymmetric: EE1 was deliberately developed as a bounded reference implementation, whereas the longitudinal corpus emerged through heterogeneous real-world activity. The comparison therefore supports architectural learning rather than claims of equivalent case replication.

Second, the longitudinal corpus is extensive but uneven. Evidence density, recoverability and provenance vary across periods and episodes, and absence of evidence cannot be interpreted as evidence that a function or mechanism did not occur.

Third, the author participated in parts of the implementation programme and subsequently conducted the analytical reconstruction and comparative synthesis. No independent second coding or external audit of the complete analytical classification set was undertaken. Structured reconstruction, explicit decision rules, cross-source corroboration, evidentiary-confidence assessment, preservation of contradictory and non-equivalent evidence, and record-level traceability were used to constrain retrospective and participant-researcher bias, but cannot eliminate interpretive dependence. The findings should therefore be understood as traceable, implementation-derived Design Knowledge rather than independently validated or universally transferable claims. Independent reconstruction or replication by other research teams would provide an important next test of the refined architecture and Design Knowledge.

Fourth, the study evaluates protocol operationalisation rather than development outcomes, organisational performance, adoption or scalability. The findings therefore concern architectural responsibilities and implementation conditions, not comparative effectiveness.

Finally, implementation maturity was asymmetric across functions. In particular, Community and Assessment remain insufficiently developed to confirm the complete adaptive architecture proposed conceptually. Future research should therefore prioritise independent operationalisation, mature Assessment implementations, community-governance mechanisms, and testing of the refined architecture across additional institutional and domain settings.

5 Conclusion

Comparative operationalisation of the Impact-Finance Protocol demonstrates that translating trusted impact information into financial action requires more than reliable data and verification logic. It requires an institutional architecture capable of coordinating authority, financial execution, community participation and evidence across recurrent and context-dependent implementation processes.

The findings demonstrate that the IFP's six functional responsibilities remain analytically coherent, but their empirical maturity is asymmetric. Data and Logic received the strongest support, particularly in relation to provenance, relational verification, explicit execution states and temporal lineage. Value and Governance were materially extended through observed mobilisation, allocation, payment, routing, authority, compliance and accountability processes. Community became visible as a source of situated implementation intelligence, while Assessment remained provisional and strongly context dependent.

The most consequential architectural refinement is that financial execution cannot be understood as a deterministic terminal response to verified information. Financial action proved governed and readiness dependent, with account, compliance, liquidity, timing, route and usability constraints feeding back into Data, Logic and Governance. Institutional enablement and lifecycle coordination therefore emerged as cross-cutting deployment substrates rather than additional protocol functions.

The study contributes a refined implementation-derived architecture, three classes of Design Knowledge and twelve transferable Design Principles for the design and evaluation of impact-linked financial systems. It also establishes a traceable analytical pathway from implementation evidence to phenomena, episodes, comparative classification, architectural refinement and Design Knowledge.

These findings do not demonstrate achieved regenerative outcomes, production-scale performance, mature multi-capital Assessment or a complete adaptive financial system. They instead identify the institutional conditions under which trusted real-world information can support governed financial action while preserving provenance, authority and accountability. In doing so, the study positions the IFP as a bounded but extensible institutional architecture for responsible digital sustainable finance and Blockchain for Good.

Data availability statement

The underlying research dataset contains confidential communications, third-party records, and commercially and personally sensitive information and therefore cannot be made publicly available or released in full. Publication-facing analytical registers and evidence traceability are provided in the

Supplementary Material. Additional information may be made available by the corresponding author on reasonable request, subject to ethical, confidentiality and commercial restrictions. Requests to access the datasets should be directed to Kate Bennett, kate.bennett@student.uts.edu.au.

Ethics statement

This research forms part of a broader practitioner-led doctoral research programme approved by the University of Technology Sydney Human Research Ethics Committee (HREC), approval number ETH24-9253. The programme included human-participant research activities alongside analysis of implementation artefacts generated through routine project activity. Human-participant activities were conducted using the approved participant-information and consent procedures, with informed consent obtained in accordance with those procedures. Where human-participant material forms part of the evidentiary record, it is limited to participants for whom written informed consent had been obtained under the approved UTS HREC procedures. The wider empirical corpus included meeting records, emails, messaging, technical documentation and implementation materials used to reconstruct protocol operationalisation. The analytical focus was the protocol rather than individual participants or organisations. Findings are reported in reconstructed and aggregated form, and no personally identifiable participant data, confidential communications or commercially sensitive information are reproduced.

Author contributions

KB: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review and editing, Project administration.

Funding

The author(s) declared that financial support was received for this work and/or its publication. The author is a PhD student supported by an Australian Government Research Training Program (RTP) Stipend, funded by the Commonwealth Department of Education. She also receives a top-up scholarship from Australia's Digital Finance Cooperative Research Centre. There were no additional funding sources for this research.

Conflict of interest

The author is the founder and Chief Executive Officer of Adaluma Tech, an Australian technology company developing verification infrastructure relevant to the research domain addressed in this paper. Although the protocol examined in this paper informed subsequent commercial activities undertaken by Adaluma Tech, the company did not fund the research and had no role in the design of the study, analysis, interpretation of the findings, or preparation of the manuscript. The research was undertaken as part of the author's doctoral studies at the University of Technology Sydney. Potential researcher bias associated with this practitioner role was mitigated through explicit analytical boundaries, transparent evidence traceability, conservative comparative classification, preservation of non-equivalence, and treatment of the protocol rather than participating organisations as the unit of analysis.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. Generative AI tools (ChatGPT, OpenAI) were used during manuscript preparation to assist with language editing, structural refinement, organisation of draft text and editorial refinement (GPT-5.5, Instant). Generative AI was also used as an assistive tool during reconstruction of the longitudinal implementation record, including organisation of author-supplied evidence, structuring of analytical registers, consistency checking and maintenance of traceability between source records and analytical outputs (GPT-5.6 Sol, High). For these tasks, the tools were provided with research materials supplied by the author, including structured evidence records, selected implementation materials, technical documentation and analytical working files; they did not independently retrieve or supplement the empirical record. Generative AI was not used to generate missing evidence or make final analytical decisions. Outputs were checked against the underlying source record and analytical registers by the author, and unsupported synthesis, omission, reorganisation or distortion was corrected or rejected. All coding decisions, comparative classifications, confidence assessments, interpretation of findings, architectural refinements and conclusions were determined and verified by the author, who accepts full responsibility for the published work.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fbloc.2026.1961818/full#supplementary-material

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