

Relational Currency in Knowledge Circulation: An Investigation of Representation and Value Conversion

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Abstract

How do representations of contributions and commitments acquire practical significance as they circulate among people, institutions, and digital systems? This paper develops an exploratory framework for examining the movement of evidence-bearing representations and their situated conversion into recognition, cooperation, permissions, and access to productive resources. It introduces *relational currency* as a provisional analytical term for context-dependent arrangements of presentation, acceptance, and consequential use, while distinguishing these arrangements from money, universal reputation scores, and transferable trust. The analysis separates documentary integrity, factual accuracy, epistemic warrant, institutional recognition, and material return. Thirteen conditional propositions characterize information loss, contextual nonfungibility, binding access constraints, commitment incentives, commons-capacity renewal, and limits of identifying extraction from observed distributions. Historical-materialist discussion examines control of complementary assets, maintenance labor, and the unequal retention of value generated through collective inquiry. The framework is compared with established accounts of credentials, permissions, reputation, relational contracts, and resource allocation, with an empirical model-comparison strategy proposed to assess any additional explanatory value. Sixteen research hypotheses and associated designs specify possible tests. The work provides a conceptual and formal investigation; it reports neither original participant data nor empirically established effects. Its scope remains open to revision through independent proof review, source-level scrutiny, and empirical comparison.

Keywords: relational currency; circulation of evidence; knowledge commons; provenance; epistemic commitments; contextual convertibility; generative value

1 Introduction

The circulation of knowledge contributions is a problem of representation, situated evaluation, and the distribution of opportunities for subsequent activity. A recorded contribution may be preserved and examined within one organization, condensed into a reference by another, recognized as evidence of competence in a third, and disregarded when a decision about access to resources is made elsewhere. The contribution and its underlying productive history may remain substantially unchanged across these encounters. The instruments by which that history is encountered, the authority assigned to those instruments, and the practical consequences of their recognition can nonetheless vary. The objective of this paper is to investigate this variation through a preliminary account of *relational currency*: context-dependent arrangements through which representations of histories and commitments become admissible, credible, or effective in further social and productive relations. The Introduction establishes the research object, locates it within historical and institutional scholarship, differentiates circulation from justified trust and resource conversion, identifies preliminary questions, and specifies the programme of inquiry. Its method is conceptual and historical, with provisional formal and empirical interfaces; it offers neither an established universal currency nor original measurements of its operation.

1.1 Knowledge Circulation as a Historical and Institutional Problem

The social life of a contribution extends beyond the occasion of its production. Scientific results are cited, checked, reproduced, disputed, translated, taught, archived, licensed, and combined with subsequent work. Technical artifacts can be adapted within organizations whose members have no direct contact with their initial developers. Educational credentials may enable entry to professional processes, and community knowledge may sustain forms of collaboration whose value is not recorded in commercial accounts. These activities involve materially organized pathways of preservation, interpretation, coordination, and allocation. They require infrastructures and labor; they also depend on historically situated conventions governing which representations count as appropriate evidence and which entities are authorized to speak for a contribution.

Scholarship on knowledge commons demonstrates the relevance of governance arrangements to the preservation and reuse of shared intellectual resources. The collection edited by Hess and Ostrom investigates knowledge as a resource sustained through institutional rules, social practices, and technical and legal conditions, rather than as an object whose public availability is automatically secured by digital reproducibility [25]. Digital materials may be replicable at low marginal cost while the capacities to maintain repositories, index holdings, adjudicate claims, or make work intelligible across languages and fields remain scarce and unequally distributed. Distinguishing these costs is especially important where productive outputs multiply more rapidly than their supporting practices of documentation and assessment.

The circulation of a contribution is also conditioned by the relation between creative activity and control over complementary capacities. Teece's analysis of innovation appropriation examines how returns can accrue to owners of complementary assets under particular market and appropriability conditions, even when another party supplies the innovative contribution [46]. This provides a comparative starting point for asking how access to distribution channels, evaluation institutions, legal protection, computing capacity, and organizational legitimacy may influence the consequences of recognized contributions. The present inquiry extends the question to scholarly, civic, educational, artistic, and commons-based settings, where monetary profit may be absent or only one among several relevant consequences. Such an extension is a research proposal, not a direct empirical consequence of firm-level innovation theory.

Economic exchange is embedded in social relations and institutions, as Granovetter's account of embeddedness makes explicit [22]. Bourdieu's differentiation among forms of capital likewise provides a vocabulary for examining the accumulation and conditional conversion of social, cultural, and economic resources [10]. These traditions motivate investigation of connections among reputational standing, access, competence, and material return. They also counsel against treating a conversion as automatic: an endorsement that opens a professional discussion may carry little significance in a legal proceeding; an

outstanding research result may be costly to validate outside its original disciplinary setting. A resource valuable in one relation can become irrelevant, prohibited, or actively contested in another.

These historical analyses leave room for a more specific object. When the same relational history is presented through different certificates, dossiers, references, or knowledge infrastructures, the resulting opportunities may differ even after controlling for features of the history itself. The relevant mediating objects include representations and institutions through which one relation becomes consequential for another. This paper proposes to examine those objects and their conversion conditions directly.

1.2 The Circulating Object: Representations of Relational Histories

A *relational history* is provisionally understood as a structured record, possibly incomplete or contested, of productive events, interactions, contributions, dependencies, and commitments. The record can contain partial orderings, alternative descriptions, revisions, access restrictions, and uncertainty about attribution. A history in this sense is neither a complete account of social reality nor an immutable ledger. It is an epistemically mediated representation whose construction and maintenance belong to the processes under investigation.

An institutional recipient ordinarily encounters a further representation of that history. A document asserting that a person implemented a research procedure, a citation linking a paper to an earlier result, a repository contribution log, an expert reference, or a verifiable credential may each provide a limited account of selected activities and relations. The recipient may examine the underlying materials, rely on an intermediary, or receive only a summary. What circulates among recipients is therefore an *instrument of representation or attestation*, together with its associated conditions of access and interpretation. The historically realized sequence of productive relations is not transferred from one recipient to another as a completed object.

Provenance standards clarify one component of this distinction. The W3C PROV ontology provides a vocabulary for interchanging descriptions of entities, activities, and agents across information systems [48]. The W3C Verifiable Credentials Data Model v2.0 specifies a framework of issuers, holders, and verifiers for claims that may be exchanged with mechanisms protecting against tampering [51]. Both bodies of work are relevant to the engineering of circulation instruments. Yet an authentic record of an assertion can contain an inaccurate assertion, and an appropriately secured credential can express a claim issued under weak substantive standards. Integrity of transmission, identity of issuer, evidentiary adequacy, and warranted confidence remain distinct analytical questions.

The concept of boundary objects offers a further historical comparator. Star and Griesemer study how objects and standardized arrangements support cooperation among actors with different commitments and viewpoints [43]. An evidentiary dossier can similarly preserve some recognizable structure across communities while sustaining different interpretations in each. The proposed model does not assume that every circulating representation is a boundary object in that precise historical sense. The comparison helps identify requirements for cross-context legibility while preserving differences in evidentiary standards.

Table 1 distinguishes several circulation instruments according to the claims they make and the kinds of scrutiny they ordinarily require. The examples are analytical possibilities. They do not assume uniform institutional behavior or confer automatic credibility on an instrument type.

The categories in Table 1 can overlap. A credential may include a reference; a licence may be attached to a repository; an endorsement may circulate with evidentiary attachments. More importantly, instruments are produced by different actors and institutions, often with distinct obligations. The originator of a contribution, the keeper of its records, the issuer of an attestation, the platform selecting its visibility, and the organization deciding on its subsequent use may exercise separate capacities. These distinctions make circulation a relational and institutional process rather than a homogeneous flow of information.

Table 1: Illustrative instruments carrying information about relational histories across contexts

Instrument	Represented relation or claim	Relevant limit of evaluation
Citation or reference	A documented connection between a later work and an earlier contribution	Citation may be inaccurate, conventional, or unrelated to independent assessment of contribution
Contribution record	Recorded participation in tasks or production events	Records may omit tacit labor, dependencies, and disputes about attribution
Credential or attestation	A situated issuer’s statement about status, completion, or competence	Issuer identity and cryptographic integrity do not establish substantive correctness
Evidence bundle	Selected materials offered for evaluation or review	Selection and inaccessible underlying records may restrict contestability
Licence or permission	Rules governing reuse or further dissemination	Permission to reuse does not imply an assessment of epistemic merit
Endorsement or commitment	An actor’s support for a claim or undertaking to perform an action	Reliability depends on scope, incentives, enforceability, and subsequent conduct

1.3 Relational Currency and Situated Acceptance

The term *currency* ordinarily evokes instruments whose acceptance supports exchange, settlement, or the comparison of values. The provisional term *relational currency* draws selectively on that intuition, emphasizing the way an acknowledged history or commitment can enable another interaction. It remains necessary to distinguish this proposed analytical category from money, official credentials, reputation scores, transferable assets, and enforceable rights. A citation is not a payment; a professional introduction is not a unit of account; a verified action is not invariably a debt that another institution is bound to honor. Many worthwhile relations, including confidential testimony, care, civic participation, and vulnerable forms of collaboration, could be damaged by their transformation into freely traded quantities.

The sociological study of monetary differentiation offers an instructive comparison. Zelizer’s analysis of special monies shows that even monetary resources can be socially marked by distinctions concerning their source, allocation, and permissible uses [54]. This work challenges a simple picture in which the meaning of money is exhausted by a uniform exchange function. The present paper takes that result as a reason to examine heterogeneity and context, while recognizing that the proposed relational-currency family includes many items that do not themselves qualify as money. The use of the currency metaphor must remain analytically productive and open to rejection in cases where it obscures obligations, dignity, or incommensurable ends.

Relational currency is therefore introduced as a candidate family of *situated acceptance arrangements*. An item qualifies for investigation when a representation or commitment, recognized by some recipient under identifiable rules, changes the feasible or expected conditions of a subsequent interaction. The change may concern access to a discussion, eligibility for review, a requirement to provide additional evidence, a decision to cooperate, the availability of equipment, the allocation of credit, or material remuneration. This criterion is intentionally broad enough to motivate comparative inquiry; later sections must determine which subfamilies warrant a common formal treatment.

The simplest analytical description requires at least a source arrangement, a representational instrument, a receiving context, a rule or practice of recognition, and a potential consequence. In a given context, the same instrument might confer strong presumptive standing, trigger intensive verification, be excluded by policy, or remain irrelevant. Such heterogeneity is consistent with legitimate specialization. It may also expose unjustified exclusion, discriminatory gatekeeping, or dependency on powerful intermediaries. Classifying a conversion requires independent examination of its evidentiary, causal, and normative properties.

Several candidate properties require particular attention. *Transferability* asks whether an instrument remains acceptable when communicated through another actor. *Decay* concerns the revision of its rele-

vance or credibility after new events, institutional changes, or the lapse of a stated validity period. *Revocability* concerns the withdrawal of a credential, permission, or undertaking under specified rules. *Contestability* describes opportunities to inspect its grounds, introduce contrary evidence, and secure correction. *Joint production* addresses how a circulation instrument depends on several contributors or custodians, potentially rendering exclusive appropriation difficult to justify. *Asymmetric convertibility* concerns unequal prospects of turning recognized contributions into further opportunities, even when the represented work has comparable relevant properties.

One cannot infer these properties from the metaphor alone. The paper must specify the actors, record types, institutions, and evaluation practices for which a property is meaningful. Such specification also protects the distinction between epistemically warranted recognition and strategic compliance. An endorsement offered to preserve employment, for example, may circulate publicly without corresponding to a private judgment about evidentiary merit.

1.4 Circulation, Recognition, and the Conversion of Value

The analytic sequence extends across several distinct events. A productive contribution may leave traces that are selectively recorded. An instrument constructed from those traces may be preserved and presented to a potential recipient. The recipient may or may not encounter the instrument, may assess it favorably or unfavorably, and may possess varying powers to act on that assessment. A resulting decision can concern further cooperation, new productive capacity, institutional acknowledgment, or the distribution of resources. Each transition is conditional, and the observed result may depend on actors who did not participate in the original contribution.

A deliberately schematic expression can keep the relevant conditioning variables visible. For a specified recipient context c , instrument r , evidentiary history h , and institutional state i , let Y denote a defined consequence of interest. Equation 1 expresses the expected consequence conditional on the information and conditions included in an eventual empirical design.

$$\mathcal{V}_c(r \mid h, i) := \mathbb{E}[Y \mid R = r, H = h, I = i, C = c]. \quad (1)$$

Equation 1 provides a *conditional descriptive index*, not an exchange rate and not a causal effect of showing the instrument. The conditioning events can be partially unobservable, Y may contain multiple incomparable dimensions, and observed recipients can select into different contexts. The expression is useful insofar as it forces the inquiry to specify a consequence and a reception setting before claiming that an instrument has gained or lost currency. Sections 4, 6, and 9 examine vector-valued outcomes, intervention contrasts, and limits of scalar commensuration under stated assumptions.

Recognition may enable value creation even when no monetary payment follows. A source used to design a new experiment may increase collective research capacity; an adequately verified contribution might justify shared access to facilities; the disclosure of an error could avert harmful investment; an open educational resource may enable community learning. These outcomes involve heterogeneous values and beneficiaries. Financial return is one possible result, but neither the exclusive meaning of success nor an automatic entitlement arising from public recognition.

A specifically generative perspective on value circulation has already been developed in Ron Eglash's work on generative justice, which examines bottom-up processes, the distribution of value, and the possibility of retaining value closer to the communities and practices that generate it [15]. This perspective is an intellectual inspiration for investigating productive activity through its consequences and circulation. The present paper's proposed distinction between representational instruments, situated epistemic judgments, and contextual conversion mechanisms is an independent analytical proposal. The argument should be evaluated on its own definitions and evidence rather than on the standing of a prior generative-justice tradition.

A historical-materialist treatment directs attention to the social organization of the means of circulation. Repositories, identifiers, search services, publishers, educational systems, translation practices, computational services, and legal-administrative procedures have owners, operators, workers, and funding structures. Their operation conditions whose work can be encountered and how scarce opportunities

are distributed. A recipient may recognize a contribution's value but still be unable to offer compensation. Conversely, an intermediary may obtain substantial returns from licensing, aggregation, or access control without being the sole generator of the underlying knowledge. The empirical question concerns the specific relation among productive participation, resource control, and institutional conversion, including arrangements in which collective production and public stewardship coexist with unequal influence over subsequent circulation.

These mechanisms occur under varying property regimes. Under private ownership, licensing and distribution may reward creators, intermediaries, or owners of complementary assets in different proportions. Under public or commons-based governance, a resource can be available for reuse while practical participation remains restricted by the burdens of maintenance, language, infrastructure, or accreditation. Commercial extraction is therefore a possible mechanism rather than a universal explanation of unequal value return; commons designation likewise provides no automatic proof of equitable participation. The paper investigates how rules, material capacities, and effective remedies change the distribution of recognition and benefit in each setting.

1.5 Epistemic and Normative Constraints on Circulation

The ability of an instrument to circulate does not demonstrate that its claims deserve trust. A reliable endorsement can summarize independent evidence; a repeated endorsement can merely retransmit the same unsupported statement. Verified provenance can establish the origins of a document while leaving questions about its substantive content unresolved. High frequency of citation may reflect usefulness, intellectual dependence, field conventions, publicity, or concentrated institutional influence. A circulation model that collapses these possibilities would misclassify attention and authority as evidence of truth.

The distinction has direct implications for governance. More circulation can improve discoverability and enable criticism, but it can also spread inaccurate attribution, disclose sensitive materials, or amplify status advantages. Selective disclosure can protect confidential participants or conceal misconduct, depending on its rule structure and implementation. The present framework accordingly treats privacy, informed participation, protection against retaliation, reason-giving, and access to independent review as dimensions of circulation design. It does not assign an intrinsic normative sign to high circulation volume.

A commitment deserves treatment distinct from an accomplished contribution. A promise to provide future access, review a dataset, maintain a public record, or credit collaborators can affect present decisions before its fulfillment is observed. The credibility of the undertaking depends on the promisor's capacity, incentives, enforceability, and opportunities for subsequent verification. Later inquiry must therefore distinguish the circulation of *commitments* from the circulation of evidence that those commitments have been discharged. A representation of a promise cannot be treated as proof of performance, and an apparent commitment may be void, coerced, expired, or contested under the relevant institutional rules.

The circulation of an individual's history also raises limits of consent and alienability. An actor might consent to the presentation of a credential for a narrow purpose without permitting unrestricted redistribution of underlying records. A collective contribution may have multiple affected parties with different claims and privacy interests. Where relational evidence is jointly produced, legal ownership of an individual artifact does not settle the ethical question of whose voice should govern onward disclosure. The proposed concept of relational currency must accommodate restricted, nontransferable, or purpose-bound instruments; a demand for universal fungibility would defeat the object of inquiry.

Power conditions the reception of circulation instruments without fully determining their epistemic value. Gatekeepers can decide whether a dossier is displayed, establish admissibility criteria, set conversion thresholds, or control the assets that make a favorable decision effective. Other actors can challenge these decisions, establish alternative evaluative venues, or cooperate through shared infrastructures. The preceding paper's analysis of epistemic power addresses those capacities directly. Paper V is concerned with their consequences at the interfaces where representations and commitments move across contexts,

where different forms of recognition become actionable, and where benefits or burdens are distributed.

1.6 Research Questions and Empirical Interfaces

The proposed research has four closely related questions. First, which features of an instrument preserve relevant information about the underlying history when it moves across audiences, and which forms of compression systematically obscure contribution, uncertainty, or dependence? Second, under which institutional conditions is an instrument accepted, questioned, rejected, or reinterpreted, and how can these changes be separated from shifts in the underlying quality of the represented activity? Third, how do recognized histories and commitments influence access to cooperation, authority, infrastructure, and material resources under different governance arrangements? Fourth, how do those conversions affect subsequent production, participation, and the capacity of affected parties to correct misleading representations?

These questions motivate a research strategy combining archival reconstruction, comparison of circulation infrastructures, controlled presentation studies, and analysis of governance and resource allocation. A hypothetical cross-institutional study might hold the evidence bundle constant while varying the format of its summary or the apparent issuer of a reference. The resulting differences in attention, evidentiary assessment, or willingness to investigate would concern an interface effect under the experiment's assumptions. They would not, without further evidence, establish the true contribution of the represented party or prove an unjustified allocation of resources. A separate study could examine licensing or access-rule changes and their effects on reuse and resource return while accounting for selection, concurrent institutional changes, and unequal opportunities for participation.

Some relevant outcomes cannot be captured by a common numerical scale. An increase in the availability of a publicly useful teaching resource and the loss of a participant's confidentiality are not interchangeable merely because both accompany a particular distribution arrangement. Qualitative inquiry can recover local meanings and obligations; quantitative methods can examine bounded outcomes under defined sampling and measurement assumptions; formal models can make proposed dependencies explicit. Method selection should be proportionate to the question rather than governed by a presumed hierarchy among these modes of inquiry.

A credible test must also consider alternative explanations. Apparent currency may arise from verified competence, reputation cues, institutional privilege, source dependence, strategic endorsements, or the compatibility of local needs with the represented contribution. Conversion into resources may be mediated by formal eligibility rules, social proximity, language, financial capacity, or chance. Disentangling these mechanisms requires observation or intervention at more than one stage of the proposed circulation pathway. The paper's definitions and empirical designs will therefore retain negative evidence, nonuse, correction, revocation, and blocked conversion among outcomes to be measured.

1.7 Contribution and Organization of the Inquiry

The intended contribution is a conceptual architecture connecting the circulation of evidentiary representations to heterogeneous consequences in social and productive relations. Its distinctive object is the *conversion interface*: a situated arrangement through which an instrument of reference, attestation, permission, or commitment can alter opportunities for subsequent interaction and resource access. The relational-currency terminology is valuable only to the extent that it improves the classification, comparison, or empirical study of these interfaces. If the objects prove too heterogeneous for a useful shared category, a plural taxonomy may provide the more adequate result.

The completed manuscript develops the investigation in a defined sequence. Sections 2–3 establish representation and circulation mechanisms, including provenance and contextual uptake. Sections 4–6 analyze situated acceptability, commitments, reliance and access to productive resources. Sections 7–8 examine capacity renewal in knowledge commons and the mechanisms behind unequal value conversion. Section 9 specifies empirical designs and identification limits, while Section 10 synthesizes the conditional results, normative questions and grounds for revising the relational-currency concept.

The relation to the preceding investigations is substantive but limited. Paper I examines mismatches between AI-mediated production and institutional recognition. Paper II analyzes heterogeneous events, evidentiary legibility, and possible occasions for trust formation. Paper III considers cognitive mediation of relational evidence and behavioral reliance. Paper IV examines power over evidentiary pathways and institutional authority. Paper V follows representations and commitments as they are carried across contexts and considers the institutional conditions under which recognition becomes a further productive capacity, a collective benefit, a restricted opportunity, or an extractive return. The proposed sequence is an architecture of research questions, not a claim that social processes unfold in a single fixed historical order.

The ultimate standard of the analysis is its capacity to preserve consequential distinctions while making conditional relationships open to investigation. The presence of a record, the validity of an attestation, the warrant for a judgment, the willingness to cooperate, and a resulting distribution of value may be connected without being identical. A relational account of currency will remain credible only if it admits that these connections can fail, reverse, and be contested within historically specific institutions.

2 Representations and Attestations of Relational Histories

The circulation of relational evidence requires an account of what is represented, how a representation is produced, and which claims a subsequent recipient may reasonably draw from it. This section develops that account for knowledge production and related institutional activities. Its objective is to specify incomplete relational histories, transformations of their evidentiary representations, and attestations made by accountable issuers, while retaining distinctions among a document’s integrity, the factual accuracy of its assertions, the warrant for an inference, and the permissions under which it may circulate. The analysis uses typed records and conditional formal results to make these distinctions examinable. It does not assume that social histories admit exhaustive encoding, that provenance records are self-verifying, or that a technical credential is sufficient to establish epistemic trust.

2.1 Evidence-Bearing Histories and the Limits of Recorded Relations

Research and creative work commonly involve activities distributed among contributors, technical systems, institutional infrastructures, and inherited resources. A publication may depend on earlier conceptual work, experimental labor, software maintenance, equipment access, collective discussion, financial provision, or translation. Some of these relations are documented contemporaneously; others become describable only through later testimony or reconstruction. The evidentiary task is to retain relevant distinctions among a recorded event, an assertion about an event, and a socially or legally consequential interpretation of that assertion.

Definition 2.1 (Evidence-bearing relational history). For a declared inquiry domain d , an evidence-bearing relational history is a structured object $H_d = (V_d, E_d, \text{ty}_d, \preceq_d, \kappa_d, \mathcal{D}_d)$. Here V_d contains represented agents, artifacts, activities, claims, and other admissible entities; E_d consists of typed, possibly disputed relations among these entities; ty_d records the stated types of nodes and relations; $\preceq_d$ is a possibly partial dependency or event-order relation where such ordering is supported; κ_d attaches provenance, confidence, contestation, and evidentiary-status annotations; and $\mathcal{D}_d$ identifies underlying records and their access constraints. The object is an account assembled within a specified evidentiary practice, rather than an exhaustive state of the world.

The definition permits multiple documentary versions of an alleged event, and it permits an unresolved relation to remain unresolved. A witness statement and a repository log may refer to the same activity without being treated as interchangeable observations. The partial relation $\preceq_d$ can record dependencies established by records or procedural requirements; its use neither assumes a total historical ordering nor resolves the ontology of time. Where an order cannot be substantiated, the object may preserve incomparability. Missing evidence should similarly be annotated as missing, inaccessible, destroyed, or

not yet searched only where those descriptions are themselves supported. Silence in one archive ordinarily has a different epistemic significance from an exhaustive search of a documented record-keeping system.

This model is compatible with existing provenance vocabularies but has a deliberately broader scope. The W3C PROV Data Model treats entities, activities, agents, their derivations, and provenance bundles as objects that can be described and exchanged across applications [47]. Its corresponding ontology supplies terms for derivation, attribution, use, and qualified relations [48]. The present construction employs analogous categories as an analytical language for evidentiary histories while allowing uncertainty, attribution disputes, incomplete source coverage, and institutional permissions to remain explicit. W3C conformity is not assumed for hypothetical instances of H_d . Nor does this construction assert that formal compliance would settle disputes concerning what people actually did or deserve.

The domain index d matters. A database audit, an oral-history archive, a scientific project, and a community contribution record will differ in their legitimate unit of description. An overly narrow schema can render maintenance or care invisible, whereas an unrestricted schema can expose private activities unrelated to the evaluative task. Ontological choice is consequently part of the research object: schemas govern which relations can be recorded and subsequently recognized. A researcher evaluating the completeness of H_d must consider not only the available records but also the selection and classification rules that made those records possible.

2.2 Representation, Selection, and Transformation Lineage

An evaluator rarely inspects the complete accessible set $\mathcal{D}_d$. Instead, a recipient encounters a representation r constructed for a communicative purpose. A project dossier may select code changes and correspondence; a short contribution statement may omit the order in which several people solved a problem; an AI-generated summary may paraphrase an earlier record; a reference letter may report an issuer’s evaluation while withholding supporting materials. These acts of selection and transformation create new evidentiary objects with their own provenance.

For a history $h \in \mathcal{H}_d$, purpose p , presentation context c , and stated transformation policy θ , Equation 2 defines a representation procedure and the resulting instrument. The parameter θ includes, where applicable, selection rules, translation criteria, redaction policies, and transformation implementations.

$$r = \text{Rep}_{c,p,\theta}(h), \quad \text{Rep}_{c,p,\theta} : \mathcal{H}_d \longrightarrow \mathcal{R}_{c,p}. \quad (2)$$

The arrow in Equation 2 expresses only a mathematical mapping. Neither technical computability of every transformation nor epistemically adequate reconstruction is implied. Real institutional selection may include human judgment, negotiation, and exceptions not adequately summarized by a stable algorithm. When the procedure is stochastic or mediated by an AI system, the deterministic map is replaced by an explicitly parameterized conditional distribution for representations. The distinction matters if a recipient wishes to infer what was omitted from a generated summary.

A representation can be analyzed through its visible content $b(r)$, stated referents $s(r)$, transform lineage $\ell(r)$, disclosure restrictions $a(r)$, and versions or corrective annotations $v(r)$. These components need not all be public. In particular, the chain by which r was derived may have its own custodians and access conditions. PROV-DM’s notion of a provenance bundle is useful here because a description of provenance can itself be an entity with its own provenance [47]. A signed statement that a summary was produced from a repository snapshot answers a question about that transformation only to the extent that the signature, repository state, and stated link are appropriately verified. It need not answer whether the snapshot covered every relevant contribution.

Transformation lineages also include intermediate representations. If r_1 is an abbreviated account of h and r_2 is a translated or algorithmically summarized account of r_1 , the final object depends on at least two operations. Equation 3 identifies the composition that must be tracked when interpreting r_2 .

$$r_2 = (\text{T}_2 \circ \text{T}_1)(h), \quad r_1 = \text{T}_1(h), \quad r_2 = \text{T}_2(r_1). \quad (3)$$

A translation may preserve the substantive claim under an agreed language pair and evaluation task while losing uncertainty markers or culturally specific qualifications. A compression algorithm can retain principal conclusions while discarding methods and dissent. A citation may accurately identify an earlier output but convey little about the underlying dependencies. Equations 2 and 3 make the chain explicit, although the interpretation of each operation still requires contextual examination. The database-provenance literature’s distinction between where a query result came from and why a particular result appeared provides a narrower computational precedent for examining such derivations [11].

Proposition 2.2 (Non-identifiability after evidentiary compression). *Let $T : \mathcal{H} \rightarrow \mathcal{R}$ be deterministic, and suppose there exist distinct admissible histories $h_1, h_2 \in \mathcal{H}$ such that $T(h_1) = T(h_2) = r$. For an observer who has access only to r and the same auxiliary information in the two cases, no decision rule based on that information can identify with certainty which of h_1 and h_2 generated the representation. Additional distinguishing evidence or model restrictions are required.*

Proof. Under the stipulated information restriction, the observer receives identical inputs when the underlying history is h_1 and when it is h_2 . A deterministic decision rule must therefore return the same answer in both cases and cannot be correct in both; a randomized rule assigns the same distribution of answers to both cases and cannot attain certainty in both. The result follows from the indistinguishability of the available inputs. $\square$

The proposition is a conditional statement about information, not a measured cognitive limitation. It does not imply that all summarization is misleading: a representation can fully preserve information relevant to a particular task even if it discards other information. Nor does it imply that the omitted information would invariably change a trust judgment. To make the preservation requirement task-specific, let $\mathcal{Q}_{c,p}$ be a declared family of evaluative queries and let $q(h)$ denote the answer warranted by a specified complete account under a given analytic convention. Equation 4 defines relative equivalence of two histories for that task.

$$h_1 \sim_{\mathcal{Q}_{c,p}} h_2 \iff q(h_1) = q(h_2) \text{ for each } q \in \mathcal{Q}_{c,p}. \quad (4)$$

A transformation is query-preserving on a declared domain if equality of its outputs implies the equivalence in Equation 4. This implication is an explicit property to test or assume; it cannot be inferred from matching document formats or general claims of semantic fidelity. In settings where query answers remain uncertain or contested, equivalence must instead be indexed by a declared evidentiary procedure and its permissible answer sets. The formal device is most useful when the relevant question is sufficiently specific to be operationalized, such as whether a set of edits was reviewed, a protocol was followed, or a decision was independently appealed.

2.3 The Structure and Scope of Attestations

A representation of an event and an attestation concerning that event have different institutional roles. A contribution log may report who edited a file; a supervisor’s attestation may assert that a particular person carried methodological responsibility; an accredited body may certify that specified training was completed. An attestation involves an issuer undertaking responsibility for a claim under some rule or communicative practice. The authority of the undertaking, its evidentiary basis, and the recipient’s standards of reliance can vary separately.

Definition 2.3 (Situating attestation). An attestation is a declared tuple $a = (\iota, \sigma, \varphi, \omega, \beta, \lambda, \nu, \chi)$ where ι is the purported issuer, σ the subject, φ the asserted content, ω the scope and intended purposes, β the described evidentiary basis, λ the applicable authority or authorization conditions, ν the stated version and validity or status information, and χ the means, if any, for authenticating and contesting the assertion. Missing fields are recorded as unknown, unavailable, or inapplicable according to the instrument’s documented properties.

This definition does not require a cryptographic credential. Signed paper declarations, institutional registers, expert references, and community acknowledgments can serve attesting functions under distinct practices. When digital credentials are used, the W3C Verifiable Credentials Data Model v2.0 supplies an architecture for claims issued, held, and verified through specified mechanisms [51]. Its own verification distinction is crucial: verification of a credential does not by itself establish the truth of its encoded assertions. Data Integrity 1.0 specifies mechanisms for cryptographic authenticity and integrity, with some cryptosuites supporting selective disclosure under defined conditions [50]. Those properties may strengthen evidence concerning who made the attestation and whether parts of it were altered. They do not establish that the issuer investigated competently, had appropriate authority, or observed the subject’s activities directly.

The relationship between an attestation and a truth-apt claim can be expressed as a conjunction of separately examined conditions. Let $I(a)$ denote integrity under a specified technical verification procedure, $J(a, c)$ the issuer’s standing for a declared claim in context c , and $W(\varphi \mid \mathcal{E}, c)$ the sufficiency of available evidence $\mathcal{E}$ for the claim under a declared evaluative standard. Equation 5 defines a *decision predicate* rather than a universal probability of truth.

$$\text{Accept}_c(a; \mathcal{E}) = \mathbf{1}\{I(a) = 1, J(a, c) = 1, W(\varphi \mid \mathcal{E}, c) \in \mathcal{W}_c, \text{Allowed}(a, c) = 1\}. \quad (5)$$

Here $\mathcal{W}_c$ is a declared acceptable range of evidentiary assessments, and Allowed represents applicable disclosure and use conditions. The conjunctive form is only one possible institutional decision architecture; a recipient may use different thresholds, may provisionally accept an unresolved claim, or may refuse even an otherwise valid credential for legitimate contextual reasons. The analytical significance of Equation 5 is that technical integrity, institutional standing, substantive warrant, and permissible use are distinguishable questions. The predicate does not create an obligation to rely, an entitlement to resources, or an equivalence among issuing institutions.

An attestation can contain descriptions of other attestations. Repeated endorsements sometimes provide genuinely new corroboration, such as independently collected observations. At other times they reproduce one originating report. A representation lineage should therefore document common informational ancestors where practicable. Apparent agreement among five certificates issued from a shared unverified database may have a different evidentiary structure from agreement among independent investigations. Determining independence requires investigation of source access, procedures, institutional relationships, and possible coordination; the mere number of records cannot determine it.

2.4 Verification Status, Corrections, and the Persistence of Earlier Decisions

Circulating records acquire new interpretations when defects, restrictions, or disputes are discovered. A digital credential may become suspended or revoked, a contribution record may be corrected, and a prior reference may be withdrawn. These operations differ from erasing an underlying action or reversing decisions already made in reliance on an earlier version. To study the process it is necessary to retain both the instrument’s version history and the conditions under which an observer obtained it.

Status can be represented as an indexed assessment rather than a timeless property. Equation 6 distinguishes the status declared by an issuer and a recipient’s knowledge of that status at an observed encounter e .

$$\text{Status}(a, e) = (\text{DeclaredStatus}(a, e), \text{ObservedStatus}(a, e), \text{EvidenceForStatus}(a, e)). \quad (6)$$

The notation indexes encounters and information states without assuming a uniform physical clock that determines all social processes. An earlier recipient may have used an instrument while its later correction was unavailable. Subsequent inquiry must separately evaluate what information was obtainable at the earlier decision, how corrections were propagated, and what remedies are warranted after discovery. A claim that an old decision was unreasonable cannot follow solely from the fact of a later revision.

The W3C Bitstring Status List v1.0 specification describes a mechanism for conveying status, including suspension and revocation, with privacy and efficiency considerations [49]. Such a standard is

Table 2: Distinct assurances associated with circulating representations and attestations

Assurance	Question it can help answer	Question it cannot settle alone
Document integrity	Has a specified representation changed since the protected version?	Was the original content accurate or complete?
Issuer authentication	Is the assertion attributable to a particular verified issuer or key?	Was the issuer competent, independent, or authorized to decide its merits?
Transformation lineage	Which recorded sources and operations produced this object?	Were unrecorded contributions or relevant alternatives omitted?
Contributor-role statement	Which roles were attributed within a declared scheme?	Who deserves authorship, credit, compensation, or remedy under all norms?
Credential status	Was a declared suspension or revocation visible through a given mechanism?	What a decision maker reasonably knew at an earlier encounter?
Disclosure manifest	Which evidentiary categories and restrictions were declared?	What remains undisclosed, disputed, or unknown beyond the manifest?

relevant where electronic instruments require current-status checks. Its technical status categories do not exhaust the range of social actions that might be appropriate: a claim can remain technically active while its supporting methodology becomes disputed, or a revoked document can remain important historical evidence of an earlier assertion. Accordingly, documentary retention and validity for new reliance should be managed as separable concerns. This separation also helps prevent the silent disappearance of records documenting institutional error.

Version identifiers, replacement links, reasons for correction, accessible appeal decisions, and the identity or office authorized to alter status can facilitate scrutiny. Yet disclosure of these fields may expose confidential complainants or reveal information protected by law or ethical obligations. An institution can therefore face a genuine governance problem concerning the granularity of public reasons, protected review access, and the right of affected parties to know the grounds of an adverse decision. The present model does not assume that making the entire evidentiary record public is the appropriate answer.

2.5 Selective Disclosure and Evidentiary Silence

Selective disclosure can support justified confidentiality, informed participation, and purposeful sharing. It can also create a misleading appearance of completeness if the recipient lacks notice of how the material was selected. The relevant question is not whether every piece of underlying evidence should circulate. It is whether a recipient can identify the scope of the representation, the policy governing withheld information, and the avenues through which disputed omissions can be investigated by suitably authorized reviewers.

For an evidentiary universe $\mathcal{E}$ under a declared scope, let $D_{c,p}(\mathcal{E})$ be the subset disclosed to a recipient and $M_{c,p}$ a disclosure manifest indicating categories of withheld or out-of-scope materials, where revealing such categories is itself permissible. Equation 7 defines the recipient’s informational interface.

$$\text{View}_{c,p}(\mathcal{E}) = (D_{c,p}(\mathcal{E}), M_{c,p}, \text{ReviewRoute}_{c,p}). \quad (7)$$

A manifest can say that a confidential statement was considered without exposing the witness or its contents; in another setting, even this disclosure could create a re-identification risk. Some cryptographic credential constructions permit a holder to reveal selected claims without invalidating the proof for disclosed content, provided the issuer and verifier use compatible mechanisms [50]. Technical selective disclosure does not settle whether the chosen subset is representative, whether metadata can link repeated presentations, or who decides which material is relevant. These remain social, legal, and epistemic questions.

Table 2 distinguishes assurances that may accompany an evidentiary instrument. It also shows why no single technical or institutional signal should be described as proof of comprehensive reliability.

The significance of inaccessible materials also depends on the process generating them. If a known record-keeping procedure should have produced a specific log whenever an event occurred, the absence of that log following an appropriately exhaustive search may bear on the event's probability. If record-keeping was voluntary, inconsistently funded, or inaccessible, the same observed absence can have substantially different implications. Public circulation systems should accordingly distinguish a missing record from negative evidence established under a defensible detection model. Section 9 will address possible designs for identifying those differences without pretending that an unobserved event has been measured.

2.6 Contribution Attribution in Collective Production

Attribution practices also act as representational filters. Project credits, bibliographies, repository contribution statistics, acknowledgments, and institutional evaluations differ in what they are designed to recognize. A record of software commits may systematically underdescribe requirements negotiation, error discovery, user support, intellectual mentorship, or maintenance. A publication byline expresses a particular claim about authorship within an institutional and disciplinary practice; it does not necessarily provide a complete map of the people and infrastructures on which the work depended.

The CRediT taxonomy provides standardized categories for fourteen contributorship roles and is used to make divisions of work more legible within research outputs [36]. Its usefulness is situated. A taxonomy can improve explicit descriptions of activities and still leave disputes over whether a role was performed, the significance of the work, and the relation between contributorship and authorship or remuneration. A proposed relational record may use such categories as metadata without treating the categories as an exhaustive ontology of creation. Revisions to a contribution statement should, when feasible, preserve what was changed, the grounds supplied, and opportunities for an affected person to contest attribution.

Consider a hypothetical collaboration in which one group designs a research instrument and another maintains the shared environment that makes its use possible. A credential that attests to successful implementation may describe a valid achievement but omit infrastructural labor. An evaluation recognizing only the credential's named subject could then convert that partial representation into unequal access to funding or further collaboration. Whether that conversion is objectionable depends on the actual contributions, institutional obligations, and applicable criteria, rather than on the mere presence of differential recognition. The analytical point is that information selection and institutional conversion are distinct mechanisms whose interaction warrants investigation.

Historical-materialist analysis asks which actors possess the means to create, preserve, sign, search, and correct these records. Work that improves legibility can itself be unpaid, precarious, or excluded from established measures of productivity. Rules allocating control over contribution metadata, certification, and appeal procedures may reproduce divisions between recognized intellectual labor and less visible maintenance or supportive activity. The same instruments may also enable collective participants to document contributions across organizational boundaries and contest misattribution. These competing possibilities should be examined within the specific property, governance, and resource arrangements of the institutions concerned.

2.7 Reviewability and Empirical Implications

A circulation instrument can serve its evidentiary function more responsibly when it makes its declared scope intelligible and allows appropriate routes for verification and correction. Practical reviewability comprises more than the existence of a hyperlink to a source. The source may be unavailable, prohibitively costly to retrieve, intelligible only to a narrow group, or governed by access rules that exclude the people most affected by its use. Conversely, a restricted-access independent review may be justified when public inspection would harm vulnerable participants. The relevant design object is a pathway combining source availability, reviewer competence, reasonable participation costs, permission to challenge, and a mechanism for implementing corrections.

Two provisional hypotheses follow from the distinctions developed above. They concern interventions that can be specified without assuming the theory’s empirical truth.

Hypothesis 2.4 (Transformation-lineage visibility). Within a specified evaluative task, making accurate transformation lineage and declared selection scope available to qualified reviewers may improve their detection of attribution or summarization errors, relative to otherwise comparable presentations without those features. The expected effect is conditional on reviewer capacity, usable source access, and the possibility that additional information imposes burdens or misleads.

Hypothesis 2.5 (Attribution and protected correction). In collaborative knowledge settings where contributors have practicable and protected access to correction procedures, errors in publicly circulating contribution statements may be more likely to receive substantiated correction than under procedures limited to nominal appeal rights. Reported correction counts alone are insufficient to identify error prevalence, since better procedures may also increase detection and reporting.

Testing these hypotheses would require a prior definition of the target claims and errors, interventions that do not alter the underlying contribution, and measurement practices sensitive to changes in reporting. A controlled study could vary whether otherwise identical dossiers disclose a verified lineage or its absence, while separately manipulating the quality of the underlying representation. Observers’ error detection, confidence calibration, and decisions to seek additional evidence could be measured as distinct outcomes. A longitudinal comparison of correction procedures might reconstruct which groups could initiate review, the evidentiary burden imposed on them, and the rate of implemented corrections, while accounting for archival missingness and institutional selection. Neither design can identify the entire history of knowledge production from the circulating instruments alone.

The conceptual architecture can be summarized by an evidentiary discipline: the content and transformation of a representation, the accountable issuance of a claim, its technical integrity, the warrant for the claim, and the recipient’s permissible reliance remain separately examinable. The conditional non-identifiability result illustrates the cost of losing that separation when records are compressed. The practical significance is not a demand for maximal documentation or unrestricted transparency. It is the possibility of designing context-appropriate instruments whose scope, limits, and correction pathways remain legible to authorized parties. Section 3 follows these instruments through multi-stage circulation networks and examines how intermediary selection and recipient context change their subsequent uptake.

3 Circulation Pathways and Contextual Uptake

This section examines how a representation of an evidentiary history travels among persons, institutions, archives, digital platforms, and automated systems, and how its significance changes across receiving contexts. The objective is to specify a circulation mechanism without equating distribution with attention, attention with evidentiary acceptance, or acceptance with a subsequent transfer of resources. The analysis combines a typed pathway model with conditional information arguments, institutional interpretation, and preliminary designs for empirical inquiry. It focuses on the passage of representations and related attestations, while reserving a systematic theory of situated convertibility for the following manuscript section. In particular, a completed history does not travel from one observer to another. What circulates is an instrument that preserves, selects, translates, compresses, or asserts something concerning that history.

3.1 Circulation Networks and Situated Instruments

A scholarly contribution may initially become available as an article, repository commit, discussion, or data deposit. A university may subsequently record it in an application file; a funding office may receive an abbreviated project description; a search interface may display a short excerpt; and an AI assistant may generate a synopsis from some retrievable representation. These successive objects may refer to

overlapping events while differing in their contents, provenance access, disclosure permissions, and institutional functions. A later excerpt may be more legible than its source for one audience, less precise for another, and entirely ineligible for a third evaluation. The movement of the instrument therefore has to be distinguished from both the transformation of its content and its recipient-specific interpretation.

The concept of a boundary object is instructive here. Star and Griesemer’s study of cooperation among differently situated contributors describes objects that sustain a recognizable identity while accommodating heterogeneous local uses [43]. Their historical account concerns collaborative scientific work and standardization practices; it does not entail that any copied evidentiary item has an invariant meaning. In the present inquiry, the extent of continuity across settings is a question to be investigated through identifiers, version records, shared referents, and practices of checking, rather than inferred from repeated use of a title or a person’s name. A citation, a machine-generated summary, and an accreditation document may be linked to the same underlying activity while expressing incompatible claims about it.

Let $G = (V, E)$ denote a directed multigraph whose nodes represent institutionally situated processing sites and whose edges represent permitted or attempted transmissions. A node may be a person acting in a professional role, a repository, an archival service, an admissions office, a search or recommendation interface, or a computational agent operating on behalf of another actor. An edge is typed by its channel, declared use, applicable access rule, and transformation capacity. This graph is an analytical representation of a selected circulation setting, not an assertion that all relevant social relations are enumerable. Nodes may be missing from the observed data, actors may hold several roles, and the same interpersonal relation may mediate more than one distinct transaction.

Definition 3.1 (Situated circulation pathway). For a source representation r_0 and a declared receiving purpose p , a circulation pathway is a finite ordered sequence $\pi = (v_0, e_1, v_1, \dots, e_k, v_k)$ with $e_j = (v_{j-1}, v_j) \in E$, accompanied by a sequence of representation states $(r_0, r_1, \dots, r_k)$ and site contexts $(c_0, c_1, \dots, c_k)$. Each transmission may depend on declared disclosure permissions d_j , a transformation operator T_j , an available verification state s_j , and a recording rule for the transition. A pathway is *evidentially reviewable for claim* φ to the extent that authorized reviewers can inspect sufficient lineage and source material to assess how φ was retained, altered, or added along the pathway.

The definition explicitly permits a zero-transmission pathway, in which a representation remains locally accessible without reaching a proposed recipient. It also permits branching and reunion when several individual pathways are considered together. A reviewer may receive a description from a collaborating institution and a translated summary from a digital intermediary. Neither the presence of two routes nor their common reference to the same work establishes that the accounts are informationally independent.

A general stochastic model of local transformation is given by Equation 8, in which z_j denotes the content-bearing state delivered at the j th site and m_j denotes the metadata and auxiliary material made available there:

$$\begin{aligned} K_{e_j}^{c_j, p}(z_j, m_j \mid z_{j-1}, m_{j-1}, d_j, s_j) &= \Pr(Z_j = z_j, M_j = m_j \mid \mathcal{I}_j), \\ \mathcal{I}_j &:= \{Z_{j-1} = z_{j-1}, M_{j-1} = m_{j-1}, \\ &\quad D_j = d_j, S_j = s_j, C_j = c_j, P = p\}. \end{aligned} \tag{8}$$

The kernel can represent literal copying, translation, selective extraction, annotation, ranking, file conversion, and summarization. Equation 8 is a descriptive probability specification and does not imply that any organization deliberately randomizes its operations. Where rule-based transformations are known, the kernel may be concentrated on a deterministic output. Where the intermediary has access to external records, that input should be represented explicitly; otherwise a supposed transformation of z_{j-1} may in fact introduce new evidence.

A useful empirical record would distinguish the original submission, the material accessible to the intermediary, the actual intermediary output, its recipient, and the system or human procedure through which the output was produced. The W3C PROV vocabulary offers a language for describing agents, activities, entities, and derivations [47, 48]. Such a provenance description can help characterize the

Table 3: Stages of circulation and the different inferences supported by their observation.

Stage	Possible observable trace	Inference requiring additional evidence
Transmission	Receipt log; copy or message transfer	Authorized delivery to the intended actor and preservation of source content
Availability	Repository or authorized search index entry	Practical retrievability by a specified recipient
Encounter	Display log, opened file, documented review	Attention to the relevant claim and accompanying caveats
Interpretation	Paraphrase, annotation, coded explanation	Understanding of source qualifications and evidentiary limitations
Admissibility	Registered assessment against stated rules	Substantive warrant or the recipient’s capacity to challenge those rules
Uptake	Citation in a decision, use in a procedure, invitation	Justified reliance, resource conversion, or fair treatment of alternative evidence

chain, but a recorded derivation does not establish the accuracy of the derived statement, the consent of its subject, or the adequacy of the recipient’s later use. Technical provenance and substantive evidentiary appraisal remain separate.

3.2 Delivery, Encounter, Interpretation, and Institutional Uptake

Circulation often appears to be measured by outputs such as file downloads, citation counts, forwarded messages, or appearances in search results. These indicators capture different events. Successful delivery does not show that an intended recipient noticed the material; a displayed result does not establish that it was read; reading does not establish accurate interpretation; and interpretation does not show that a claim met the receiving institution’s decision rules. Table 3 distinguishes stages whose practical observability also varies.

For an intended recipient u , a claim-bearing item r , and an evaluation context c , write L_1 for authorized delivery, L_2 for encounter, L_3 for sufficiently accurate interpretation under a declared test, L_4 for institutional admissibility, and L_5 for some specified act of uptake. If the stages are defined as nested events $L_5 \subseteq L_4 \subseteq L_3 \subseteq L_2 \subseteq L_1$, their joint probability factors by the chain rule as

$$\Pr(L_5 \mid r, u, c) = \Pr(L_1 \mid r, u, c) \prod_{j=2}^5 \Pr(L_j \mid L_{j-1}, r, u, c), \quad (9)$$

where the conditional factors are taken only for conditioning events of positive probability. If any upstream event has zero probability, the nested joint event has zero probability and later conditional terms are left undefined. Equation 9 is a sequential decomposition, *not* an assumption that the stages are statistically independent or that every institutional process must pass through the same stages. In practice, an admissibility decision may rely on automated filters rather than demonstrated comprehension, and informal uptake may precede formal review. The nested construction is therefore a purpose-specific measurement choice that should be declared and tested against the target setting.

A path can increase delivery opportunities while reducing opportunities for checking. An indexed excerpt may substantially improve a document’s discoverability while omitting methods, uncertainty statements, or contribution qualifications that were visible in the complete work. Similarly, a direct professional introduction may reduce the cost of encounter while also introducing reputational cues. Whether these effects support or impair responsible uptake depends on the claim, the recipient, the transformation, and the available review process. More circulation is consequently neither an assurance of more correct recognition nor a measure of fairer resource allocation.

3.3 Transformation Lineage and Conditional Information Loss

Multiple transformations can preserve a recognizable topic while losing evidence relevant to an inference. Consider an initial investigation that provides an estimand, sample frame, uncertainty intervals, and study limitations. A later abstract may contain the estimand and a central estimate. A search preview may retain only a declarative sentence, and a downstream summary may omit the population restriction. A reader of the final summary could correctly infer that someone made the reported claim while lacking sufficient information to assess its applicability. Compression is sometimes essential for accessibility and useful orientation, but the conditions under which it is epistemically adequate are question-specific.

The following proposition describes a narrow information-theoretic limit. It does not treat the social meaning or normative adequacy of a text as a single random variable. Instead, a researcher first specifies a relevant property X of the source record, a fixed recipient context C , and representational states $Y_0, \dots, Y_k$ with a well-defined probability model. For the restricted model, each intermediary processes only the preceding representation plus a transformation mechanism whose randomness is independent of X conditional on that representation and C .

Proposition 3.2 (Information bound for a closed transmission chain). *Suppose the variables have finite or otherwise well-defined mutual information and, conditional on a fixed context $C = c$, they satisfy the Markov chain $X \rightarrow Y_0 \rightarrow Y_1 \rightarrow \dots \rightarrow Y_k$. Then for every $j \in \{1, \dots, k\}$,*

$$I(X; Y_j \mid C = c) \leq I(X; Y_{j-1} \mid C = c). \quad (10)$$

In particular, no recipient restricted to the final representation can recover information about X that is absent from its immediate predecessor merely by applying another transformation governed by the assumed chain.

Proof. The assumed conditional Markov property implies $I(X; Y_j \mid Y_{j-1}, C = c) = 0$. Applying the mutual-information chain rule to (Y_{j-1}, Y_j) in its two orders yields $I(X; Y_{j-1} \mid C = c) = I(X; Y_j \mid C = c) + I(X; Y_{j-1} \mid Y_j, C = c)$. The last term is nonnegative, proving Equation 10. Iteration supplies the bound for every subsequent step. $\square$

The proposition is conditional on the specified property, the specified information state, and the absence of supplementary inputs. An annotator who consults the original data, an independent witness, or a corrected repository version can introduce relevant information, so the Markov condition may fail and the bound does not apply to the enlarged evidence set. A translation may lose distinctions in one dimension while making other distinctions intelligible to its recipient; the proposition does not adjudicate such cross-language or cross-cultural gains in understanding. Nor does it say that the shorter message is necessarily worse for a decision: some compressed messages preserve the information sufficient for a particular decision rule. Its contribution is to locate an explicit limit on claiming that successive rephrasings alone provide increasing *independent evidence* about their unchanged source.

This treatment complements the representation non-identifiability result of Section 2. That earlier result concerns pairs of source histories that a representation procedure cannot distinguish for an evidentiary question. Proposition 3.2 concerns the information available after a succession of transformations under additional probabilistic assumptions. The results concern different analytic objects and should not be collapsed into a claim that every practical circulation chain is lossy. A verbatim, checked, complete transmission may preserve the relevant information. A supplementary inquiry may expand the evidentiary base.

A circulation ledger may therefore record not only a transformation identifier and parent representation but also a declared preservation target: numerical estimates, causal qualifications, speaker identity, contested status, licensing conditions, or collective attribution. When preservation targets are defined in advance, a researcher can evaluate omissions and additions separately from style, readability, or audience preference. The targets themselves may remain contestable, especially where groups disagree on which relational details matter. Recording the disagreement is analytically preferable to assuming that one institution's compression rubric reflects a universal standard of relevance.

3.4 Intermediary Selection and Dependence Between Routes

An intermediary does more than transmit. A publisher selects submissions, a repository enforces meta-data requirements, a search engine chooses what to rank, an organization decides which recommendation letters to include, and an AI retrieval system selects source passages before producing a synthesized response. Some operations are routine and justified by task constraints; some involve delegated authority; others may introduce asymmetrical access or opaque selection. The existence of a selection effect does not, by itself, demonstrate discriminatory intent or epistemic misconduct. Its institutional importance turns on the declared standards, relevant alternatives, affected persons, and mechanisms for correction.

Network diffusion models show how the position of an initial actor and the rules of diffusion can affect the spread of a message. Kempe, Kleinberg, and Tardos studied influence propagation under explicit stochastic network models and associated optimization problems [28]. Such models motivate the representation of reach as process-dependent, while their assumptions about influence transmission should not be mistaken for laws of scholarly recognition. Likewise, the observational study by Bakshy, Messing, and Adamic separated potential exposure, algorithmically presented content, and users' engagement in a particular social-platform setting [4]. Its empirical quantities and political-news context do not automatically transfer to institutional selection or knowledge attribution. The general methodological lesson is narrower: observed uptake may arise through several selection mechanisms, and the distinctions among them matter.

Suppose an intermediary g generates a presentation decision $R_g \in \{0, 1\}$ for a record r . With Q denoting its admissible query or application context and B_g the intermediary's available information, define a descriptive exposure mechanism by

$$\rho_g(r, q, b) = \Pr(R_g = 1 \mid r, Q = q, B_g = b). \quad (11)$$

The mechanism may depend on relevance estimates, available language, format compliance, permissions, prior reputation, user behavior, or institutional policy. Equation 11 cannot identify the causal importance of one factor without a design that addresses confounding and relevant intervention conditions. A comparison among already visible records conditions on a selected population and may misrepresent the distribution of contributions that were never indexed. Audit samples should, where possible and lawful, include eligible but unrepresented items and distinguish platform-side selection from recipients' subsequent choices.

A second issue arises when multiple intermediaries share the same source. Let H denote the proposition under evaluation, Z a common originating statement or dataset, and E_1, E_2 two downstream reports. Under the conditional-independence model $E_1 \perp E_2 \mid (Z, H)$, their joint likelihood is

$$\Pr(E_1, E_2 \mid H) = \sum_z \Pr(Z = z \mid H) \Pr(E_1 \mid Z = z, H) \Pr(E_2 \mid Z = z, H), \quad (12)$$

for discrete Z , with integration in the continuous case. Equation 12 is generally distinct from the product $\Pr(E_1 \mid H) \Pr(E_2 \mid H)$. Thus agreement between two summaries derived from one unverified report cannot be valued in the same way as independently investigated agreement without additional assumptions. If both downstream texts do nothing beyond faithfully relaying a known Z , then conditional on Z they add no new evidence concerning H under the assumed model. Conversely, a relay that independently checks the report or supplies an independently verified correction changes the dependency structure. The task is to investigate source relationships rather than automatically discount every repeated mention or count every citation as a fresh witness.

Multi-hop duplication also interacts with reputational aggregation. A researcher's work might be cited by several review articles, which are themselves copied into institutional profiles and summarized by search assistants. A metric that counts appearances can capture diffusion or public visibility, but it may overstate the number of independent judgments endorsing the work. Conversely, the absence of a discoverable citation may reflect indexing, language, access, or preservation limitations. Neither a high appearance count nor an absence of indexed traces independently settles epistemic merit. The appropriate

evidence depends on the inferential question: tracing a message’s diffusion, evaluating a contribution, or assessing the independent corroboration of a particular claim require different units of analysis.

3.5 Semantic Translation and AI-Mediated Presentation

A receiving context can change the required evidentiary granularity. In one setting a disciplinary specialist may inspect a dataset and replication code; elsewhere an interdisciplinary committee may rely on an executive abstract; another recipient may need translation into a different language, terminology, or access modality. Translation can increase practical accessibility by connecting concepts previously unfamiliar to the recipient. It can also displace the distinctions through which a community describes its own contributions. The assessment of translation should therefore take both source integrity and audience-specific intelligibility seriously, rather than treating fidelity as literal lexical identity or fluency as adequate equivalence.

For a declared evidentiary question q , let $\mathcal{A}_q(r, c)$ be the set of answers to q that a competent review procedure permits given representation r and context c . A transformation T may be examined through the paired conditions of intelligibility and *question-relative retention*:

$$\text{Retain}_{q, c \rightarrow c'}(T, r) = \mathbf{1}\{\mathcal{A}_q(r, c) = \mathcal{A}_q(T(r), c')\}, \quad \text{Access}_{c'}(T(r)) \in [0, 1]. \quad (13)$$

Equation 13 uses an answer-set equality that is intentionally stringent and only meaningful when the evaluative procedures and the question are comparable across contexts. The accessibility term is a declared operational measure, such as success on a comprehension task among a defined population, rather than an intrinsic property of a language. A transformation may improve accessibility while failing answer-set equivalence; such a result should motivate closer examination of the altered assertion, not automatic rejection of all translation. Different epistemic questions may require different retained qualifiers or evidence bundles.

AI-mediated circulation is particularly relevant because a single system may retrieve, rank, paraphrase, synthesize, and present evidence in one interface. These activities are technically and institutionally distinct even when they appear to the user as a single answer. Scholarship on large language models has emphasized the importance of documenting training data, environmental costs, and downstream risks [6]. Research on explainability has also investigated how explanatory displays affect users’ assessment of model outputs [40]. Neither line of work warrants the assumption that every AI-generated summary is inaccurate or that explanation guarantees faithful provenance. What matters for the present analysis is whether recipients can inspect source claims, distinguish quotations from generated inferences, access materially relevant caveats, and correct inaccurate attribution where authorized.

An AI interface can create a distinctive asymmetry between apparent documentary abundance and actual source independence. A synthesis citing multiple webpages may have one originating report behind them; a polished answer may incorporate only a fraction of the retrieved materials; an apparently comprehensive overview may omit work that is poorly indexed in the interface’s supported languages. Conversely, well-designed retrieval and citation interfaces can improve practical access to otherwise dispersed records. These are conditional possibilities requiring evaluation of retrieval logs, source coverage, transformations, and recipient comprehension. No single outcome should be inferred from the presence of AI mediation alone.

In practice, the review of AI-mediated evidence could distinguish four recorded objects: a source corpus and its access permissions; the subset actually retrieved; the excerpts or passages provided to the generation component; and the displayed result, including any references. Tests would evaluate whether the displayed result accurately reports relevant propositions, whether citations support the specific nearby claims, and whether corrections reach affected recipients. For consequential decisions, the recipient should also have a proportionate route to challenge source selection and inferred attribution without requiring unrestricted exposure of confidential evidence. Technical auditability and lawful access can be designed together, although conflicts between them sometimes require institutional adjudication.

3.6 Rights, Material Infrastructure, and Unequal Circulation Capacities

Circulation depends on infrastructures maintained through social labor. Metadata curators establish persistent identifiers and subject classifications; archivists preserve collections; translators make work accessible across linguistic communities; editors review claims; software maintainers keep discovery systems operational; and contributors supply the work that becomes indexed. The material costs of these activities influence what can circulate, where, and for whose benefit. A resource-poor archive with excellent collections may have less visibility than a platform with preferential indexing, without this difference expressing comparative scholarly quality. Similarly, the ability to circulate professionally formatted representations can depend on funds, training, institutional affiliation, access to networks, and translation capacity.

The knowledge-commons literature offers a setting for studying how shared infrastructures, contributors, and governance practices shape access and reuse [25]. This argument should be kept separate from claims that open distribution automatically produces equitable acknowledgment or material return. A freely accessible record can be cited without adequate attribution, reused within a commercially controlled service, or made difficult to correct by institutional gatekeepers. Conversely, protected access may be necessary to respect personal privacy, research subjects, Indigenous governance arrangements, security, or jointly held intellectual commitments. The normative issue concerns the legitimacy and contestability of circulation rules, not a universal demand to maximize exposure.

Nissenbaum’s conception of contextual integrity directs attention to how information practices depend on roles, purposes, and norms of transmission [37]. In a circulation model these restrictions should be represented as admissible transitions, not treated merely as transmission failures. Let $\mathcal{P}(r, c, c', p)$ be a declared policy predicate for sharing representation r from context c to c' for purpose p . The set of authorized circulation edges for that operation is

$$E_{r,p}^{\text{allow}} = \{(u, v) \in E : \mathcal{P}(r, c_u, c_v, p) = 1\}. \quad (14)$$

A prohibited edge may be a legitimate restriction on data use, while an unjustified restriction may be a contestable exercise of authority. The predicate records the governing standard as specified; it does not establish that the standard is lawful, ethically justified, or consistently enforced. Those questions require institutional and normative examination beyond the graph’s formal construction.

Unequal circulation capacity can arise even where disclosure permission is formally uniform. Some participants may afford professional translation, repository deposits, or repeated submission to evaluators; others may have limited access to hardware, stable communication channels, research assistance, or protected time. The resulting differences in visibility can enter subsequent funding and recruitment decisions, reinforcing pre-existing institutional advantages. Conversely, public archives, interoperable identifiers, translation support, and accessible review routes may reduce some burdens. Their effectiveness depends on maintenance commitments, actual adoption, and governance over what counts as a credible representation. The paper’s historical-materialist interpretation treats circulation capacity as produced through relations of labor, access, ownership, and institutional control, rather than as a property that inheres naturally in each contribution.

These distinctions also preserve the boundary between circulating an instrument and converting it into a valuable consequence. A recipient may understand a contribution, judge it well supported, and still lack the resources or authority to offer collaboration. An institution may recognize an item as procedurally eligible while limiting its use to a specific purpose. Neither case warrants describing circulation volume as an exchange rate, income, or transferable entitlement. Section 4 investigates the stronger conditions under which an instrument becomes contextually acceptable for a particular interaction and why that acceptability may remain nonfungible across institutions.

3.7 Operational Measures, Competing Explanations, and Research Tests

Empirical inquiry should take a specified *instrument–pathway–recipient–purpose* combination as its initial observational unit. This avoids assigning a single fixed uptake value to an entire work or person when

Table 4: Illustrative comparisons for the study of pathway-dependent uptake.

Comparison	Targeted outcome	Principal identification concern
Direct source versus shortened relay	Claim comprehension and retained qualifications	Different reading burden, motivation, and evidence volume
Source-linked versus source-opaque summary	Provenance inspection and appropriately calibrated attribution	Source-interface salience and differences in comprehension
High versus low search placement	Encounter probability among eligible items	Endogenous relevance, prior popularity, and interface adaptation
Single origin versus independent corroboration	Diagnostic use of multiple reports	Hidden common sources and differences in true report quality
Accessible review versus no practical appeal	Correction uptake and confidence after challenge	Selection into disputes and uneven reviewer resources

substantially different representations reach different audiences. A prospective study might distribute matched representations through differently documented channels while recording permitted access, actual encounter, comprehension, provenance checking, and reasoned eligibility decisions. Institutional records could provide complementary historical traces, subject to privacy protections and the possibility of incomplete preservation. Table 4 outlines contrasts that can be tested without assuming that every difference is caused by a single intermediary.

A clean randomized design can identify the effect of a deliberately assigned display condition for a defined sample and outcome under standard experimental assumptions. It does not by itself show that a difference arose through the hypothesized cognitive mechanism; attention, perceived institutional authority, readability, and effort can mediate the same treatment. When an experiment requires a reading test, the test itself may change later behavior. A factorial design that separately randomizes source-link visibility and an opportunity to consult the source could better distinguish their effects, provided the participants can choose whether to exercise the opportunity and the estimand is specified accordingly. Historical studies should examine selection into preserved collections, changes in institutional rules, shared platform shocks, and cases where the same contribution circulated by contrasting routes. Unobserved, uncited, or deleted material should be treated as a measurement challenge rather than presumed absent from the underlying practice.

Hypothesis 3.3 (Pathway lineage and attribution accuracy). For specified recipient populations and tasks, representations accompanied by usable transformation lineage and accessible source links will produce higher accuracy in identifying the originating evidentiary basis and relevant qualifications than otherwise matched source-opaque representations, conditional on actual use of the links and on the design’s comprehension and effort constraints. The effect may be absent or reversed when information overload, interface confusion, or restricted access dominates the benefit of provenance visibility.

Hypothesis 3.4 (Context-dependent uptake under matched content). Holding substantive claim content and declared source evidence constant to the extent feasible, institutionally distinct admissibility rules and recipient purposes will be associated with different uptake decisions. A stronger causal version predicts changes when decision rules are exogenously assigned or defensibly varied, after accounting for recipient selection, compliance, and the legitimacy of the receiving context. A null result in settings where the rules genuinely differ would constrain the proposed importance of contextual uptake.

These hypotheses are provisional and do not report measured effects. A useful research programme would also seek counterexamples: cases where compressed representations improve judgment by removing irrelevant detail; where metadata-rich interfaces increase mistaken confidence; where translation changes terminology without changing the defensible answer set; and where different institutions converge on the same uptake outcome despite divergent formal rubrics. Such cases can reveal whether the framework’s distinctions provide empirical discrimination or simply rename familiar stages of communication. Source verification for any application should further separate bibliographic existence, accurate interpretation of the cited text, and empirical support for a proposed mechanism.

The section establishes a limited but necessary basis for the remainder of Paper V. Representations move through controlled, resource-dependent channels; their transformations can alter available evidence; and their uptake depends on both receiving practices and observable pathways. Proposition 3.2 establishes an information limit only for a defined closed Markov chain. Equations 9, 11, and 14 distinguish encounter processes, intermediary selection, and authorization rather than resolving their empirical or ethical justification. A subsequent theory of relational currency can use these mechanisms to specify the conditions under which representations acquire limited, situated capacities to support decisions and interactions, while allowing many circulated claims to remain disputed, ineligible, or without material return.

4 Relational Currency and Situated Convertibility

Relational currency names a provisional analytical family of arrangements through which evidence-bearing representations acquire *conditional usability* in specified interactions. The immediate task is to distinguish an instrument’s documentary properties from its eligibility for an action, to characterize the plurality of consequences that eligibility might enable, and to identify the institutional conditions under which such capacities can be recognized, transferred, revised, or withheld. The analysis proceeds through context-indexed acceptance, set-valued conversion, heterogeneous valuation, bounded portability, temporal and institutional revision, and empirical tests. Its formal constructions describe possible relations among rules and instruments; they are not estimates of economic value or evidence that a new circulating medium has arisen.

A citation may allow a source to be located; a credential may establish that a specified issuer made a statement; a license may authorize a limited use; an endorsement may prompt a reviewer to inspect a claim. These effects occur under different rules. A credential issued for research training may satisfy one eligibility condition for an educational programme while contributing little to a decision about the ownership of intellectual work. A verifiable signature may support attribution to the issuer without independently establishing the truth of the issuer’s assertions. A publicly reusable source may be practically inaccessible to a person unable to afford translation or specialist software. Calling each item *currency* is defensible only when the metaphor names the contextual capacity to mediate a specified interaction, rather than implying that people, reputations, or evidentiary warrants form an exchangeable stock.

This distinction draws on, while remaining independent from, scholarship on socially differentiated money, plural forms of capital, and institutionalized assessment. Zelizer’s analysis of special monies challenges a socially unmarked conception of monetary use [54]; Bourdieu’s discussion of capital forms provides a comparator for the conditions under which social recognition may be convertible into advantages [10]. Espeland and Stevens analyze the social and political work of constructing common metrics [16], while Anderson emphasizes the ethical significance of valuing different goods in different ways [1]. The present section uses these arguments as conceptual resources, without identifying relational currency with money, capital, personal worth, or a proposed universal measure of contribution.

4.1 Acceptance Rules and the Usability of Evidentiary Instruments

The relevant observational unit is an instrument presented for an action in a receiving context. Let $\mathcal{I}$ denote a set of representations, attestations, permissions, endorsements, and other recorded instruments. An element $i \in \mathcal{I}$ includes a representational content and, where available, its provenance, issuer, scope, transformations, licensing conditions, and status history. These components are incomplete or disputed in some cases. A receiving context $c \in \mathcal{C}$ identifies an evaluating institution or community, an intended purpose, the operative rules, the available information, and the resources required to exercise those rules. Equation 15 records a deliberately typed abstraction.

$$c = (j, p, \rho, \mathcal{E}, \mathcal{R}), \quad i = (r, \pi, \iota, \ell, \sigma), \quad (15)$$

Here j indicates the institutional or interpersonal setting, p the relevant purpose, ρ a versioned family of institutional rules, $\mathcal{E}$ the evidentiary information available to the decision-maker, and $\mathcal{R}$ the feasible resources for verification and action. The instrument comprises represented content r , provenance π , issuer or attributed agent ι , rights and use conditions ℓ , and a status record σ . The notation is a bookkeeping device: a distributed record may have multiple issuers and rights-holders, and its interpretation may be contested. Nothing in the tuple warrants the contents of a claim or assigns the instrument a price.

An institution may set rules for different actions rather than declaring an instrument generally valid or invalid. Let $a \in \mathcal{A}_c$ be an action, such as making a citation admissible, granting archive access, permitting reuse, inviting a candidate to a review stage, or opening a correction proceeding. Define $A_c(i, a)$ as a *rule-relative admissibility indicator*, as specified in Equation 16.

$$A_c(i, a) = \mathbf{1}\{\rho_c(i, a, \mathcal{E}_c) = \text{eligible}\} \in \{0, 1\}. \quad (16)$$

The displayed predicate presumes that a rule and its informational inputs are sufficiently specified to yield a determinate result. Where interpretation is contested, a more adequate representation is a set of defensible outcomes or an interval of uncertainty rather than an invented crisp decision. The indicator concerns recorded eligibility according to ρ_c ; an ethically objectionable rule may be applied consistently, and a legitimate rule may be applied incorrectly. Legality, justice, and epistemic accuracy require separate inquiry. In particular, $A_c(i, a) = 1$ says neither that the claim is true nor that a reviewer believes it.

Eligibility does not imply practical availability. An action may demand fees, protected time, translation, technical equipment, administrative standing, or disclosure of information that the participant cannot lawfully or safely provide. Let $F_c(u, a)$ indicate that person or collective u can feasibly exercise action a in context c ; let $P_c(i, u, a)$ indicate that the contemplated use is permitted under the instrument's relevant rights and privacy constraints. Equation 17 defines one narrow form of usable acceptance.

$$U_c(i, u, a) = A_c(i, a) F_c(u, a) P_c(i, u, a). \quad (17)$$

The binary product is an idealization of three necessary gates, not a comprehensive theory of participation. Where assistance, negotiation, waiver, or appeal may change one of the inputs, U_c must be recomputed under the revised conditions. The model specifically separates institutional eligibility from actual ability to exercise it; treating these as interchangeable would obscure the labor and material conditions described in Paper IV.

A proposed *relational-currency capacity* can now be stated with a precise, bounded meaning. It is the situated ability of an instrument to enter at least one authorized and feasible pathway for an identified interaction or outcome. The capacity belongs to a relation between an instrument, an actor, a context, and an available action; it is not an intrinsic asset possessed independently of others' rules. Table 5 contrasts examples whose mechanisms could otherwise be conflated.

The final row is included as a comparator. Monetary payment instruments typically operate with institutionalized units of account and settlement rules; a research citation ordinarily does not. The concept of relational currency therefore captures a *family resemblance in mediated access* rather than a demonstrated equivalence of instruments. Its explanatory value will depend on whether it distinguishes actual mechanisms better than the less metaphorical descriptions of eligibility, attestation, authorization, and reputation.

4.2 Conversion Pathways and Heterogeneous Consequences

A representation can be admissible for an action without producing the desired outcome. A university can accept a verified qualification as part of an application yet reject that application after further review. A community repository can permit reuse while imposing conditions that protect contributors from unauthorized commercialization. A professional group can consider a testimonial statement credible yet decline to make a resource commitment for budgetary reasons. Conversion requires an additional relation

Table 5: Distinct functions of instruments sometimes treated as relational currency.

Instrument	Possible context-bound function	What possession alone does not establish
Source citation or reference	Enables retrieval, examination, attribution, or procedural citation	Factual accuracy, independent corroboration, or practical access
Verifiable credential	Supports issuer-linked attestations and status checking under adopted standards	Truth of a substantive claim, ongoing competence, or universal acceptance
Recommendation or endorsement	Supplies testimony or grounds for opening further evaluation	Independent evidence, merit, or enforceable entitlement
License or consent record	Specifies authorized reuse, constraints, and sometimes permissions for disclosure	Ownership of underlying rights, absence of competing claims, or obligation to accept
Collective contribution record	Records specified roles or participation in documented activity	A complete account of labor, distributive fairness, or individualized value shares
Monetary payment instrument	May settle denominated obligations where accepted and legally operative	Epistemic warrant, consent to unrelated uses, or deserved recognition

between eligible action and possible consequences; the term therefore should not designate automatic remuneration or an unrestricted exchange right.

Let $\mathcal{O}_c$ contain contextually meaningful consequences, such as eligibility for a review process, permission to reuse a method, access to a facility, an invitation to cooperate, partial attribution correction, a remunerated task, or increased public availability of knowledge. The *feasible conversion correspondence* in Equation 18 includes an outcome only where some feasible and authorized action can support it under a specified institutional transition rule T_c . The symbol $\rightsquigarrow_{T_c}$ expresses procedural possibility, not deterministic causation.

$$\mathcal{K}_c(i, u) = \{o \in \mathcal{O}_c : \exists a \in \mathcal{A}_c, U_c(i, u, a) = 1 \wedge a \rightsquigarrow_{T_c} o\}. \quad (18)$$

The correspondence may be empty, contain several mutually exclusive outcomes, or vary under alternative lawful decisions. Its use requires an independently specified map of institutional procedures and resources. Observing an outcome after a credential is presented does not identify whether that credential caused the outcome; prior competence, political influence, complementary assets, selection into eligibility, and institutional capacity may explain both. Section 9 will specify research designs capable of distinguishing some of these pathways.

Consequences are heterogeneous even when they can be compared under an explicit purpose. For an instrument i and context c , define a provisional vector of assessed consequences in Equation 19.

$$\mathbf{v}_c(i) = (v_c^{\text{evid}}(i), v_c^{\text{coop}}(i), v_c^{\text{mat}}(i), v_c^{\text{commons}}(i), v_c^{\text{rights}}(i)). \quad (19)$$

The entries index evidentiary usefulness, cooperative opportunity, material return, commons-related capacity, and rights-related effects. Their scales can differ, some components may be qualitative, and some may be undefined. The notation does not assume measurement equivalence between dimensions, or that a positive material benefit can compensate for a rights violation. It makes visible the limits of reducing a complex outcome to a single reward metric. An accessible dataset, for example, can support collective inquiry without yielding comparable income for its original contributors; a payment can be made while attribution remains distorted.

For contexts with defensible componentwise measurement, a *partial comparison* can be constructed from a declared subset D_c of dimensions. Equation 20 specifies only the corresponding weak dominance relation.

$$i \succeq_{c, D_c} i' \iff v_{c, k}(i) \geq v_{c, k}(i') \text{ for every comparable } k \in D_c. \quad (20)$$

The relation can leave two instruments incomparable: one may support broader citation access and the other offer stronger privacy protection. Even where every component is numerical, selecting D_c , orienting the direction of preference, and determining acceptable tradeoffs remain normative and institutional

choices. A Pareto-style relation does not overcome disagreement about which dimensions matter. Anderson’s pluralist account of valuation provides a relevant ethical challenge to treating all goods as reducible to a common measure [1]. Stark’s research on competing organizational logics of worth likewise cautions against presuming that institutional actors evaluate work through a single settled ordering [44].

The corresponding historical-materialist question concerns who acquires the authority to specify D_c , to collect the data from which its components are estimated, and to define the thresholds used in consequential decisions. A ranking system may reduce costly search and support public scrutiny, while also concentrating attention on dimensions that incumbent institutions can easily count. Espeland and Stevens characterize commensuration as a social process with political stakes [16]. This paper investigates an analogous issue in evidence circulation without assuming that any particular ranking is inherently oppressive or that all comparisons should be prohibited. The salient questions include whether criteria are publicly contestable, whether quality signals reflect the assessed practice, and whether actors can offer reasons for departures from a standardized score.

4.3 Contextual Ranking Reversals and Limits of a Common Scale

The absence of a universal scalar valuation can be made precise for one restricted claim. A single context-independent score might represent differences in popularity or documentation volume, but it cannot *exactly preserve opposing strict rankings* assigned to the same two items by two contexts. This elementary impossibility is helpful because the metaphor of a general relational currency sometimes invites stronger assumptions than the empirical practices justify.

Proposition 4.1 (Limits of a context-independent strict ordering). *Let $i_1, i_2 \in \mathcal{I}$ and $c_1, c_2 \in \mathcal{C}$. Suppose a criterion in c_1 strictly ranks i_1 above i_2 , while a criterion in c_2 strictly ranks i_2 above i_1 . There exists no scalar map $s : \mathcal{I} \rightarrow \mathbb{R}$ that represents both strict rankings by the same direction of numerical comparison, with $s(i_1) > s(i_2)$ if and only if the relevant context strictly ranks i_1 above i_2 .*

Proof. Exact representation of the first strict ranking requires $s(i_1) > s(i_2)$. Exact representation of the second requires $s(i_2) > s(i_1)$. Both inequalities cannot hold in the ordinary ordering of real numbers. Hence a single context-independent scalar cannot reproduce both strict rankings under the stated representation rule. $\square$

The proposition establishes a logical constraint on a *particular representation demand*. It does not prohibit numerical appraisal within an institution, context-specific functions s_c , partial common metrics, negotiated conversion rates, or a scoring system that openly sacrifices one institution’s ordering. It also does not establish that actual institutions exhibit reversals; this is an empirical question. For example, one institution might rank an openly licensed public dataset higher for a commons-oriented programme, while another might rank a tightly controlled, clinically validated tool higher for a task requiring controlled access. Either evaluation could be defensible given its purpose and verified evidence. The existence of alternative legitimate purposes makes the scope of any proposed common score a subject for explanation, not an automatic defect.

Research on markets for singularities provides a useful analogy here. Karpik analyzes products and services whose quality is multidimensional and uncertain and whose valuation relies upon distinctive judgment devices [27]. Relational evidentiary instruments share some of those assessment difficulties but occupy different normative spaces: a professional credential or consent declaration is neither a consumer good nor simply a product whose worth is revealed through a market. The analogy is most useful for studying why labels, rankings, peer endorsements, and procedural certification become influential under uncertainty, and why their influence remains dependent on who controls the evaluating apparatus.

A contextual ranking reversal also differs from a contradiction about factual truth. One institution may accept an instrument for verifying research participation and another reject it for certifying technical skill because their evidentiary questions differ. A genuine factual conflict arises when two warranted claims about the same proposition under the same relevant conditions cannot be jointly maintained. The formal separation between purpose-dependent acceptance and proposition-level warrant is essential if

the proposed theory is to avoid treating institutional disagreement as mere relativism. In particular, the fact that an item has high acceptance in several contexts does not make its unsupported claim true, and a well-supported claim can be refused for a specific use on defensible procedural grounds.

4.4 Transfer, Use Restrictions, and Institutional Status Changes

Portability concerns whether an instrument accepted in one context can be meaningfully used in another. Such movement can involve copying a record, translating its contents, presenting an issuer attestation, requesting recognition of a prior decision, or transferring a legally specified right. These are distinct processes with different constraints. In particular, the transmission of a source file does not necessarily transfer intellectual-property rights, a certificate’s recognized scope, consent for a new audience, or an institution’s obligation to act upon it. Standards for provenance and verifiable credentials support the recording and technical checking of selected features of these processes, while leaving substantive truth and institutional entitlement to additional rules [48, 51].

A directed *permitted portability* relation can be specified for an instrument, a source context, a destination context, a recipient, and a proposed use. Equation 21 records the need for authorization at both the originating and receiving ends.

$$M(i; c \rightarrow c', u, a) = P_c(i, u, a) P_{c'}(i, u, a) A_{c'}(i, a). \quad (21)$$

This model is intentionally asymmetric: $M(i; c \rightarrow c', u, a)$ need not equal $M(i; c' \rightarrow c, u, a)$. Reuse permission in one environment may not imply admissibility elsewhere, and a destination’s willingness to consider an instrument may not create permission to disclose it. The first factor is a shorthand for the originating context’s governing conditions, rather than a claim that one jurisdiction can unilaterally decide all relevant rights. Real cases may require joint authorization from multiple right-holders, protection of third parties, and further constraints imposed by law or professional duties.

Even permitted transfers can be conditional on purpose and may require transformations that alter the instrument’s meaning. A multilingual abstract might increase accessibility while omitting methodological reservations that affect a reviewer’s confidence; a redacted recommendation might protect the issuer but prevent independent checking. Section 3’s information-processing constraints describe what cannot be recovered from a closed transformation chain without additional information. They do not dictate that every form of compression is harmful. A carefully constructed translation can improve comprehension in a particular setting, and privacy-conscious disclosures can be preferable to unlimited copying when a participant faces retaliation or secondary misuse.

The validity of a representation can also evolve through correction, expiration, revocation, replacement, changing institutional standards, or new evidentiary findings. Let λ index the *version of the relevant record-and-rule configuration*, without identifying it with a metaphysically privileged present or a universal chronological ordering. Equation 22 expresses context-relative usability following a change in recorded status or evaluation rules.

$$U_{c,\lambda}(i, u, a) = A_{c,\lambda}(i, a) F_{c,\lambda}(u, a) P_{c,\lambda}(i, u, a). \quad (22)$$

A record’s technical validity at one version can coexist with a later finding that its contents were mistaken. Withdrawal of a credential can alter an institution’s permission to rely upon it, yet a past decision made while it was accepted may continue to shape a person’s opportunities. The resulting questions about correction, remedy, and reliance losses require institutional histories rather than only a status flag. The W3C specification for credential status illustrates one technical component of this broader issue; its mechanisms cannot establish the normative adequacy of revocation procedures [49].

The governance of portability is therefore also a question of power over standards. Large institutions may require small organizations to adopt their metadata formats, preferred languages, and credentialing conventions. Such conventions can foster interoperability while placing the labor of conformity on those least able to fund it. Open technical standards can reduce some barriers but need sustained infrastructure, public documentation, accessible dispute procedures, and attention to whose local knowledge is rendered

invisible by classification. In this setting, a right to inspect or correct provenance may be more practically valuable than permission to generate another unreviewed score.

4.5 Binding Eligibility Constraints and Conversion Bottlenecks

A high credibility rating can coexist with nonacceptance for a particular action. Consider a research assistant whose work is technically sound but whose documentary record does not qualify under a grant's specified applicant category. More favorable peer testimony might increase confidence in the work without changing that exclusion. Conversely, a credential might open procedural eligibility while its holder's contribution remains under substantive review. A formal model should distinguish such cases before explaining why conversion fails.

Consider a restricted setting in which the action requires independent necessary conditions for eligibility, lawful use, and feasible participation. Equation 23 represents the event of reaching the associated decision stage as a conjunction rather than as an additive total of interchangeable merits.

$$G_c(i, u, a) = \mathbf{1}\{E_c(i, a)\} \mathbf{1}\{L_c(i, u, a)\} \mathbf{1}\{R_c(u, a)\}. \quad (23)$$

Here E_c is a necessary eligibility condition, L_c a necessary lawful-use condition, and R_c the availability of minimum resources and standing. The correspondence to Equation 17 is conceptual, while Equation 23 makes their independently binding roles explicit. It is not a claim that all institutions actually use noncompensatory rules; some permit discretionary exceptions, alternative pathways, or negotiated support.

Proposition 4.2 (Binding-gate limit on improvements in a separate merit score). *Suppose the decision-stage gate is exactly G_c in Equation 23, and one of its necessary indicators is zero under the operative rules. Suppose further that a change in an auxiliary credibility or merit score q leaves the values of all three necessary indicators fixed. Then changing q alone cannot change G_c from zero to one.*

Proof. At least one multiplicative factor remains zero by assumption. The product therefore remains zero independently of the value of q . $\square$

The proposition is elementary, and its significance is diagnostic. It identifies the precise assumption under which another endorsement or better score cannot repair a separate access barrier. If an institution's rules link the credibility score to eligibility, if additional evidence can satisfy a missing requirement, or if appeals modify the rule, the proposition's fixed-gate premise no longer applies. The appropriate intervention would then target the relevant gate, not merely accumulate further nominal recognition. Failure of conversion under such a model should not automatically be attributed to discrimination: some requirements protect patients, participants, confidentiality, or the integrity of scarce resources. A normative assessment asks whether each requirement is justified for its purpose, consistently administered, proportionate in burden, and practically contestable.

Material complementarities produce a related bottleneck even without formal exclusion. Citations may generate interest in a method whose implementation depends on a closed facility; favorable reviews may produce visibility without time or funding to develop the work; and public contributions may supply a commercial actor with useful inputs without guaranteeing a return to contributors. Teece's analysis of profiting from innovation offers a relevant comparison concerning complementary assets and the distribution of returns [46]. The extension to public knowledge production is an additional hypothesis about institutional histories, control over infrastructure, and contracting, rather than a mechanical transfer from firm strategy to academic or commons governance.

The distinction between *recognition* and *conversion* therefore has at least three layers. An observer may form an evidential judgment; an institution may designate an instrument eligible for a decision; and material or collective consequences may depend on resource-bearing acts beyond either judgment. The layers can reinforce one another through repeated institutional practice, but their association does not identify an inevitable sequence or a guaranteed return. In some cases, nonconversion is normatively

appropriate because evidence is weak or a use would violate protected rights. In others, the barrier can expose asymmetric dependence, excessive documentary labor, or an unjustified veto over access to a collectively produced resource.

4.6 The Explanatory Boundary of Relational Currency

An integrative term is not made theoretically distinctive merely by collecting phenomena under a shared name. Authentication, testimonial credibility, legal authorization, reputation, contractual obligation, and resource allocation already have substantial literatures and distinct procedures. The expression *relational currency* would be dispensable if it only renamed these mechanisms. Its strongest defensible role is narrower: it may organize an investigation of how an evidence-bearing instrument passes through *several different* institutional rules, where one act of acceptance changes the possibilities for another, while preserving the distinctions among epistemic warrant, authorized conduct, effective access, and the renewal of productive capacity. This is a proposed level of analysis, not the discovery of a newly existing unit of account.

This distinction creates three possible statuses for the concept. First, it may be an *editorial umbrella*: a convenient shorthand for multiple established objects without independent explanatory yield. Second, it may be a *structural representation*: a comparatively economical way to record interfaces among provenance, status, rights, uptake, and resource pathways, even though those interfaces are built entirely from already recognized mechanisms. Third, it might become an *empirically useful model family* if precisely specified cross-context relations support better calibrated, reproducible explanations or transport predictions than suitable mechanism-specific alternatives. None of these statuses entails a moral claim that the instrument should be traded, accumulated, monetized, or made transferable. The word *currency* must not conceal the fact that some permissions and collective rights are inalienable or purpose-bound.

A candidate observational register should identify at least an instrument, its represented proposition or undertaking, its provenance lineage, its applicable rights and status, a receiving rule and purpose, a feasible action, and a consequence measured separately from eligibility. Such a register can trace *conditional conversion* without treating an individual’s worth as a tradable asset. Importantly, the representation does not add information that is absent from the component records. If its cross-context descriptors are deterministic functions of complete constituent data, those descriptors cannot, by themselves, create additional predictive information under an unrestricted predictor that already uses all constituent data. What the integrative model may supply is a warranted choice of structure, interpretable constraints, more effective data collection, or economical generalization to newly specified circumstances. These advantages require demonstration, not terminological assertion.

For a disciplined comparison, let B comprise prespecified constituent-mechanism measurements (credential validity, testimonial source, permission scope, commitment terms, evaluative rules, and available resources), let C describe the receiving contexts and their changes, and let Y be a separately recorded outcome such as correctly classified admissibility, implemented access, or sustained maintenance capacity. Let $\mathcal{F}_0$ be a sufficiently serious family of models using the constituent mechanisms, including plausible interactions, and let $\mathcal{F}_1$ be a declared relational-interface family specifying cross-context transitions and gate dependencies. For a preregistered loss ℓ , the empirical comparison in Equation 24 is to be estimated on genuinely held-out contexts or institutional changes, not on the same observations used to select the specification.

$$\hat{\Delta}_{\text{held-out}} = \hat{\mathcal{R}}_{\text{test}}(\hat{f}_0; B, C, Y) - \hat{\mathcal{R}}_{\text{test}}(\hat{f}_1; B, C, Y), \quad \hat{f}_j \in \mathcal{F}_j. \quad (24)$$

Here $\hat{\mathcal{R}}_{\text{test}}$ is the same outcome-specific test loss evaluated on the same held-out cases. The two models must receive comparable access to pre-decision information, with complexity, tuning effort, and missing-data treatment reported transparently. A positive empirical difference favors the specified interface model under that design; it does not prove ontological novelty or identify the causal mechanism. A zero or negative difference is evidence against its claimed predictive advantage there. A baseline deliberately denied crucial interactions would be a weak comparison, and postdecision variables must

Table 6: Conditions for retaining or replacing the relational-currency vocabulary.

Research object	Preferred narrower account when adequate	Potential task for an integrated account
Issuer and status of a claim	Credential verification and provenance lineage	Track how corrections and issuer scope alter use across different receiving rules
Permission for a proposed act	License, consent, authorization, or eligibility rule	Trace separate source and destination permissions with practical feasibility
Confidence in a source	Testimony, reputation, evidence quality, or epistemic trust	Distinguish confidence changes from changed institutional admissibility and action
Promise and performance	Contract, undertaking, incentive, and discharge evidence	Represent propagation of commitment status into later access and remedy decisions
Allocation and productive return	Resource-allocation and commons-governance models	Compare recognized contribution, actual access, and renewal of a specified capacity

not be leaked into predictions of predecision choices. If the constituent model already encodes the joint institutional structure equally well, explanatory equivalence is an acceptable conclusion.

A small discriminating study could assign the same documented claim to several specified purposes and compare the effects of independently varied issuer authentication, validity status, receiving eligibility rule, and available verification resources. It should measure factual discrimination, acceptance, implemented action, and burden separately. A second setting could follow corrections across institutions with different rules for reliance and remedy. The relevant theoretical prediction is not simply that *context matters*; that insight already exists in studies of differentiated money, boundary objects, commensuration, and institutional governance [54, 43, 16, 25]. The question is whether an explicitly specified map of interacting rules explains otherwise poorly anticipated *transitions* between statuses and actions. Inference would require adjudicated outcomes, rights-respecting records, and careful attention to shared sources, institutional selection, and network interference.

The concept should be narrowed when separate established accounts give equally interpretable and better supported explanations, when context definitions cannot be operationalized, or when the metaphor encourages ungrounded claims of fungibility. A scientifically useful umbrella need not have unique predictive content: comparative clarity, transparent documentation of neglected dependencies, or a more discriminating empirical protocol can be worthwhile. But those are accomplishments to establish through comparison, not evidence of an autonomous currency system. The appropriate default remains *plural institutional instruments and situated conversion pathways*; relational currency is a provisional name for the research question connecting them.

4.7 Empirical Identification and Comparative Institutional Cases

A programme studying situated convertibility should operationalize its cases before attaching a currency label. Suitable observational units include *instrument–issuer–recipient–purpose–institution–rule–version* records, linked where permitted to decisions and subsequent opportunities. Relevant measures include status validity, authorized scope, retrieval effort, actual source consultation, evaluator understanding, procedural admissibility, appeal availability, and downstream action. Records should distinguish outcomes from the claims people made about them. Comparisons across institutions need to account for the possibility that an apparent divergence reflects different applicant pools, purposes, eligibility rules, or evidentiary quality.

Table 7 gives an illustrative research design matrix. It foregrounds the alternative explanations that would otherwise make relational currency a descriptive metaphor with little empirical content.

A randomized vignette could vary an instrument’s valid scope and the stated receiving purpose while

Table 7: Candidate empirical contrasts for context-dependent acceptance and conversion.

Contrast	Measured outcome	Principal limitation
Same evidence, assigned review purpose	Eligible or ineligible decision, reasons for judgment	Real differences in purpose; experimental simplification
Credential with or without scope metadata	Correct identification of authorized uses	Interface comprehension and issuer familiarity
Direct versus portable attestation	Cross-institution uptake and verification cost	Recipient selection and hidden rule variation
Revoked versus currently valid status	Reliance decision and correction response	Unequal error severity and time of discovery
Appeal support versus nominal standing	Completed challenges and implemented corrections	Self-selection, spillovers, and changing administrative resources
Merit enhancement with fixed gate	Changes in stage entry versus evaluative confidence	Merit might actually alter the supposed fixed gate

holding its underlying evidentiary content constant. Such a design can estimate how assigned descriptions change decisions in a specified population; it does not automatically identify the effects of real accreditation law or institution-wide practices. One useful target is the average difference in a measured uptake outcome Y under two assigned receiving contexts. Equation 25 gives the estimand for a randomized display experiment, with c_1 and c_0 interpreted as assigned context presentations rather than as entire institutions whose memberships are randomly interchangeable.

$$\tau_{\text{display}} = \mathbb{E}[Y(c_1) - Y(c_0)]. \quad (25)$$

To support a causal reading of Equation 25, assignments must be exchangeable for the sample, treatments must be sufficiently well defined, and interference and attrition must be addressed. The outcome should be prespecified: procedural acceptability, perceived credibility, willingness to verify, resource access, and observed reliance are different variables. Real-world comparisons between institutions additionally require attention to differential selection and institutional spillovers. Where a credential issuer and receiving authority share a platform or administrative network, errors and changes in standards may affect several nominally independent evaluators simultaneously.

Hypothesis 4.3 (Context-sensitive acceptability under matched evidence). Among otherwise matched instruments presented for distinct specified purposes, institutionally recognized acceptance can differ with receiving rules even when underlying evidentiary content and issuer authenticity are held fixed. A controlled study that finds no meaningful acceptance differences despite verified rule variation would restrict the empirical scope of the proposed contextual-convertibility mechanism.

Hypothesis 4.4 (Distinct effects of documentary improvement and binding access barriers). Where a genuinely independent standing, rights, or resource requirement remains binding, improvements in documentary clarity or evaluative confidence alone will have smaller effects on reaching an action stage than an intervention that validly changes the binding condition. The prediction is conditional: its failure can indicate mistaken classification of the gate, compensatory institutional discretion, or additional pathways absent from the specified model.

Evaluation should include cases that challenge the framework’s organizing concept. A citation that travels widely yet has no identifiable role in institutional decisions, a credential accepted for incompatible purposes without measurable discrimination, or a context in which a transparent scalar ordering accurately predicts all relevant actions would narrow the explanatory need for a plural currency family. Equally informative are cases in which a restriction protects vulnerable contributors and thereby sustains long-term cooperation, even when it reduces immediate transmission. Studies should identify decision rules from accessible policy documents and contemporaneous records rather than infer them entirely

from observed acceptance patterns. Where the relevant rules or permissions are private, credible bounds and explicit missingness assumptions are preferable to unwarranted claims of identified effects.

Relational currency is thus an *analytical proposal about situated capacity for authorized interactions*. Equations 16–18 specify limited acceptance and possible conversion; Equations 19 and 20 preserve heterogeneous dimensions of consequence; Proposition 4.1 identifies a restricted obstruction to universal numerical ordering; and Proposition 4.2 states the consequence of a binding necessary condition. The remaining constructs explain portability, revision, and empirical testability without reducing normative questions to scores. Section 5 examines a related but distinct object: commitments whose effects depend on performance, default, enforcement, and contested reliance over extended institutional relationships.

5 Commitments and Conditional Reliance

Representations of completed contributions and undertakings concerning prospective conduct occupy different positions in knowledge circulation. A provenance record may document the creation of a method; a letter of commitment may announce access to equipment, coauthorship support, data stewardship, or continuing maintenance. Each can influence cooperation, yet the undertaking concerns performance whose conditions, evidence, and consequences remain open to assessment. This section develops a typed account of commitments, their institutional recognition, the evidence through which performance is assessed, and the conditions under which reliance may be warranted or materially constrained. The argument combines conceptual distinctions, deliberately restricted formal models, and comparative research proposals. Its purpose is to locate commitments within the family of situated relational-currency instruments without equating their circulation with completed exchange, contract formation, or trustworthiness.

The analysis distinguishes the moral grounds of promising, possible legal obligations, and incentive arrangements that can make cooperation sustainable. Scanlon’s treatment of promising emphasizes the normative significance of assurances and the expectations they create; Fried develops a promise-based account of contractual obligation, while relational-contract scholarship examines repeated interaction and institutional adjustment [41, 18, 33, 3]. These are different explanatory projects. Their coexistence in the present framework is intended to keep moral responsibility, formal enforceability, and strategic performance analytically visible, rather than to suggest that one automatically entails the others. The illustrative cases below are constructed analytical cases, not reports of identifiable institutional misconduct.

5.1 Undertakings, Conditions, and the Scope of Promissory Claims

An undertaking may assign future work, pledge access, authorize an action if specified conditions hold, or establish continuing obligations of care and correction. The research object is a versioned commitment instrument whose terms can be represented without supposing that all consequences are contractual. Some statements are informal expectations, others are internal administrative resolutions, public policy declarations, or legally cognizable agreements. The authority of an issuer to make a statement, the issuer’s capacity to perform, and the validity of the underlying obligation require separate assessment. A document may be authentic and remain outside the issuer’s authority; an authorized promise may nevertheless be impossible to perform; and an adequately performed action may occur without any promise at all.

Definition 5.1 (Situated commitment instrument). For a specified evaluative context c , let a commitment instrument be the tuple $\kappa = (p, b, a, \phi, \mathcal{M}, \mathcal{D}, \mathcal{Q}, \nu)$, where p identifies the undertaking party or authorized collective, b identifies its addressee or a defined beneficiary class, a specifies the conduct or result addressed, ϕ states conditional triggers and authorized exceptions, $\mathcal{M}$ describes assessment milestones, $\mathcal{D}$ gives acceptable documentary and other evidentiary routes, $\mathcal{Q}$ identifies review, correction, and remedy arrangements, and ν identifies the version of the instrument and associated governing rules. The

tuple is a representation of a claimed undertaking; its issuance alone establishes neither moral validity nor legal enforceability.

A commitment with multiple beneficiaries may have heterogeneous obligations, including nonexclusive provision of an open dataset, confidentiality obligations to contributors, and separate reporting duties to funders. Consequently, treating b as a beneficiary class need not imply that all members enjoy identical rights or remedies. Equally, a commitment made by a collective requires evidence about the entity’s decision process and the authority of the actor who purportedly bound it. An authenticated signature can establish that a key was used to sign an instrument under specified technical assumptions, but institutional competence, informed consent, and the substance of the undertaking demand additional inquiry. This distinction follows the representation–attestation separation developed in Section 2.

The activation of an obligation depends on rules and circumstances rather than the mere visibility of its text. Equation 26 defines a deliberately limited indicator for an undertaking recognized as operative in a context. The precedence relation $e \succeq_{\kappa} e_{\phi}$ means only that an event meets an instrument-specific milestone or trigger relation; it introduces no universal chronology or global event ordering.

$$O_{\kappa,c}(e) = V_{\kappa,c}(e) A_{\kappa,c}(e) \Phi_{\kappa,c}(e), \quad V_{\kappa,c}, A_{\kappa,c}, \Phi_{\kappa,c} \in \{0, 1\}. \quad (26)$$

Here V records validity under the relevant normative or institutional rule, A records necessary authority, and Φ records satisfaction of the specified trigger conditions at event e . The equation is a local book-keeping convention for conjunctive requirements, not a general theory of moral obligation. For example, a promised archival release conditional on ethics approval may be authentic and authorized while its trigger remains unsatisfied. A receiving institution may nonetheless have separate duties to communicate delays, safeguard existing records, or refrain from misleading collaborators; Equation 26 does not attempt to exhaust those duties.

Commitments also differ in their temporal and distributive structure. A one-time undertaking to transmit a verified dataset has a potentially identifiable completion event. A promise to maintain access, correct errors, or respect consent is ongoing and cannot be established as permanently fulfilled by a single snapshot. Some duties are divisible into independently checkable milestones; others are joint, because integration, safety, or mutual compatibility is integral to adequate performance. Rule versions and authorized amendments matter: a change may validly release a party, add a new condition, or undermine previously formed expectations, depending on the context. The historical sequence of instrument versions should therefore be preserved with provenance rather than silently replacing earlier representations.

5.2 Milestones, Discharge Evidence, and Evidentiary Status

A promissory document is evidence that an undertaking was represented; a progress certificate is evidence about a narrower stage of performance; and a discharge determination is an evaluation under rules concerning satisfactory completion, excuse, waiver, or remedy. These objects have overlapping provenance but different truth conditions. Documentary integrity and competence of the certifying authority matter, as do observable work, independent testing, and the parties’ capacity to challenge mistaken records. A statement that a project is “complete” may conceal unresolved integration requirements, continuing maintenance, or a disputed interpretation of the agreed standard.

Let P_{κ} denote performance adequate to discharge an undertaking within a specified rule version, and Z the evidence received. Equation 27 represents an evidentiary update only where a probability model for report generation and selection is appropriately specified. The account is descriptive of a benchmark inference, not a claim that institutional evaluators actually compute Bayesian likelihoods.

$$\frac{\Pr(P_{\kappa} = 1 \mid Z = z, c)}{\Pr(P_{\kappa} = 0 \mid Z = z, c)} = \frac{\Pr(P_{\kappa} = 1 \mid c) \Pr(Z = z \mid P_{\kappa} = 1, c)}{\Pr(P_{\kappa} = 0 \mid c) \Pr(Z = z \mid P_{\kappa} = 0, c)}. \quad (27)$$

The displayed odds require positive denominators; limiting cases must be handled separately. Source selection, unavailable records, and shared reports can invalidate an assumed likelihood ratio. An issuer’s

Table 8: Commitment records and the claims they may support under specified rules.

Instrument or event	Bounded evidentiary role	Remaining question
Signed undertaking	Identifies a stated commitment and a purported issuer	Authority, consent, validity, feasibility
Milestone report	Documents a declared state of progress	Test criteria, independence, unobserved defects
Independent inspection	Reports findings within an auditor’s scope	Sampling, competence, information access
Amendment or waiver	Records a purported change in applicable obligations	Standing, procedural validity, affected parties
Default allegation	Records a challenge to claimed performance	Opportunity to respond, applicable standard
Discharge decision	States an authorized assessment of completion or release	Correctness, appeal, continuing duties
Remedy implementation record	Documents an attempted corrective measure	Adequacy, affected-party access, durable effect

self-certification may be materially relevant but need not have the evidentiary properties of independent inspection. Nor does a high posterior assessment itself determine the governing legal or ethical status of performance.

Table 8 separates the principal documentary events and the claims they can appropriately support. The table also illustrates the difference between a recognized breach, a merely alleged default, and an approved alteration of obligations.

The distinction between promissory evidence and evidence of discharge can be expressed as an identification limit. Suppose the only observed variable is the presence of a formally equivalent undertaking S , and there exist two admissible performance-generating models M_1 and M_2 with the same distribution of S but different conditional distributions of P_κ . Under these assumptions, observations of S alone cannot identify the rate of fulfilled undertakings. Equation 28 specifies the observational equivalence underlying the statement.

$$\Pr_{M_1}(S = s) = \Pr_{M_2}(S = s) \text{ for all } s, \quad \Pr_{M_1}(P_\kappa = 1) \neq \Pr_{M_2}(P_\kappa = 1). \quad (28)$$

Proposition 5.2 (Non-identification of discharge from equivalent promissory records). *Within the model class characterized by Equation 28, a dataset containing only the observed promise variable S cannot point-identify the population discharge probability $\Pr(P_\kappa = 1)$ without further restrictions.*

Proof. The two admissible models induce the same observable distribution for every possible sample of S , while implying different discharge probabilities. Any function of that observable distribution therefore takes the same value under both models and cannot equal both distinct target quantities. $\square$

The result is deliberately narrow. A promissory record can become predictive where independent information relates issuance to subsequent performance, and historical outcomes may support calibrated forecasts. The proposition concerns what the specified observation class alone establishes. It does not imply that promises lack normative force, that some issuers cannot be reliable, or that reliable certification systems are impossible. It cautions against operational measures of “trust fulfilled” that count published undertakings or endorsements without testing performance under their actual terms.

5.3 Reliance Decisions Under Uncertainty and Unequal Choice Sets

The decision to rely on a commitment is an action under a situated choice set. An actor may believe that a promised resource is likely to arrive while choosing an alternative because the cost of failure is catastrophic. Another may doubt the undertaking but proceed because suitable alternatives are unavailable, because interruption would threaten employment, or because a superior has imposed a course of

action. Self-reported trust, institutionally recorded acceptance, observed delegation, and a freely chosen act of reliance are therefore different outcomes. Section 4 treated a representation’s eligibility for use; the present distinction concerns the consequential decision to depend upon performance.

Let $\mathcal{A}_b(c)$ be the feasible actions for beneficiary b in context c . Let ω describe the uncertain state relevant to promised performance and u_b the beneficiary’s payoff or welfare description for a specified inquiry. Equation 29 supplies a normative decision benchmark with explicitly context-dependent implementation and exit costs K_b , and report information z .

$$a_b^*(z, c) \in \arg \max_{a \in \mathcal{A}_b(c)} \{ \mathbb{E}[u_b(a, \omega) \mid z, c] - K_b(a, c) \}. \quad (29)$$

The benchmark depends on the adequacy of the payoff model, the accuracy of perceived probabilities, and whether the feasible set is genuinely available. It should not be mistaken for an empirically validated cognitive theory. A scholarship recipient offered a conditional grant may rationally defer another opportunity, while a precariously employed researcher may have no realistically sustainable alternative to relying on a supervisor’s informal assurance. The same observed reliance action can arise from different beliefs and materially structured choice sets. Equally, refusal to rely may express legitimate protection against risk rather than unjustified distrust.

For a simple binary undertaking, Equation 30 identifies a threshold under restrictive assumptions. Let p be the assessed probability of satisfactory performance; let $B \geq 0$ be the incremental benefit if relying succeeds; let $L \geq 0$ be the incremental loss if it fails; and let $C \geq 0$ be the incremental verification, coordination, and opportunity cost. When the alternative’s incremental payoff is normalized to zero, reliance has weakly nonnegative expected value if the stated condition holds.

$$pB - (1 - p)L - C \geq 0 \iff p \geq \frac{L + C}{B + L}, \quad B + L > 0. \quad (30)$$

The formula abstracts from nonlinear utility, dependence between costs and performance, external effects, and changing alternatives. Its implication is limited but instructive: the same degree of evidentiary confidence can support reliance in a low-stakes collaboration and rejection in a high-stakes clinical or safety-critical setting. Where the threshold exceeds one, no probability of performance in the model justifies the proposed action at the assumed payoffs. Where action is compelled, the observed choice need not satisfy the actor’s unconstrained decision threshold. The analysis therefore cannot infer trust directly from compliance, attendance, or delegated work.

Relational commitments may also concern multiple parties whose expectations and benefits cannot be summarized from a single beneficiary’s viewpoint. Distributing costs to unrepresented contributors can make an apparently efficient arrangement exploitative under independently stated normative criteria. Decision models should therefore keep third-party rights, collective interests, and consent constraints explicit rather than bury them in an aggregate scalar payoff. Informal understandings may legitimately evolve with changing circumstances, yet the same flexibility can conceal imbalances when one side controls the means to define satisfactory performance. Macneil’s account of long-term contractual adjustment provides a historically grounded legal-theoretical comparison, not a demonstration that all research collaborations constitute relational contracts [33].

5.4 Performance Incentives, Verification, and Conditional Credibility

Commitment credibility can have several grounds: demonstrable technical capacity, an independently verified performance history, an institution with effective enforcement, a reputational interest in future cooperation, or values that make faithful performance important to the promisor. These mechanisms may reinforce one another, but their operation depends on setting. Williamson analyzes safeguards designed to support exchange, and Klein and Leffler examine the market conditions under which repeated purchases and future rents can help sustain performance [53, 29]. Baker, Gibbons, and Murphy further study relational contracts maintained by continuation values within and between firms [3]. The present

paper draws a conditional comparison with knowledge collaborations; it does not presume that scientific or public commitments can be reduced to market incentives.

Consider a restricted performance-versus-deviation decision for a party with a specified viable obligation. Let $G_\kappa \geq 0$ be the one-occasion net gain from deviating rather than fulfilling. Let $q_\kappa \in [0, 1]$ be the conditional probability that deviation triggers an enforceable consequence, $F_\kappa \geq 0$ its incremental expected severity conditional on enforcement, $\delta \in [0, 1]$ a discount factor, and $\Delta V_\kappa \geq 0$ the difference between continuation values following fulfillment and deviation. Equation 31 describes a sufficient condition for faithful performance under an additive, risk-neutral payoff comparison.

$$G_\kappa \leq q_\kappa F_\kappa + \delta \Delta V_\kappa. \quad (31)$$

Proposition 5.3 (Restricted incentive compatibility of performance). *Assume a party chooses between the two specified actions, their incremental payoffs are additive and risk-neutral, and G_κ , $q_\kappa F_\kappa$, and $\delta \Delta V_\kappa$ exhaust the payoff difference. If Equation 31 holds, performance weakly dominates deviation within this restricted comparison.*

Proof. By definition, deviation's incremental current gain is G_κ . Relative to performance, deviation also incurs expected enforceable consequences $q_\kappa F_\kappa$ and loses discounted continuation value $\delta \Delta V_\kappa$. The payoff difference, deviation minus performance, is therefore $G_\kappa - q_\kappa F_\kappa - \delta \Delta V_\kappa$, which is nonpositive by Equation 31. $\square$

The proposition is a conditional comparison, not a general theorem about actual human motives or institutional ethics. Detection may be imperfect and endogenous; sanctions may be unenforceable or disproportionate; actors may be risk-averse; future relationships may be inaccessible; and the option to renegotiate may change the entire action set. When performance is infeasible, the model's binary choice is inadequate. Moreover, increasing sanctions can create chilling effects, concealment, or retaliatory asymmetries. The existence of an incentive-compatible performance rule does not show that the undertaking was entered freely, that its terms are just, or that beneficiaries possess meaningful remedies. A credible coercive threat can be strategically effective while remaining normatively impermissible.

Verification design also matters for the productive use of resources. A milestone audit requiring inaccessible proprietary tools may be formally precise yet impossible for independent contributors to complete. Reputational discipline may favor parties with durable institutional identities while offering little protection against a one-off intermediary able to disappear or rebrand. Informal cooperation can work well in communities with reciprocal monitoring, but small-group familiarity may also exclude outsiders. Ostrom's analysis of collective-action institutions attends to monitoring, graduated sanctions, conflict resolution, and actors' capacities to devise rules [38]. Those observations provide relevant comparison points for public knowledge infrastructures, while the particular governance mechanisms for an AI-mediated archive or multi-institution project require separate evidence.

5.5 Default, Revision, and Effective Remedy

The practical meaning of default depends on the undertaking's trigger, standard of adequate performance, recognized excuses, and decision procedure. Failure to complete a promised task, inability resulting from events beyond a party's control, a beneficiary's waiver, and an allegation of deliberate withholding can demand different responses. Recording an allegation as established breach risks unjust attribution; conversely, allowing an issuer to certify its own discharge without review may leave beneficiaries unprotected. A sound information infrastructure should preserve the alleged event, reasons offered, competing evidence, decision authority, and a route for lawful correction, subject to privacy and other legitimate restrictions.

For an abstract remedy pathway, define the indicators L_κ for standing to request review, X_κ for practically accessible evidence and procedure, J_κ for effective review authority, and I_κ for implementability of the selected remedy. Equation 32 is a minimal conjunctive representation of an *effective remedy route*

in one specified institutional design.

$$R_{\kappa,c}^{\text{eff}} = L_{\kappa,c} X_{\kappa,c} J_{\kappa,c} I_{\kappa,c}, \quad L_{\kappa,c}, X_{\kappa,c}, J_{\kappa,c}, I_{\kappa,c} \in \{0, 1\}. \quad (32)$$

Equation 32 deliberately abstracts from graded access, informal alternatives, and substitute remedies. It shows how one pathway can fail when a necessary condition is absent; the existence of another route can change the overall outcome. Legal standing and legitimate confidentiality rules can be justified independently of a beneficiary’s satisfaction, and implemented remedies may be partial. An institution should therefore distinguish availability of an appeal form, completed review, correction of the underlying record, fulfillment of the outstanding duty, and delivery of any authorized compensation. An apology or visible correction may have significance without restoring a lost opportunity or the resources required to participate.

A durable commitment architecture needs version control for a reason more substantive than technical neatness. A mistaken completion record can circulate through credential platforms and AI summaries, thereby affecting later eligibility decisions even after an authoritative correction. A revoked undertaking may have generated costly reliance before revocation. An authorized settlement may discharge a legal claim without establishing that performance occurred as originally promised. Therefore a publicly visible status label should preserve the difference between *performed*, *released*, *waived*, *disputed*, and *remedied*. Where privacy precludes exposing documents, an appropriately scoped attestation to the status and available review route may be preferable to broad disclosure of sensitive materials.

Formal protections are also conditioned by material resources. A contributor who must risk employment, access to facilities, or immigration status to pursue a complaint faces a different practical opportunity set from a well-resourced institution. The same procedural rules can yield unequal rates of filed complaints or successful remedies because verification costs, counsel, translation support, and fear of reprisals differ. Treating low complaint rates as proof of high compliance ignores selection into voice. Historical-materialist inquiry should therefore examine who finances documentation, who bears uncertainty, who controls independent review, and whose productive capacities are depleted while claims remain unresolved. The normative analysis is not exhausted by whether the relevant enforcement mechanism is strategically credible.

A further difficulty arises when a commitment is executed through delegated computational systems. An automated service can schedule data access, issue periodic integrity reports, deliver model outputs, or trigger payments, while the persons and institutions responsible for those operations remain distinct from the software. In such a case, an audit needs to connect the human or collective undertaking to its technical delegation: who authorized a system’s task, which conditions it was allowed to evaluate, what evidence it actually observed, how exception handling occurred, and who could intervene when the automated execution was defective. An automatic status change is evidence that a configured process ran under a specified environment; its relevance to performance depends on whether the process adequately implemented the undertaking. Machine-readable provenance and credential formats can help preserve lineage and issuer identity [48, 51], yet their availability does not settle disputes about adequate judgment or responsibility. A status interface that equates “executed” with “discharged” would compress a normatively important distinction.

Distributed undertakings also create conflicts between partly independent commitments. A research consortium might undertake to share a derived dataset, preserve contributor confidentiality, and permit qualified verification. Fulfilling any one of those conditions may complicate fulfillment of another without automatically excusing it. Their interaction requires an authorized process for prioritizing duties, developing privacy-preserving alternatives, seeking renewed permission, or renegotiating feasible deliverables. The existence of multiple institutional signatories does not by itself establish jointly distributed liability, and a project coordinator’s instruction may exceed the authority delegated to that role. The relevant object for inquiry is therefore a graph of actor-specific obligations, conditional dependencies, revision rights, and evidentiary responsibilities, rather than an undifferentiated declaration that a group “committed.” In public or commons arrangements, these distinctions also help identify maintenance duties whose benefits are collective although their daily costs fall on a small number of workers.

Table 9: Candidate empirical contrasts for commitments, reliance, and remedies.

Contrast	Distinct outcomes	Primary identification risk
Undertaking versus verified milestone	Forecast accuracy, reliance and actual discharge	Milestone selection and certifier dependence
Same promise, independent audit access	Confidence, verification effort, subsequent corrections	Audit cost and differential comprehension
Equivalent evidence, different remedy access	Willingness to rely and completed complaints	Unobserved risk, standing, and retaliation
Conditional versus unconditional offer	Acceptance, implementation and assessed fairness	Different feasible choices and obligations
Performance status before and after correction	Downstream uptake and record propagation	Exposure to corrections and changing audiences
Comparable tasks with exit alternatives	Expressed trust, voluntary reliance, observed compliance	Resource dependence and sorting of participants

Correction rights should accordingly attach to both the substantive undertaking and the chain of representations circulated in its name. A reliable pathway may require revision of a status entry, notification of relevant recipients, and a means of identifying versions on which decisions were based. Reversal is sometimes impossible: a withdrawn opportunity, disclosed secret, or missed research deadline may leave effects that a later data correction cannot erase. In such cases, the response should distinguish forward-looking repair, restitution or compensation where authorized, restoration of participation, and documentation of residual harm. An evaluation that counts only the final status of a record can miss the distribution of these consequences among beneficiaries, intermediaries, and affected third parties.

5.6 Institutional Comparisons and Testable Consequences

Empirical inquiry should distinguish promissory communication, evidentiary assessment, reliance behavior, realized performance, and effective correction as separate variables measured at appropriately linked units. Useful observations include an instrument’s text and versions; authorized issuers; trigger events; milestone evidence; certification source; reliance decisions; implementation records; appeals; and parties’ actual ability to leave, refuse, or demand verification. Observing only public declarations selects on willingness and capacity to announce commitments. Observing only resolved disputes excludes cases in which participants could not initiate or sustain a complaint. Both selection processes can induce misleading associations between institutional status and apparent reliability.

Table 9 summarizes candidate comparisons and the principal mechanisms they would identify only with additional assumptions. The cases are proposed study designs, not completed experiments.

One target for a randomized information-display study is the effect of being offered verified progress evidence alongside an otherwise identical undertaking. Let $Z = 1$ denote such display, $Z = 0$ the undertaking alone, and Y a prespecified reliance or evidence-evaluation outcome. Equation 33 defines the sample-population average treatment effect under a well-defined randomized intervention.

$$\tau_{\text{milestone}} = \mathbb{E}[Y(1) - Y(0)]. \quad (33)$$

Identification of Equation 33 from a study still depends on assignment, measurement, consistency, attrition, and interference assumptions. A display manipulation cannot automatically change real performance or enforceability, and an effect on stated reliance is not evidence of a causal effect on subsequent delivery. To study the latter, researchers would need longitudinal performance data and a design addressing institutional selection, joint production, and changing baseline obligations. Where full outcomes are unavailable, reporting plausible bounds or transparent missingness scenarios is preferable to interpreting missing performance documents as proven default.

Hypothesis 5.4 (Performance evidence and calibrated conditional reliance). When source independence and the correspondence between milestone evidence and the promised task are experimentally controlled,

presentation of diagnostic performance records will improve the discrimination of reliable from unreliable undertakings relative to a promise-only condition. Increased overall acceptance without improved discrimination would instead indicate a possible confidence or persuasion effect, narrowing the proposed evidentiary mechanism.

Hypothesis 5.5 (Remedy access and the interpretation of observed acceptance). In otherwise comparable settings, measures of voluntary reliance will diverge more from observed compliance where effective alternatives and practical complaint access are restricted. This prediction requires independent measurement of perceived risk, resource dependence, choice sets, and institutional constraints; a failure to observe divergence after such measurement would weaken the proposed dependence mechanism for the studied setting.

The section's distinctions have a particular bearing on relational currency. An undertaking may circulate as a recognized resource for initiating collaboration, but its promissory acceptance and its eventual performance are different institutional events. The issuer's legitimacy, the terms of authorized use, the existence of reliable performance evidence, and the possibility of accessible remedy mediate conversion into productive cooperation. Thus a commitment can facilitate a relationship without constituting an exchangeable asset, guaranteeing delivery, or warranting an inference of reciprocal justice. Equations 26, 27, and 29 articulate distinct stages of recognition, inference, and action; Propositions 5.2 and 5.3 state two conditional limits. The proposed empirical programme should remain sensitive to cases where accountability supports cooperation as well as cases where an apparently credible undertaking is sustained by disproportionate dependence. Section 6 takes up the related but separate process through which recognition and fulfilled or unfulfilled commitments condition access to productive resources and material returns.

6 Recognition and Access to Productive Resources

The circulation of a credible account of contribution may alter the possibilities for scientific collaboration, professional training, access to equipment, eligibility for public support, or remuneration. Those possibilities depend on institutional rules, available resources, competing applicants, and the practical capacities of participants. This section develops a staged account of the conversion of recognition into productive access, distinguishes its evidentiary and material components, and examines the allocation mechanisms through which its benefits and burdens are distributed. The analysis combines typed formal representations, two conditional propositions, historical-political-economic interpretation, and testable research designs. The proposed mechanism is a contingent institutional process, rather than a presumption that recognized contributions produce equitable material returns.

The study of recognition and reward in science has long identified the possibility of cumulative advantage. Merton’s account of the Matthew effect addresses the allocation of credit and the visibility of scientific contributions, while Bourdieu’s discussion of forms of capital provides a different vocabulary for historically situated conversion among resources and recognized standing [35, 10]. Neither approach licenses the identification of scholarly merit with accumulated prestige. More recent evidence provides relevant but bounded illustrations: a study of applicants around a science-funding threshold reports consequential differences in later funding, while research on early-career grant near misses documents both subsequent attrition and different outcomes among investigators who remain active [9, 52]. These studies concern particular institutions and selected populations; they do not validate a universal feedback law. The section’s formal objects therefore describe hypotheses about specific conversion arrangements that require independent empirical identification.

6.1 Institutional Pathways from Recognition to Resource Access

In the preceding sections, an evidentiary instrument became potentially usable only relative to a context, an action, and applicable authorization and feasibility conditions. Material access requires further distinctions. A published method might be noticed by a research group, attributed to its authors, deemed relevant to a facility’s mission, and used to support an invitation. Yet the invitation might confer neither laboratory entry nor a funded appointment. Conversely, access may arise from a legal entitlement, a universal public service, or an open commons with no individualized recognition gate. The present account is accordingly indexed by the particular route through which recognition is proposed to matter; it does not impose recognition as a necessary condition for all knowledge production.

Let u identify a person or contributor collective, i an instrument representing a contribution, c an institutional context, a an access action, and r a requested resource bundle. Examples of r include protected research time, storage and computing capacity, laboratory facilities, supervision and instruction, a network of potential collaborators, or a monetary transfer. An institution may recognize the evidence relevant to one resource while denying access to another. The available resource class, relevant permissions, rights of other parties, and terms of use must consequently form part of the context. In the following definition, *realization* refers to a particular documented act of provision, not to the full resulting improvement in a participant’s productive capabilities.

Definition 6.1 (Situating resource-access pathway). For a specified (u, i, c, a, r) , a resource-access pathway $\Pi_c(u, i, a, r)$ is an ordered set of procedurally meaningful stages: evidentiary encounter E , contribution recognition R , rule-relative eligibility L , authorization or allocation G , practical provisioning D , and usable access X . Each stage refers to the occurrence of the specified event in the pathway, under a recorded rule version and with an identified decision-maker where applicable. The order represents administrative dependencies in the selected route, not an invariant sequence across all institutions or an ontology of social time. A missing stage may be bypassed or replaced if the pathway’s rules permit it.

For a recognition-mediated pathway in which those six stages are jointly necessary and implemented in the order specified, let $Z_k = 1$ denote successful completion through stage k and $Z_0 = 1$. Equation 34 is the probability chain rule for the event of fully usable access. The conditional factors are defined only

Table 10: Stages of a recognition-mediated resource pathway and their empirical boundaries.

Stage	Illustrative observable trace	Unresolved question after the trace
Encounter E	Logged receipt, a reviewed portfolio, or documented examination of a contribution	Whether the reviewer understood the evidence or its provenance
Recognition R	Explicit attribution, contribution assessment, or an accepted evaluative finding	Whether the recognition is warranted, accurate, or fairly distributed
Eligibility L	Formal assessment under a versioned programme rule	Whether the rule is legitimate or a feasible application is available
Authorization G	Selection, invitation, admission, grant decision, or approved access request	Whether promised resources are allocated and can actually be supplied
Delivery D	Transfer record, issued credential, facility activation, or executed support agreement	Whether the provision is usable given time, privacy, accessibility, and related constraints
Usable access X	Documented capability to use the resource for the approved purpose	Whether access improves productivity or yields fair material returns

where the preceding cumulative event has positive probability; if some preceding stage is impossible, the joint probability of completion is set to zero.

$$\Pr(X = 1 \mid c, i, u, a, r) = \prod_{k=1}^6 \Pr(Z_k = 1 \mid Z_{k-1} = 1, c, i, u, a, r), \quad \Pr(Z_{k-1} = 1) > 0. \quad (34)$$

The equality presumes that $X = 1$ is precisely the completion of the designated nested pathway. It makes no independence assumption: stage probabilities may depend on prior decisions, hidden institutional characteristics, or the circumstances of rival applicants. In particular, the six factors should not be treated as independent success probabilities estimated by multiplying marginal rates. Equation 34 is a bookkeeping identity for one operational definition of access. Alternative routes, including guaranteed public entitlements, require a corresponding event structure rather than automatic application of this factorization.

Table 10 specifies the kinds of observations that might distinguish each stage. It also records characteristic sources of ambiguity. An aggregate count of awarded fellowships cannot identify how many qualified contributors lacked information about the call, could not apply, withdrew, or received unusable awards. The importance of stage-specific participation has been demonstrated outside the science-specific setting by Heckman and Smith, who distinguish eligibility, awareness, application, acceptance, and enrollment in the analysis of a training programme [23]. Their empirical decomposition motivates measurement discipline; the proposed stages and their relationship to relational evidence remain a separate hypothesis.

The final distinction matters because a nominal award may entail duties incompatible with its intended use. A computing allocation can be unusable when input data cannot legally be transferred to the provider; a scholarship can fail to cover required living costs; an invitation can be inaccessible because travel arrangements are unavailable; and a nominally open archive can require specialized infrastructure that users cannot obtain. These examples are generic counterexamples to an assumption of automatic conversion, not claims about particular programmes. In applications, indicators should be accompanied by records of exceptions, accommodations, appeals, and nonparticipation rather than interpreted as universal binary states.

6.2 Productive Capabilities and Binding Resource Constraints

Productive access may be understood as an expansion of feasible activity rather than simply the receipt of an asset. Sen’s capability approach provides a useful comparator: an individual’s opportunities and the resources nominally held by that individual require distinct assessment [42]. The present paper uses a narrower, institutionally operational notion. A capability is an action an actor can practically and permissibly perform with a specified bundle of complementary resources in a specified setting. This

notion does not purport to reproduce Sen’s complete theory of human development or establish that scientific productivity exhausts human freedom.

Let $\mathbf{q}_u = (q_{u1}, \dots, q_{um})$ denote the resources available to u , including permitted equipment access, protected time, data rights, financial means, and relevant technical support. An action a has a requirement vector $\mathbf{n}_c(a)$, and $P_c(u, a)$ indicates the necessary permissions. Under a deliberately simple non-substitutable input model, Equation 35 defines the feasible productive-action set:

$$\mathcal{F}_c(u; \mathbf{q}_u) = \{a \in \mathcal{A}_c : P_c(u, a) = 1 \wedge q_{uj} \geq n_{cj}(a) \text{ for every required } j\}. \quad (35)$$

The componentwise inequalities apply only when resources have meaningful comparable units and cannot be substituted across dimensions. They are inappropriate for negotiations in which money substitutes for assistance, remote access substitutes for travel, or co-production reorganizes work requirements. Such cases demand an explicit production or substitution correspondence. Nevertheless, Equation 35 identifies an important feature of resource access: additions to one component may leave an action infeasible because a different component remains binding.

Suppose a grant covers equipment but does not establish lawful data access. The recipient’s equipment endowment has improved, while the contemplated data-dependent action remains outside the feasible set. Conversely, a repository license may open use without remunerating the original authors; inclusion in the feasible set concerns permissible productive activity, while distribution of returns requires additional arrangements. Rights and protected interests also do not function merely as scarce inputs: a requirement to disclose another person’s confidential records cannot automatically be purchased or waived by a higher resource allocation. Rights-related constraints therefore enter through the authorization predicate and must be assessed according to the governing law and justified normative criteria.

Actual productive outcomes may be diverse. Let $\mathbf{y}_u(a, \mathbf{q}, c)$ record an appropriately defined vector of consequences, such as learning, reproducible outputs, supported collaborations, public-knowledge additions, research continuity, participant well-being, and monetary compensation. Equation 36 represents attainable consequences as a correspondence, allowing uncertainty and multiple implementations:

$$\mathcal{Y}_c(u; \mathbf{q}_u) = \bigcup_{a \in \mathcal{F}_c(u; \mathbf{q}_u)} T_c(a, \mathbf{q}_u, u), \quad (36)$$

where T_c is a contextually specified set-valued production or outcome relation. This correspondence is intentionally not a single scalar utility or monetary return. If an institution offers an opportunity that increases open scientific knowledge while shifting unpaid verification burdens onto a small group, describing only publications or grant revenue would provide an incomplete account of its consequences. Distributional assessment must identify who contributes labor, who receives access, who retains usable capacity, and who bears maintenance and legal responsibilities.

6.3 Recognition Thresholds and Allocation Bottlenecks

An explicit authorization may depend on recognized contribution while still being limited by conditions beyond the contributor’s control. Let $R_c(i, u) \in \{0, 1\}$ describe a narrowly defined favorable recognition finding, $L_c(i, u, a)$ the governing eligibility condition, $G_c(u, a)$ a valid allocation decision, $F_c(u, a)$ practical feasibility, and $P_c(u, a)$ the necessary authorization or rights compatibility. For a designated route in which these are all necessary, define the access indicator in Equation 37. The notation does not imply that each gate is morally justified or statistically independent.

$$X_c(i, u, a) = R_c(i, u) L_c(i, u, a) G_c(u, a) F_c(u, a) P_c(u, a). \quad (37)$$

The indicator differs from a claim about the personal worth of u . Recognition may be institutionally misallocated, eligibility conditions may be contested, and practical feasibility may depend on accommodation. Moreover, the gate R_c should be omitted from routes in which admission is unconditional or based on an independently established right. The multiplicative expression is a restricted description of a specified selection rule, not a recommendation that access be made contingent on prestige.

Proposition 6.2 (Binding-gate limit on recognition-only improvements). *Fix a context c , actor u , action a , and recognition-mediated route described by Equation 37. Suppose a particular gate among L_c, G_c, F_c, P_c is zero under both of two compared arrangements, and all four nonrecognition gates are otherwise unchanged. Then changing $R_c(i, u)$ from zero to one cannot change $X_c(i, u, a)$ from zero to one.*

Proof. The product in Equation 37 contains a zero factor under both arrangements. Consequently it equals zero for either value of $R_c(i, u)$. The result requires that the other gates, particularly the binding gate, remain fixed. If recognition induces a rule waiver, new financing, an alternative pathway, or a valid accommodation, the assumption is violated and the conclusion need not hold. $\square$

Proposition 6.2 is deliberately elementary. Its purpose is to rule out an illicit inference that better documentation or reputation must increase actual access even where a distinct veto remains binding. The empirical task is to determine whether an institution uses the proposed route, whether the alleged gate is truly binding, and whether a recognition intervention changes other gates through negotiations or institutional adaptation. The result offers no grounds for concluding that a denial was arbitrary or discriminatory without further normative and factual investigation.

Capacity creates a separate problem even when no individual applicant faces an absolute veto. For resources such as unique laboratory slots, limited supervisory hours, or a fixed annual award budget, access by one applicant may displace access by another. Let $d_{ua} \geq 0$ be the quantity of resource a assigned to user u , and let Q_a be the fixed capacity available in the specified allocation period. Feasible assignments obey Equation 38:

$$\sum_{u \in \mathcal{U}_c} d_{ua} \leq Q_a, \quad d_{ua} \geq 0. \quad (38)$$

Here Q_a is a contextual constraint, not a universal scarcity claim. Scientific ideas, nonrival digital artifacts, and permissively shared methods may be usable simultaneously by many people, although their hosting, maintenance, and interpretation still consume resources. Allocation may also expand capacity through infrastructure investment or collective provision. An analysis that combines rival grants with reusable methods in one undifferentiated total would obscure both dynamics.

Proposition 6.3 (Fixed-capacity bound on aggregate allocations). *Under Equation 38, if Q_a is fixed across two allocation arrangements and d_{ua} measures the same rival resource in both, then a recognition-driven reassignment cannot increase the total assigned quantity beyond Q_a . If the baseline already allocates exactly Q_a , any strict increase in one user's allocation requires an offsetting decrease in the total allocations of other users.*

Proof. For any feasible postintervention allocation, the sum is bounded by Q_a . If the baseline sum equals Q_a and $d'_{va} > d_{va}$ for user v , the sum over all other users in the postintervention arrangement satisfies $\sum_{u \neq v} d'_{ua} \leq Q_a - d'_{va} < Q_a - d_{va} = \sum_{u \neq v} d_{ua}$. This is an aggregate accounting result. It does not specify the allocation rule, the desirability of any assignment, or effects on productivity. $\square$

Proposition 6.3 separates allocation effects from capacity expansion. A credential-display experiment could change the recipient of a scarce award without increasing total awards. A new open infrastructure, in contrast, could expand available productive activity while requiring ongoing maintenance labor. The distinction matters for causal inference and distributive judgment: an estimated effect on an individual's grant receipt may combine gains to that applicant with losses to another, whereas an estimate of aggregate scientific capacity concerns a different outcome.

6.4 Unequal Conversion, Scientific Work, and Material Returns

The conversion of recognition into resources occurs within particular political-economic organizations of science. In some arrangements, peer esteem serves as an input to grant competition, grants fund labor and infrastructure, and subsequent publications influence further evaluation. In others, a local

community collectively maintains reusable tools with little individualized ranking. Universities, public institutes, foundations, private firms, cooperatives, and independent groups possess different legal mandates, budget procedures, contractual relations, and practices of disclosure. Their arrangements should be compared rather than compressed into a single account of academic competition.

The historical sociology of scientific reward illuminates one possible reinforcing mechanism. Merton’s analysis of credit and visibility makes it possible to distinguish an actual intellectual contribution from the prominence assigned to it in communication networks [35]. In a particular funding setting, Bol and colleagues report that narrowly selected grant winners later secured substantially more funding than near-identical-scored nonwinners close to a threshold [9]. Such findings motivate scrutiny of recognition-dependent feedback, but they do not establish that all funding arrangements reward status in the same way. Wang, Jones, and Wang report heterogeneous consequences of an early grant setback, including an elevated risk of exit and stronger later impacts among surviving near-miss researchers [52]. Their study is an important caution against inferring a homogeneous effect from the trajectories of those who remain observable.

The resulting framework must distinguish *recognition of work*, *access to productive capacity*, and *return of created value*. A cited software library can lower the costs of subsequent research across a large population; its volunteer maintainers may receive extensive acknowledgments yet lack stable maintenance support. A funded project may provide salaries to some contributors while relying on uncompensated translation, curation, patient participation, peer review, or community expertise. Conversely, a person can receive remuneration under an employment contract without being assigned appropriate scholarly credit. These possibilities show why attribution data, wage data, access data, and documentary evidence of performed work require separate measures and ethical analysis.

Teece’s analysis of complementary assets in innovation offers a useful comparison: economic returns may depend on control of specialized complementary assets as well as the original innovation [46]. Transposition to public knowledge systems is bounded. Access to a laboratory, authority to approve a research protocol, ownership of an essential database, patent rights, or the ability to host and maintain a platform can each function as a complement, but their legal and governance characteristics differ. A resource controller may make essential and fairly compensated contributions, or may exercise an exclusionary power that deserves scrutiny. Identifying a complement therefore establishes neither exploitation nor legitimate reward by itself.

To make the distributional question inspectable, define $\ell_c = (\ell_{u,c})_{u \in \mathcal{U}_c}$ as contributions of labor and maintenance effort, and $\omega_c = (\omega_{u,c})_{u \in \mathcal{U}_c}$ as a vector of separately specified access and return outcomes. No proportionality between ℓ_c and ω_c is assumed. Equation 39 records the dependence of an allocation on the institutional configuration Γ_c , complementary resources $\mathbf{Q}_c$, evidence and commitments $\mathcal{I}_c$, and the participants’ contributions. It represents a family of mechanisms rather than a fitted structural equation:

$$\omega_c \in \mathfrak{R}_c(\ell_c, \mathcal{I}_c, \mathbf{Q}_c, \Gamma_c). \quad (39)$$

Different components of ω_c may include an attribution correction, a research place, salary, a shared public dataset, or the removal of an access barrier. The correspondence need not be monotone in an individual’s reputation and need not be transferable between contexts. Actual causal claims require identifying which institutional rules or resource endowments changed while accounting for other conditions. A favorable allocation can coexist with poor distributive justice; a commons arrangement can distribute broad use rights while underpaying maintainers. Neither institutional label decides the question without examining the corresponding resource flows and responsibilities.

The book-length literature on knowledge commons treats shared knowledge as a resource whose production, preservation, and governance require institutional arrangements [25]. That insight becomes especially important for Section 6: increasing the social recognition of an open resource is different from sustaining the labor that keeps it usable. Section 7 examines commons-based governance and the retention of generative capacity; Section 8 investigates possible mechanisms of extraction and asymmetric appropriation. The present section restricts itself to mapping the material interfaces through which recognized work may lead to productive opportunities or fail to do so.

Table 11: Productive access and returns supported by different institutional mechanisms.

Resource or return	Possible conversion mechanism	Analytical limit or responsibility
Research infrastructure	Grant, facility authorization, public provision, or pooled commons membership	Rights to data, technical support, maintenance, and scheduling may remain binding
Education and mentorship	Admission, recognized preparation, funded training, or open instructional community	Recognition does not identify available teaching capacity or actual learning
Collaboration and networks	Evidentiary referral, negotiated invitation, shared project governance	Invitation may provide neither compensation nor decision-making voice
Employment and remuneration	Authorized appointment, contract, wage, fee, or paid service arrangement	Monetary payment need not entail proper attribution or fair control
Collective knowledge assets	Reuse permission, public archiving, interoperable infrastructure, community stewardship	Shared access may conceal unequal maintenance burdens and access barriers
Institutional standing and remedy	Procedural recognition, accredited role, protected dissent, appeal rights	Formal standing must be distinguished from usable procedures and implemented correction

6.5 Institutions, Rights, and Nonmonetary Forms of Access

The availability of productive resources does not imply that they should be represented as exchangeable commodities. A credential enabling supervised access to clinical records may be deliberately nontransferable; a contributor's consent to one use of a recorded interview does not confer a transferable entitlement to unrelated purposes. Membership in a learning community can yield instructional or relational opportunities that have no authorized sale price. Access rights, governance powers, qualifications, and payments therefore belong to different institutional categories even when they jointly shape research opportunities.

Table 11 presents examples that should be assessed independently. The rows distinguish potential benefits from the conditions under which the same instruments might fail to provide a meaningful return. Their purpose is to preserve heterogeneity rather than establish a universal typology of all possible economic value.

These forms are not levels on a common ladder of worth. A research collaborator may value participation for intellectual learning while rejecting payment arrangements that compromise independence; another person may require predictable compensation for the same participation to be practicable. Where a resource is provided as a right, imposing an extraneous reputation gate can undermine that right. Where access is necessarily selective, the criteria of selection may still need public justification, appropriate expertise, proportionality, and routes for correction. In either case, a plural description of access outcomes is better suited to identifying competing legitimate interests than an assumed scalar return on relational currency.

The historical-materialist significance of such distinctions lies partly in the organization of work that sustains recognition itself. Editors, research librarians, curators, repository maintainers, translators, infrastructure engineers, instructors, and community participants perform activities whose contributions can become obscured when the visible output is a publication or an award. A serious analysis of access therefore tracks both the final provider of a resource and the less visible productive relations that make the resource possible. This also enables comparisons between capitalist, public, nonprofit, and commons-based systems without assuming that the presence of money determines whether value creation is just or unjust.

6.6 Empirical Identification and Distributional Tests

The staged framework yields research questions that are more discriminating than an aggregate association between a person's citation count and subsequent funding. Suitable administrative or observational data would record the population at risk of access, the instruments presented, assessment rubrics, recognized contributions, eligibility determinations, selections, deliveries, practical use, relevant constraints, and subsequent outcomes. When records are incomplete, claims should be bounded by the available sampling frame. A database of funded investigators excludes eligible nonapplicants and many unsuccessful

applicants, while a database of published outputs may underrepresent contributors who leave the field or whose maintenance work produces few publications.

A randomized intervention could vary the disclosure or presentation of verified contribution evidence while fixing the underlying application content. Let $T \in \{0, 1\}$ denote assignment to a provenance-rich recognition display and $Y(t)$ denote a prespecified access outcome under assignment t . Equation 40 defines the average intention-to-treat estimand for the sampled population $\mathcal{S}$:

$$\tau_{\text{ITT}}^{\mathcal{S}} = \mathbb{E}[Y(1) - Y(0) \mid u \in \mathcal{S}]. \quad (40)$$

Identification by random assignment requires valid implementation, observed or appropriately handled outcomes, and a clear unit of assignment. It does not by itself identify recognition as the mediating psychological mechanism. The display may alter search effort, reviewer confidence, institutional processing time, or other pathways. When applicants compete for a fixed number of awards, assignments can also affect others' outcomes; an intervention on one application need not have a well-defined no-interference potential outcome. Such settings require an explicit assignment and interference design, potentially at the committee or programme level.

A policy reform that changes resource eligibility or verification support offers a different estimand. Depending on institutional context, staggered changes in rules may support comparisons among programmes, but the resulting estimates require defensible counterfactual trends and careful treatment of concurrent funding or staffing changes. A threshold design near grant review cutoffs can reveal effects for marginal applications under continuity and nonmanipulation conditions; it cannot directly identify effects for contributors far from the cutoff, persons who never applied, or institutions with different procedures. The studies of science funding already mentioned therefore inform plausible mechanisms and identification designs rather than supply numerical parameters for Equation 39.

The most useful outcome definitions separate receiving a favorable decision from obtaining usable resources and from producing a further intellectual or social good. Potential measures include application and enrollment rates, time until facility access becomes operative, feasible research hours, continuity of employment, documented access to data or mentorship, completed corrective remedies, and independently assessed research outputs. Each measure has limitations. Hours of access may be a poor proxy for autonomy; number of publications is sensitive to discipline and collaboration structures; and recorded complaints may increase when protected reporting improves. Ethical evaluation should also attend to whose labor becomes more intensive, whether confidential information is exposed, and whether access mechanisms change the distribution of bargaining power.

Two explicit research hypotheses follow from these distinctions. They are conjectures about specified institutional settings and are not consequences of the preceding propositions.

Hypothesis 6.4 (Recognition effects under feasible and binding access conditions). In an institutional setting where a favorable contribution evaluation can affect authorization, an intervention improving accurate recognition will change actual usable resource access more strongly among participants with otherwise feasible authorization, participation, and rights conditions than among participants whose access remains constrained by an independent, binding gate. The contrast should be evaluated on prespecified outcomes and with measurement of any intervention-induced changes in the gates.

The qualification concerning gate changes is essential: institutions may respond to public recognition by waiving a requirement, providing support, or reassigning scarce resources. Such responses form possible mechanisms of conversion, rather than errors to be suppressed. The hypothesis could fail if recognition has no practical role in the examined institution, if resource providers rely chiefly on other evidence, or if compensatory policies deliberately prioritize previously unrecognized participants.

Hypothesis 6.5 (Recognition-to-return gaps across governance arrangements). Across comparably defined knowledge-production settings, the association between documented contribution recognition and later material or productive returns will vary with complementary-resource control, available support, and rules for allocating and maintaining common infrastructure. Where recognition is held constant,

interventions that relax independently measured access or maintenance constraints may alter realized productive outcomes. No universal direction or effect magnitude is stipulated across private, public, nonprofit, and commons-based regimes.

The second hypothesis is intentionally comparative. A finding of no difference across governance arrangements, or evidence that resource constraints do not account for recognized contributors' unequal access in a specified setting, would narrow the proposed mechanism. Strong claims about fairness require normative criteria that have been stated independently of the measured resource effects. An association between status and later opportunity does not by itself establish either causal dependence or injustice, while a causal advantage for status cues does not demonstrate that the resulting allocations were deserved.

Section 6 thus supplies the material interface required by the paper's account of relational currency: instruments may condition the availability of actions, but productive access occurs through rule-governed, resourced, and sometimes competitive institutions. Propositions 6.2 and 6.3 delimit recognition-only claims under explicit gates and capacities. Hypotheses 6.4 and 6.5 identify circumstances under which the proposed effects may be observed, limited, or overcome by broader institutional change. The analysis of collective capacity retention and of asymmetric capture can now be developed without treating a record of contribution, the award of an entitlement, the receipt of income, and the regeneration of public knowledge as equivalent forms of value.

7 Commons Circulation and Retention of Generative Capacity

The circulation of knowledge representations can create opportunities for shared inquiry while leaving the infrastructures and labor required for further production underfunded. A publicly available dataset may become the basis of many downstream studies even as its curators lack stable employment; an open software package may be incorporated into numerous systems while only a small group is available to repair it. These are possible patterns of institutional organization rather than necessary properties of knowledge commons. This section examines the conditions under which collective circulation contributes to the retention and development of productive capabilities. It distinguishes the availability of intellectual outputs from the ongoing regeneration of the material, technical, interpersonal, and governance arrangements through which those outputs can be used and improved. A stock–flow representation, two restricted propositions, and research hypotheses locate this question within the paper’s framework of situated relational currency.

Knowledge commons have been studied as constructed arrangements of resource sharing, production, governance, and collective action. Hess and Ostrom emphasize the opportunities and threats associated with treating knowledge as a shared resource [25]; the comparative framework edited by Frischmann, Madison, and Strandburg identifies institutional rules, community boundaries, and resource characteristics as matters for investigation rather than assuming a common organizational recipe [19]. Benkler’s account of commons-based peer production similarly identifies a form of coordination in information production that can differ from both firm hierarchy and market price signals [7]. None of these contributions makes an open licence alone an adequate measure of cooperation, democratic governance, labor security, or distributive justice. The present inquiry uses these studies as established intellectual comparators while developing a separate, provisional representation of value circulation and productive-capacity retention.

7.1 Knowledge Outputs and the Capacities Supporting Their Reproduction

The central analytical distinction concerns an *available output* and the *conditions of its reproducible generation and responsible use*. A publication, dataset, computational model, or methodological description may be copied or accessed widely under appropriate permissions. Its continued usefulness nevertheless depends on context: the accuracy and maintenance of documentation, functioning storage and software, expertise for error diagnosis, legitimate permissions for sensitive material, and a community or institution capable of deliberating over changes. Even when another user is able to copy an existing output at low marginal cost, the production of a reliable new version or the adaptation of the output for a different task may be materially costly.

Knowledge therefore presents a mixed resource structure. Certain informational expressions are non-rival under ordinary conditions of copying; scarce goods such as scientific instruments, compute capacity, protected working hours, and professional attention remain rival or congestible. Other resources have more complex constraints. Access to an archive may be legally or ethically restricted despite technical reproducibility; a training network may expand through mutual learning but depend on scarce mentorship time; the maintenance of reliable source attribution can require labor that is not captured in counts of published outputs. Calling the entire arrangement a “commons” should indicate a governance relationship whose membership, rules, rights, and responsibilities are specified. It should not dissolve those distinctions.

In the present framework, *generative capacity* refers to the set of practically exercisable conditions supporting further knowledge production under a given institutional and ecological arrangement. It includes, as relevant, people with protected time and skills, usable equipment and computing, documentation and preservation, permission to conduct and verify inquiries, institutional procedures for correction, and the relationships that enable mutual learning. This is an operational research construct, not a scalar measure of the intrinsic worth of researchers, communities, ecosystems, or their products. The term *retention* denotes the continued availability or renewal of those supporting conditions along an investigated

Table 12: Distinct layers of knowledge-commons circulation and possible retention conditions.

Layer	Circulating object or activity	Condition relevant to renewed generation
Representations	Publications, datasets, code, methods, provenance records	Versioning, preservation, correction pathways, usable documentation
Human capability	Skills, mentoring, interpretation, peer review, local knowledge	Protected time, training, succession, safe participation, recognition of care and maintenance
Material infrastructure	Instruments, networks, storage, computing, facilities	Energy, repair capacity, predictable access and replacement resources
Institutional authority	Licences, admission rules, access rights, delegation, conflict procedures	Accountable rule revision, privacy safeguards, effective appeals and participation
Collective production	Shared projects, coauthorship, interdisciplinary translation	Coordination, attribution, adequate support for integration and verification
Ecological conditions	Energy supply, physical materials and environmental services	Context-specific assessment of environmental burdens and replenishment

sequence of institutional changes. It does not imply that the same participants, organizational form, or resource stock must remain fixed.

Table 12 separates sites of generation from the resources that may be required to sustain them. The categories overlap in practice, and some capacities are only intelligible at the level of interacting institutions. The table is an analytical guide for evidence collection, not a universal taxonomy.

The same circulating representation can contribute to several layers. A carefully documented method can facilitate training and reduce duplicated effort; its wider use may generate requests for troubleshooting that increase the curator’s workload; a public grant may supply equipment while imposing reporting tasks on the research group. The effect of circulation on collective capacity thus depends on complementary arrangements. A circulation count, citation score, repository download statistic, or aggregate monetary receipt has no independent claim to stand for the entire vector of resulting productive conditions.

7.2 Capacity Renewal and the Distribution of Maintenance Labor

To state the retention problem explicitly, consider an investigated institutional sequence indexed by s . Here the index identifies analytically ordered changes in an administrative or production process; no privileged present or uniform physical clock is assumed. Let $K_{\ell,s} \geq 0$ denote an operational capacity stock for resource class ℓ under a specified measurement protocol, such as supported maintainer hours or available computing capacity. Let $A_{\ell,s}$ represent renewal or additions, $D_{\ell,s}$ consumption or wear, and $L_{\ell,s}$ loss arising, for example, from access withdrawal or the departure of a necessary capability. Equation 41 is the accounting relation for each consistently measured resource class.

$$K_{\ell,s+1} = K_{\ell,s} + A_{\ell,s} - D_{\ell,s} - L_{\ell,s}, \quad \ell \in \mathcal{L}. \quad (41)$$

The four quantities in Equation 41 require a common unit *within* each resource class, not across classes. Protected research hours cannot be added directly to terabytes of storage or to the availability of an appeals procedure. Institutional rights and duties may be encoded as discrete constraints rather than continuous stocks. Some capacities—particularly trust, situated skills, and living relationships—may be poorly described by a simple stock and should be recorded qualitatively or with a different model. Equation 41 is therefore a deliberately restricted accounting device, and the empirical meaning of its variables is part of the proposed research.

For a class with measurable minimum operational requirements, define a local viability condition by a capacity threshold and the presence of necessary permissions. Equation 42 expresses a conditional, conjunctive criterion under one chosen institutional purpose c .

$$\text{Viable}_c(s) = 1 \iff [K_{\ell,s} \geq k_{\ell,c}^{\min} \text{ for all } \ell \in \mathcal{L}_c] \wedge \text{Rights}_c(s) = 1. \quad (42)$$

The threshold $k_{\ell,c}^{\min}$ is a context-specific operational requirement, not a natural lower bound on knowledge creation or a criterion of moral legitimacy. Many productive groups function with improvised, varying, or substitutable inputs. Equation 42 is most appropriate for specified services—such as maintaining a secure archive or running a particular scientific facility—whose minimum conditions can be documented. It can be relaxed for substitutable resources or multiple alternative pathways.

Proposition 7.1 (Capacity depletion under persistent renewal shortfall). *Fix a measurable resource class ℓ and a starting index s_0 . Suppose Equation 41 applies on the investigated nonnegative-capacity sequence, the fixed operating threshold satisfies $k_{\ell,c}^{\min} > 0$, and for every applicable step through $s_0 + m - 1$ the net consumption satisfies $D_{\ell,s} + L_{\ell,s} - A_{\ell,s} \geq \delta$ for some $\delta > 0$. Then Equation 43 holds. In particular, any such sequence that remains defined through a sufficiently large m crosses the stipulated positive threshold. If operation ends or the accounting conditions change earlier, the bound cannot be extrapolated beyond that point.*

$$K_{\ell,s_0+m} \leq K_{\ell,s_0} - m\delta, \quad m > \frac{K_{\ell,s_0} - k_{\ell,c}^{\min}}{\delta} \implies K_{\ell,s_0+m} < k_{\ell,c}^{\min}. \quad (43)$$

Proof. Summing Equation 41 across the designated m transitions telescopes the change in capacity. The stipulated lower bound on net consumption makes each change at most $-\delta$, giving the inequality in Equation 43. The displayed strict threshold condition follows algebraically. The statement is conditional on the persistence of those resource and measurement conditions. Because $K_{\ell,s} \geq 0$ is required by the model, indefinite extrapolation of a strictly negative update beyond exhaustion is inadmissible. The conclusion concerns an operational threshold reached along a defined sequence, not a physically negative stock; no persistence is asserted for actual institutions. $\square$

Proposition 7.1 supplies a narrow but useful conceptual safeguard. A knowledge commons can increase the circulation of available outputs while depleting a service-critical capacity if the additional use is accompanied by insufficient renewal. The proposition does not establish that increased use *causes* a shortfall, that community participation necessarily becomes unsustainable, or that sustaining a resource requires charging for every use. Its assumptions can cease to hold when new maintainers join, tasks are automated, infrastructure becomes more efficient, public funding changes, or activity is reorganized. The inequality establishes only the consequence of a *specified* persistent shortfall for one capacity class.

This analytical focus corresponds to the documented significance of maintenance labor. Eghbal’s study of open-source software emphasizes that widely used public digital artifacts may rely heavily on individual maintainers whose work is less visible than outputs [14]. In a small qualitative study of maintainers, Linåker, Link, and Lumbard examine how working conditions, human relationships, funding, and social pressures affect the maintenance of open software projects [31]. Champion and Hill propose a relative operational measure of software underproduction, comparing indicators of maintenance effort with the importance of software components in their Debian package study [13]. This measure is not a direct quantification of all required maintenance work or of a universal threshold for sustainability. These sources motivate attention to a particular maintenance problem; software ecosystems provide neither a representative sample of all knowledge institutions nor parameters for the present renewal equation.

Maintenance should also be understood broadly. In knowledge infrastructures it can include acquiring ethical access permissions, preserving archival context, updating scientific protocols, translating materials across languages, checking provenance, addressing security issues, training successors, and maintaining forums for disagreements. The same work may be carried out by paid employees, unpaid volunteers, independent researchers, or participants with duties outside formal membership. Work that keeps a commons accessible may remain uncredited precisely because its effectiveness is expressed in the absence of visible failures. The resulting distributional question concerns not only the number of contributions but also whose time is consumed, which activities create bargaining power, and how the community can negotiate adequate support.

7.3 Reciprocal Learning, Pooling, and Complementary Resources

Commons-based circulation can contribute to productive capacity through multiple mechanisms: reciprocal instruction may spread previously concentrated expertise; shared facilities may reduce duplicated fixed expenditure; a maintained open repository can allow heterogeneous research groups to develop different applications from common inputs; and jointly governed licensing can protect specified reuse rights. These mechanisms have distinct requirements. Skill transfer depends on comprehension, language, mentorship, and opportunities to practice. Pooling of material assets depends on compatible technical requirements, fair scheduling, and sufficiently reliable contributions. Joint governance requires effective participation and dispute procedures. Exchange of representations alone does not complete any of these processes.

Let $B_{u,\ell,s}$ denote the renewal contribution made available by participating actor u for a particular service class ℓ . Let $\kappa_{\ell,s}$ denote the costs of integration, coordination, and collectively required safeguarding expressed in that same service unit. The effective aggregate provision for that class is defined by Equation 44 when a common accounting unit and agreed conversion within the class are available.

$$A_{\ell,s}^{\text{pool}} = \max \left\{ 0, \sum_{u \in \mathcal{U}_s} B_{u,\ell,s} - \kappa_{\ell,s} \right\}. \quad (44)$$

Equation 44 concerns effective contribution to one defined service, not a subtraction of human worth from coordination overhead. Neither voluntary labor nor a shared legal label makes the integration cost vanish. When the contributors supply unlike things—time, equipment, information, and legal authorizations—a single sum may be inappropriate; the process then requires a multidimensional production function and explicit institutional decisions about tradeoffs.

Pooling may also distribute demand shocks or continuity risks. A stylized statistical comparison makes the relevant assumptions visible. Suppose $n \geq 2$ units face centered demand fluctuations $X_1, \dots, X_n$, each with variance σ^2 , and every distinct pair has the same correlation ρ , where the covariance matrix is feasible. Equation 45 gives the variance of the mean fluctuation.

$$\text{Var} \left(\frac{1}{n} \sum_{u=1}^n X_u \right) = \sigma^2 \left(\rho + \frac{1-\rho}{n} \right). \quad (45)$$

Proposition 7.2 (Variance reduction under exchangeable imperfect correlation). *If the moment assumptions of Equation 45 are jointly feasible for both sizes n and $n+1$, and the same $\sigma^2 > 0$ and $\rho < 1$ apply in both groups, increasing the number of exchangeable units from n to $n+1$ strictly reduces the variance of their average demand fluctuation. The admissibility condition is important for negative equicorrelation, which cannot be fixed arbitrarily as group size grows. The result alone provides no guarantee of lower absolute total demand, adequate pooled capacity, equitable burden allocation, or successful coordination.*

Proof. The variance identity follows by expanding the covariance of the sum: there are n diagonal terms σ^2 and $n(n-1)$ off-diagonal terms $\rho\sigma^2$. For any admissible comparison in which the common ρ and σ^2 can be maintained as n changes, the difference between the right-hand sides for sizes n and $n+1$ equals $\sigma^2(1-\rho)/(n(n+1)) > 0$. This gives the stated comparison of averages. For $n+1$ exchangeable units with positive common variance, positive semidefiniteness of the equicorrelation matrix requires $-1/n \leq \rho \leq 1$: its eigenvalues are $1-\rho$ (multiplicity n) and $1+n\rho$ (multiplicity one). This condition also makes its n -unit principal submatrix feasible. The exchangeability and fixed-parameter assumptions remain substantive restrictions, especially for institutions with shared infrastructure shocks. $\square$

Proposition 7.2 concerns one statistical property of an exchangeable model, not a general theorem that larger commons perform better. Correlated outages, central points of failure, unequal access privileges, governance conflicts, and concentration of specialized skills may eliminate anticipated operational benefits. Furthermore, risk pooling and pooling of productive ownership are different institutional operations.

A jointly funded server may diversify payment obligations but remain controlled by one intermediary; a collaborative project can share publications while maintaining exclusive access to core datasets. It is therefore necessary to document the allocation of effective authority over pooled capacities alongside their technical performance.

7.4 Governance of Rights, Responsibility, and Attribution

The social organization of a commons includes rules defining membership, resource contributions, permitted uses, withdrawal and succession, decision-making, accountability, and external relationships. Ostrom’s work on common-pool resource institutions supplies conceptual questions concerning monitoring, rule fit, and conflict resolution [38]. Its results concern particular resource settings; constructed knowledge commons differ in the copyability of some outputs, the role of intellectual-property entitlements, and their dependence on specialized technical infrastructure. The framework for governing knowledge commons places those particularities at the center of institutional comparison [19]. A public repository, a university-led consortium, a community archive, and a worker-governed platform may all provide shared knowledge while allocating the rights to amend rules, withdraw access, license derivatives, and direct revenues in different ways.

For each relevant resource or representation class ℓ , a governance record should document the actors permitted to contribute, consult, transform, allocate, and contest decisions, as well as any privacy or fiduciary duties. Let $G_{u,\ell}^a \in \{0,1\}$ denote whether actor u holds a specified governance capability a for resource class ℓ under a particular rule version. The practical ability to exercise that capability may require technical access and a realistic path to appeal. A formal right with no feasible channel for exercising it may be substantively weaker than its written description suggests. This returns to the distinction developed in Section 6: recognition or formal eligibility can be valuable while remaining insufficient for access.

Attribution poses an additional problem. Commons production frequently combines originating research, derivative improvements, error correction, hosting, translation, mentoring, and ordinary maintenance. Contributors may exercise distinct rights and responsibilities without sharing a single authorship category. A contribution ledger could therefore record role-specific attestations and evidence of revision, with an appeal mechanism for disputed attributions; it should avoid turning the recorded quantity of activity into a metric of deservingness. Individuals may justifiably withhold their identities or restrict the circulation of personal data, while collective entities may require consent procedures for representations that affect them. The design of attribution records must preserve source traceability where appropriate without assuming that public exposure maximizes either transparency or safety.

Table 13 presents a compact institutional analysis matrix. It separates the question of who owns a resource from the capacities to operate, explain, maintain, or challenge its governance. The categories also prevent a public or nonprofit organizational form from functioning as an automatic proxy for participatory legitimacy.

A principle of governance symmetry cannot be inferred from the existence of a commons. Some decisions may reasonably require specialist safety review, while other decisions concern distributional claims that require broad procedural participation. A technically competent steward may exercise delegated control without that delegation being unlimited; a rule permitting general participation may still place disproportionate workload on the most vulnerable contributors. The appropriate evaluation therefore examines a balance of expertise, accountable decision-making, legal obligations, and effective contestability. Such criteria require normative argument and evidence concerning actual practice rather than being established by the use of an open licence.

7.5 Value Circulation and the Retention of Collective Productive Conditions

The preceding distinctions permit a more precise use of the paper’s provisional relational-currency metaphor. Instruments such as provenance-rich acknowledgments, contributor credentials, permission records, public-funding commitments, and maintenance attestations may facilitate the circulation of

Table 13: Governance capabilities and retention-related questions for a knowledge commons.

Governance site	Observable institutional provision	Question requiring further evidence
Entry and contribution	Eligibility, review standards, rights to contribute and reuse	Whether language, costs, and institutional status foreclose practical entry
Maintenance and succession	Assigned work, support budget, handover records, continuity plans	Whether invisible work is supported and whether succession is feasible
Attribution and correction	Provenance ledger, role-specific credit, protected correction procedure	Whether disputed claims receive effective and timely review
Allocation of pooled assets	Budget, scheduling rules, decision authority, open accounting	Who can actually use and redirect scarce common resources
External agreements	Licences, partnerships, commercial use terms, benefit-sharing rules	Whether outside returns support or constrain further production
Collective rule revision	Member voting, delegated expertise, appeal and privacy provisions	Who can participate meaningfully in changing rules

recognition and commitments. Their practical consequence depends on what other actors accept them for and whether the resulting interactions renew capacities. For example, a well-documented contribution record may support a request for shared equipment, yet the benefit may accrue only to one institution if use rights cannot be transferred. A licensing arrangement may permit wide reuse while creating a maintenance funding channel; it may also prohibit direct monetization of a particular resource while ensuring publicly funded stewardship. Neither arrangement can be evaluated solely by the number of circulating instruments.

A formal measurement proposal should track returns to the *productive conditions* of knowledge generation without equating heterogeneous values. For a selected measurable resource class ℓ , define the share of eligible externally generated support actually received for renewing that class, where both numerator and denominator are measured in the same unit. Equation 46 is a contextual accounting indicator, with $F_{\ell,s} > 0$ denoting eligible support and $R_{\ell,s}$ denoting the part received and assigned for renewal.

$$\eta_{\ell,s} = \frac{R_{\ell,s}}{F_{\ell,s}}, \quad 0 \leq R_{\ell,s} \leq F_{\ell,s}, \quad F_{\ell,s} > 0. \quad (46)$$

The quantity $\eta_{\ell,s}$ cannot measure all generative value, and a small share does not independently establish exploitation. The denominator excludes unpaid but important reciprocity, household support, environmental impacts, and returns that are ethically inappropriate to monetize. It also depends on how eligible revenue or resource support is defined. A zero-denominator case is undefined rather than evidence of zero collective value. An institution could display a large assigned renewal share while restricting access or assigning maintenance work unfairly; conversely, a service supported through a public budget may retain capacities without tying its funding to each downstream user. The measure belongs in a multi-dimensional institutional account alongside labor conditions, access rights, maintenance adequacy, and the realization of participants' legitimate claims.

The intellectual motivation for attending to bottom-up generation and circulation of value includes Eglash's discussion of generative justice [15]. The present paper takes this as one relevant inspiration, while specifying its own research object and independent formal questions about provenance, contextual conversion, capacity renewal, and institutional governance. This bounded acknowledgment neither makes Eglash's particular proposals the governing theory of relational currency nor treats every commons arrangement as an example of generative justice.

Historical-materialist inquiry adds questions about the organization of necessary labor and control over its conditions. Sharing a public output can coexist with privatized control over the storage, computing, evaluation, or distribution infrastructure required to use it. Firms can contribute to genuinely useful commons while deriving commercially valuable complementary services; public organizations can provide broadly available resources while transferring invisible labor to unpaid participants; community institutions can generate common capabilities while maintaining exclusionary membership practices. Such arrangements differ in their productive and normative characteristics. Their classification

therefore depends on the actual rights, labor relations, control of assets, and routes by which benefits are returned to those who produce and maintain capacities. The question of asymmetric capture remains analytically distinct from commons renewal and will be investigated in the next research section.

A mature study of relational circulation should also distinguish short-term distribution from the creation of future possibilities. Redirecting a fixed grant may alter who receives a currently available resource; training new investigators and building repairable infrastructure may alter the set of feasible projects for several communities. Those consequences can be investigated as sequences of institutional changes without presuming that one scalar welfare index exhausts scientific, social, and ecological value. Communities may justifiably prioritize different dimensions, and the legitimacy of those priorities depends in part on inclusive deliberation and protection for affected parties.

7.6 Empirical Tests of Capacity Retention and Commons Governance

The proposed mechanisms permit empirical designs at several levels. A comparative historical study could reconstruct the development of distinct archives, open-source foundations, community laboratories, research consortia, or publicly funded digital infrastructures. For each case, researchers could identify the relevant representations and licences, maintenance responsibilities, financial and in-kind contributions, decision rights, use conditions, conflicts, and changes in the feasible capacities of participants. Historical reconstruction should explicitly address selection into the observed sample: well-maintained projects leave more complete records, and unsuccessful or dissolved institutions may be disproportionately absent from publicly accessible accounts. The observation that surviving commons had a particular governance feature is not sufficient to show that the feature caused survival.

A prospective evaluation could measure service-specific capacity stocks and renewal flows under Equation 41, followed by use demand, maintenance backlogs, error response times, contributor turnover, documentation quality, and effective access. Administrative records should be complemented by protected interviews with those performing maintenance and by independent documentation of tasks that official contribution metrics omit. More visible reporting may initially increase recorded faults or complaints; such changes could reflect better detection rather than declining underlying quality. Likewise, fewer reported incidents may reflect reduced participation or suppression of reporting. The measurement model must be identified before interpreting those outcomes.

A suitably governed intervention might introduce dedicated maintenance funding, protected contributor time, a succession mechanism, or a participatory allocation procedure to comparable organizational units. Let $T \in \{0, 1\}$ denote assignment to a prespecified support arrangement, and $Y_u(t)$ the resulting measured, service-specific capability outcome for unit u under assignment t . Equation 47 states an intention-to-treat contrast within the sampled setting $\mathcal{S}$ under no-interference notation.

$$\tau_{\text{commons}}^{\mathcal{S}} = \mathbb{E}[Y_u(1) - Y_u(0) \mid u \in \mathcal{S}]. \quad (47)$$

In actual commons, spillovers are often part of the intended mechanism: contributors share knowledge across projects, and a funded maintenance team may assist untreated users. Equation 47 would therefore need an exposure mapping, cluster-level treatment assignment, or an explicit interference model when such effects are present. Randomized funding or rule changes may identify a total policy effect but ordinarily do not identify a unique mediator such as reciprocal learning without additional design and assumptions. Ethical procedures must also avoid depriving persons of established rights or essential safety maintenance for experimental convenience.

Hypothesis 7.3 (Maintenance renewal and continuity under increasing reuse). For a defined class of knowledge infrastructures whose use and maintenance requirements can be measured, increases in externally recorded reuse will be associated with diminished service continuity primarily when renewal and maintenance support fail to adjust to the additional load, conditional on technological, task-composition, and governance changes. An intervention addressing an identified maintenance shortfall is predicted to improve the corresponding prespecified continuity outcome, subject to competing constraints and possible spillovers.

This hypothesis could be contradicted by cases where reuse increases while maintenance demand remains constant or decreases, where automation changes unit costs, or where observable continuity improves without additional support because previously idle capacity is redeployed. Such cases would limit the proposed mechanism; they should not be dismissed as measurement error merely because they diverge from a depletion narrative.

Hypothesis 7.4 (Governance participation and retention of shared capability). Across comparable knowledge-production settings, arrangements that permit affected maintainers and users to exercise effective influence over renewal priorities and access rules may show different patterns of retained productive capability and distributional burden from arrangements offering only nominal participation. The direction and magnitude of any effect are conditional on institutional competence, conflict procedures, available support, and the comparative design; greater participation is not presumed to improve every operational outcome.

The second hypothesis can be investigated through versioned rule changes, structured participation records, confidential labor surveys, administrative resource-allocation evidence, and measures of realized access. A finding that participation rights exist without practical influence would challenge an assumption of effective governance; a finding of little association between actual influence and capacity outcomes in well-measured settings would narrow the conjecture. Claims of fair governance further require normative assessment of consent, responsibilities, privacy, and who bears costs. A design focused only on organizational survival might otherwise count a durable institution as successful even where contributors have little autonomy or experience persistent uncompensated burdens.

The analysis presented in Section 7 provides a bridge between the eligibility and productive-resource pathways of Section 6 and the distinct problem of asymmetric appropriation examined next. Commons circulation is a possible arrangement for renewing the means of knowledge creation, rather than an automatic guarantee of that renewal. Its assessment requires evidence of service continuity, labor and infrastructure support, collective governance, and practical rights of affected participants. Propositions 7.1 and 7.2 state only conditional features of restricted renewal and pooling models; Hypotheses 7.3 and 7.4 identify possible observations and interventions that could support, modify, or challenge their broader institutional interpretation.

8 Extraction and Asymmetric Value Conversion

Relational representations may circulate widely and acquire institutional significance while the material and organizational returns associated with their use accrue disproportionately to actors who did not produce or maintain the underlying evidence. Such disparities arise within heterogeneous production arrangements, including commercial platforms, public research infrastructures, nonprofit intermediaries, and knowledge commons. This section examines the conditions under which circulation and resource conversion become asymmetrical. Its objective is to separate an observed distribution of returns from the causal mechanisms producing that distribution and from the normative evaluation of those mechanisms. The analysis proceeds through a typology of conversion sites, a restricted accounting and bargaining representation, two conditional propositions, and empirical hypotheses. In keeping with the rest of the paper, an evidentiary representation is treated as a context-dependent instrument rather than a universally fungible store of value.

The economic literature supplies useful comparisons without settling the proposed framework. Teece's analysis of appropriability and complementary assets explains why an innovator may fail to capture returns when other actors control complementary production and commercialization capacities [46]. Research on the governance of global value chains shows that the organization of transactions and relative capabilities can structure dependence and bargaining positions [20]. These are mechanisms to investigate, not sufficient criteria for extraction. A producer receiving a smaller financial share may nevertheless obtain substantial nonmonetary benefits; a distributor receiving a larger share may have

Table 14: Potential sites of asymmetry and the evidence required for mechanism assessment.

Institutional site	Possible condition of dependence	Evidence needed for mechanism assessment
Source custody and licensing	Permission to reproduce, adapt, audit, or correct a representation	Rights assignments, licence histories, legitimate restrictions, rejected access requests
Discovery and presentation	Indexing, ranking, repository integration, or AI-mediated summaries	Exposure logs, interface changes, comparative source availability
Certification and attribution	Recognition of authorship, provenance, competence, or role	Contribution records, rubric changes, appeals, revision decisions
Complementary assets	Compute, equipment, deployment channels, funding, or procurement access	Capacity costs, alternative providers, contract terms, counterfactual access
Contracting and implementation	Negotiated shares, exclusivity, revocation, audit duties, enforcement	Bargaining documentation, exit costs, consent procedures, dispute outcomes
Maintenance and verification	Stewardship, translation, error correction, incident response, data protection	Labor logs, allocated support, rework, allocated risk, renewal expenditure

supplied scarce infrastructure and borne significant risk. Conversely, a formally voluntary contract may be concluded under severely restricted alternatives. Each interpretation requires further evidence.

8.1 Sites of Control Across Knowledge Production and Conversion

An asymmetry becomes relevant to the paper’s research object when an actor’s control over an institutional or material condition alters another actor’s feasible circulation or conversion pathways. Possible controls include rights over a source representation, archival access, dissemination interfaces, legal authorizations, credit assignment, computation, certification, procurement, or implementation. Their effects should be assessed at the relevant point in the circulation chain. For example, the capacity to edit a record is distinct from the capacity to decide which records a search interface presents; both differ from the capacity to allocate a funded position on the basis of the resulting evaluation.

Platform mediation introduces an additional institutional layer. Gillespie’s account of the politics of platform terminology identifies the complex claims through which intermediaries position themselves with respect to users, advertisers, and regulators [21]. Plantin and colleagues show how platforms and infrastructures can acquire overlapping characteristics, combining provision of shared services with the capacity to constrain their conditions of use [39]. These contributions motivate an investigation of governance affordances and contractual arrangements. They do not license the assumption that every platform is intentionally extractive or that centralization is invariably illegitimate.

Table 14 differentiates six illustrative sites of conversion-related influence. Its third column specifies observable evidence that may distinguish mechanisms which otherwise produce similar distributions.

The categories are neither exhaustive nor mutually exclusive. An institution may finance a collection, license its dissemination, perform quality checks, provide facilities for further research, and resolve disputes. The same functions can be distributed across public and private participants or embodied in collective governance. Thus the classification concerns *control rights and exercised powers*, not the organizational label of an actor. In particular, public ownership or a nonprofit charter does not guarantee equitable participation, while commercial organization does not itself demonstrate an extractive mechanism. Ownership, access, management, exclusion, and alienation should be distinguished when assessing who can make decisions about a commons resource [25].

A further distinction concerns extraction of *information* and extraction of *value*. A system may gather information under a lawful, proportionate, and mutually beneficial arrangement; another may use a small volume of data to impose substantial costs or bargaining disadvantages. The quantity of data copied or citations transmitted is consequently a poor standalone indicator of whether economic returns or productive capabilities were appropriated under objectionable terms. Disentangling consent, confidentiality, competitive dependence, and the effects of downstream use requires knowledge of the particular governance arrangement.

8.2 Distributional Accounting and Context-Specific Returns

Let $\mathcal{A}_c$ be the actors participating in a particular conversion arrangement c , including contributors, stewards, intermediaries, recipients, and governing bodies where appropriate. For each actor i , let $\mathbf{r}_{i,c}$ record a vector of observed returns, such as remuneration, compensated time, access to facilities, educational opportunities, institutional influence, or durable rights. Let $\mathbf{b}_{i,c}$ record corresponding burdens, including uncompensated labor, fees, lost opportunities, exposure to legal liability, and ecological costs where measurable. An empirical descriptive record may then be written as Equation 48:

$$\mathcal{D}_c = \{(i, \mathbf{r}_{i,c}, \mathbf{b}_{i,c}, \mathcal{F}_{i,c}) : i \in \mathcal{A}_c\}, \quad (48)$$

where $\mathcal{F}_{i,c}$ is the set of practically feasible choices under the rights, resources, and institutional conditions of c . Elements of $\mathbf{r}$ and $\mathbf{b}$ need not share a scale. One should not subtract access to a laboratory from a legal risk or assume that a citation compensates for unpaid technical maintenance. The set $\mathcal{F}_{i,c}$ matters because identical receipts can accompany radically different freedom to decline an arrangement, revise its terms, or pursue alternative collaborations.

For a narrow transaction with an auditable common monetary unit, an ordinary account can supplement the vector description. Let G_c be gross receipts traceable, under an explicit attribution protocol, to a defined use; let $p_{i,c}$ be transfers to actor i ; and let $C_{i,c}$ be documented costs borne by that actor for the same activity and accounting scope. Equation 49 defines a restricted monetary net return:

$$N_{i,c} = p_{i,c} - C_{i,c}, \quad \sum_{i \in \mathcal{A}_c} p_{i,c} \leq G_c + F_c, \quad (49)$$

where F_c denotes any separately recorded financing. The inequality requires appropriate accounting boundaries: revenue, direct payments, public subsidies, transfers within organizations, and retained investment cannot be double-counted. In many knowledge collaborations, a defensible transaction-specific G_c is unavailable because outputs are jointly produced, reused across applications, or nonmarket. Equation 49 then should not be forced onto the case. Gross transaction shares also say nothing by themselves about the value of contributed intellectual labor or the legitimacy of contractual rules.

A descriptive concentration statistic can be defined where receipts are measured consistently. For $G_c > 0$ and an internally exhaustive partition of receipts, write $s_{i,c} = p_{i,c}/G_c$. Such shares may reveal which actors receive or administer money, but they do not provide a measure of surplus appropriation absent credible cost, contribution, entitlement, and counterfactual evidence. Cross-project comparisons also require matching project age, expenditure accounting, exposure to risk, and the scope of public support. A research institute reporting zero profit can still channel professional recognition and decision authority toward a narrow group; a public repository reporting large income may reinvest extensively in preservation and access.

8.3 Complementary-Asset Dependence and Bargaining Constraints

Complementary assets are consequential when a contribution cannot reach a specified use without access to facilities, distribution channels, authorized evaluations, or implementation capabilities. Their controllers may supply genuinely productive services; they may also shape the terms on which another participant can convert recognition into returns. The resulting outcomes depend on outside options, substitutability, legal protections, actual costs, and the capacity to negotiate or coordinate alternative provision. The governance patterns identified by Gereffi and colleagues make the latter conditions empirically variable rather than inherent features of the “platform” or “commons” categories [20].

Consider a restricted bargaining model with one contributor u and one intermediary g . Assume a jointly realized, monetary surplus $S \geq 0$ after verified production and service costs and after respecting enforceable third-party claims. Let d_u and d_g denote their respective net outside-option payoffs, and let $\beta \in [0, 1]$ denote the contributor’s bargaining weight in the specified Nash bargaining problem. Under

transferable utility, complete information, a feasible agreement, and a fixed total surplus, the resulting payoffs take the form in Equation 50:

$$U_u = d_u + \beta S, \quad U_g = d_g + (1 - \beta)S. \quad (50)$$

The expression is an analytical benchmark, not a measured bargaining law. It omits dynamic learning, nontransferable rights, heterogeneous valuations, incomplete contracts, and third parties. Moreover, β should not be inferred mechanically from the observed payment split: investments, opportunity costs, prior agreements, and institutional constraints can produce similar observed divisions. The model's value is that it identifies variables whose independent estimation is necessary for claims about bargaining-driven redistribution.

The effect of an enforceable contractual ceiling can be stated more sharply. Let an actor's monetary return from a use of gross receipts $G \geq 0$ be

$$R_u(G) = \min\{\alpha G, \bar{r}\}, \quad R_g(G) = G - R_u(G) - C_g, \quad (51)$$

where $\alpha \in (0, 1]$ is an effective revenue share, $\bar{r} > 0$ is a fixed, binding payment ceiling, and C_g is a constant verified intermediary cost over the compared range. Any additional claims, taxes, subsidies, and costs are assumed absent or already included. This is a deliberately simplified contractual model; whether the ceiling is freely negotiated, socially justifiable, or enforceable is a separate inquiry.

Proposition 8.1 (Return concentration under a binding payment ceiling). *Suppose Equation 51 holds for two receipt levels $G_2 > G_1 \geq \bar{r}/\alpha$, and C_g is unchanged. Then the contributor's return remains constant, whereas the intermediary's net return increases by $G_2 - G_1$.*

Proof. At both receipt levels the cap is binding, so $R_u(G_2) = R_u(G_1) = \bar{r}$. Consequently $R_g(G_2) - R_g(G_1) = (G_2 - \bar{r} - C_g) - (G_1 - \bar{r} - C_g) = G_2 - G_1 > 0$. $\square$

Proposition 8.1 is an accounting implication of its assumptions. It neither evaluates whether the cap is exploitative nor shows that a particular intermediary caused receipt growth. Its empirical applicability requires documentation that the same underlying cost and attribution bases apply, that the ceiling truly binds, and that the additional receipts can be traced to the relevant use. A comparable mechanism could arise from capped royalties, fixed-fee content procurement, or compensation arrangements; in other arrangements, the contributor might gain nonmonetary opportunities from greater use, which Equation 51 does not represent. The broader empirical question concerns which institutions can revise the ceiling and how changes to the compensation rule affect feasible participation and capacity renewal.

8.4 Verification Work, Contractual Rights, and Productive Dependencies

Asymmetric conversion may occur through unpaid or poorly supported activities essential to a circulating instrument's reliability. A dataset may be widely licensed while its documentation, error correction, security assessments, and provenance response obligations remain with its original custodians. A developer may receive public attribution while the costs of adapting a library to changing dependencies fall on a small group of volunteers. Licensing that permits widespread re-use addresses a particular category of rights; it does not automatically assign responsibility for maintenance or provide a durable material return. Lerner and Tirole discuss the labor-market and career incentives involved in open-source development, while Baldwin and Clark examine how architecture can affect participation incentives [30, 5]. The present paper extends the inquiry to evidentiary stewardship and verification, without assuming that volunteers share identical motivations or that contribution must always be monetized.

Let $h_{i,c}$ represent verifiable work hours required of actor i by activity c , $w_{i,c}$ the portion compensated or institutionally supported under an explicitly stated protocol, and $e_{i,c}$ any estimated labor hours the actor affirmatively chooses to contribute without compensation. A residual indicator is

$$B_{i,c} = \max\{0, h_{i,c} - w_{i,c} - e_{i,c}\}, \quad (52)$$

subject to consistent conversion of supported resources into equivalent labor capacity. Equation 52 is a diagnostic proxy for *uncovered obligations*, not a moral verdict. Voluntary contribution $e_{i,c}$ should be evidenced rather than inferred from the absence of a wage. Relevant evidence includes the possibility of declining new demands without sanctions, the availability of institutional support, the distribution of safety and liability risks, and whose work becomes necessary for downstream commercial or governmental use. The measure should also exclude double-counting work already recorded under Section 7’s resource-specific stock–flow account.

Property and contractual regimes can shape these burdens, yet a single rule rarely determines the result. A restrictive licence may finance maintenance, enable responsible handling of protected data, or foreclose downstream competition. An open licence may support independent scrutiny while allowing some well-capitalized recipients to obtain disproportionate financial benefit. Exclusive research access may protect participants or facilitate necessary investment, yet its renewal and appeal mechanisms may also reproduce institutional dependence. Evaluation should therefore separate authorization, proportionality, actual use, governance voice, and access to correction. For mixed public–private arrangements, the analysis should additionally examine public financing, procurement standards, data-use rights, and what benefits or capacities return to the public institutions supplying initial research resources.

Fitter and Kaplinsky’s value-chain analysis illustrates how differentiated markets can redistribute product rents across positions in a chain [17]. Its empirical setting concerns coffee, not research knowledge, and a direct transfer of estimated effects to knowledge systems would be unjustified. Its methodological relevance lies in reconstructing *where* costs, differentiation, price formation, and control occur before judging who benefits. Analogous research into a knowledge-production pathway would need transaction accounts, labor requirements, intellectual-property conditions, institutional transfers, and counterfactual opportunities rather than treating high downstream revenues as sufficient proof that upstream contributors were wronged.

8.5 Distributional Asymmetry, Causal Extraction, and Normative Appraisal

The word *extraction* can refer to several distinct propositions. A descriptive statement may identify disproportionate returns or uncompensated obligations. A causal statement claims that a specific exercise of control changes the returns or capacities available to someone else. A normative statement judges the arrangement objectionable under an articulated standard of consent, reciprocity, distributive fairness, procedural legitimacy, contractual obligation, or protection of basic rights. These propositions should be separately assessable. In particular, an uneven distribution is compatible with unequal but defensible contributions or voluntary exchange, just as a superficially equal split can accompany coercion or violation of established rights.

Let $Z_c \in \{0, 1\}$ represent a well-specified institutional arrangement such as a restrictive exclusive-distribution rule versus an otherwise comparable alternative. Let $Y_{i,c}(z)$ denote a defined outcome for actor i under regime z , such as net supported maintenance capacity, and let $\Delta_{i,c}$ denote the corresponding potential-outcome contrast:

$$\Delta_{i,c} = Y_{i,c}(1) - Y_{i,c}(0). \quad (53)$$

This contrast is an estimand requiring a particular population, exposure definition, measurement window or ordered institutional sequence, and consistency assumptions. Only one potential outcome is generally observed per institutional instance; interference among repositories, licensing networks, or collaborating organizations may also alter the meaning of treatment. An observed compensation gap cannot independently identify $\Delta_{i,c}$. Nor does the sign of $\Delta_{i,c}$ yield an ethical judgment without a justified account of entitlements, restrictions, and relevant effects on other actors.

For purposes of disciplined evidence collection, Table 15 specifies levels of inference and competing explanations. The table’s normative column does not presume that one criterion is universal or sufficient in all contexts.

Proposition 8.2 (Observed shares do not identify extraction mechanisms). *Consider a model class that admits at least two institutional arrangements having the same aggregate receipts and actor-level mon-*

Table 15: Distinct questions and evidence requirements in evaluating asymmetric conversion.

Assessment level	Target question	Competing explanations or evidence needed
Descriptive	Who receives returns, bears costs, and retains decision powers?	Boundaries of accounting, hidden subsidies, nonmonetary gains, omitted labor
Mechanistic	Which access, certification, contract, or asset control shapes conversion?	Alternative suppliers, enforceable rules, process traces, fee schedules, interventions
Causal	What would change under a specified alternative arrangement?	Selection, simultaneous reforms, general-equilibrium responses, interference, credible comparison
Normative	Which expectations or rights make the observed mechanism acceptable or objectionable?	Consent, standing, obligations, public purpose, protection of vulnerable parties, review and remedy
Generative	Does circulation sustain the capacities needed for subsequent production?	Maintenance stocks, training, infrastructure renewal, exit, ability to revise governance

etary payment shares but different statuses under a specified procedural standard. If the observation scheme contains only those receipts and shares, the procedural status is not point-identifiable within that model class. Whether such observationally equivalent arrangements are admissible for a particular payment vector and standard must be established separately.

Proof. As a constructive witness, consider a hypothetical conversion with gross receipts of 100 units, 40 paid to the contributor, and 60 retained by an intermediary before separately assessed costs. Let the procedural criterion be the contributor’s meaningful opportunity to accept or reject the proposed arrangement, rather than a minimum-payment rule. One admissible history contains documented independent alternatives and informed, voluntary acceptance of the 40–60 division. A second admits the same receipts and payments but makes intermediary access indispensable and removes a meaningful opportunity to decline. Their observed monetary records coincide, while the stipulated procedural criterion differs. A decision rule using only receipts and shares must assign the same status in both histories, so it cannot classify both correctly. More generally, any two admissible arrangements agreeing on all observed monetary variables and disagreeing on the target status establish the same non-identification result. $\square$

The constructive example is deliberately existential. A procedural standard requiring a particular payment floor could make one of these histories inadmissible at other payment vectors, and knowledge of enforceable contracts, rights, or outside options might identify procedural status in a restricted population. The result therefore rules out *automatic inference from shares alone* in the stipulated model class; it does not assert observational ambiguity for every possible payment division or legal standard.

Proposition 8.2 is a result about an intentionally restricted observation scheme. It does not claim that extraction is inherently unobservable. Contracts, testimony, institutional histories, alternative-market conditions, labor audits, governance decisions, and ethically collected participant accounts can reduce the ambiguity. A further limitation concerns normative disagreement: whether a particular procedural or distributive expectation is justified is itself an argument requiring specification of whose claims count and how conflicts are evaluated. A legitimate review mechanism may therefore need to make reasons publicly inspectable where possible while protecting confidential evidence and affected participants.

8.6 AI-Mediated Recomposition and the Allocation of Contribution

AI-mediated knowledge production adds layers of representation and decision authority to already heterogeneous circulation networks. A source contribution may be selected for retrieval, embedded in a synthesized report, presented without a direct navigable reference, or used in a workflow whose final output depends on additional human judgment. In a different arrangement, a system may operate on data under a licence with restrictions on training, redistribution, or automated inference. These activities pose distinct questions of legal entitlement, technical lineage, research ethics, and distributive consequences.

They should not be collapsed into the generic claim that an AI system “takes” a contribution whenever a generated text resembles or discusses it.

Provenance techniques can record some stages of transformation, but neither machine-readable lineage nor model-output attribution necessarily recovers a unique allocation of epistemic or economic credit. Database provenance and related representational standards provide useful descriptions of derivation under specified operations [47, 11]. Large-model outputs may also depend on diffuse training and deployment histories that are incompletely observed or not meaningfully decomposable into individual author shares. Attribution decisions may therefore need to rely on documented roles, governing agreements, permitted uses, specific output evidence, and transparent contestation procedures. A model’s confidence score or a citation embedded in generated content cannot substitute for these distinct inquiries.

The effects of mediation on value conversion should be measured at several institutional sites: the originator’s capacity to inspect reuse, the intermediary’s control over training and deployment conditions, the recipient’s opportunity to verify a representation, and the organizations that finance maintenance and corrective responses. Automated production may reduce certain marginal costs while increasing demands for audit, redress, storage, and independent evaluation. Consequently, improved throughput may coexist with worsening capacity retention for a particular group, but it may also fund broader knowledge access or new kinds of collaborative work. The sign and magnitude of these effects require context-specific evidence rather than a presumption about technology.

For research design, the key methodological task is to define a treatment narrowly enough to isolate a governance mechanism: for example, disclosure of source lineage versus its omission, the presence versus absence of a negotiated maintenance obligation, or an enforceable contributor appeal process versus a merely nominal one. A shift from human-mediated to AI-mediated presentation changes many factors simultaneously, including content, speed, labor allocation, exposure, and uncertainty. Unless those dimensions can be separated or credibly modeled, an estimated difference in total revenue or citation frequency cannot be attributed specifically to a changed recognition mechanism. This point also limits the use of an apparently universal “relational currency” metric: the rights, purposes, and capabilities involved in human–human, human–AI, and AI–AI systems can differ even where the same technical attestation format is used.

8.7 Historical Forms and the Reproduction of Conversion Power

Historical-materialist analysis directs attention to the organization of productive relations rather than inferring an institution’s character from the language it adopts. Scientific production can depend simultaneously on publicly financed education, collaborative method development, paid research labor, volunteer maintenance, commercial publication channels, private intellectual property, and nonprofit repositories. Revenue may be appropriated at a different location from the one where knowledge is generated, while the material requirements of further work remain elsewhere. The relevant unit of investigation is thus a historically specified relation among productive actors, rights, infrastructure, and conversion pathways.

Under a capitalist arrangement, the ability to exclude, bundle, market, or deploy knowledge outputs may convert ownership of complementary assets into a recurring source of receipts, professional authority, or expansion capacity. Under public or commons-based arrangements, control over appointment, accreditation, procurement, and maintenance budgets may reproduce privileges even where distribution is formally nonmarket. Cooperative structures can change bargaining positions and return mechanisms, but they can also face scarcity, managerial hierarchies, or dependence on outside hosting and funding. These possible patterns demand historically grounded comparison; institutional labels are not substitutes for causal evidence.

The issue also has a generative dimension. An actor may receive immediate recognition or a transfer while losing the practical ability to conduct subsequent inquiry because continuing obligations, litigation risk, or inaccessible infrastructure undermine productive time and security. Another actor may receive modest monetary benefits yet gain substantial training, protected autonomy, shared tools, or membership in a resilient commons. Section 7’s capacity analysis supplies a way to investigate these differing

consequences without collapsing them into a common exchange rate. The value-circulation approach is informed in part by the generative perspective of Eglash [15], while the present distinctions among circulation instruments, conversion gates, and counterfactual inference constitute a separate proposed analytical framework.

The possibility of extraction also motivates a distinction between *value production*, *value realization*, and *control over conditions of further production*. The same representation may contribute to many uses without giving its producers a durable role in governing reuse. In contrast, transparent funding arrangements, participatory decision processes, accessible alternatives, and enforceable remedies can improve the conditions under which generated benefits return to the infrastructures and people supporting continued inquiry. The model predicts no necessary direction of historical change. Its empirical purpose is to investigate which governance arrangements preserve or diminish practical productive capacities and whose judgments determine what counts as an adequate return.

8.8 Hypotheses and Identification Priorities

A research programme should make the proposed mechanisms falsifiable. Transaction-based research could begin with auditable histories of licensing and deployment decisions, costs of intermediary services, relevant producer alternatives, and detailed maintenance assignments. Network analysis may help trace where representations are received, transformed, and bundled, but link counts and citation graphs cannot independently recover contractual terms or welfare effects. Process tracing can establish sequences of rule change and challenged decisions; complementary field or quasi-experimental designs would be needed to estimate well-defined causal consequences. Measurement must also distinguish formal rights from actual ability to exercise them and account for strategic reporting, missing records, and selection into contracts.

Hypothesis 8.3 (Asset dependence and conversion returns). Within comparable knowledge-production settings, greater dependence on a non-substitutable distribution, implementation, or certification asset is associated with a larger share of monetary receipts or decision authority accruing to its controller, conditional on documented service costs, contributor alternatives, and relevant contractual rights.

Hypothesis 8.3 may fail where strong collective bargaining, regulation, public procurement terms, cooperative ownership, reputational incentives, or alternative infrastructures limit the controller's discretion. Identification could exploit plausibly exogenous changes in the availability of substitute intermediaries, while accounting for the fact that such entry may simultaneously change demand, service quality, and participant composition. The hypothesis concerns distributions and institutional control; an independent normative assessment remains necessary.

Hypothesis 8.4 (Supported verification and productive-capacity retention). Among comparable circulation arrangements with similar reuse demand, institutions assigning traceable resources and enforceable decision rights for verification and maintenance exhibit higher subsequent retention of the relevant operational capacities than institutions imposing equivalent uncovered tasks on dependent contributors, conditional on baseline capacity and institutional selection.

Hypothesis 8.4 requires longitudinal measures of resource-specific capacities, credible classification of voluntary and compelled tasks, and attention to simultaneous changes in reuse and funding. It could be contradicted by arrangements where independently motivated contributors sustain capacities without earmarked support, where monetary support displaces other effective practices, or where support is accompanied by costly administrative restrictions. The test should not classify unpaid activity as coercive without evidence about choice and feasible alternatives.

The empirical and ethical requirements extend beyond the measurement of prices. Participants may face retaliation risks when discussing contracts, unpaid work, or institutional disputes. Researchers should minimize disclosure of personally identifying information, obtain appropriate permissions, and avoid inferring culpable motives from aggregate patterns. Comparing arrangements also requires sensitivity to diverse epistemic and social norms: the meaning of rightful attribution, acceptable secrecy,

voluntary contribution, and collective stewardship can differ across institutional and cultural contexts. The capacity to challenge a norm and obtain a reasoned remedy is itself an observable governance feature that may matter for both factual accuracy and legitimacy.

Section 8 thus establishes a bounded research object: unequal distributions of circulation-related returns, the institutional mechanisms that may cause them, and the separately justified normative claims that might classify a mechanism as extractive or unjust. The distinction is essential to the next task, which is to develop empirical research designs capable of discriminating among competing explanations and assessing alternative institutional arrangements without assuming that the conceptual model has already been validated.

9 Research Designs for Situated Circulation

The proposed theory of relational currency concerns relationships among documentary representations, their circulation, context-dependent assessments, institutional commitments, and subsequent opportunities or returns. These relationships require empirical investigation at multiple scales. The purpose of this section is to specify research designs capable of distinguishing circulation itself from the mechanisms that determine its reception and consequences. The analysis develops an auditable measurement architecture, historical and institutional reconstruction, randomized presentation and correction experiments, longitudinal comparisons of rule changes, partial identification under incomplete records, network-sensitive inference, and safeguards for research participants. Each design identifies a different object. Convergence across designs may improve a causal explanation; disagreement may show that the proposed family of relational-currency mechanisms is too broad, unstable across contexts, or badly operationalized.

Empirical inquiry should begin with defined questions and cases rather than the presumption that every endorsement, citation, or act of recognition constitutes circulation of the same kind. The observable events may include a research output being indexed, a digital credential being presented for evaluation, a correction being displayed, a knowledge contributor entering an eligibility review, an undertaking being accepted, or a maintained resource receiving support. Such events create partly overlapping but analytically distinct populations. Studies should specify whether they concern persons, jointly authored contributions, instruments, evaluation decisions, institutions, or interactions between them. A claim about one unit cannot be extended automatically to another.

9.1 Units of Analysis and an Auditable Circulation Register

The formal machinery developed in Sections 3–8 distinguishes the production of a representation from its use. For empirical purposes, let a *circulation episode* be an observational unit comprising a source-linked instrument, an intended or actual recipient context, an identifiable opportunity for encounter, and a specified observation interval. One instrument may enter several episodes; multiple instruments may derive from one source history; and a recipient may have encountered the source through an unrecorded channel. The resulting dependence should be represented explicitly in the data structure. No assumption of independent observations follows from the episode definition.

At a minimum, a preregistered or prospectively maintained study register should identify the relevant source and transformation links, allowable purposes of disclosure, context of receipt, applicable decision rules, exposure opportunities, and outcomes at several stages. The register should separate information obtained from administrative logs from participant reports and reconstructed archival judgments. It should also record what the investigator cannot observe. For an episode indexed by i , a restricted measurement vector may be stated as in Equation 54.

$$O_i = (H_i^{\text{ref}}, P_i, A_i, E_i, J_i, U_i, Q_i, K_i, M_i), \quad (54)$$

Here H_i^{ref} is a source-history reference rather than the completed history itself; P_i is available provenance and transformation information; A_i records applicable access and authorization conditions; E_i records measurable opportunities for encounter; J_i is an evaluator’s documented assessment; U_i is the relevant

Table 16: A provisional measurement framework for situated circulation studies.

Analytical stage	Candidate record or measurement	Important ambiguity or missingness
Source and transformation	Versioned document, provenance link, source-consent condition, transformation log	Absent source material, uncertain authorship, unrecorded redaction
Exposure opportunity	Eligibility to see a representation, retrieval query, controlled display or recorded delivery	Visibility does not establish encounter; logging coverage differs
Interpretive assessment	Admissibility decision, source-support verification, rubric-specific judgment	Evaluators differ in expertise, burden and access to underlying records
Commitment and reliance	Undertaking, procedural acceptance, delegation or documented performance milestone	Agreement may be compelled; a promise is not performance
Resource conversion	Decision to authorize, provision of a resource, verified usable access	Allocation differs from receipt; receipt differs from productive capability
Capacity and return	Maintainer resources, usable infrastructure, contributor time, appeal outcomes	Benefits heterogeneous; costs and delayed consequences may be omitted

uptake or acceptance event; Q_i records consequential decisions about commitments or resources; K_i is a context-specific measure of productive capacity or return; and M_i is a vector of observation and missingness indicators. Components may remain undefined when a corresponding stage does not occur. They must not be imputed as negative outcomes merely because a log is absent. Equation 54 is a measurement proposal, not an assertion that these variables can generally be recovered from existing administrative data.

Table 16 sets out an initial operational separation. A measurement instrument should specify the denominator for every recorded rate. An apparent rise in the proportion of corrected records, for example, could reflect more inaccurate records, more effective detection, changed reporting incentives, or a change in which records are counted. A comparable denominator and a model of observation are necessary before interpreting the rate as an improvement or deterioration.

The register should include identity-protective linkage mechanisms when longitudinal reconstruction requires joining records from different institutions. Separate fields should indicate whether the link is observed, probabilistically inferred, or asserted by a party. Research based on restricted data requires a governance plan for storage, minimum necessary access, consent or other lawful basis, correction requests, and time-limited retention. Reproducibility can be supported through public schemas, synthetic examples, versioned code, and controlled audit access without placing sensitive underlying histories in a public repository.

9.2 Institutional Histories and Provenance-Sensitive Process Tracing

Historical reconstruction is especially relevant when institutions change their criteria for accepting, licensing, attributing, or circulating evidence. A historical study may follow the adoption of a repository rule, the addition of an accreditation requirement, a revision to attribution procedures, or a change in the distribution of maintenance funding. Process tracing supplies techniques for organizing within-case evidence about sequences and possible mechanisms [8]. Its relevance here lies in separating evidence for a proposed institutional pathway from a retrospective story made persuasive only by a selected outcome.

A defensible archive-based study should establish an event chronology from contemporaneous records where possible, specify rival accounts, and seek evidence that could disconfirm the proposed mechanism. If contributors report that an intermediary withheld recognition, for example, rival explanations may include incomplete provenance, a purpose-specific eligibility rule, insufficient review capacity, a lawful privacy restriction, a material bottleneck, or selective presentation by a later platform. The investigator should distinguish these explanations using documents that record who could act, which rules applied, what options were feasible, and which decisions were actually implemented. Absence of a record is informative only relative to a characterized record-production and preservation process.

Institutional fieldwork may add interviews, observation of deliberation, technical audit trails, and

comparison of written rules with practical access. Interview testimony can reveal practices not otherwise recorded, but recollection may be incomplete, strategically shaped, or exposed to risk. Researchers should avoid allowing powerful actors' administrative records to become the sole definition of the event universe. Sampling should consider disputes that were never formally lodged, applicants who could not complete a procedure, and contributors whose participation left little documentary trace. At the same time, an investigator cannot reconstruct every unrecorded interaction; uncertainty must remain explicit.

A comparative historical programme could select cases with contrasting governance arrangements while keeping the analytical object relatively constant: comparable shared infrastructures with different maintenance-financing models, for instance, or similar contribution attestations evaluated under different accreditation procedures. Selection on a known success or failure alone risks obscuring routine cases. The resulting comparison may establish institutional regularities and refine the theory, although such evidence does not substitute for the identification assumptions of a causal intervention design.

9.3 Randomized Presentation, Provenance, and Correction Designs

Controlled experiments can identify narrower causal questions. One design randomizes whether an evaluator receives a source-linked provenance panel or an otherwise equivalent summary without the panel, while preserving the substantive claim and its review task. A second design manipulates the placement or clarity of a correction or revocation notice. A third varies an issuer cue while holding constant the underlying evidence and eligibility rubric. These interventions answer different questions: provenance legibility, correction uptake, and cue-based deference should not be collapsed into a single treatment labeled *trust*.

Let $Z_i \in \{0, 1\}$ denote randomized assignment to one well-defined display condition and $Y_i(z)$ a specified potential outcome, such as correct verification of a source-support claim under that display. For eligible units in a defined experimental population $\mathcal{P}$, the intention-to-treat contrast is Equation 55.

$$\tau_{\text{ITT}, \mathcal{P}} = \mathbb{E}_{i \in \mathcal{P}}[Y_i(1) - Y_i(0)] . \quad (55)$$

Under randomized assignment with positive treatment probabilities, consistency of the display conditions, outcome ascertainment, and an appropriate handling of interference and missing data, the relevant arm contrast estimates Equation 55. Random assignment does not identify why the effect occurred. A displayed provenance panel may increase attention, encourage longer inspection, activate institutional deference, or change the interpretation of available evidence. The measured outcome should therefore separate correctness, confidence, reported willingness to rely, and actual permissible action. An increase in acceptance rates alone does not establish improved epistemic judgment.

A factorial experiment may randomize the availability of provenance links and an institutional issuer label independently. This allows the researcher to test whether the two displays interact, provided sample size supports the interaction analysis. More demanding experiments can distinguish source-document access, display of a citation, and independent confirmation that the cited material supports the claim. Evaluation tasks should contain both supported and unsupported claims, with defensible reference answers established through an appropriately qualified, blinded process. The same task must not rely on contested institutional rules as though they were neutral ground truth; rubric-relative accuracy and factual source support should be coded separately.

A mediated explanation of a treatment effect requires additional assumptions. For example, if the investigator asks whether a provenance panel works *through* attention or comprehension, ordinary post-treatment regression may conflate mediation with confounding or measurement error. Methods for causal mediation explicitly state their identification assumptions and encourage sensitivity analysis [26]. When those assumptions are implausible, the study should report an intervention effect and exploratory process measures without assigning a unique psychological pathway.

The act of measurement may itself affect evaluation. Asking a participant to explain a source's provenance before deciding could induce scrutiny that a naturally encountered representation would not receive. Separate arms should therefore distinguish routine presentation from measurement probes, with

prespecified outcomes and debriefing appropriate to the risk. Randomization should occur only within settings in which the researcher may ethically and lawfully alter displays; high-stakes adjudications, vulnerable participants, and nonconsensual manipulations require stricter protections or nonexperimental designs.

9.4 Longitudinal Commitments, Institutional Reforms, and Dynamic Effects

Longitudinal designs are needed because circulation and conversion can be temporally distributed without depending on a single privileged historical clock. A representation may be corrected after a decision, a commitment may be partly performed before a formal discharge, and support for shared infrastructure may affect capacity in later operational cycles. The empirical time index should consequently refer to a specified archival, contractual, or operational measurement convention. Such an index is a pragmatic coordinate, not an ontological assertion about the unique ordering of all relational processes.

A longitudinal data structure can link version histories, relevant rule periods, use of instruments, decisions, appeal opportunities, and documented implementation. An event study might assess the introduction of a correction-notification rule or an accessible provenance standard. If different institutions adopt a reform in different periods, a suitable family of estimands is the group-time treatment effect in Equation 56.

$$\text{ATT}(g, t) = \mathbb{E}[Y_{it}(1; g) - Y_{it}(0; g) \mid G_i = g], \quad t \geq g. \quad (56)$$

Here $G_i = g$ denotes adoption in operational period g ; $Y_{it}(1; g)$ denotes an outcome under adoption at g , while $Y_{it}(0; g)$ denotes the relevant no-adoption potential outcome at t . This is an estimand, not an estimate recoverable merely from a before-and-after comparison. Modern approaches to staggered difference-in-differences distinguish group-time effects and require assumptions about untreated trends, relevant comparisons, anticipation, overlap, and treatment assignment [12]. In circulating knowledge systems, a further complication arises if one institution's rule change alters exposure or expectations in neighboring institutions.

Interventions should be described with enough precision to distinguish a formal rule revision from its implementation. An institution may announce a new appeal pathway without providing reviewers, evidence access, or an enforceable remedy. Treating announcement and implementation as equivalent generates misclassification of treatment exposure. Adoption also may be driven by controversy, legal obligations, or deteriorating institutional performance; pre-reform outcomes can therefore differ systematically between adopters and comparators. Explicitly specifying an observational analogue of a target trial helps clarify eligibility, intervention timing, outcomes, follow-up, and analysis decisions [24].

Event studies of correction and revocation should preserve the history of reliance decisions made under earlier attestations. Correcting an issued credential can change its later eligibility while leaving earlier opportunities, decisions, and costs partly irreversible. Study designs should record when the correction became available, whether it was encountered, whether a decision could be reopened, and whether the remedy was implemented. Rates of successful correction alone are insufficient: the denominator includes disputed or inaccessible cases, and correction may be more likely in institutions that already document mistakes.

9.5 Missing Records, Selective Observation, and Partial Identification

Some of the most consequential circulation episodes may leave weak records. A person prevented from applying may appear in no applications database; an informal credential may never enter a central registry; a correction refused before formal submission may be absent from appeals statistics. Other episodes may be recorded but withheld under legitimate confidentiality rules. The implications differ across types of missingness, and routine complete-case analyses can produce misleading comparisons. Missing-data research distinguishes mechanisms and models of observation, including assumptions that are not testable from observed records alone [32].

When a binary display treatment is randomized, treatment assignment is independent of the relevant potential outcomes and potential observation indicators, and a normalized outcome satisfies $0 \leq Y_i(z) \leq 1$, partial identification remains possible without treating the unobserved responses as missing at random. The bounds below are defined in terms of population potential-outcome quantities; identifying their observed-arm analogues additionally requires consistent assignment, response and outcome measurement. Let $R_i(z)$ indicate whether the outcome would be observed under assignment z ; define $r_z = \Pr(R_i(z) = 1)$ and $\mu_z^{\text{obs}} = \mathbb{E}[Y_i(z) \mid R_i(z) = 1]$ for $r_z > 0$. Equation 57 gives worst-case bounds on the arm-specific population mean.

$$r_z \mu_z^{\text{obs}} \leq \mathbb{E}[Y_i(z)] \leq r_z \mu_z^{\text{obs}} + (1 - r_z), \quad z \in \{0, 1\}. \quad (57)$$

Proposition 9.1 (Outcome bounds with unrestricted missingness). *Assume well-defined potential outcomes $Y_i(0), Y_i(1)$ in $[0, 1]$, arm-specific observation indicators, a fixed study population, and no restrictions on the dependence between potential outcomes and observation. If r_z and the conditional observed means are known (with the product convention $r_z \mu_z^{\text{obs}} = 0$ when $r_z = 0$), the average treatment effect $\tau = \mathbb{E}[Y_i(1) - Y_i(0)]$ lies within the bounds in Equation 58.*

$$\begin{aligned} r_1 \mu_1^{\text{obs}} - r_0 \mu_0^{\text{obs}} - (1 - r_0) &\leq \tau \\ &\leq r_1 \mu_1^{\text{obs}} + (1 - r_1) - r_0 \mu_0^{\text{obs}}. \end{aligned} \quad (58)$$

Proof. For each arm, partition the expectation by observed and unobserved potential outcomes. The unobserved conditional mean is within $[0, 1]$, which yields Equation 57. Subtracting the largest allowable control mean from the smallest allowable treatment mean gives the lower bound in Equation 58; the reverse extremal choices give the upper bound. Without additional restrictions, choices of unobserved conditional means at the interval endpoints are consistent with these extrema. $\square$

Proposition 9.1 is a simple partial-identification result in the spirit of bounding approaches to incomplete counterfactual evidence [34]. Random assignment and well-measured observation indicators can make the arm-specific quantities estimable, but randomization alone does not recover the unseen outcomes. The bounds may be wide and uninformative about the sign of the effect. An investigator should report such a possibility rather than choosing a favorable point estimate. Additional assumptions, independent follow-up samples, and justified sensitivity parameters can narrow the interval, although those choices must be declared and examined critically.

The same logic applies cautiously to records of disputed circulation and resource conversion. When no comprehensive denominator exists, even the response rate r_z may be unidentified. In that setting, Equation 58 cannot simply be applied to the available documents. Researchers may construct plausible observation scenarios, compare multiple archival sources, or provide qualitative bounds on what the evidence excludes. An archival omission should not be interpreted as intentional erasure without evidence about custody, preservation rules, administrative practices, and alternative explanations.

9.6 Network Spillovers and Interdependent Circulation

Evidence-bearing instruments circulate across networks rather than isolated recipients. A repository correction can propagate into many derivative summaries; an institutional issuer cue can influence multiple evaluators; a changed licensing policy can affect contributors and intermediaries beyond the adopting organization. One evaluator’s decision may alter another evaluator’s available evidence or feasible resources. Studies that assume all units receive independent exposures can therefore misstate their estimate and its uncertainty.

Let $\mathbf{Z} = (Z_1, \dots, Z_n)$ be an assignment vector for a defined network and let $e_i(\mathbf{Z}; \mathcal{G})$ summarize a preregistered exposure mapping under network representation $\mathcal{G}$. A restricted interference-sensitive potential-outcome model is Equation 59.

$$Y_i(\mathbf{Z}) = Y_i(Z_i, e_i(\mathbf{Z}; \mathcal{G})). \quad (59)$$

Equation 59 assumes that own assignment and the stated exposure summary are sufficient to characterize assignment-related variation in the outcome; it need not hold for actual knowledge infrastructures. Randomization-based approaches to general interference show how explicit exposure mappings and assignment probabilities organize causal estimands [2]. In practice, the network itself may be incompletely known and may change when a record is corrected or a platform alters ranking. Researchers should test sensitivity to alternative plausible network specifications and avoid counting several copies of the same source record as independent experimental clusters.

Cluster assignment at the level of a repository, collaborating group, or reviewing institution can reduce some forms of spillover. It does not remove cross-cluster communication or shared services. A design should specify whether it estimates the direct effect of a display, the effect of peers' exposure, the total effect of a coordinated policy, or a mixture. Distinguishing these quantities matters for fairness and infrastructure governance, because a reform that benefits one set of contributors may shift verification costs to a different group.

9.7 Transportability and Heterogeneous Institutional Contexts

Relational instruments can cross disciplinary, national, linguistic, and organizational contexts in which admissibility and value conversion differ. A well-identified effect within one research setting is therefore not automatically an effect in another. A study of grant-review displays may provide limited information about professional licensing or volunteer commons, even if each setting circulates credentials. Research on generalizing randomized trials emphasizes the need to compare study and target populations rather than extrapolate from assignment validity alone [45].

Let $S = 1$ denote inclusion in a study population and $S = 0$ membership of a designated target population. Under an explicit set of assumptions—including consistency of the intervention, conditional transportability of mean potential outcomes given pretreatment covariates X , and support overlap—the target-population effect can be written as Equation 60.

$$\tau_{\text{target}} = \int \{ \mathbb{E}[Y \mid Z = 1, X = x, S = 1] - \mathbb{E}[Y \mid Z = 0, X = x, S = 1] \} dF_{X|S=0}(x). \quad (60)$$

For Equation 60, treatment must also be exchangeable conditional on X within the study, each treatment arm must have positive assignment probability over the target-supported values of X , and relevant outcome and assignment measurement must be comparable. If outcomes are missing, additional observation or partial-identification assumptions are required before the displayed conditional means can be recovered. These assumptions may fail when institutional rules constitute the very mechanism under investigation, when marginalized groups lack study representation, or when a translation changes the evidentiary object. This equation thus states an identification target, not a general license for transport.

Cross-language measurement requires more than literal translation. A response option labeled *trust*, *recognition*, or *participation* may capture different practical and normative meanings in different environments. Studies should document how terms are interpreted, use context-specific validation, and avoid assuming scale invariance. When equivalence cannot be justified, reporting separate context-specific estimands may be more defensible than pooling data into one scalar index. This restraint is especially important for normative judgments: similar observed acceptance need not imply shared ethical endorsement or comparable practical freedom.

Table 17 summarizes the different evidentiary roles of these strategies. A programme can combine them sequentially: historical reconstruction can define interventions and plausible confounders, pilot experiments can test narrow display effects, and institutional comparisons can examine practical implementation. This combination should remain open to failed replication and mechanisms that resist generalization. The aim is to identify the conditions in which circulation instruments make a difference, including cases where they have no consequence.

Table 17: Research strategies, attainable inferences, and principal identification threats.

Study strategy	Most direct research contribution	Limitation demanding explicit treatment
Historical process tracing	Reconstruct rules, decisions, alternatives, evidence circulation and mechanism sequences	Selective archives; ambiguous motives; rival institutional pathways
Randomized instrument display	Identify a defined presentation or correction intervention effect	Mechanism mediation; outcome reactivity; constrained external validity
Comparative reform analysis	Estimate context-specific changes following institutional rule adoption	Endogenous adoption; parallel-trend violations; implementation gaps
Missingness and bounds analysis	State claims supportable without point-identifying unobserved outcomes	Unknown denominators; wide bounds; untestable stronger assumptions
Network-aware experiments	Define direct and spillover effects of circulating information	Unknown networks; interference across clusters; changing exposures
Transport and multi-context studies	Examine which intervention effects persist across populations and rules	Limited overlap; semantic nonequivalence; different feasible actions

9.8 Hypotheses, Counterevidence, and Research Ethics

Two hypotheses provide a concrete starting point for empirical investigation, chosen to distinguish claims about the presentation of records from claims about institutional conversion and capability. Neither is a necessary prediction of the entire framework. Each can be rejected while other proposed mechanisms remain possible.

Hypothesis 9.2 (Provenance-legible presentation and calibrated evidentiary decisions). Within a specified decision context and among participants with comparable opportunities for document access, an intervention that makes source links, transformations, and correction status inspectable increases discrimination between well-supported and unsupported claims relative to an otherwise comparable summary-only display, conditional on usable interface design and task comprehension.

Hypothesis 9.2 calls for an independently adjudicated criterion of source support, multiple supported and unsupported items, and outcomes including both false acceptance and false rejection. It could fail if a complex provenance display imposes excessive cognitive costs, directs attention to issuer prestige, offers links that cannot be accessed, or supplies redundant information already understood by evaluators. Studies should record inspection behavior while recognizing that recorded clicks are imperfect measures of interpretation. A rise in self-reported confidence unaccompanied by better discrimination would challenge a central proposed benefit of inspectable lineage in that context.

Hypothesis 9.3 (Implemented access remedies and productive-capacity retention). Among comparable knowledge-production arrangements facing similar demand and initial resource conditions, the implementation of accessible correction or appeal procedures together with traceable support for verification and maintenance is associated with improved retention of specified productive capabilities relative to otherwise comparable arrangements lacking such implementation, conditional on institutional selection and concurrent resource changes.

Hypothesis 9.3 tests a bundled institutional arrangement, not the isolated effect of formal appeal rights. A study seeking component effects would require independent variation in remedy accessibility and maintenance support. Outcomes might include usable repository functionality, maintainer availability, protected contributor time, or actual restoration of contested access, specified separately rather than combined into an unvalidated value score. The hypothesis may fail if additional administrative requirements consume more capacity than they return, if procedures exist mainly symbolically, or if preexisting collective governance already supplies equivalent functions without a dedicated programme.

A serious investigation must also confront results that could undermine the broader conceptual apparatus. The proposed relational-currency vocabulary would lose explanatory value if measured acceptance and conversion were explained adequately by existing concepts of legal permission, ordinary reputation,

direct payment, or organization-specific eligibility without adding a discriminating prediction. Persistent inability to identify recurring instrument families, instability of classifications across observers, or systematic divergence between supposed currency measures and observable decisions would support narrowing the concept or abandoning it in some domains. A formal model's internal consistency does not protect it from these empirical failures.

Research ethics concern both the production of evidence and its circulation. A study that makes disputed contribution records easier to locate could expose individuals to retaliation, breach confidentiality, or falsely imply misconduct. Institutional audit datasets may contain legal, employment, or medical information unsuitable for open release. The research protocol should specify informed participation where appropriate, protected reporting channels, minimization of identifying information, access governance, and an opportunity to contest factual errors in the study's own records. Independent ethical or legal review may be required for consequential field interventions. Researchers should avoid covertly manipulating real allocation or accreditation decisions merely to obtain stronger identification.

The historical-materialist dimension adds a further methodological obligation: the work of producing and correcting the evidence should itself be visible in research accounting. Data extraction, translation, maintenance, re-contact, and participants' verification time carry unequal costs. Recording the resources required for a research design may reveal whether the study reproduces the very asymmetries it seeks to examine. Comparative work should document who provided the labor, which institutions controlled the evidence, and whether research outputs and interpretive opportunities return to affected contributors, subject to their rights and preferences.

Taken together, Section 9 offers a research programme rather than empirical validation. Its measurement objects and estimands permit independent testing of bounded mechanisms while preserving distinctions among truth, credentials, acceptance, institutional authority, actual material access, and heterogeneous generative value. The concluding section can therefore synthesize the theory at its appropriate level of standing: a provisional account with formal consequences under specified assumptions and a set of empirical and normative questions that remain open to revision.

10 Conclusion

This paper has examined the circulation of representations of relational histories and commitments, and the conditions under which their reception affects further interactions, opportunities, and productive resources. Its principal proposal is deliberately limited. *Relational currency* designates a provisional family of instruments and practices whose situated acceptance may enable particular forms of cooperation, institutional action, and value conversion. A citation, attestation, credential, permission, recommendation, or commitment can matter because a receiving actor has reason or authority to act upon it under specified conditions. These instruments do not thereby become instances of a universal medium of exchange, nor does their circulation certify their truth, guarantee justified trust, or entail a material return to the people whose activities they describe. The distinction between the represented history, the representation, the conditions of its acceptance, and the consequences of action is the central organizing result of the inquiry.

The preceding sections have developed this proposal at three levels: a formal vocabulary for typed circulation and conversion relations; conditional results about the limitations of specified representations and institutional arrangements; and a programme of empirical and normative questions concerning who can produce, verify, challenge, and benefit from circulating knowledge. The levels should not be conflated. Mathematical propositions establish consequences of stated assumptions; historical analysis identifies possible mechanisms and institutional differences; empirical designs indicate what evidence would be needed to decide whether those mechanisms operate in a particular setting. Normative judgments about fairness, obligation, consent, and justice require additional reasons that do not follow from a circulation rate, a valuation score, or a causal estimate alone.

10.1 What Circulates, and What Circulation Does Not Establish

A completed productive history is not literally transported when a recipient encounters a reference to it. What moves through an archive, a platform, a professional network, or an AI-mediated interface is a representation with a particular content, provenance, transformation lineage, attributed source, and set of applicable use conditions. The distinction matters because different histories can be compressed into the same report. Proposition 2.2 states this limitation for a specified non-injective representation: information not retained in an output cannot be uniquely recovered from that output alone. Neither confidence in a summary nor the presence of a plausible citation eliminates the underlying ambiguity. Additional documents, testimony, independent records, or lawful opportunities to inspect the source may narrow it, but each supplies new evidentiary conditions rather than retroactively changing what the original representation contained.

Section 3 adds that a representation's trajectory is not merely an address-to-address transfer. Intermediaries can select, summarize, translate, delay, annotate, or rank material. Recipients can possess different interpretive capacities, rights of access, practical resources, and criteria for admitting a claim into a decision. A record may be technically delivered without being encountered, encountered without being understood, or understood without being admissible for the intended purpose. Under the closed Markov-chain assumptions of Proposition 3.2, later transformations cannot increase mutual information about a specified source property. This bounded statement is compatible with effective translation, interpretation, and correction: a better explanation can make preserved information easier for a particular observer to use, and an independently checked addition need not satisfy the closed-chain assumption.

The epistemic consequences of circulation are therefore contingent. Authentication of an issuer or an intact document does not verify every claim within it. Repetition of a shared source does not create independent corroboration merely by increasing the number of visible messages. An endorsement may be relevant testimony while remaining partial, contestable, or beyond the competence of its issuer. These limitations also apply to automated citation chains and machine-generated digests. The evidentiary history of a generated response may encompass many human and technical contributors without admitting a unique or morally authoritative allocation of credit. Any attempt to convert such a response into an institutional credential or material entitlement must specify which claims are being assessed and whose rights govern the relevant use.

This conclusion is not skeptical about representation as such. Social cooperation and science require selective records, linguistic abstraction, and trusted procedures. The relevant choice is not between perfect disclosure and unqualified belief. It concerns whether a representation is sufficiently fit for a stated purpose, whether uncertainty and changes in status are communicable, and whether people affected by consequential uses can obtain proportionate explanation and correction. Reviewable provenance is valuable as a possible aid to these practices, not as an independent substitute for them.

10.2 The Scope and Limits of Situated Relational Currency

The theoretical object introduced in Section 4 is a relation among an instrument, a recipient or participant, an intended action, and a receiving context. Its acceptance can depend on evidentiary rules, rights, privacy constraints, technical compatibility, standing, and material ability to act. Consequently, the same instrument can support a citation in one context, eligibility for a review in another, and no authorized action in a third. A credential may make an application permissible without making the applicant competent, accepted, or funded. A permission record may establish a specific authorized reuse while withholding permission for onward transmission. These differences are not imperfections to be eliminated by presuming an exchange rate; they are constitutive features of what the paper calls situated convertibility.

Proposition 4.1 formalizes one reason to avoid universal scalar valuation. Where two receiving contexts impose opposing strict orderings on the same pair of instruments, a single context-independent score cannot reproduce both orders while preserving their stipulated strictness. The result does not show that all comparisons are impossible, or that quantitative measures are inherently undesirable. Within a specific decision problem, carefully justified weights, thresholds, and measures may be useful. What

is not warranted is the inference that a convenient index captures the entire evidentiary, cooperative, material, rights-related, and commons-related value of a contribution. Context-sensitive comparisons require explicit objectives and governance of the comparison procedure itself.

The binding-gate proposition in Section 4, Proposition 4.2, supplies a related caution. Improving a merit score or circulating a more persuasive representation does not overcome an independent eligibility condition that remains fixed and unsatisfied. A highly regarded result cannot secure access to a restricted archive for a person who lacks necessary legal permission; a carefully authenticated claim may not produce a collaboration when necessary facilities or protected time are unavailable. This is not an argument for disregarding evidentiary quality. It is an argument against treating recognition as an automatically convertible asset whose practical value is independent of rules and complementary capacities.

The word *currency* is therefore useful only under a discriminating definition. In its narrow sense, it refers to a representation or undertaking that can be presented, assessed, and acted upon across a specified set of relations, with identifiable acceptance and conversion conditions. It should not imply fungibility, universal portability, monetary denomination, impersonally transferable trust, or the possibility of purchasing every right and obligation. In some domains, “credential,” “permission,” “reference,” “testimonial record,” “contractual undertaking,” or “institutional eligibility” will be more precise and sufficient. The proposed umbrella term must earn its place by revealing cross-domain regularities about reception, conversion barriers, and unequal return that those established categories do not already explain as well.

10.3 Commitment, Reliance, and the Difference Between Formal and Effective Rights

The paper also examined how representations can bear on relations extending beyond an initial evidentiary judgment. A promissory document can record a defined undertaking, its parties, scope, conditions, milestones, and possible remedies. Yet accepting that the undertaking was made is distinct from determining whether it was discharged. Proposition 5.2 shows, under specified observational equivalence, that identical promissory records may be consistent with different underlying performance histories. Status checks, independently grounded completion evidence, and opportunities for dispute are therefore separate parts of responsible reliance.

The restricted incentive result in Proposition 5.3 identifies conditions under which the payoffs of a two-action model can favor performance over nonperformance. It establishes neither that parties consented freely nor that the offered terms were proportionate, fair, or legally enforceable. A strategically credible commitment can be normatively objectionable; a morally meaningful undertaking can lack an accessible enforcement mechanism. Moreover, the decision to rely on another party may reflect urgency, unequal alternatives, employment dependence, or fear of sanction rather than a private belief that the commitment is trustworthy. The analysis accordingly keeps promissory evidence, expected performance, observed acceptance, actual behavior, and justified reliance apart.

Remedies have the same layered character. A formal appeal right differs from procedural standing, evidence access, protected time, affordable representation, independent review, and implementation of the resulting correction. A nominally available challenge may be ineffective if a participant cannot bear its costs or fears credible retaliation. Conversely, confidentiality and restricted disclosure can protect legitimate interests while allowing proportionate independent scrutiny. The aim is not maximum disclosure irrespective of context, but a defensible allocation of review authority, rights, obligations, and correction capacities. This perspective connects Paper V with the separate investigation of epistemic power in Paper IV without reducing circulation governance to the power relations of a single institution.

A dynamic interpretation of commitment also needs an explicit account of change. An instrument’s validity may be revised, suspended, revoked, or contested through ordered institutional acts; later corrections may affect new decisions without undoing every earlier consequence of reliance. These are relations among records, decisions, and governing procedures, not evidence that a privileged present moment provides the ontological foundation of the system. What matters for the model is an identifiable relation of transformation or precedence where the institution makes such a relation relevant. A changing institutional sequence is a methodological convenience whose adequacy must be judged against the

investigated process.

10.4 Recognition, Productive Capacity, and Heterogeneous Returns

A second major result of the paper is that recognition and production are connected by contingent institutional pathways. Section 6 distinguishes encounter, acknowledgement, eligibility, authorization, delivery, and actual usable access to a resource. The distinction prevents an increase in citations, endorsements, awards, or institutional visibility from being counted automatically as an increase in research capability. Recognition can open doors, but the door may remain administratively closed, materially inaccessible, or too narrow for the intended activity. Proposition 6.2 establishes this limitation for a model with an unchanged binding constraint; Proposition 6.3 identifies the aggregate allocation bound when the specified resource pool is fixed. Neither rules out expansion of productive capacity, improved allocation, or collaborative provision under different assumptions.

The distinction is especially important where knowledge production depends on shared, maintained infrastructures. Section 7 treats generative capacity as a heterogeneous set of resources and relationships supporting further inquiry, rather than as a scalar total of circulating outputs. Scientific labor, technical upkeep, mentorship, translation, record correction, protected participation, lawful reuse, coordination, and ecological provision can each be necessary for particular forms of production. They are not interchangeable merely because an institution records them under one budget or reports them in one dashboard. The stock–flow model is useful only for specified capacity classes with coherent units and an appropriate operational interpretation.

Within those restrictions, Proposition 7.1 states a clear conditional result: a persistent renewal shortfall eventually brings a measured capacity below a fixed operational threshold if the modeled sequence continues under the stipulated conditions. The proposition shows why rising circulation and diminishing capacity can coexist, not that greater use invariably causes depletion. Its assumptions may be changed by training new maintainers, allocating funds, revising responsibilities, replacing infrastructure, or finding less costly forms of service provision. Proposition 7.2, concerning variance reduction for an exchangeable demand model, similarly indicates a possible advantage of pooling under its covariance assumptions without proving that larger commons are more just, effective, or democratically governed.

This analysis places collective value circulation within a historical-materialist question about reproduction: which arrangements return adequate resources and decision-making capacity to the people and infrastructures required for further productive activity? The answer cannot be read from revenue totals alone. An arrangement may return monetary income while constraining autonomy, or produce little immediate income while expanding usable education, equipment access, secure collaboration, and collectively governed knowledge. Neither outcome is automatically desirable; participants may attach different significance to each, and rights may rule out certain conversions regardless of potential aggregate benefit. An adequate account must therefore distinguish value creation, conversion into institutionally recognized outcomes, and the maintenance or transformation of the conditions of subsequent creation.

10.5 Power, Asymmetry, and the Burden of Normative Justification

Section 8 extends the analysis to institutions that control complementary assets, licensing terms, visibility, implementation channels, accreditation, or the terms on which knowledge can be reused. These controls can shape the allocation of opportunities and returns without establishing that an actor intentionally sought to suppress another. They can exist in commercial enterprises, public agencies, nonprofits, or commons organizations. A distributional difference is an observable pattern; a mechanism of appropriation or extraction is a causal explanation requiring further evidence; an accusation of injustice additionally requires defensible normative criteria.

The two propositions in Section 8 illustrate this separation. Under a model with a binding payment ceiling, Proposition 8.1 shows how further receipts may accrue to an intermediary without increasing the capped monetary return of the contributor. Proposition 8.2 shows that the same observed shares can be produced by different cost structures, agreements, and governance arrangements. The first is a

consequence of a stipulated contract; the second limits inference from aggregates. Neither is a proof that the contract was coerced or that a particular intermediary acted unjustly. Questions about bargaining alternatives, documentation, indispensable services, negotiated risks, feasible exit, informed consent, and accessible remedy cannot be resolved by a share statistic alone.

Nor is the correction simply to distribute all outputs through an undifferentiated common ownership form. Public and collective governance may reduce some exclusionary powers while introducing new sources of administrative dependence. An institution can promote open access while shifting uncompensated verification work onto a small number of maintainers; it can preserve formal participation while concentrating agenda-setting or technical control. In contrast, specialized expertise or differential compensation may be justified by demonstrable contributions and responsibilities where the decision rules remain intelligible and contestable. The appropriate normative object is a situated arrangement of production, recognition, distribution, rights, and accountability, not a presumption that every unequal outcome has the same cause.

The historical-materialist perspective thus concerns the organization and reproduction of generative conditions. Who controls the instruments required to transform represented contributions into opportunities? Which forms of labor are made visible, priced, or ignored? Who determines the accepted evidentiary representation of a contribution, who can correct it, and where do the resulting returns sustain further work? These questions become especially consequential when AI systems mediate aggregation, synthesis, evaluation, and dissemination at scale. Technical acceleration can reduce some costs while increasing reliance on concentrated computational infrastructure or intensifying demands for auditing and attribution. Which effects dominate is an empirical question. Claims about AI subjects, independent agency, or intrinsic moral status are neither presupposed nor resolved by treating generated outputs as circulation instruments.

10.6 What the Formal Results Establish and What Evidence Must Still Show

The thirteen propositions in this manuscript should be read as a collection of bounded analytical safeguards rather than as deductions from one universal generative law. They address non-identifiability after compression, information preservation under a closed transmission chain, context-dependent rankings, binding acceptance gates, the limits of promise-only evidence, restricted incentive compatibility, fixed resource allocations, persistent capacity deficits, particular pooling assumptions, intermediary payment caps, and missing-outcome bounds. Their premises vary; an equation justified for one observation model cannot simply be transferred to another. The formal results clarify what cannot be concluded from thin evidence and what follows if a specified institutional mechanism is actually in force. They do not establish that the proposed taxonomy is complete or that the term *relational currency* uniquely explains the institutions under discussion.

The sixteen hypotheses are similarly local and defeasible. Some concern whether inspectable transformation lineage improves the accuracy of attribution and evidentiary discrimination. Others concern context-sensitive uptake, performance evidence, binding access barriers, governance of maintenance labor, and the distribution of returns under complementary-asset dependence. An evaluation that finds no significant benefit from adding provenance to a particular interface may undermine the relevant design hypothesis without negating the existence of relational representations. A study that shows adequate maintenance without formal earmarking may challenge a proposed governance association without contradicting a stock–flow identity. The propositions and the hypotheses should be tested, refined, or rejected at their own level of generality.

The empirical programme in Section 9 identifies several feasible points of entry. Historical and archival inquiry can reconstruct how an instrument’s legal status, attributed issuer, transformation lineage, or recipient audience changed. Controlled presentation studies can isolate the effects of visible provenance or credential cues for a precisely defined decision task. Comparative institutional analyses can examine the implementation of admission, licensing, maintenance, or remedy procedures. Longitudinal work can test whether actual resource access and retained capacity follow measured recognition

while allowing for selection, changing baselines, and resource constraints. Network-aware designs can examine shared sources and interference; privacy-preserving audits may be required to inspect consequential but confidential records.

Each approach has characteristic limits. Randomization of an interface can identify its treatment effect under a specified design but not automatically reveal the cognitive pathway that caused it. Institutional reforms may be endogenously adopted, and their effects may differ across participants with unequal access. Missing records and outcomes can produce wide partial-identification intervals; Proposition 9.1 describes such bounds under its stated support assumptions, not a point estimate rescued from incomplete data. Comparable categories may not have equivalent meanings across legal, linguistic, or disciplinary contexts. Measurement instruments and value classifications should therefore be co-specified with the institutions and affected participants, subject to appropriate ethical protections. No original observations, participant data, or identified causal estimates are offered in this manuscript.

The new comparison in Section 4.6 specifies a demanding baseline: constituent concepts must be allowed plausible joint effects before the integrative term can claim greater predictive economy. Its held-out-loss contrast is a proposed research design, not a fitted empirical result. The proposed framework should face direct conceptual and empirical countertests. If the phrase *relational currency* merely re-names credentials, permissions, reputational signals, and contracts without yielding clearer operational distinctions or useful comparative questions, a more plural and less metaphorical vocabulary should replace it. If there is no reproducible way to specify an instrument's receiving context, authorized action, or feasible conversion, claims about its currency capacity should not be maintained. If apparently coherent scalar measures systematically suppress context-specific reversals or obscure nontransferable rights, they should be withdrawn or limited to the particular decisions they can justify. If supposedly distinctive value-conversion mechanisms disappear under credible adjustment for service costs, participant selection, bargaining alternatives, or direct payments, the extraction explanation should be revised. A theory gains discipline from specifying when its own categories cease to be useful.

10.7 Institutional Responsibilities and the Open Research Programme

The practical implications are procedural rather than an instruction to universalize any particular circulation regime. Institutions that rely on evidence-bearing instruments should specify what those instruments claim, what they omit, which uses are authorized, and how status changes are communicated. They should distinguish issuer authentication from substantive evaluation and make correction routes intelligible and materially accessible where decisions have significant effects. Systems for recognition and allocation should report not only the volume of outputs or endorsements but also barriers between nominal eligibility and usable access. Commons governance should examine whether maintenance, mentoring, verification, and participation can be renewed without shifting disproportionate burdens onto actors with few alternatives. Contractual and platform arrangements should be evaluated through actual terms, relevant service costs, alternatives, governance powers, and remedy mechanisms rather than reputational inference alone.

These responsibilities can conflict. Wider access to records may aid verification yet expose confidential information; standardized indicators may simplify coordination while flattening locally significant forms of contribution; strong review requirements may deter erroneous claims while exhausting scarce productive time. The framework does not determine a universal resolution by maximizing recognition, transparency, circulation, or monetary returns. It instead calls for explicitly justified institutional choices, proportionate safeguards, accountable revision, and recognition of the plurality of consequences experienced by affected parties. In cross-cultural, interdisciplinary, and technologically heterogeneous settings, translation of rules and values may be as important as transmission of representational content. Incompatibility need not imply a deficiency in either party's account; it may indicate that the intended conversion requires negotiation, a new common procedure, or a decision to preserve difference.

Several questions remain foundational. It is not established that a single formal category can accommodate all legitimate evidentiary, cooperative, rights-related, and material uses without concealing

important asymmetries. A rigorous account of nontransferable permissions and collective rights may require richer deontic and institutional representations than the present typed correspondences. Causal models of capacity retention require empirically meaningful descriptions of substitution, nonlinear loss, institutional change, and ecological limits. The interaction between changing representational systems and changing evaluative rules challenges any fixed set of context labels. Further work is also needed to describe when autonomous software agents may participate in circulation or undertake commitments through governing human and institutional arrangements, without presupposing parity of legal or moral status across heterogeneous actors.

The five-paper research programme offers complementary perspectives on these questions. Analysis of production and recognition concerns which contributions become legible; analysis of relational trajectories concerns what kinds of history and evidence are available; cognitive mediation concerns how situated observers form judgments and reliance decisions; the study of epistemic power concerns control over admissibility, authority, resources, and remedies; and the present study concerns the circulation of representations and the conditional conversion of their reception into further interactions and productive consequences. The distinctions are intentionally maintained. No one paper establishes a general theory of deserved reward, trustworthy cognition, institutional justice, or the monetary valuation of human activity.

The provisional conclusion is accordingly neither that knowledge ought to become a universal currency nor that circulation is inherently emancipatory or extractive. It is that circulation arrangements can be studied as historically situated relations among representations, rights, evaluation procedures, practical capacities, and heterogeneous returns. A defensible account must remain sensitive to the epistemic difference between a claim and its evidence, the institutional difference between formal recognition and effective opportunity, and the productive difference between distributing outputs and sustaining the conditions of further creation. The proposed terminology is justified only to the extent that it helps identify these differences, supports discriminating empirical inquiry, and remains open to correction by those whose histories and productive conditions are at stake.

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Declarations and Research Scope

Research status. This is an exploratory theoretical preprint. Its thirteen propositions are conditional on the specified models; the sixteen hypotheses and comparative research designs have not been empirically tested here. No original human-participant study, fieldwork, or causal estimates are reported. All examples are illustrative and make no allegations about identifiable persons or institutions.

Sources and limitations. The accompanying source archive documents bibliographic-record checks for the 54 cited references and a model-level proof audit. These checks are not a substitute for comprehensive full-text, page-specific interpretive verification, external mathematical review, or empirical validation. The comparison between the proposed relational-currency account and established mechanism-specific explanations remains a proposed research test.

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