

A Generative Relational Ethics of Knowledge-Capital Expansion in Public Knowledge

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Abstract

This paper develops a generative relational approach to the ethics of knowledge-capital expansion in public knowledge. Public knowledge enables learning, reuse, recombination, circulation, and cumulative epistemic development, while the same processes may also contribute to concentration, dependency, enclosure, extraction, and renewed restrictions upon generative access. Ethical evaluation of these processes is complicated by the historical and relational dependence of normative meaning. Formally similar arrangements of openness, restriction, control, appropriation, or circulation may acquire different ethical significance under different cultural, institutional, technological, political-economic, and historical conditions. The paper first distinguishes the relational syntax of knowledge processes from their normative interpretation. Relational states are represented through typed graph configurations, while histories of interaction and transformation are represented through labelled 2-complexes connecting successive relational boundaries. The formal representation structures the object of ethical inquiry by preserving actors, roles, relations, events, trajectories, and changes in access, control, dependency, and knowledge capital. Ethical judgment itself remains outside the formal model. The analysis then draws upon political economy to examine accumulation, appropriation, concentration, enclosure, dispossession, dependency, extraction, rent formation, institutional capture, and re-enclosure in public knowledge. These categories provide interpretive resources for identifying consequential transformations without assigning them invariant ethical values. A Generative Relational Ethics is subsequently developed in which normative interpretation emerges within historically evolving generative-relational systems. Different relational systems may generate different hermeneutic conditions for ethical judgment, and these conditions may themselves change through subsequent relational development. Openness therefore carries no fixed ethical priority over closure: under some conditions restriction may protect generative conditions, while under others similar restrictions may sustain dependency or enclosure. The paper consequently develops an account of ethical judgment that is relationally situated, role-dependent, historically generated, reason-responsive, and recursively revisable, while resisting its reduction to a fixed rule set or optimization procedure.

Keywords: knowledge-capital expansion; public knowledge; Generative Relational Ethics; political economy; knowledge commons; relational syntax; normative interpretation; 2-complex; enclosure; generative conditions; normative revisability

Discussion Paper Note

This paper develops a generative relational approach to the ethics of knowledge-capital expansion in public knowledge. Its central concern arises from a tension internal to public knowledge itself. Public availability can support learning, reuse, recombination, criticism, circulation, and cumulative knowledge production. The same conditions can also participate in processes of knowledge-capital accumulation, concentration, dependency, extraction, re-enclosure, institutional capture, and forms of downstream use whose consequences may impair the generative conditions of other participants.

The ethical problem cannot be resolved through a categorical commitment to openness or closure. Public accessibility can enlarge the generative possibilities of readers, researchers, institutions, communities, and downstream creators. Under different conditions, unrestricted circulation can also facilitate harmful use, enable disproportionate appropriation, accelerate concentration of infrastructural control, or expose actors and communities to risks for which adequate governance mechanisms do not yet exist. Restriction can accordingly function as protection in one relational configuration and as enclosure in another. The ethical meaning of a knowledge arrangement therefore depends upon the historically evolving relational system in which the arrangement operates.

This observation motivates a basic distinction developed throughout the paper. The relational structure of a knowledge process and the normative meaning attributed to that structure belong to different analytical levels. An arrangement of access, restriction, transfer, concentration, dependence, appropriation, or circulation can first be described through its relational configuration. Ethical interpretation requires a further account of the historical, cultural, institutional, technological, political-economic, and epistemic relations within which that configuration acquires practical significance.

The paper refers provisionally to the first level as relational syntax. Relational syntax describes actors, roles, relations, events, transformations, dependencies, trajectories, and changes in the organization of knowledge production and circulation. It provides a structured representation of what has occurred within a relational field. The term does not imply that social relations are literally reducible to a formal language. It marks an analytical distinction between the form of a relational configuration and the normative interpretation subsequently given to that configuration.

The formal representation begins from a typed relational graph configuration. At a given time t , a public-knowledge field can be represented through a graph Γ_t whose vertices correspond to relevant actors or role-instances and whose edges represent typed relations among them. The relevant labels can record such relations and conditions as access, publication, modification, distribution, attribution, control, dependency, recognition, governance, financing, commercial use, or other domain-specific relations.

The graph configuration represents a relational state. Ethical inquiry, however, commonly concerns processes whose significance lies in their development through time. A reader can become an aggregator, an aggregator can become a platform operator, a platform operator can become an infrastructural gatekeeper, and a previously distributed field can gradually acquire a centralized dependency structure. Knowledge can move through sequences of publication, reuse, transformation, commercialization, restriction, and redistribution. Provenance and responsibility can likewise extend across multiple events.

The paper therefore represents relational histories through labelled 2-complexes connecting successive graph configurations. A relational history can be written schematically as $\mathcal{F} : \Gamma_t \rightarrow \Gamma_{t+1}$, where the boundary graphs describe relational states and the intervening complex represents events, continuities, transformations, and relational histories connecting those states. Event vertices can represent interactions or transitions, while extended cells can preserve the continuity and transformation of relevant relations through multiple events.

This representation is inspired structurally by the use of boundary graphs and 2-complexes in spin-foam formalisms. The present inquiry does not assign a quantum interpretation to public knowledge, introduce physical spin labels, or claim that political-economic processes obey a quantum-gravitational dynamics. The value of the analogy lies in its capacity to represent evolving relational states, histories connecting those states, higher-order interactions, and the composition of relational histories within a common formal architecture.

A principal methodological commitment follows from this distinction. The formal model structures the object of ethical inquiry without computing ethical judgment. The 2-complex can preserve relational information that would be lost by treating an ethical problem as an isolated action or as an unordered collection of actors. It can show that access has narrowed, that control has become concentrated, that a new dependency relation has appeared, that an actor has acquired a gatekeeping position, or that a public resource has entered an increasingly exclusive downstream structure. None of these formal descriptions independently determines whether the resulting configuration is ethically justified.

The paper therefore rejects the reduction of ethical judgment to an optimization problem. Generativity is not treated as a quantity whose global maximization would supply a universal ethical criterion. Different generative conditions can conflict. An intervention that expands one actor's capacity can constrain another actor's future possibilities. A restriction that reduces immediate openness can preserve safety, privacy, cultural continuity, or the future generativity of vulnerable participants. Conversely, a restriction initially introduced for protective reasons can persist after its original justification has weakened and can subsequently support dependency, concentration, rent extraction, or enclosure.

Ethical judgment must consequently remain responsive to reasons that can be heterogeneous, historically situated, and partially incommensurable. The relevant considerations can include the generative conditions of affected actors, the distribution of control, the availability of alternative paths, the reversibility of an intervention, the severity and probability of foreseeable harms, prior relations of dependence, historical experiences, institutional competence, epistemic uncertainty, cultural meanings, and the capacity of a governance arrangement to revise itself when circumstances change.

Political economy provides an intermediate interpretive layer between formal relational description and normative judgment. The paper examines processes including accumulation, appropriation, concentration, enclosure, dispossession, dependency formation, extraction, rent formation, externalization, institutional capture, recursive advantage, and re-enclosure. These concepts make visible changes in control, access, productive capacity, infrastructural dependence, and the distribution of benefits and burdens within a knowledge field.

The political-economic analysis does not assign invariant moral values to these transformations. Accumulation can represent learning, improved productive capacity, institutional development, or the creation of useful public infrastructure. Concentration can sometimes arise from efficiency, expertise, coordination, or temporary governance requirements. Restriction can protect vulnerable subjects or reduce the risk of foreseeable misuse. Political-economic categories therefore function as interpretive resources for identifying consequential relational transformations whose normative meaning requires further inquiry.

Knowledge-capital expansion is particularly important because it can alter both the capacities and the relational positions of actors. An increase in knowledge capital can enable an actor to conduct more research, interpret more information, combine more resources, generate more outputs, or enter new epistemic domains. Under certain institutional conditions, accumulated knowledge capital can also increase control over infrastructure, visibility, standards, distribution, evaluation, or access. A participant in a commons can thereby become an obligatory intermediary through which other participants must increasingly pass.

The political-economic significance of capital expansion therefore extends beyond the amount of knowledge possessed by an actor. It concerns changes in relational position. An actor can acquire greater control over conditions that other actors require for their own knowledge production. Public knowledge can serve as an input into privately controlled infrastructures, and those infrastructures can subsequently become conditions upon which the original public field depends. Such recursive transformations provide one route through which open resources can participate in the formation of new relations of dependency or re-enclosure.

The paper nevertheless avoids treating every asymmetric relation as domination. Differences in knowledge, expertise, recognition, productive capacity, institutional position, or access to resources can emerge through ordinary processes of learning and specialization. Generative Relational Ethics does not require the elimination of difference or asymmetry. The ethical inquiry concerns how differences operate

within relational systems, how they affect the capacity of other participants to continue generating, and whether the resulting relations remain contestable, revisable, and capable of supporting further generative development.

The role occupied by an actor is therefore ethically significant. Public knowledge contains contributors, publishers, readers, learners, modifiers, distributors, archivists, platform operators, commercializers, funders, reviewers, governance participants, and many other functional positions. A single actor can occupy several of these roles simultaneously and can move between them over time.

Role multiplicity prevents ethical responsibility from being assigned solely according to institutional identity. A university can simultaneously publish knowledge, control access infrastructure, commercialize research, govern a repository, employ reviewers, and receive public funding. A platform can simultaneously distribute knowledge, rank its visibility, train models upon public resources, provide tools for subsequent production, and determine conditions of access. The relevant ethical reasons therefore emerge from the actor's position within particular relations and events rather than from a fixed moral identity attached to the actor as a whole.

This role dependence also prevents the ethical analysis of public knowledge from collapsing into judgments about isolated acts. The ethical significance of publication differs for a contributor, a repository operator, a platform governor, a downstream commercializer, and a reviewer. Each role enters a different set of relations, capacities, dependencies, and possible interventions. Responsibility accordingly requires attention to the relations through which an actor can foreseeably affect the generative conditions of others.

The normative interpretation developed in the paper draws upon Generative Relational Ethics. Within this framework, ethical meaning is understood as emerging within historically evolving generative-relational systems. A relational configuration does not carry a timeless ethical value independent of the cultural, material, institutional, technological, linguistic, epistemic, and historical systems in which it is embedded.

Let $\mathcal{G}_{x,t}$ denote provisionally the relevant generative-relational system at a spatiotemporal location x, t . The system contains heterogeneous relations through which subjects, institutions, knowledge practices, values, expectations, vulnerabilities, capacities, and forms of responsibility have historically developed. Within this evolving field, an interpretive or hermeneutic structure $\mathcal{H}_{x,t}$ can emerge through which actions and relational configurations acquire normative significance.

The notation is analytical rather than computational. The relation between $\mathcal{G}_{x,t}$ and $\mathcal{H}_{x,t}$ does not define a deterministic algorithm by which ethical conclusions can be calculated. It expresses the claim that ethical interpretation occurs within historically generated conditions of intelligibility. What counts as protection, exploitation, responsible restraint, unacceptable dependency, legitimate authority, harmful appropriation, or justified openness depends in part upon the relations through which those concepts and concerns have acquired meaning.

The ethical interpretation of a relational history $\mathcal{F}$ can therefore be represented provisionally by $\llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t}}$. The notation emphasizes that normative meaning is interpretation-dependent and historically situated. Two relational histories with closely similar local syntax can acquire different ethical significance when embedded within different generative-relational systems. The same local structure can also receive a different interpretation at two historical moments if the surrounding relations, available knowledge, technological capabilities, institutional arrangements, or foreseeable consequences have materially changed.

This temporal dependence is particularly visible in questions of openness and closure. An organization can possess knowledge whose unrestricted release would create serious risks while effective safeguards remain unavailable. Temporary restriction can then operate as a protective intervention within the prevailing relational system. Subsequent technological, institutional, or governance developments can reduce those risks. If the restriction persists and begins to function primarily as a means of maintaining dependency, excluding alternative producers, or extracting rents from an avoidable bottleneck, the normative interpretation of a formally similar restriction can change.

The example illustrates a broader proposition. Ethical interpretation in Generative Relational Ethics

is generated through evolving relations. A judgment appropriate to an earlier configuration can become inadequate after the system has changed. Normative revisability therefore follows from the generative character of the relational field itself. An ethical framework that cannot respond to transformations in the relations it governs risks becoming detached from the conditions through which its earlier interpretations acquired relevance.

The historical orientation of this approach has an important affinity with historical materialism. Normative consciousness is not treated as independent of the social and historical relations through which human life is organized. Relations of production, material dependency, control of productive conditions, and patterns of accumulation remain important elements of the analysis.

Generative Relational Ethics broadens the relevant field beyond material production alone. Cultural, linguistic, symbolic, legal, institutional, technological, epistemic, interpersonal, and ecological relations can also participate in the generation of normative interpretation. These relations can interact recursively with material and political-economic conditions. Ethical judgments and institutions generated within a relational system can themselves enter subsequent events and alter the system from which they emerged.

The resulting structure is therefore recursive. A generative-relational system contributes to the formation of an interpretive horizon. That horizon informs judgments and actions. Those judgments and actions modify relations within the system. The transformed relational field can subsequently generate revised interpretive conditions. Normativity thereby participates in the historical development that makes further normative interpretation possible.

Historical generation does not provide automatic normative justification. The fact that a norm, hierarchy, practice, or interpretive system emerged from a particular history does not establish that it should continue. Historically generated systems can preserve domination, erase participants, suppress alternative generative paths, reproduce dependency, or become resistant to evidence and revision. The genealogy of a normative interpretation and the justification of that interpretation must therefore remain analytically distinct.

This distinction also prevents historical situatedness from collapsing into arbitrary relativism. Different communities, cultures, institutions, and historical periods can generate different interpretive systems without making every interpretation immune from criticism. A normative system can itself become an object of relational inquiry. The analysis can examine whose generative conditions it recognizes, whose experiences remain invisible, which relations it stabilizes, which alternatives it excludes, how it responds to new evidence, and whether its own categories and institutions remain open to revision.

Re-cognizability is relevant to this problem. A generative relation can alter the concepts and interpretive capacities through which a subject subsequently encounters the world. Ethical concern therefore extends beyond immediate outputs and includes the preservation of capacities for renewed recognition, reinterpretation, and engagement with alternative conceptual worlds. Systems that irreversibly eliminate the ability to recognize other forms of experience or interpretation can raise ethical concerns even when their immediate outputs appear productive.

Epistemic humility follows from the same structure. Ethical actors and governance institutions rarely possess complete knowledge of the relational systems they influence. Effects can be delayed, distributed, nonlinear, or difficult to recognize from the position of a single participant. A decision concerning openness, restriction, platform governance, knowledge reuse, or institutional intervention should therefore preserve the possibility that future evidence and changing relations may require reconsideration.

The paper accordingly treats ethical judgment as situated, reason-responsive, role-dependent, historically generated, and revisable. It does not prescribe a single invariant ordering of openness, closure, equality, autonomy, safety, generativity, or efficiency. These considerations can become normatively salient in different ways under different relational conditions. Ethical inquiry concerns their interpretation within the particular generative field and the reasons available to actors occupying particular relational positions.

Several methodological commitments guide the discussion:

The formal model represents relational states and histories while leaving ethical judgment outside the formal calculus.

Relational syntax does not carry an invariant normative value.

Political-economic concepts identify consequential transformations without serving as automatic moral verdicts.

Knowledge-capital accumulation is evaluated through its relational operation and subsequent effects upon generative conditions.

Asymmetry is distinguished from domination, and concentration is distinguished from unjustified concentration.

Openness is treated as a relational configuration whose ethical significance depends upon the conditions under which knowledge circulates.

Closure can function as protection, enclosure, restraint, exclusion, or other relations according to the generative-relational system in which it operates.

Normative interpretation is historically generated without acquiring justification merely from its historical emergence.

Different relational systems can sustain different ethical interpretations while remaining open to cross-relational criticism and revision.

Ethical uncertainty is treated as a legitimate condition of inquiry when the available relational and epistemic conditions do not support a determinate judgment.

Normative revisability follows from the continuing evolution of the generative-relational systems within which ethical interpretation occurs.

The paper is consequently foundational and exploratory in scope. It proposes a formal representation of the relational object of ethical inquiry, develops a political-economic vocabulary for interpreting transformations in public knowledge, and situates normative interpretation within Generative Relational Ethics. It does not offer a universal ethical calculus, a complete theory of justice, a final taxonomy of political-economic wrongs, or a comprehensive institutional governance system.

The paper also does not assume that the proposed 2-complex representation exhausts the relational complexity of public knowledge. The formalism is a working syntax whose adequacy should be evaluated according to the structures it preserves and the inquiries it enables. Alternative graph, hypergraph, categorical, cellular, or higher-order representations may prove preferable for particular domains. The present model is retained because it provides a useful language for boundary states, higher-order events, relational continuity, transformation, and composable histories.

The inquiry is situated within a broader series on knowledge-capital expansion. Earlier work examines the formation and expansion of knowledge capital, public knowledge as generative infrastructure, epistemic capitalization, differential capacities for transforming public knowledge, and the intensification of these processes under artificial intelligence. The present paper takes the resulting political-economic transformations as objects of ethical inquiry.

Questions of factual governance, provenance, historical priority, public contestability, licensing, and transnational institutional architecture require related but distinct treatment. Those questions concern the factual and institutional governance of public knowledge. The present inquiry focuses more narrowly upon the normative interpretation of knowledge-capital expansion and the relations through which openness, accumulation, appropriation, restriction, dependency, and generative capacity acquire ethical significance.

The structure of the paper follows this conceptual architecture. It begins with knowledge commons, political economy, relational ethics, context-sensitive normativity, historical materialism, and higher-order relational representation. It then develops the ethical structure of public knowledge and introduces relational graph configurations and labelled 2-complexes as a syntax for knowledge processes and their histories. Subsequent sections distinguish relational syntax from normative meaning, analyze knowledge-capital expansion through political economy, and examine access, control, dependency, gate-keeping, role transformation, and recursive advantage as relational transformations.

The later sections develop Generative Relational Ethics as a historically generated and revisable account of normative interpretation, examine its relation to historical materialism, and use openness and closure as a central case through which formally similar relational structures can acquire different ethical meanings. Role-dependent ethical interpretation is then examined across contributors, readers, reusers, platforms, reviewers, commercial actors, and governance participants. The paper concludes by returning to the limits of formal ethical representation and to the requirement that ethical judgment remain responsive to the evolving generative-relational systems within which public knowledge continues to develop.

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1 Introduction

1.1 Knowledge-Capital Expansion in Public Knowledge

Public knowledge provides conditions through which knowledge can be read, learned, criticized, reproduced, recombined, translated, extended, and incorporated into subsequent processes of inquiry. Digital networks have substantially enlarged these possibilities by reducing many of the material constraints that historically limited the reproduction and circulation of informational resources. The literature on knowledge commons has consequently treated knowledge as a shared resource whose institutional organization affects both access and continued production [9]. Accounts of networked information production have similarly emphasized the importance of nonproprietary and commons-based forms of production within digitally mediated economies [2]. At the same time, the expansion of intellectual property, technical restrictions, and other mechanisms of exclusion has generated sustained concern over the enclosure of informational and cultural resources [5].

These developments create a distinctive environment for knowledge-capital formation. Publicly available knowledge can enter the generative organization of an individual, research group, corporation, public institution, artificial intelligence system, or other knowledge-producing actor. Prior knowledge can reduce the cost of subsequent learning, increase the range of problems an actor can address, provide reusable conceptual and technical resources, and enable combinations that would have been difficult from a position of lower epistemic capacity. Knowledge already accumulated can therefore participate in the production of further knowledge. The resulting process can exhibit a recursive character in which epistemic capacity contributes to the acquisition of additional epistemic capacity.

The term *knowledge-capital expansion* is used in this paper for this broader dynamical process. The term does not identify a fixed class of actors and does not imply that every increase in knowledge reproduces a capitalist social relation. A student who learns from an open textbook, an independent researcher who combines materials from several disciplines, a public institution that improves its analytical capacity, and a corporation that incorporates public research into a proprietary infrastructure can all undergo forms of knowledge-capital expansion. Their political-economic positions, resources, downstream relations, and effects upon the surrounding knowledge field can nevertheless differ substantially.

The ethical problem therefore cannot begin from the proposition that knowledge accumulation itself constitutes a wrong. Learning and cumulative development are among the principal reasons for maintaining public knowledge in the first place. The relevant questions arise when the expansion of one actor's knowledge capital participates in wider transformations of access, control, dependency, recognition, productive capacity, infrastructure, or the future conditions of knowledge generation. Accumulated knowledge can remain one contribution to a plural field of inquiry. Under other conditions, it can be converted into infrastructural centrality, gatekeeping capacity, proprietary advantage, definitional authority, or control over resources upon which subsequent participants increasingly depend.

Public knowledge therefore creates a political-economic problem precisely because openness can sustain heterogeneous processes at once. The same knowledge commons can enable individual learning, collective research, commercial innovation, public service, automated recombination, institutional capacity building, and large-scale private accumulation. These processes can coexist, interact, and alter one another. Ethical analysis consequently requires attention to the relations through which knowledge capital expands and to the transformations that follow from that expansion.

1.2 Openness, Accumulation, and Normative Tension

A simple ethics of maximum openness cannot adequately interpret these relations. Openness has substantial generative value because it enlarges the set of actors capable of accessing existing knowledge and forming subsequent relations with it. Open publication can reduce barriers to learning, enable verification and criticism, support independent reuse, and permit new combinations across institutional and disciplinary boundaries. The knowledge commons literature has accordingly emphasized both the productive potential of shared knowledge and the institutional conditions required to sustain that potential

[9].

The normative significance of openness nevertheless depends upon the relations through which openness operates. Knowledge can concern vulnerable persons, culturally restricted materials, dangerous technical capacities, security-sensitive information, or other objects whose unrestricted circulation can produce serious consequences. An institution can also possess incomplete knowledge concerning downstream risks and lack effective mechanisms for mitigating them. Under such conditions, restricting access can protect the generative conditions of persons or communities who would otherwise be exposed to substantial and difficult-to-reverse harms.

Contemporary open-science governance already reflects part of this tension. The UNESCO Recommendation on Open Science couples openness with responsibility, accountability, sensitivity to possible social and ecological consequences, flexibility across different scientific systems, and attention to unintended effects including exploitation and privatization [22]. Such principles indicate that openness is governed within a field of additional responsibilities rather than functioning as a self-sufficient normative command.

The inverse problem is equally important. A restriction can originate from a defensible concern and later persist within a changed relational environment. New safety mechanisms may emerge, risks may become better understood, or less restrictive alternatives may become feasible. A restriction that previously protected affected actors can then acquire another political-economic function. It can preserve an avoidable bottleneck, maintain dependence upon a dominant intermediary, sustain rent extraction, or prevent alternative producers from developing capacities that no longer present the original risk.

The same difficulty appears in processes of accumulation. Knowledge-capital expansion can increase the generative capacity of an actor without materially reducing that of others. In other cases, accumulated capacity can be converted into control over infrastructures, standards, visibility, evaluation, distribution, or access. Public knowledge can thereby become an input into a process whose later stages restrict some of the generative pathways from which the process initially benefited. A public field can contribute to the formation of a powerful private intermediary and subsequently become dependent upon that intermediary for search, computation, publication, visibility, evaluation, or other functions.

The ethical problem is therefore structured by a tension among openness, accumulation, responsibility, control, and continued generativity. None of these terms has an invariant ethical ordering that resolves every case. Expanding access can be ethically important under one configuration and ethically hazardous under another. Restriction can protect a vulnerable generative field and can also participate in its enclosure. Accumulation can support learning and innovation and can also contribute to dependency and control concentration. Ethical inquiry must retain these distinctions instead of attaching a fixed moral value to a single visible feature of the configuration.

1.3 Relational Structure and Ethical Interpretation

The paper approaches this difficulty by separating the formal description of a relational process from the normative interpretation of that process. The distinction is described provisionally through the terms *relational syntax* and *normative interpretation*. Relational syntax concerns the organization of actors, roles, relations, events, trajectories, dependencies, and transformations that constitute a knowledge process. Normative interpretation concerns the ethical meaning that such a process acquires within a historically generated field of intelligibility.

This distinction matters because formally similar relational transformations can carry different normative meanings. A transition from broad access to restricted access can represent protective restraint, temporary risk management, privacy protection, cultural preservation, strategic exclusion, commercial enclosure, or another relation whose significance depends upon the larger system in which the transition occurs. A movement toward centralized coordination can constitute necessary institutional organization in one setting and the formation of an avoidable gatekeeper in another. The local shape of the relation therefore underdetermines its ethical interpretation.

The formal component of the paper is designed to preserve the structure upon which such interpretation operates. A public-knowledge field at a particular time is represented through a typed relational

graph configuration Γ_t . Actors or role-instances occupy vertices, while typed relations record relevant connections involving access, publication, modification, distribution, control, dependency, recognition, governance, financing, commercialization, or other relations. The representation is subsequently extended through labelled 2-complexes that connect relational boundary states and preserve events, relational continuities, transformations, and higher-order interactions through time.

The use of a 2-complex responds to a temporal and relational problem. Knowledge political economy rarely consists of a single interaction between two fixed actors. A reader can become a contributor, an aggregator can become a platform, and a platform can become a gatekeeper. Public knowledge can pass through publication, reuse, model training, commercialization, restriction, and renewed distribution. Relationships can continue across several events, change their type, branch into multiple downstream histories, or disappear. The object of ethical inquiry is therefore often a relational history rather than a single act.

The formal model has a deliberately limited normative role. It can identify which relations changed, which actors acquired new positions, which access paths disappeared, whether control became more concentrated, and how dependencies or provenance relations developed. These descriptions can make political-economic structures more legible. They do not generate an ethical answer by calculation. The paper therefore formalizes the object of ethical inquiry while leaving ethical judgment outside the formal calculus.

Political economy supplies an intermediate interpretive vocabulary. Processes such as accumulation, appropriation, enclosure, dispossession, concentration, dependency formation, rent extraction, externalization, capture, and re-enclosure describe consequential transformations in the relations through which knowledge is produced and circulated. These concepts help identify why a particular relational history matters. Their application still does not supply an invariant moral verdict. A political-economic diagnosis and an ethical judgment remain analytically distinguishable.

Generative Relational Ethics provides the final interpretive orientation. Its starting point is that ethical meaning emerges within evolving generative-relational systems. Historical experience, material relations, culture, language, technology, institutions, epistemic capacities, power relations, vulnerabilities, and available forms of action contribute to the hermeneutic conditions under which a relational configuration becomes normatively intelligible. These conditions themselves evolve. A judgment appropriate to an earlier relational state can consequently require revision when the field that sustained the earlier judgment has materially changed.

This account gives the paper a historicist orientation without making historical emergence sufficient for ethical justification. A practice can be deeply rooted in a historical system and still sustain relations that deserve criticism. Ethical inquiry can examine which subjects and generative conditions an interpretive system recognizes, which relations it obscures, which dependencies it stabilizes, and whether it can respond to new evidence and changing circumstances. Historical situatedness therefore establishes the conditions of normative interpretation while preserving the possibility of critique and revision.

1.4 Scope and Research Questions

The inquiry focuses on knowledge that is publicly available, openly circulating, or situated within institutional arrangements that substantially support public access and downstream reuse. Relevant domains include scholarly publication, open repositories, open educational materials, public data, networked knowledge infrastructures, and AI-mediated reuse of public knowledge. The term *public knowledge* is used broadly enough to include heterogeneous modes of accessibility while remaining narrower than knowledge in general.

The analysis concerns processes through which public knowledge enters subsequent production and contributes to changing relational positions. Particular attention is given to publication, access, learning, reuse, modification, aggregation, distribution, commercialization, restriction, governance, and recursive knowledge-capital formation. Actors are treated through functional and relational roles. Contributors, publishers, readers, reusers, distributors, platform operators, commercializers, funders, reviewers, commons members, and governance institutions can therefore occupy different ethical positions even when

several roles are instantiated by the same organizational actor.

The paper does not attempt to produce a universal ethical calculus for public knowledge. It does not assign numerical values to generativity, optimize an aggregate ethical objective, or provide a fixed ranking among openness, safety, autonomy, equality, efficiency, and other potentially relevant considerations. The formal representation is not proposed as an empirical simulation of the whole knowledge economy. The 2-complex is introduced as a structural language for relational histories and remains open to revision or replacement where another representation preserves the relevant relations more effectively.

The inquiry also remains distinct from a complete jurisprudence of public knowledge. Questions of copyright, licensing, factual provenance, historical priority, evidentiary adjudication, and transnational institutional authority can interact with the ethical problems examined here, but each has additional legal or governance structures that exceed the present scope. The present paper concentrates on the normative interpretation of knowledge-capital expansion and the political-economic relations through which that expansion operates.

Within these boundaries, the principal research question is:

How can the ethics of knowledge-capital expansion in public knowledge be understood when relationally similar processes may acquire different normative meanings across evolving historical, cultural, institutional, technological, and political-economic conditions?

This question is developed through five subsidiary inquiries. The first concerns how the relational object of ethical inquiry can be represented without converting ethical judgment into a formal optimization procedure. The second concerns which political-economic transformations become relevant when public knowledge contributes to accumulation, concentration, dependency, enclosure, extraction, or re-enclosure. The third concerns how historically evolving generative-relational systems contribute to the interpretive conditions under which these transformations acquire normative significance. The fourth concerns the dependence of ethical reasons and responsibilities upon relational roles. The fifth concerns how a historically situated account of normativity can remain revisable and critical while avoiding arbitrary relativism.

These questions place the paper at the intersection of political economy, knowledge-commons research, relational ethics, historical approaches to normativity, and formal relational representation. The intersection is used to construct a limited analytical framework rather than to subsume these fields within a single comprehensive theory.

1.5 Contributions

The paper makes three principal contributions.

The first contribution is an analytical distinction between relational syntax and normative interpretation in the ethics of public knowledge. The distinction prevents ethical conclusions from being assigned directly to formal properties such as openness, closure, concentration, or decentralization. It permits the same relational syntax to receive different normative interpretations when embedded in different historical and generative conditions. Political-economic descriptions can consequently be retained with greater precision while ethical judgment remains sensitive to the reasons available within a particular relational field.

The second contribution is a formal representation of the object of ethical inquiry through typed relational graphs and labelled 2-complexes. The representation captures relational states, higher-order events, actor and role transformations, continuing relations, and histories connecting successive configurations. Its purpose is methodological. Formalization preserves relational structure for interpretation and does not calculate moral truth. This distinction allows formal reasoning to assist ethical analysis without transforming ethics into an optimization problem.

The third contribution connects the political economy of knowledge-capital expansion with Generative Relational Ethics. Political-economic concepts are used to identify transformations involving

accumulation, appropriation, control, enclosure, dependency, extraction, and recursive advantage. Generative Relational Ethics then locates their normative meaning within historically evolving generative-relational systems. Normative interpretation is consequently treated as historically generated, relationally situated, role-dependent, reason-responsive, and recursively revisable.

Together, these contributions support a conception of ethical inquiry in which formal structure, political-economic interpretation, and normative judgment remain connected while retaining distinct functions. The approach also provides a basis for examining a central tension of public knowledge: the institutional arrangements that make cumulative knowledge generation possible can participate in processes that later alter, restrict, or protect the generative conditions of other actors. The ethical significance of these processes must be reconstructed from their relational histories and from the evolving systems within which those histories acquire meaning.

1.6 Structure of the Paper

The remainder of the paper develops this argument in successive analytical layers. Section 2 reviews the literature on knowledge commons, the political economy of knowledge, knowledge-capital formation, openness, relational and context-sensitive ethics, historical materialism, and higher-order relational representation. The review identifies the conceptual resources used by the paper and the boundary of the proposed contribution.

Section 3 develops the ethical structure of public knowledge, with particular attention to recursive reuse, functional roles, role multiplicity, role transformation, and relational dependence. Sections 4 and 5 then introduce the formal representation. Relational graph configurations describe states of the knowledge field, while labelled 2-complexes represent events and relational histories connecting successive states.

Section 6 develops the distinction between relational syntax and normative interpretation. It examines the dependence of normative meaning upon historical, cultural, institutional, and technological embedding. Sections 7 and 8 turn to political economy and analyze accumulation, enclosure, dependency, extraction, gatekeeping, role transformation, and recursive advantage as transformations within public knowledge relations.

Section 9 develops the account of Generative Relational Ethics used in the paper. It examines historically generated hermeneutic systems, generative conditions, relational responsibility, re-cognizability, epistemic humility, and normative revisability. Section 10 considers the relationship between this account and historical materialism, including the distinction between the historical emergence of normative systems and their ethical justification.

Section 11 uses openness and closure as a central case through which the framework can be examined. It distinguishes protective restriction, safety-oriented intervention, extractive closure, and re-enclosure while considering how the normative meaning of formally similar arrangements can change through relational evolution. Section 12 then examines role-dependent ethical interpretation across contributors, readers, reusers, platforms, commercial actors, reviewers, and governance institutions.

Section 13 states the limits of formal representation and addresses ethical optimization, incommensurable reasons, uncertainty, indeterminacy, and institutional humility. Section 14 discusses the implications of the framework for knowledge capital, commons governance, historical normativity, AI-mediated knowledge production, and the relation between formal structure and hermeneutic judgment. The conclusion returns to the central proposition that the ethical meaning of knowledge-capital expansion depends upon the evolving generative-relational systems in which its relational histories are embedded.

2 Literature and Conceptual Background

This section situates the present inquiry within several bodies of literature that address different components of the ethical problem developed in Section 1. The review has two objectives. The first is to identify established conceptual resources for understanding knowledge commons, capital accumulation,

enclosure, contextual normativity, relational ethics, historical conditioning, and higher-order relational representation. The second is to delimit the contribution of the present paper. No single literature reviewed below supplies the complete architecture developed here. The relevant components instead appear across fields whose objects, vocabularies, and normative commitments remain partly distinct.

2.1 Knowledge Commons and Public Knowledge

The knowledge-commons literature provides the principal institutional background for the present inquiry. Hess and Ostrom developed knowledge commons research by examining knowledge and information through the broader commons tradition, directing attention toward collective resources, institutional arrangements, enclosure pressures, and the conditions under which shared knowledge can be sustainably produced and maintained [9]. This perspective displaced a simple opposition between private and public ownership by emphasizing governance arrangements, communities, rules, infrastructures, and patterns of participation.

The Governing Knowledge Commons framework subsequently extended this institutional orientation. Frischmann, Madison, and Strandburg adapted Ostrom-inspired institutional analysis to knowledge and innovation, emphasizing the systematic study of resources, communities, rules-in-use, action arenas, outcomes, and relevant background conditions [8]. The framework is particularly important for the present paper because it treats commons governance as context-dependent and institutionally heterogeneous. Different knowledge communities can organize access, contribution, exclusion, sharing, secrecy, and responsibility through different combinations of formal and informal rules.

Benkler's analysis of networked information production provides a related political-economic account of nonmarket and commons-based production [2]. Networked environments can support forms of collaboration whose productive organization differs from both conventional firm hierarchy and market exchange. Boyle's analysis of the public domain similarly identifies pressures toward informational enclosure and emphasizes the social consequences of expanding exclusionary control over informational resources [5].

These literatures establish several premises used by the present paper. Knowledge can function as a shared productive resource; access conditions matter for future generation; commons require governance; and institutional arrangements influence how knowledge is created, preserved, and reused. However, the primary object of these approaches is generally the governance, institutional design, or political economy of shared resources. The present paper introduces a narrower ethical problem concerning the changing normative meaning of relational transformations generated within such fields.

This difference becomes important when commons governance includes apparently contrasting practices. A knowledge commons can depend upon broad publication, restricted access, confidentiality, membership boundaries, delayed release, or differentiated permissions. The institutional category of commons therefore does not by itself determine the ethical status of openness or closure. Ethical interpretation requires attention to the relations through which a governance arrangement operates and to the historical conditions under which those relations acquire significance.

2.2 Political Economy of Knowledge and Information

Political-economic approaches to information and digital systems provide a second foundation. Their central contribution is to direct analysis away from informational artefacts considered in isolation and toward the ownership, control, infrastructure, labour, market structure, extraction, and accumulation processes through which informational production is organized.

Digital knowledge environments can support substantial concentration despite the low marginal cost of copying information. Benkler identifies the productive possibilities of distributed networked production while also examining institutional and technological conditions capable of constraining those possibilities [2]. Boyle's account of intellectual enclosure similarly demonstrates how legal mechanisms can transform informational resources into objects of exclusion and controlled access [5].

Recent political economy of artificial intelligence intensifies this analysis. Verdegem characterizes contemporary AI capitalism through the commodification and extraction of data together with concentration in data, talent, computing infrastructure, and corporate power [23]. The analysis is relevant because artificial intelligence changes the scale at which publicly available informational resources can be accumulated, processed, recombined, and converted into privately controlled productive capacities.

The political economy of academic content provides an especially close example. Komljenovic, Williamson, Birch, and Beiter analyze the assetization of teaching materials, student work, scholarly publications, publisher databases, and content used for generative AI training [11]. Their analysis shows how academic content can be transformed through legal, contractual, technical, and financial arrangements into controlled assets capable of generating future revenue. Of particular relevance to this paper is the observation that assetization alters governance relationships around academic content rather than merely attaching a market price to an otherwise unchanged object.

These approaches support the treatment of public knowledge as a field in which access, control, accumulation, infrastructure, and downstream dependency can evolve together. They also demonstrate why public availability does not prevent later concentration. Public knowledge can enter processes that produce privately controlled infrastructure, market power, databases, models, standards, or platforms.

The present inquiry draws upon this political-economic vocabulary while separating descriptive diagnosis from ethical determination. A process can be identified as accumulation, concentration, assetization, enclosure, or dependency formation before the paper asks how that process should be normatively interpreted within a particular generative-relational system.

2.3 Capital Accumulation and Enclosure

Classical political economy supplies a deeper genealogy for the concepts of accumulation, control, productive conditions, dispossession, and enclosure. Marx's analysis of capital directs attention toward capital as a social relation reproduced through processes of accumulation and through historically specific relations among labour, productive resources, property, and control [14]. This relational orientation is important for the present paper because knowledge capital is likewise treated as a dynamical property of a relational process rather than as a moral identity assigned to a class of persons.

The historical analysis of enclosure and primitive accumulation is especially relevant to public knowledge. Enclosure concerns more than the existence of a boundary. Its political-economic significance can involve the transformation of prior relations of access, use, dependence, and productive possibility. When actors lose direct relations to conditions required for production and must subsequently pass through a controlling intermediary, the topology of productive dependence has changed.

Informational enclosure differs materially from enclosure of land or other rival physical resources. Knowledge can frequently be copied without depriving the previous possessor of a copy, and legal control over expression, data, databases, models, or infrastructure can take forms that differ from physical possession. Boyle therefore cautions against treating informational enclosure as a simple extension of tangible-property intuitions while still showing that exclusionary legal expansion can alter the public domain [5].

The present paper accordingly uses enclosure as a relational and political-economic category whose precise operation must be reconstructed in each case. Relevant transformations can include loss of access paths, creation of obligatory intermediaries, conversion of public inputs into exclusive downstream infrastructures, restriction of future reuse, or concentration of control over productive conditions.

This treatment also distinguishes accumulation from domination. An actor can accumulate knowledge without acquiring coercive or infrastructural control over other actors. Expertise, learning, memory, and research capacity can develop unevenly through ordinary generative processes. Ethical inquiry therefore concerns the relations through which accumulated capacity is converted into control, dependency, exclusion, vulnerability, or other consequential transformations.

2.4 Knowledge Capital and Epistemic Capitalization

The concept of knowledge capital used in this paper intersects with several established accounts of capital that extend beyond immediately monetary assets. Bourdieu's treatment of cultural, social, and symbolic capital demonstrates how accumulated resources can operate differently according to the fields in which they become effective and convertible [4]. Recognition, credentials, cultural competence, and social position can acquire durable effects because their value is relational to institutions and fields.

The sociology of science provides a closely related account of cumulative recognition. Merton's work on scientific priority and the Matthew effect shows how recognition and prior advantage can become unevenly distributed and can contribute to subsequent advantage [16, 17]. Scientific credit therefore offers an example in which epistemic production and social recognition develop through recursive relations rather than through isolated acts of discovery.

The present series uses *knowledge capital* in a broader generative sense. Knowledge becomes capital-like when accumulated epistemic resources increase an actor's capacity to acquire, organize, interpret, recombine, or produce further knowledge. Such expansion can remain largely internal to the actor's productive capacity. It can also become institutionally convertible into recognition, visibility, economic resources, infrastructural control, standard-setting power, or differential access to future opportunities.

The related concept of epistemic capitalization concerns processes through which knowledge, recognition, visibility, reputation, computational capacity, institutional position, or other epistemic resources enter recursively advantage-producing relations. The concept therefore directs attention to dynamic conversion rather than to a fixed stock. A prior epistemic advantage can improve access to resources that facilitate further production, whose outputs can generate additional recognition and further access.

This perspective overlaps with Bourdieu and Merton while extending the object toward AI-mediated and infrastructural processes in which the speed and scale of recursive accumulation can change substantially. The present paper does not require every epistemic advantage to be interpreted as capital in the classical economic sense. The analytical interest lies in identifying when knowledge-related capacities acquire self-reinforcing and relationally consequential properties.

The ethical significance of epistemic capitalization remains open at this stage. Recursive advantage can support expertise, continuity, institutional memory, and socially valuable specialization. It can also contribute to gatekeeping, concentration, recognition monopolies, or structural dependency. The normative interpretation developed later in the paper therefore follows the relational operation of capitalization rather than assigning a fixed ethical status to accumulation itself.

2.5 Open Knowledge and Responsible Openness

Open-access and open-science movements have established strong normative and institutional arguments for widening access to scholarly knowledge. Public availability can support verification, participation, reuse, education, collaboration, and wider distribution of research benefits [21]. Open licensing provides legal infrastructures through which many downstream permissions can be granted in advance [6].

Institutional approaches to openness nevertheless increasingly recognize that openness operates alongside responsibilities concerning privacy, security, indigenous and community interests, sensitive data, harmful use, and institutional capacity. The UNESCO Recommendation on Open Science combines openness with responsibility, accountability, flexibility, and attention to possible unintended consequences [22]. The resulting framework treats openness as an institutional practice situated within wider social obligations.

Knowledge-commons research supplies an even stronger precedent for the generative significance of selective closure. Frischmann, Haenschen, and Waldman examine knowledge-producing contexts in which privacy and confidentiality norms help establish the trust required for productive exchange [7]. In such cases, restriction can contribute positively to knowledge generation because participants can disclose, deliberate, or experiment under conditions that would be impaired by immediate unrestricted publicity.

This literature is important for the ethical position developed here. Generativity cannot be identified with maximum circulation. A system can increase public accessibility while damaging privacy, safety, trust, cultural continuity, or other conditions needed for future generation. Conversely, protective restrictions can become obsolete, strategically maintained, or converted into instruments of dependency after the conditions that originally supported them have changed.

The present inquiry therefore treats responsible openness as a temporally revisable relational problem. The relevant ethical question concerns how a particular configuration of access and restriction operates within its current generative field, including whether the reasons supporting that configuration remain valid as institutions, knowledge, technologies, and risks evolve.

2.6 Context-Sensitive Normativity

Contextual Integrity provides one of the closest conceptual neighbors to the present paper. Nissenbaum argues that the normative appropriateness of information flows depends upon the social contexts within which those flows occur and upon context-specific informational norms [18]. The framework directs attention toward actors, information types, transmission principles, social purposes, and context rather than treating information disclosure through a universal public-private distinction.

The relevance to public knowledge is substantial. A formally similar transfer of information can have different normative significance according to the roles of sender, recipient, subject, and the social context governing the flow. Contextual Integrity therefore offers an established framework in which the ethical interpretation of informational movement depends upon relational and institutional positioning.

More recent work has explicitly connected Contextual Integrity to knowledge commons governance. Shvartzshnaider, Sanfilippo, and Apthorpe use Contextual Integrity as a gauge for examining privacy expectations and norm evolution in knowledge commons [20]. This work is particularly relevant because it emphasizes that technological and social change can alter information flows and the norms through which those flows are evaluated.

The present paper shares the rejection of context-free evaluation while extending the analytical object in three directions. First, its object includes political-economic relations extending beyond information transfer, including accumulation, control, dependency, extraction, role transformation, and enclosure. Second, context is treated as an evolving generative-relational field whose history participates in producing the interpretive system itself. Third, the formal representation concerns relational histories across successive states rather than a single informational transaction.

The difference is therefore one of scope and architecture. Contextual Integrity supplies a sophisticated account of contextually appropriate information flow. Generative Relational Ethics asks how normative interpretation itself develops and changes within historically evolving relational systems, including systems whose political-economic structure can be transformed by the very actions under evaluation.

2.7 Relational Ethics

Relational approaches to ethics provide a second close normative neighbor. They challenge accounts that treat moral subjects as fully separable, self-sufficient units and direct attention toward interdependence, vulnerability, responsibility, encounter, and the quality of relationships. Bergum and Dossetor develop relational ethics through healthcare practice, where ethical responsibility emerges within concrete relations among persons rather than through abstract application detached from those relations [3].

Feminist work on relational autonomy develops a broader philosophical critique of atomistic accounts of agency. Mackenzie and Stoljar's collection shows how autonomy, identity, responsibility, self-conception, and agency are shaped through social relations and can be impaired through oppression or relational conditions [13]. This tradition is especially relevant to the present concern with dependency, role-specific responsibility, and the capacity of relational structures to alter future agency.

Generative Relational Ethics shares this attention to relational constitution. It also treats actors as occupying multiple relational roles whose responsibilities cannot be derived solely from institutional

identity. A platform operator, contributor, reviewer, commercializer, and reader enter different relations with the same knowledge object and possess different capacities for intervention.

The present framework adds a stronger temporal and generative emphasis. Relations are examined through their emergence, persistence, transformation, and potential rigidification. The ethical subject is situated within a historical relational system that continues to evolve, while ethical interpretation participates in that evolution. The framework therefore emphasizes the revisability of normative interpretation when the system that generated an earlier judgment has materially changed.

Generative Relational Ethics also avoids treating relationality itself as a sufficient ethical criterion. A relation can sustain domination, dependency, erasure, exploitation, care, learning, protection, or mutual generation. Ethical inquiry therefore concerns the form and operation of the relation within a wider generative system rather than the mere existence of interdependence.

2.8 Historical Materialism and Normative Historicity

Historical materialism supplies an important intellectual background for the claim that normative consciousness cannot be understood independently of historically specific social relations. In *The German Ideology*, Marx and Engels connect forms of consciousness with the material life-processes, productive relations, and forms of social intercourse through which human life develops [15]. Morality and other forms of consciousness consequently acquire historical conditions of emergence.

This orientation contributes two important insights to the present paper. The first is methodological: ethical concepts should be examined in relation to the social and material structures within which they become intelligible. The second is dynamic: transformations in productive and social relations can participate in transformations of consciousness and normative interpretation.

The relationship between Marx and ethics is nevertheless contested and cannot be reduced to a simple deterministic doctrine. Kain's study of Marx's ethical development documents significant changes across Marx's writings and challenges an interpretation in which historical materialism produces a single stable position on morality [10]. This complexity is relevant to the present inquiry because historical conditioning does not by itself settle the normative validity of historically generated judgments.

Generative Relational Ethics adopts a related commitment to historicity while broadening the relevant generative field. Material production, property, labour, and economic dependence remain important, particularly in the political-economic analysis of knowledge capital. The relevant relational system also includes cultural, linguistic, symbolic, institutional, technological, epistemic, interpersonal, legal, and ecological relations.

The resulting account is recursive. Historically generated interpretive systems guide judgments and actions, while those judgments and actions can alter the relations from which later interpretations emerge. Normative historicity therefore describes an evolving feedback relation rather than a one-directional derivation of ethical meaning from a fixed material base.

A further distinction is essential. Historical emergence explains how a normative interpretation became possible within a relational field. Justification concerns whether that interpretation can withstand criticism, new evidence, alternative perspectives, and changes in the generative conditions of affected actors. The paper preserves this distinction in order to maintain historical situatedness without granting normative immunity to historically established practices.

2.9 Higher-Order Relational Representation

The formal component of the paper also has established precedents outside ethical theory. Complex-network research has long represented systems through nodes and pairwise links, but many social, biological, and technological processes involve interactions among groups whose effects cannot be adequately captured by pairwise decomposition. Battiston and colleagues survey the importance of such higher-order interactions and the use of hypergraphs and simplicial complexes for representing them [1].

The choice of higher-order representation is itself consequential. Zhang, Lucas, and Battiston show that hypergraphs and simplicial complexes can produce different collective dynamics even when they

encode related higher-order interaction structures [24]. Formal representation therefore cannot be treated as a neutral decorative choice. The representation should correspond to the kinds of relational continuity, interaction, and transformation relevant to the research question.

The present inquiry requires more than a static higher-order interaction structure because its primary object is a history connecting relational configurations. Actors can change roles, relations can persist across multiple events, and events can modify the topology of the field. The formal language therefore requires both boundary states and a representation of the intervening relational history.

Spin-foam formalisms provide a structural analogy for this purpose. In the spin-foam approach, histories are represented through labelled 2-complexes related to boundary states, and such structures can be composed through compatible boundaries [19]. The present paper borrows this combinatorial intuition while leaving behind its quantum-gravitational physical interpretation.

The resulting model is therefore described as spin-foam-inspired rather than as a spin-foam model of knowledge. It uses typed relational graphs for boundary configurations and labelled 2-complexes for histories connecting them. Physical spin labels, quantum amplitudes, intertwiners, and claims of quantum dynamics play no role in the present framework.

This limitation is substantively important. The purpose of the formalism is to preserve actors, roles, events, higher-order interactions, relational continuity, and transformations in a form suitable for subsequent political-economic and normative interpretation. Ethical significance remains outside the combinatorial representation.

2.10 Boundary of the Present Inquiry

The preceding literatures establish substantial prior work around every major component of the present inquiry. Knowledge-commons research already provides context-sensitive institutional analysis of shared knowledge resources [9, 8]. Political economy already analyzes informational enclosure, commodification, assetization, concentration, and infrastructural power [5, 23, 11]. Contextual Integrity already demonstrates that the normative appropriateness of information flows depends upon roles and social contexts [18]. Relational ethics and relational autonomy already challenge atomistic moral subjects [3, 13]. Historical materialism already provides a powerful account of the historical conditioning of consciousness [15]. Higher-order network and spin-foam literatures already provide formal tools for relations extending beyond pairwise static graphs [1, 19].

The contribution of the present paper therefore does not rest upon priority for any of these individual propositions. Its contribution lies in the architecture constructed among them.

The first component of that architecture is the separation of relational syntax from normative interpretation. Political-economic transformations are represented and identified without assigning their ethical meaning directly from their formal structure. This allows formally similar configurations to receive different normative interpretations when embedded in different historical and generative systems.

The second component is the use of relational graph configurations and labelled 2-complexes to represent the object of ethical inquiry through time. The formal model records the relational history that normative interpretation must confront while refusing to convert ethical judgment into a formal optimization procedure.

The third component is the placement of political economy between formal description and ethical interpretation. Accumulation, enclosure, dependency, extraction, concentration, and related concepts identify politically and economically consequential transformations. They remain diagnostic categories whose normative significance depends upon the generative-relational system in which they operate.

The fourth component is an account of normative interpretation as historically generated and recursively revisable. A generative-relational system contributes to the formation of a hermeneutic horizon through which relational histories acquire ethical meaning. Changes in that system can alter the reasons relevant to later judgment. The ethical interpretation of openness, restriction, accumulation, or control can consequently change without any requirement that the local relational syntax itself change.

The framework therefore occupies a deliberately intermediate position between formal relational modeling, political economy, and normative philosophy. It does not seek to replace knowledge-commons

governance, Contextual Integrity, relational ethics, historical materialism, or higher-order network theory. Its aim is to connect selected resources from these traditions in order to analyze a specific problem: how the ethical meaning of knowledge-capital expansion should be interpreted when public knowledge participates in evolving relational histories whose political-economic and normative significance changes through time.

3 Ethical Structure of Public Knowledge

This section develops the ethical object that will later be represented formally. Its purpose is to identify the relational features of public knowledge that make isolated-act analysis insufficient. The discussion begins from public knowledge as a generative field, then examines recursive reuse, knowledge-capital formation, functional roles, role multiplicity, role transformation, and relational dependence. The section concludes by showing why the relevant ethical object frequently consists of an evolving relational history rather than a single act considered independently of its surrounding field.

3.1 Public Knowledge as a Generative Field

Public knowledge can be understood as more than a collection of publicly accessible informational objects. It also constitutes a field of possible relations among persons, institutions, infrastructures, documents, datasets, models, communities, and subsequent acts of interpretation and production. A publicly available article can be read, criticized, translated, cited, recombined, incorporated into teaching, used as evidence, transformed into a technical implementation, included in a dataset, or connected with concepts from another field. Public availability therefore creates relational possibilities whose consequences extend beyond the moment of publication.

Knowledge-commons research provides an important institutional foundation for this perspective. Shared knowledge resources are embedded within communities, rules, infrastructures, practices, and patterns of access that influence their continued production and use [9, 8]. Networked information production likewise demonstrates that distributed access to informational resources can support forms of production whose organization extends beyond conventional firm and market structures [2].

The present inquiry refers to such an environment as a *generative field*. A generative field is a relational environment within which existing knowledge can participate in subsequent acts of learning, interpretation, criticism, combination, transformation, and production. The term does not imply that every relation within the field is productive or ethically desirable. A field can contain exclusion, dependency, misinformation, concentrated control, or destructive forms of use. Its defining feature is that existing relations condition the possibilities through which further relations and knowledge practices can emerge.

The generative character of public knowledge is therefore distributed. A document acquires different consequences according to the infrastructures through which it is found, the languages in which it is available, the competencies of readers, the institutional conditions of reuse, the availability of computational resources, and the relations through which subsequent outputs are recognized and circulated. Public accessibility can increase the number of possible generative relations while leaving substantial differences in the capacity to activate those possibilities.

This distinction becomes ethically important because the existence of a public resource does not imply equal generative capacity among participants. Two actors may possess formal access to the same corpus while differing greatly in time, education, infrastructure, computational capacity, institutional support, recognition, linguistic competence, or access to complementary resources. Public knowledge therefore exists within a field already structured by heterogeneous capacities and dependencies.

The ethical analysis developed in this paper consequently concerns the conditions through which public knowledge becomes generatively operative. The relevant object includes access to knowledge, the capacity to interpret and transform it, the relations required for downstream production, and the institutional structures through which resulting knowledge can enter further cycles of use.

3.2 Knowledge Production and Recursive Reuse

Public knowledge is recursively productive because outputs from one generative process can become inputs into later processes. A published analysis can become evidence for another inquiry. A dataset can support a new model. A conceptual distinction can be transferred into another discipline. A software implementation can become infrastructure for later research. A critical response can alter how an earlier work is understood and can itself become an object of subsequent criticism.

Recursive reuse is therefore broader than literal reproduction. It includes learning, transformation, reinterpretation, combination, translation, abstraction, implementation, criticism, and other processes through which existing knowledge modifies the conditions of subsequent production. Open access and permissive reuse can enlarge such possibilities, although the practical realization of those possibilities depends upon additional resources and institutional conditions [21, 6].

The recursive structure also introduces temporal depth into ethical analysis. The consequences of making knowledge public may emerge several stages after the original act. A contributor can publish a resource for educational or scholarly use. Another actor can aggregate the resource with many others. A third actor can construct infrastructure around the aggregate. Subsequent participants can become dependent upon that infrastructure. The ethical significance of the original public release cannot therefore be reconstructed solely from the immediate relation between contributor and first reader.

Recursive reuse can also amplify differences in generative capacity. Actors with greater infrastructure, accumulated knowledge, institutional support, or computational resources may be able to transform the same public materials more rapidly and at greater scale. The resulting outputs can then increase their ability to acquire additional resources and participate in further cycles of knowledge production.

Such recursive development is not intrinsically problematic. Cumulative learning and specialization are normal features of knowledge production. Ethical questions arise when recursive reuse alters the surrounding relational field in ways that materially affect the future generative possibilities of other participants. These changes can include new dependencies, barriers, concentrations of control, or reductions in alternative paths through which knowledge can be produced and circulated.

Recursive reuse therefore connects the ethics of public knowledge with the political economy of accumulation. The important question is not only what an actor does with a public resource at one moment, but how repeated reuse changes the actor's position within subsequent relational configurations.

3.3 Knowledge-Capital Formation

Knowledge-capital formation refers to the process through which accumulated knowledge increases an actor's capacity for further epistemic production. The relevant resources can include conceptual understanding, methodological competence, disciplinary knowledge, technical skills, organized corpora, institutional memory, models, analytic tools, research infrastructure, and relations that provide access to further expertise.

The concept is relational because the productive significance of accumulated knowledge depends upon the field in which it operates. Bourdieu's treatment of capital emphasizes that resources acquire effects through fields and through their possibilities of conversion into other forms of advantage [4]. Merton's account of cumulative advantage in science similarly demonstrates how prior recognition can contribute to later recognition and resource acquisition [17].

Knowledge capital in the present paper is broader than recognition or credentialed cultural capital. It refers to epistemic capacities whose accumulation can alter what an actor is able to understand, produce, combine, or transform. These capacities can remain largely internal to the actor's own generative organization. They can also become externally consequential when converted into institutional position, economic resources, visibility, standard-setting capacity, infrastructural control, or authority over the conditions through which other actors produce knowledge.

The distinction between accumulation and conversion is central. An increase in knowledge can improve an actor's own generative capacity while leaving the surrounding field substantially unchanged. A different process can convert that increased capacity into a position through which the actor controls

access, distribution, ranking, evaluation, or infrastructure. Ethical analysis must therefore follow the relational trajectory through which knowledge capital becomes effective.

Knowledge-capital formation is also cumulative across heterogeneous sources. Public documents, education, interpersonal exchange, institutional training, software, data, models, archives, and machine-mediated synthesis can all enter the same generative organization. The resulting capacity rarely has a single origin. Its provenance can form a network of contributions, transformations, and enabling conditions.

This distributed formation complicates simple accounts of ownership and desert. An actor can make substantial creative contributions while also depending upon public infrastructures and prior knowledge. Another actor can benefit heavily from existing resources while adding little new material but providing critical organization or distribution. The ethical significance of knowledge-capital formation therefore depends upon the relations through which capacity is acquired, transformed, converted, and used.

3.4 Roles in Public Knowledge Relations

Ethical analysis in public knowledge requires attention to functional roles. Institutional categories such as individual, corporation, university, government agency, journal, or nonprofit organization are often too coarse because the same entity can participate in several distinct relations and possess different capacities in each.

Relevant roles include contributors, publishers, depositors, readers, learners, reusers, modifiers, translators, distributors, curators, archivists, platform operators, funders, commercializers, reviewers, adjudicators, governance participants, and downstream institutions. The list is provisional and domain-dependent. Its purpose is to identify the function an actor occupies within a particular relation rather than to establish a permanent classification of actors.

Role-based analysis is important because ethical reasons are frequently position-sensitive. A contributor can have responsibilities concerning accuracy, provenance, and foreseeable consequences of publication. A repository operator can have responsibilities concerning preservation, access, correction, and continuity. A reviewer can have responsibilities concerning evidentiary restraint and procedural fairness. A platform operator can possess capacities to shape visibility, access, ranking, and dependency that ordinary readers do not possess.

The role therefore affects both capacity and responsibility. A participant with no practical ability to change an infrastructural condition cannot be assigned the same responsibility as an actor who controls that condition. A platform capable of modifying access rules occupies a different relational position from a user whose participation is constrained by those rules. Responsibility should accordingly be interpreted through the actor's actual position within the relevant relational field.

Role-based analysis also reduces the risk of converting ethical inquiry into a judgment about institutional identities. A commercial actor can contribute valuable public infrastructure. A public institution can create restrictive dependencies. A nonprofit organization can become a gatekeeper. A private individual can exercise substantial platform power. Ethical interpretation therefore follows relations and capacities rather than relying upon the nominal category of the actor.

3.5 Role Multiplicity

Actors in public knowledge commonly occupy several roles at once. A university can fund research, employ contributors, operate a repository, publish materials, license technology, provide computing infrastructure, review research, and participate in governance. A scholarly publisher can curate, distribute, archive, monetize, correct, and provide metadata. An AI platform can aggregate public knowledge, transform it through model training, distribute generated outputs, rank sources, sell access, and establish technical conditions for downstream production.

Role multiplicity creates ethical complexity because responsibilities associated with different positions can conflict. A platform can have a responsibility to preserve broad access while also facing legitimate safety, privacy, or security concerns. A publisher can seek sustainable revenue while also

controlling access to knowledge generated through publicly supported research. A university can support openness while entering exclusive commercial agreements intended to finance further research.

The ethical interpretation of an actor therefore cannot be derived from a single role label. The relevant analysis must identify which role is active in which event, what capacities accompany that role, how the role interacts with other positions occupied by the same actor, and whether control acquired in one relation affects responsibilities in another.

Role multiplicity can also produce internal transfers of power. An actor that first enters the field as a distributor can use accumulated data and infrastructure to become a producer. A producer can acquire platform functions. A platform can subsequently participate in governance or standard-setting. The ethical significance of these developments depends upon how powers obtained through one role become operative in other relations.

This observation is especially important for knowledge-capital expansion. Accumulated epistemic capacity can facilitate the acquisition of additional roles. Knowledge capital can therefore change the range of positions an actor is capable of occupying. The resulting ethical problem concerns both the expansion of capacity and the transformation of the relational field through which that capacity becomes effective.

3.6 Role Transformation

Roles are temporally variable. An actor can enter a knowledge field as a reader and later become a contributor. A contributor can become an editor, reviewer, or institution-builder. An aggregator can become a platform operator. A platform operator can become an indispensable infrastructural intermediary. These transformations can occur gradually through repeated events rather than through a single institutional decision.

Role transformation is therefore one reason a static ethical snapshot can be misleading. A relation that appears unproblematic at an early stage can acquire different consequences after accumulated knowledge, users, data, infrastructure, recognition, or capital alter the actor's position.

The transition from participant to gatekeeper provides a particularly important example. At an early stage, an actor can use public resources while remaining one participant among many. Repeated accumulation can later place the actor in control of infrastructure through which others increasingly must pass. The actor's responsibilities can change because the relational consequences of its decisions have changed.

Role transformation can also reduce previous asymmetries. A dependent reader can acquire expertise and become capable of independent production. A community previously reliant on external infrastructure can develop local capacity. A centralized platform can open interfaces that enable alternative providers. Ethical analysis must therefore recognize both the formation and dissolution of dependencies.

The relevant ethical object consequently includes trajectories of role formation. Later sections represent such trajectories within relational histories rather than treating role labels as permanent properties of actors.

3.7 Relational Dependence

Dependency arises when one actor's capacity to continue a valued activity depends materially upon relations controlled or maintained by another actor. Dependency can involve access to information, computational infrastructure, publication channels, funding, identity systems, repositories, standards, distribution networks, search systems, or other conditions required for continued participation in a knowledge field.

Dependency is not intrinsically equivalent to domination. Knowledge production is extensively interdependent. Researchers depend upon archives, journals, libraries, standards, collaborators, infrastructures, and prior scholarship. Institutions depend upon specialized expertise and shared systems. Interdependence can sustain productive coordination and distributed generativity.

Ethical concerns become more acute when dependencies acquire characteristics such as avoidable exclusivity, severe exit costs, lack of alternative paths, unilateral control, opacity, or the capacity to

impose conditions that substantially alter another actor's generative possibilities. These features can transform ordinary reliance into a relation through which one actor gains disproportionate influence over another's future participation.

The distinction between dependency and domination is particularly important for the political economy developed later in the paper. A centralized infrastructure can provide efficient coordination while remaining contestable, interoperable, replaceable, and accountable. A similar infrastructure can become a bottleneck whose operator can determine access, visibility, pricing, or permissible use without meaningful alternatives.

The ethical analysis therefore concerns the structure of dependency. Relevant questions include whether alternative paths exist, whether exit is practicable, whether the dependency is transparent, whether its terms can be contested, whether control is revisable, and whether the dependent actor retains meaningful possibilities for subsequent generation.

Dependency also has historical depth. A field can become dependent upon an actor gradually through convenience, accumulated adoption, technical standards, data concentration, or network effects. The ethical significance of a later restriction can therefore depend upon a dependency produced by many earlier events.

3.8 Ethical Problems beyond Individual Acts

The preceding analysis establishes why many ethical problems in public knowledge exceed the boundaries of isolated acts. A single act of reading, copying, publishing, restricting, commercializing, or aggregating can be insufficient to explain the relation that ultimately becomes ethically significant. The relevant problem can emerge through a sequence of individually ordinary events whose cumulative effect transforms the structure of the field.

Consider a process in which a public resource is accessed, aggregated, converted into a productive service, adopted widely, and gradually made indispensable to downstream users. None of the early events alone need contain the later dependency structure. The ethical problem can emerge from the history through which the actor's position changes and alternative paths decline.

The same temporal structure applies to protective governance. A temporary restriction can be justified under conditions of severe uncertainty and limited safeguards. If the surrounding system changes, the continuation of the restriction can acquire a different ethical significance. Evaluating the restriction requires knowledge of its origin, its continuing function, the development of alternatives, and the present distribution of risks and dependencies.

Public-knowledge ethics therefore requires an object capable of preserving relational history. The analysis must identify participants, roles, relations, events, persistent dependencies, role transformations, and changes in the conditions through which future knowledge can be generated. Ethical interpretation can then address the historically situated configuration rather than an abstract act detached from its generative field.

This requirement motivates the formal development in the following sections. Section 4 introduces typed relational graph configurations for representing the structure of public-knowledge relations at a given state. Section 5 extends this representation through labelled 2-complexes capable of representing the events and relational histories through which such configurations are generated and transformed.

4 Relational Syntax of Knowledge Processes

This section develops the formal syntax used to represent the relational states identified in Section 3. Its objective is limited and methodological. The representation records actors, role-instances, typed relations, relational conditions, and changes among successive states of a public-knowledge field. It thereby provides a structured object for later political-economic and normative interpretation. The representation assigns no ethical value to the configurations it records.

The basic state representation is a labelled relational graph. Higher-order events and histories connecting successive graph configurations are introduced in Section 5. This separation allows a relational state and the history through which that state emerged to remain analytically distinct.

4.1 Relational Configurations

Let a public-knowledge field at time t be represented by a relational configuration Γ_t . The minimal structure used in this paper is

$$\Gamma_t = (V_t, E_t, \tau_V, \tau_E, \lambda_t), \quad (1)$$

where V_t is a set of relationally relevant vertices, E_t is a set of directed relations, τ_V assigns vertex types, τ_E assigns relation types, and λ_t records additional state-dependent labels. Equation 1 defines the basic relational state used throughout the formal development.

The representation is deliberately heterogeneous. A vertex can represent an actor occupying a particular functional position, an institutionally relevant role-instance, or another entity whose participation must remain identifiable for the analysis. Relations can record access, publication, contribution, control, dependence, distribution, financing, recognition, review, governance, modification, commercialization, or other domain-specific connections.

The graph is therefore a structured representation of relational conditions at a selected temporal resolution. It does not claim that the full social world has a naturally privileged graph decomposition. The selection of vertices, relations, labels, and temporal boundaries is an analytical act whose adequacy depends upon the problem under examination.

This qualification is important for ethical analysis. A highly aggregated graph can erase role differences or dependencies that later prove normatively important. An excessively detailed graph can preserve distinctions that contribute little to the inquiry. The formal representation should therefore retain enough structure to reconstruct the relations through which the relevant political-economic transformations operate.

4.2 Actors and Role Instances

The vertices of Γ_t should not be identified automatically with social actors considered as indivisible units. Section 3.5 showed that the same person or institution can simultaneously occupy several functional roles. The formal syntax therefore distinguishes an underlying actor from the role-instance through which that actor enters a particular relation.

Let A denote a set of actors and R a set of functional role types. A vertex can then be represented through an actor-role pairing,

$$v_i(t) = (a_i, r_i, t), \quad a_i \in A, \quad r_i \in R. \quad (2)$$

Equation 2 allows one actor to instantiate several vertices when several analytically distinct roles are active. A university, for example, can appear in one relation as a funder, in another as a repository operator, and in another as a commercial licensor. These role-instances can share the same underlying actor while remaining distinct within the relational configuration.

This distinction prevents institutional identity from carrying responsibilities that arise from a more specific relational position. A platform's role as a distributor can involve different capacities from its role as an access governor. A researcher's role as a contributor can differ from the same researcher's later role as a reviewer. The syntax therefore records the position through which an actor participates in the relation being analyzed.

Role types remain revisable. The set R is an analytical vocabulary rather than a final ontology of public-knowledge participation. New infrastructures or institutional arrangements can generate roles that are absent from an earlier classification. A sufficiently flexible representation should permit the role vocabulary to evolve together with the field it describes.

4.3 Typed Relations

Relations in public knowledge differ substantially in their practical operation. Reading a document, controlling a repository, funding a project, reviewing a manuscript, and depending upon a platform are relationally different events even when the same actors participate. A graph containing untyped edges would therefore discard much of the structure required for subsequent interpretation.

For a directed edge $e_{ij} \in E_t$, let

$$e_{ij}(t) = (v_i, v_j, \rho_{ij}, \lambda_{ij}(t)), \quad \rho_{ij} \in T_E, \quad (3)$$

where ρ_{ij} identifies the relation type and $\lambda_{ij}(t)$ records state-dependent properties of the relation. Equation 3 distinguishes the existence and direction of a relation from the attributes through which that relation is presently realized.

A publication relation can carry labels concerning accessibility or licensing. A dependency relation can record the availability of alternative paths. A governance relation can record scope, procedural constraints, or institutional authority. A distribution relation can record reach or intermediation. The relevant labels depend upon the research question.

Relation types can coexist between the same pair of vertices. A platform can simultaneously distribute an author's work, control its visibility, monetize access, and maintain the infrastructure on which the author depends. These relations should remain separately identifiable because later political-economic interpretation can assign different significance to each.

Direction also matters. An author can provide knowledge to a platform while the platform provides visibility to the author. The two relations have different objects, capacities, and consequences. Their coexistence can produce mutual dependence, asymmetric dependence, or a relation whose character changes as the field evolves.

4.4 Relational States

The configuration Γ_t represents a relational state at a selected time. The term *state* refers here to the analytically relevant configuration of roles and relations rather than to a complete description of every property of the participating actors.

The label function λ_t can contain heterogeneous information. For the political-economic inquiry developed later in the paper, relevant dimensions can include knowledge capital, access, control, visibility, recognition, dependency, available alternatives, infrastructural capacity, and other properties required for reconstructing the operation of a relation. A convenient abstract notation is

$$\lambda_t(x) = (K_t(x), A_t(x), X_t(x), D_t(x), V_t(x), G_t(x), \dots), \quad (4)$$

for an analytically relevant vertex or relation x . In Equation 4, K denotes knowledge-capital conditions, A access, X control, D dependency, V visibility or recognition, and G generative conditions.

Equation 4 does not require these dimensions to share a common numerical scale. A label can be categorical, ordinal, qualitative, relational, interval-valued, or represented through another domain-specific structure. The tuple is therefore a bookkeeping device for heterogeneous relational information.

This point preserves an important methodological boundary. The existence of several analytically relevant dimensions does not imply that they can be combined into an ethical objective function. Greater access can coexist with greater risk. Increased coordination can coexist with increased dependency. Expanded knowledge capital can coexist with reduced generative alternatives for other actors. The syntax records these conditions while leaving their normative interpretation to later analysis.

A state representation can also include information concerning uncertainty. Some relations can be directly observable, while others can be inferred from institutional behavior, technical dependence, or incomplete records. Relational syntax therefore need not presume perfect epistemic access to the field being represented.

4.5 Events and State Transitions

Public-knowledge fields evolve through events. Publication, withdrawal, licensing, acquisition, platform adoption, model training, access restriction, policy revision, funding, commercialization, correction, and institutional reorganization can each modify the relational configuration.

At the level of successive states, an event or collection of events can be represented provisionally through a transition

$$\Gamma_{t+1} = T_{e_t}(\Gamma_t), \quad (5)$$

where e_t denotes the relevant event and T_{e_t} denotes the corresponding relational transformation. Equation 5 states only that the later configuration is related to the earlier configuration through the event under analysis.

The transformation can create or remove vertices, create or remove relations, change relation types, alter labels, or change the actor-role structure. A reader can become a contributor. A distributor can acquire governance capacity. A previously direct access relation can become mediated through a platform. A temporary dependency can disappear when alternative infrastructure becomes available.

The transition operator is not assumed to be deterministic. The same nominal event can produce different relational consequences in different fields. A new repository can diversify access in one environment and become another centralized dependency in another. The transformation therefore belongs to a concrete relational history rather than to an invariant event rule.

Equation 5 also provides no ethical evaluation. A transition that reduces access, increases control, or alters dependency remains at this stage a formally described change. Later sections consider the political-economic and normative interpretation of such transformations.

4.6 Higher-Order Interactions

Many knowledge processes involve more than two relationally relevant participants. Peer review can involve authors, reviewers, editors, publishers, and institutions. Model training can simultaneously implicate content providers, repositories, model developers, infrastructure operators, users, and downstream institutions. Governance decisions can be generated collectively through committees, membership organizations, or multi-party procedures.

Higher-order network research has emphasized that group interactions can carry structure that is lost when every interaction is decomposed into independent pairwise edges [1]. Different higher-order representations can also generate different dynamical implications [24]. The choice of representation therefore matters when the collective participation of several roles is itself part of the phenomenon.

The present syntax retains the typed relational graph as the representation of a boundary state while allowing higher-order interaction events to be identified separately. Let a higher-order event at time t have an incidence set

$$I(e_t) = \{v_{i_1}, v_{i_2}, \dots, v_{i_k}\}, \quad k \geq 2. \quad (6)$$

Equation 6 records the role-instances that participate jointly in the event. The collective event need not be reduced to the set of all pairwise relations among those vertices.

This distinction prepares the transition to the 2-complex representation in Section 5. There, interaction events become part of the history connecting graph configurations, permitting several relations and role-trajectories to meet within the same event structure.

The graph therefore functions as the relational boundary syntax, while the higher-order history carries the processes through which boundaries are generated and transformed.

4.7 Temporal Persistence of Relations

Successive graph configurations must preserve more than similarity if they are to represent a meaningful relational history. Ethical and political-economic analysis frequently requires knowledge that a relation

at $t + 1$ is the continuation, transformation, or termination of a relation present at t .

A partial persistence map can be introduced between successive relation sets,

$$\pi_t : E_t \rightharpoonup E_{t+1}, \quad (7)$$

where $\pi_t(e)$ identifies the continuation of relation e when such a continuation is analytically meaningful. Equation 7 is partial because some relations terminate, divide, merge, or undergo changes that make direct identity inappropriate.

Persistence does not require invariance. A continuing access relation can become more restrictive. A dependency can intensify or weaken. A governance relation can change scope. A distribution relation can acquire a monetization condition. The relation can therefore persist historically while its labels or practical operation change.

This distinction is especially important for normative interpretation. A restriction can have been created for one reason and later continue under different conditions. A platform dependency can begin as a convenient option and become difficult to exit after widespread adoption. Reconstructing these changes requires preservation of relational continuity across time.

Temporal persistence also prevents later states from erasing the history through which they emerged. The ethical significance of a current configuration can depend upon earlier commitments, prior harms, accumulated dependencies, or historical reasons whose traces remain relevant even after the visible state has changed.

4.8 Provenance and Relational Histories

Provenance provides a final requirement for the relational syntax. A current relation often acquires significance from the events through which it was generated. A platform's present control over an infrastructure can depend upon earlier public contributions. A downstream knowledge product can depend upon several generations of public resources, modifications, aggregations, and institutional transformations. A current restriction can inherit a justification from an earlier risk environment even when that environment has changed.

Provenance standards such as PROV-O provide established vocabularies for describing entities, activities, agents, and derivational relations [12]. The present paper shares the concern with reconstructable lineage while extending the object toward changing political-economic relations and role configurations.

For the purposes of the present framework, provenance is therefore treated as part of relational history. The relevant question can concern where a knowledge object originated, how it was transformed, which actors participated in its circulation, how an infrastructural position was acquired, or through which events a dependency emerged.

A relational configuration Γ_t provides only a boundary state. Successive states together with persistence information provide part of the history, but increasingly complex processes require an explicit structure connecting those states. This requirement motivates the next formal step.

Section 5 therefore represents the history between relational configurations through a labelled 2-complex. The purpose of that extension is to preserve events, higher-order interactions, continuing role-trajectories, relational transformations, and composable histories within a single structure. The graph configurations developed in the present section serve as the boundaries of those histories.

5 Relational Histories through 2-Complexes

Section 4 represented a public-knowledge field at a selected time through a typed relational graph Γ_t . That representation records a relational state, but many of the ethical and political-economic problems considered in this paper depend upon the history through which such a state emerged. Access can become mediated, dependencies can intensify, roles can change, and a previously peripheral actor can acquire a gatekeeping position through a sequence of events whose significance cannot be recovered from the final graph alone.

This section therefore introduces a labelled 2-complex as a representation of relational history. The construction is structurally inspired by spin-foam formalisms, in which graph-like boundary states are related through labelled 2-complexes representing histories between them [19]. The present use is combinatorial and relational. No quantum interpretation, transition amplitude, physical spin label, or gravitational dynamics is introduced.

A useful distinction must be maintained from the beginning. The relational graph Γ_t and the interior 2-complex do not assign identical semantics to cells of the same dimension. Instead, Γ_t is treated as a relational trace obtained by taking a transversal cut through the event complex. Actor-role instances arise where the cut intersects continuing actor-role trajectories, while typed relations arise where the cut intersects relational faces. This construction preserves the state semantics introduced in Section 4 while permitting the interior complex to represent temporal development.

5.1 Boundary Graphs

Let $\mathcal{F}$ denote a finite labelled 2-complex representing a relational history. A temporal cut Σ_t through $\mathcal{F}$ induces a relational graph

$$\Gamma_t = \text{Tr}_{\Sigma_t}(\mathcal{F}), \quad (8)$$

where Tr_{Σ_t} denotes the relational trace of the complex at the selected cut.

The cut is analytical rather than physical. It identifies a stage in the relational history at which the configuration of actors, roles, and relations is to be examined. The parameter t can represent chronological time, an ordered sequence of institutional events, or another temporally meaningful index appropriate to the empirical problem.

The vertices of the induced graph arise from intersections between the cut and continuing actor-role trajectories. If c_α^1 denotes a relevant one-dimensional trajectory within the complex, then

$$v_\alpha(t) = \Sigma_t \cap c_\alpha^1 \quad (9)$$

defines the corresponding actor-role instance whenever the intersection is nonempty and transversal.

Likewise, graph relations arise where the cut intersects relational two-cells. If c_β^2 denotes a relational face, then its intersection with the cut induces a typed relation in Γ_t ,

$$e_\beta(t) = \Sigma_t \cap c_\beta^2. \quad (10)$$

The boundary graph therefore records a relational state extracted from a history whose additional structure remains represented in the surrounding complex.

This distinction avoids an ambiguity that would arise if the graph were identified literally with the one-dimensional skeleton of the 2-complex. In the state graph, vertices represent actor-role instances and edges represent relations. In the history complex, one-cells represent continuities or trajectories, while two-cells represent relational histories. The trace construction connects these two representations without requiring them to share identical cell semantics.

For a history extending between two selected cuts, Σ_{in} and Σ_{out} , the corresponding boundary states are

$$\Gamma_{\text{in}} = \text{Tr}_{\Sigma_{\text{in}}}(\mathcal{F}), \quad \Gamma_{\text{out}} = \text{Tr}_{\Sigma_{\text{out}}}(\mathcal{F}). \quad (11)$$

The complex can then be written schematically as

$$\mathcal{F} : \Gamma_{\text{in}} \longrightarrow \Gamma_{\text{out}}. \quad (12)$$

Equation 12 is a compact notation for a relational history rather than a deterministic transition function.

5.2 Event Vertices

The zero-dimensional cells of the interior complex represent events at which relational trajectories meet, separate, terminate, begin, or undergo a relevant transformation. An event can correspond to publication, licensing, aggregation, acquisition, model training, access restriction, policy change, commercial deployment, correction, institutional reorganization, or another interaction capable of modifying the relational field.

Let $C_0(\mathcal{F})$ denote the set of event vertices. For an event $q \in C_0(\mathcal{F})$, its incident trajectory set is

$$I_1(q) = \{c_\alpha^1 \in C_1(\mathcal{F}) : q \in \partial c_\alpha^1\}, \quad (13)$$

and its incident relational-face set is

$$I_2(q) = \{c_\beta^2 \in C_2(\mathcal{F}) : q \in \partial c_\beta^2\}. \quad (14)$$

These incidence sets permit a single event to involve several actors, roles, and relations simultaneously. A model-training event, for example, can connect content providers, repositories, model developers, computational infrastructure, licensing arrangements, and downstream distribution structures. Treating the event only as a collection of pairwise interactions can obscure the fact that the relations become operative together.

The event vertex therefore provides a natural location for higher-order interaction. This use is compatible with the broader motivation of higher-order network research, which emphasizes that collective interactions can contain structure unavailable in pairwise decompositions [1].

Event labels can preserve additional information such as event type, institutional setting, applicable rules, declared purpose, uncertainty, available alternatives, or relevant external conditions. These labels remain descriptive. An event identified as an acquisition, restriction, or commercialization event has not thereby received an ethical evaluation.

5.3 Actor and Role Trajectories

The one-dimensional cells of $\mathcal{F}$ represent the continuity of actor-role participation between events. They provide the historical counterpart of the actor-role instances defined in Equation 2.

Let $c_\alpha^1 \in C_1(\mathcal{F})$ be a trajectory carrying an actor label a_α and a role label r_α . Between two events, the trajectory records the continuing participation of that actor-role instance in the relational history.

Role labels need not remain invariant across the entire history. Suppose an actor first participates as a reader and later becomes a contributor. The change can be represented through an event vertex q at which an incoming trajectory labelled

$$(a, \text{reader})$$

is connected by identity-preserving provenance to an outgoing trajectory labelled

$$(a, \text{contributor}).$$

The underlying actor can therefore persist while the functional role changes.

More complex transformations are also possible. An actor can acquire several roles and generate several outgoing role-trajectories. A platform, for example, can continue simultaneously as distributor, model operator, access governor, and commercializer. The complex need not collapse those positions into a single trajectory if their distinction is relevant to later analysis.

Conversely, several previously distinct institutional roles can become consolidated within one actor. Such consolidation is especially relevant to political-economic analysis when an actor acquires control over functions that were previously distributed across several institutions.

The trajectory representation therefore accommodates

$$\text{reader} \longrightarrow \text{aggregator} \longrightarrow \text{platform operator} \longrightarrow \text{gatekeeper} \quad (15)$$

as a historical sequence rather than as a static classification.

Equation 15 does not imply that every such trajectory occurs or that the later role is ethically objectionable. Its purpose is to represent a possible transformation whose political-economic meaning can subsequently be examined.

5.4 Relational Faces

The two-dimensional cells of $\mathcal{F}$ represent relational histories. A relational face records the persistence, transformation, creation, or termination of a relation among the actor-role trajectories forming its boundary.

A face can therefore represent the history of an access relation, dependency, licensing relation, governance relation, distribution channel, financial relation, recognition relation, or another typed relational structure.

Let $c_\beta^2 \in C_2(\mathcal{F})$. Its label can be written abstractly as

$$\ell_2(c_\beta^2) = (\rho_\beta, \mu_\beta), \quad (16)$$

where ρ_β identifies the relational type and μ_β records its historically varying conditions.

A dependency face, for example, can preserve whether alternative routes remain available, whether exit costs increase, or whether the dependent actor retains meaningful control over the terms of participation. An access face can record a transition from unrestricted to conditional access. A governance face can record changes in the scope or procedure of institutional authority.

A relational face need not represent a relation of constant type or intensity. Its history can contain marked events at which labels change. If the change is sufficiently significant, the original face can terminate at an event vertex and a differently labelled face can begin. This permits the modeler to choose whether a transformation is represented as variation within a continuing relation or as replacement by a new relation.

Relational faces can also involve more than two trajectories. A collective governance relation, collaborative project, multi-party licensing arrangement, or other higher-order structure can have a boundary involving several actor-role trajectories. The 2-complex therefore does not require every social relation to be reduced to a dyadic edge history.

The face representation is especially useful for distinguishing relational continuity from momentary events. A restrictive policy can be introduced by one event while the resulting access relation persists through many later events. Ethical interpretation can then consider both the event that created the relation and the history through which the relation continued.

5.5 Labelled 2-Complexes

The complete relational history can now be represented abstractly as

$$\mathcal{F} = (C_0, C_1, C_2, \partial, \ell), \quad (17)$$

where C_0 is the set of event vertices, C_1 the set of actor-role trajectories, C_2 the set of relational faces, ∂ records incidence and boundary relations among cells, and ℓ assigns the labels needed for the inquiry.

The label function is heterogeneous:

$$\ell = (\ell_0, \ell_1, \ell_2), \quad (18)$$

where ℓ_0 assigns event attributes, ℓ_1 assigns actor and role attributes to trajectories, and ℓ_2 assigns relational attributes to faces.

The representation can also carry global labels describing conditions that apply to an extended region of the complex. These can include the legal regime, technological environment, market structure, institutional rules, linguistic environment, or other background conditions that cannot be adequately attached to one event or relation alone.

Context is therefore distributed across the relational history rather than compressed into a single static variable. Some contextual information belongs to events, some to actors and roles, some to continuing relations, and some to the broader institutional environment in which the complex is embedded.

This distributed representation is important for the later ethical analysis. A formally similar local event can occur inside two histories whose legal, technological, institutional, or political-economic embeddings differ substantially. The local event syntax can remain similar while the surrounding relational conditions differ.

The labelled complex therefore records the structure available for subsequent interpretation. It does not define a scalar state variable for the ethical quality of the history and does not assume that heterogeneous labels are commensurable.

5.6 Boundary Transitions

A relational history can transform the topology and labels of the boundary graph. Between Γ_{in} and Γ_{out} , vertices can appear or disappear, role labels can change, relations can be created or terminated, and the structure of access and dependency can be reorganized.

Consider an initial configuration in which several actors possess direct access to a public resource K :

$$A_i \longrightarrow K, \quad i = 1, \dots, n. \quad (19)$$

A later history can introduce an intermediary P through which access is increasingly mediated,

$$A_i \longrightarrow P \longrightarrow K. \quad (20)$$

Equations 19 and 20 describe different boundary configurations. The intervening complex records how the intermediary entered the field, which relations became dependent upon it, which direct paths remained available, and whether the mediation resulted from technical coordination, voluntary adoption, contractual restriction, institutional policy, or another process.

The later topology alone cannot reconstruct these distinctions. A centralized boundary state can arise through many histories. The history can therefore matter to political-economic and normative interpretation even when two final graphs are structurally similar.

Boundary transitions can also increase relational diversity. A centralized repository can become interoperable with several alternative infrastructures. A previously exclusive access route can be supplemented by public mirrors. A dependent community can develop local capacity. The 2-complex representation therefore accommodates both concentration and decomposition of control.

5.7 Composition of Relational Histories

Long histories can be constructed by composing shorter relational histories. Suppose

$$\mathcal{F}_1 : \Gamma_0 \longrightarrow \Gamma_1 \quad (21)$$

and

$$\mathcal{F}_2 : \Gamma_1 \longrightarrow \Gamma_2. \quad (22)$$

When the outgoing trace of $\mathcal{F}_1$ is compatible with the incoming trace of $\mathcal{F}_2$, the histories can be joined along the shared configuration Γ_1 :

$$\mathcal{F}_2 \circ_{\Gamma_1} \mathcal{F}_1 = \mathcal{F}_1 \cup_{\Gamma_1} \mathcal{F}_2 : \Gamma_0 \longrightarrow \Gamma_2. \quad (23)$$

Composition is useful because political-economic processes frequently unfold over several analytically distinguishable stages. A history can contain

$$\text{publication} \rightarrow \text{aggregation} \rightarrow \text{commercial deployment} \rightarrow \text{infrastructural dependence} \rightarrow \text{access restriction}. \quad (24)$$

Each stage can be studied separately, while Equation 23 preserves the possibility of treating the stages as one extended history.

Composition also prevents the analyst from assigning all significance to the final event. A later restriction can depend politically and ethically upon earlier public contributions, adoption patterns, investments, representations, promises, or dependency-forming events. The composed history preserves those relations for subsequent interpretation.

The construction has a categorical flavor: graph configurations function as relational boundary objects and compatible histories can be composed through shared boundaries. The present paper does not require a full category-theoretic development. The compositional property is introduced only to formalize the fact that relational histories can be joined without erasing their intermediate structure.

5.8 Local and Extended Relational Neighborhoods

Ethical inquiry can concern a local event while still requiring information from a larger relational history. A licensing decision, access restriction, or platform policy can appear similar when viewed only at the immediate event vertex but operate differently because of prior dependencies or surrounding institutional relations.

For a cell c in $\mathcal{F}$, let

$$\mathcal{N}_k(c; \mathcal{F}) \quad (25)$$

denote the relational neighborhood obtained by extending through at most k incidence steps from c . The precise construction can be adapted to the incidence graph of the complex or to another domain-specific adjacency relation.

The immediate neighborhood $\mathcal{N}_1$ can identify the actors and relations directly participating in an event. Larger neighborhoods can reveal dependencies, prior transformations, alternative access paths, upstream public contributions, downstream effects, or institutional structures that are not visible locally.

The distinction between local syntax and extended embedding becomes important when two local neighborhoods are structurally similar:

$$\mathcal{N}_k(q_1; \mathcal{F}_1) \cong \mathcal{N}_k(q_2; \mathcal{F}_2). \quad (26)$$

Equation 26 expresses formal similarity only. The two neighborhoods can remain embedded in histories with different institutional, political-economic, cultural, or historical conditions.

Section 6 develops the normative consequence of this distinction. Formal similarity of local relational syntax does not entail identity of ethical meaning.

5.9 Scope of the Formal Representation

The labelled 2-complex is proposed as a working representation of relational histories rather than as a complete ontology of public knowledge. Its usefulness depends upon whether it preserves the distinctions required by the political-economic and normative inquiry.

Several limitations follow.

First, the decomposition into actors, roles, events, trajectories, and relational faces depends upon analytical judgment. Different research questions can require different granularities. An institution can

be treated as one actor in one inquiry and decomposed into departments, offices, committees, or technical systems in another.

Second, the temporal cuts used to obtain Γ_t are selected rather than given naturally. A rapid technical event and a gradual institutional transformation can require different temporal resolutions. The model therefore does not assume a universal clock for relational change.

Third, some phenomena can require structures richer than a 2-complex. Persistent higher-order relations, nested institutions, probabilistic dependencies, continuous dynamics, or multiscale processes can motivate hypergraphs, higher-dimensional cell complexes, sheaf-like structures, categorical models, dynamical systems, or other representations. The present formalism should be extended or replaced where such alternatives preserve the relevant structure more effectively.

Fourth, the spin-foam analogy remains structural. The complex carries no physical spin representation, intertwiner, path-integral amplitude, quantum state, or spacetime interpretation. The analogy is retained because spin-foam formalisms provide a clear example of graph-like boundary states connected by composable 2-complex histories [19].

Fifth, the formalism contains no ethical optimization rule. It can represent that access narrowed, that an actor acquired a new role, that dependencies increased, that alternative paths disappeared, or that control became concentrated. It cannot determine from these facts alone whether the resulting history is ethically justified.

The central methodological principle can therefore be stated as follows:

The 2-complex formalizes a relational history upon which ethical inquiry can operate; it does not formalize ethical judgment itself.

This boundary prepares the next stage of the argument. Section 6 examines why relational syntax underdetermines normative meaning and why formally similar histories can receive different ethical interpretations when embedded in different historically generated relational systems.

6 Relational Syntax and Normative Meaning

Sections 4 and 5 developed a formal representation of public-knowledge relations and their histories. The present section addresses the normative consequence of that formalization. The central claim is that relational syntax underdetermines ethical meaning. A formally similar configuration or history can acquire different normative significance when it is embedded in different historical, cultural, institutional, technological, and political-economic conditions.

This underdetermination does not make formal analysis ethically irrelevant. Relational syntax identifies the structure upon which normative interpretation operates. It can reveal who occupies which role, which relations have changed, whether access has narrowed, whether dependencies have formed, and whether an actor has acquired a new position within the field. These facts constrain ethical inquiry. They do not by themselves complete it.

The distinction developed in this section is therefore between the formal organization of a relational history and the historically generated interpretive conditions through which that history becomes normatively intelligible.

6.1 Formal Equivalence and Normative Difference

Consider two relational histories, $\mathcal{F}_1$ and $\mathcal{F}_2$, whose relevant formal structures are isomorphic:

$$\mathcal{F}_1 \cong \mathcal{F}_2. \tag{27}$$

Equation 27 states that the selected combinatorial structures correspond under an appropriate structure-preserving mapping. The same kinds of roles, events, trajectories, relations, and boundary transformations can therefore appear in both histories.

Formal equivalence does not imply normative equivalence:

$$\mathcal{F}_1 \cong \mathcal{F}_2 \not\Rightarrow \llbracket \mathcal{F}_1 \rrbracket = \llbracket \mathcal{F}_2 \rrbracket. \quad (28)$$

The notation $\llbracket \mathcal{F} \rrbracket$ denotes the normative interpretation of the relational history. Its full historical and hermeneutic dependence will be developed later.

A simple example concerns access restriction. Two institutions can undergo the same local transformation:

$$\text{broad access} \longrightarrow \text{restricted access}. \quad (29)$$

At the level of local relational syntax, the transformations can be isomorphic. Their ethical meaning can nevertheless differ substantially.

In one history, access can be restricted temporarily because publication would expose vulnerable persons to a severe and difficult-to-reverse risk, while effective protective mechanisms remain unavailable. In another history, the restriction can occur after risks have become manageable and can primarily serve to preserve an avoidable commercial bottleneck.

The syntax records narrowing access in both cases. Ethical interpretation must also consider why the restriction emerged, whose generative conditions it affects, which alternatives exist, what risks are present, how long the restriction persists, and what role the restriction plays within the larger relational history.

Formal equivalence therefore supplies a useful test case. If two histories with equivalent local syntax can support different ethical interpretations, then ethical value cannot be encoded as an invariant property of that syntax alone.

6.2 Descriptive Structure and Normative Interpretation

The distinction between descriptive structure and normative interpretation does not require a complete separation between facts and values. Political and ethical descriptions frequently employ concepts that already contain evaluative dimensions. The present distinction is instead methodological.

At the first level, relational analysis identifies changes in the structure of the field. Examples include:

- access becoming more restricted;
- control becoming more concentrated;
- alternative paths disappearing;
- dependency upon an intermediary increasing;
- an actor acquiring additional roles;
- a relation becoming difficult to exit;
- public resources entering a privately governed downstream structure.

These descriptions can be empirically contested, but their truth does not depend upon a complete ethical theory.

At a second level, political-economic interpretation identifies the broader significance of such transformations. A concentration of control can be interpreted as gatekeeper formation. A loss of alternative productive paths can participate in dependency. A transition from shared access to exclusive control can constitute a form of enclosure. Repeated conversion of accumulated capacity into additional control can constitute recursive accumulation.

At a third level, normative interpretation asks how these transformations should be evaluated within the relevant generative-relational system.

The analytical sequence can therefore be represented schematically as

$$\text{relational syntax} \longrightarrow \text{political-economic interpretation} \rightsquigarrow \text{normative interpretation.} \quad (30)$$

The final relation in Equation 30 is written as $\rightsquigarrow$ rather than as an ordinary function arrow. Normative judgment is not treated as the deterministic output of a fixed mapping from political-economic categories to ethical verdicts.

This distinction is especially important for concepts such as *enclosure*, *exploitation*, and *domination*. Some political-economic concepts can operate partly as thick normative concepts. Their use therefore requires care. The present framework attempts to reconstruct the underlying relational transformations before relying upon the ethical force carried by a contested label.

For example, the observation that a single intermediary now controls an important access path can be established before deciding whether that intermediation is exploitative, protective, efficient, necessary, or dominating. This sequencing preserves analytical transparency.

6.3 Ethical Underdetermination by Syntax

The underdetermination claim can be expressed more formally by introducing a generative-relational environment $\mathcal{G}_{x,t}$ within which the history $\mathcal{F}$ is embedded.

Let

$$\iota : \mathcal{F} \hookrightarrow \mathcal{G}_{x,t} \quad (31)$$

denote the embedding of the selected relational history into a wider generative-relational system.

The same local relational history can admit different embeddings:

$$\mathcal{F} \hookrightarrow \mathcal{G}_A, \quad \mathcal{F} \hookrightarrow \mathcal{G}_B. \quad (32)$$

The surrounding systems can differ in law, institutional capacity, available technology, historical experience, cultural meaning, political economy, risk distribution, epistemic resources, or other relations relevant to normative interpretation.

The ethical meaning of $\mathcal{F}$ is therefore embedding-dependent.

This proposition can also be expressed locally. Suppose

$$\mathcal{N}_k(q_1; \mathcal{F}_1) \cong \mathcal{N}_k(q_2; \mathcal{F}_2), \quad (33)$$

while the extended histories or generative systems differ. The isomorphism of the selected local neighborhoods does not determine whether the corresponding events should receive the same ethical interpretation.

The result is a form of normative underdetermination:

$$\text{syntax} \not\vdash \text{unique ethical meaning.} \quad (34)$$

Equation 34 should not be interpreted as saying that syntax imposes no normative constraints. Some relational facts can rule out interpretations that depend upon facts that did not occur. The claim is that relational syntax is generally insufficient to determine a unique ethical interpretation without information concerning its embedding.

This distinction protects the formalism from an inappropriate use. A graph metric, centrality measure, dependency index, or structural classification can be highly informative about the political economy of a knowledge field. None of these measurements should be treated as a self-sufficient ethical score.

6.4 Historical Embedding

Normative interpretation has historical depth because relational configurations inherit significance from prior events. A present restriction, dependency, privilege, obligation, or institutional role can be intelligible only through the history that produced it.

Consider two institutions that exercise formally similar control over a knowledge resource. One institution can hold that control as the temporary custodian of material collected under explicit expectations of confidentiality. Another can have acquired equivalent control through the progressive conversion of previously public resources into proprietary infrastructure. The present topology of control can appear similar while its historical provenance differs.

Historical embedding matters in at least three ways.

First, earlier relations can generate legitimate expectations. Agreements, promises, representations, established practices, and prior governance arrangements can alter the reasons relevant to present conduct.

Second, historical processes can generate vulnerabilities and dependencies. An actor can become dependent upon an infrastructure through years of institutional adoption. A later change in access conditions therefore cannot be evaluated as though the dependent actor were encountering the platform for the first time.

Third, the knowledge available to ethical decision-makers changes through time. A restriction adopted under severe uncertainty can later become unnecessary when new evidence, technologies, or safeguards appear. Normative judgment that ignores such development risks treating past reasons as permanently valid.

The same relational configuration can consequently receive different ethical interpretations at different moments:

$$[\mathcal{F}]_{t_1} \neq [\mathcal{F}]_{t_2}. \quad (35)$$

Equation 35 does not imply that ethical truth changes arbitrarily with time. The relevant reasons can change because the relations, risks, capacities, knowledge, and alternatives that constitute the ethical situation have changed.

Historical situatedness therefore requires continuing attention to the conditions that originally supported a judgment and to whether those conditions remain operative.

6.5 Cultural Embedding

Public knowledge also operates within culturally heterogeneous systems. Knowledge objects can carry meanings that depend upon collective practices, historical memory, language, ritual, community boundaries, and expectations concerning legitimate circulation.

A purely formal account of access cannot capture all such distinctions. Making a resource publicly downloadable can increase technical accessibility while violating culturally generated expectations concerning custodianship, interpretive authority, sacredness, community consent, or appropriate modes of transmission.

Conversely, cultural difference should not be treated as a universal justification for any restrictive practice. Cultural systems can contain internal disagreements, unequal authority, excluded participants, historical domination, and changing interpretations. The relevant culture should not be represented as a homogeneous actor with a single timeless normative position.

Generative Relational Ethics therefore treats cultural meaning as internally relational and historically evolving. Relevant questions include which actors participate in the production of a norm, whose interpretations are recognized, which voices are excluded, and whether the system allows its own meanings to be reconsidered.

This approach distinguishes cultural situatedness from cultural immunity. Ethical interpretation can take culturally generated meanings seriously while remaining attentive to relations of exclusion, silencing, dependency, and loss of generative possibility within the same field.

Cross-cultural normative difference can therefore be represented schematically as

$$\llbracket \mathcal{F} \rrbracket_{\mathcal{H}_A} \neq \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_B}, \quad (36)$$

where $\mathcal{H}_A$ and $\mathcal{H}_B$ denote distinct historically generated interpretive systems.

The purpose of Equation 36 is descriptive and philosophical. It states the possibility of divergent normative interpretation without asserting that every interpretation is equally justified.

6.6 Institutional Embedding

Institutions shape the relational meaning of public knowledge by defining roles, permissions, procedures, accountability mechanisms, dispute processes, and expectations concerning access and responsibility.

The same formal concentration of decision-making power can operate differently under different institutional arrangements. Centralized authority can be temporary, procedurally constrained, reviewable, and accountable to affected participants. A formally similar authority can be opaque, indefinite, difficult to contest, and insulated from external review.

The ethical significance of concentration therefore depends in part upon the institutional relations surrounding it. Relevant considerations can include procedural safeguards, transparency, representation, review, exit possibilities, interoperability, appeal, legal constraints, and the availability of alternative institutions.

Institutional embedding also affects role responsibility. A reviewer who possesses advisory influence occupies a different position from an adjudicator with final authority. A repository operator that implements rules created through collective governance occupies a different relational position from an operator that unilaterally sets access conditions.

The syntax can encode these differences through role types and relation labels. Normative interpretation must then consider how institutional design distributes capacities, responsibilities, dependencies, and possibilities for revision.

Institutional structures can themselves change through the knowledge-capital processes examined in this paper. A service provider can acquire sufficient infrastructural importance to participate in governance. A publisher can become a data platform. A platform can become a standard setter. Institutional embedding is therefore both a condition of interpretation and a possible outcome of the relational histories under evaluation.

6.7 Technological Embedding

Technology alters the practical operation of formally similar knowledge relations. A permission to access information can have different consequences when access requires manual consultation of a physical archive, bulk download through an application interface, automated processing by a computational system, or continuous incorporation into a large-scale model.

The relational syntax “actor accesses public knowledge” can therefore conceal large differences in scale, speed, reproducibility, aggregation, searchability, and downstream transformation.

Artificial intelligence makes this distinction especially visible. Public knowledge that previously required substantial human time to locate, interpret, and combine can become available for large-scale automated processing. The formal availability of the source may remain unchanged while the productive consequences of access are transformed by new computational capacity.

Technological change can similarly alter the justification for restriction. A disclosure that once generated limited risk can acquire different consequences when automated aggregation, identification, synthesis, or replication becomes possible. Conversely, technologies for privacy preservation, access control, audit, provenance, or safety can reduce risks that previously supported restrictive governance.

Normative interpretation must therefore remain sensitive to technological conditions that change the causal and generative consequences of a relation.

Technology can also reshape the topology of the relational field. Search engines, repositories, model providers, identity infrastructures, citation systems, and computational platforms can become obligatory intermediaries. Their significance arises from the relations they mediate rather than from their technical character alone.

The ethical interpretation of technological infrastructure therefore depends upon how it changes generative possibilities, dependency structures, control, alternatives, and the capacity of participants to revise or leave the resulting arrangement.

6.8 Interpretive Dependence of Normative Meaning

The preceding analysis can now be stated in terms of a historically generated hermeneutic system. Let $\mathcal{G}_{x,t}$ denote the generative-relational system within which the relevant history is embedded. The system includes the material, cultural, institutional, technological, linguistic, epistemic, and political-economic relations needed for the normative inquiry.

Within such a system, let

$$\mathcal{G}_{x,t} \rightsquigarrow \mathcal{H}_{x,t} \quad (37)$$

denote the historical formation of a hermeneutic-normative system $\mathcal{H}_{x,t}$.

The relation in Equation 37 is intentionally not represented as a deterministic function. Normative interpretation is not mechanically derivable from the total state of a social system. The notation states instead that the concepts, distinctions, reasons, values, and practices through which ethical judgment becomes possible are generated within historical relational conditions.

The normative interpretation of a relational history can then be written as

$$\llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t}} \quad (38)$$

Equation 38 captures the central semantic claim of the paper. Ethical meaning is neither an intrinsic label attached to $\mathcal{F}$ nor a universal scalar that can be computed from its topology. It is an interpretation generated within a historically evolving relational system.

Because both the relational field and its interpretive system can change,

$$\llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t_1}} \neq \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t_2}} \quad (39)$$

can hold even when the selected formal structure of $\mathcal{F}$ remains unchanged.

This proposition requires an important limitation. The fact that $\mathcal{H}_{x,t}$ emerged historically does not establish the correctness of every judgment generated within it.

The distinction can be stated as

$$\text{historical emergence of normativity} \neq \text{normative justification}. \quad (40)$$

A historically generated interpretive system can reproduce exclusion, domination, epistemic blindness, or conditions that destroy the generative possibilities of some participants. It can fail to recognize relevant experience or become incapable of revising categories whose original conditions have disappeared.

The interpretive system must therefore remain available for reflexive ethical inquiry. Normative judgment can examine both the relational history $\mathcal{F}$ and the hermeneutic conditions through which that history is being interpreted.

This reflexive structure prevents historical situatedness from collapsing into simple relativism. Normative interpretation is historically generated, but historically generated norms remain criticizable. Reasons can be reconsidered, excluded perspectives can become visible, new evidence can alter the field, and transformations in generative conditions can require the revision of earlier judgments.

The resulting architecture can be summarized as

$$\mathcal{F} \hookrightarrow \mathcal{G}_{x,t} \rightsquigarrow \mathcal{H}_{x,t} \rightsquigarrow \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t}}. \quad (41)$$

Equation 41 does not represent an ethical algorithm. It identifies four analytically distinct elements: the relational history, its wider generative-relational embedding, the historically generated interpretive system, and the revisable normative judgment produced through that system.

The next section adds the political-economic layer in greater detail. It examines accumulation, appropriation, enclosure, dependency, extraction, concentration, and recursive advantage as descriptions of transformations within the relational field. Their ethical meaning remains governed by the interpretive architecture established here.

7 Political Economy of Knowledge-Capital Expansion

The preceding section established that relational syntax does not determine a unique normative interpretation. A further analytical layer is therefore required between formal description and ethical judgment. Political economy provides such a layer by identifying transformations in productive capacity, access, control, dependency, appropriation, and institutional position.

The purpose of the present section is diagnostic rather than condemnatory. Terms such as accumulation, concentration, enclosure, extraction, and capture identify different ways in which knowledge-capital expansion can alter a relational field. Some of these concepts carry substantial normative associations in established political-economic traditions. The analysis nevertheless attempts to reconstruct the underlying relational transformation before assigning an ethical conclusion.

This separation is especially important in public knowledge. Accumulation can support learning and institutional capacity. Concentration can facilitate coordination. Restriction can protect vulnerable actors. Commercialization can finance further production. The same processes can also contribute to dependency, exclusion, rent extraction, and the reduction of alternative generative paths. Political-economic interpretation therefore identifies what kind of transformation has occurred and how it operates within the field, while normative evaluation remains dependent upon the generative-relational conditions developed in later sections.

7.1 Knowledge-Capital Accumulation

Knowledge-capital accumulation occurs when an actor's existing epistemic resources contribute to an increase in its capacity for subsequent knowledge production. The accumulated resources can include conceptual understanding, technical competence, organized corpora, models, research infrastructure, institutional memory, recognition, or access to complementary expertise.

The process can be represented at a minimal level as a change in an actor's knowledge-capital condition:

$$K_a(t+1) > K_a(t), \quad (42)$$

where $K_a(t)$ denotes an analytically selected representation of actor a 's knowledge-related productive capacity.

Equation 42 should not be interpreted as requiring a universal scalar measurement of knowledge capital. The relation can instead represent an empirically meaningful increase in capacity along one or more dimensions. Its purpose is to express the direction of change rather than to define a complete metric.

Accumulation becomes politically consequential when increased epistemic capacity alters the actor's position within the surrounding relational field. Knowledge can be converted into reputation, funding, infrastructure, standard-setting capacity, market position, computational capacity, or control over channels through which subsequent knowledge circulates. The relevant process is therefore not merely

$$K_a \uparrow,$$

but the conversion of that increase into changes elsewhere in the relational configuration.

A more informative schematic sequence is

$$K_a \uparrow \rightsquigarrow C_a \uparrow \rightsquigarrow P_a \uparrow, \quad (43)$$

where C_a denotes capacities consequential for the surrounding field and P_a denotes the actor's relational position.

The arrows in Equation 43 are not necessary or deterministic. Many increases in knowledge produce no substantial increase in control or institutional position. The political-economic inquiry concerns the conditions under which such conversion occurs.

This relational emphasis distinguishes knowledge-capital accumulation from a moral characterization of knowledgeable actors. An individual researcher can accumulate considerable knowledge while remaining one participant among many. A platform can accumulate similar or even less substantive knowledge while acquiring control over infrastructure essential to thousands of other actors. The ethical and political-economic consequences depend upon the conversion of capacity into relations.

7.2 Appropriation

Appropriation concerns the incorporation of resources produced within one relational field into another actor's productive organization or control. Public knowledge makes appropriation especially complex because reuse is often one of the purposes of making knowledge public.

The existence of appropriation therefore does not itself indicate a wrong. Reading, learning, citation, translation, implementation, and recombination all involve forms of incorporation. Commons-based production depends upon the ability of later participants to use prior contributions [2, 9].

Political-economic significance arises from the conditions of incorporation. Relevant distinctions include whether the resource remains available to others, whether provenance remains visible, whether downstream control becomes exclusive, whether the appropriating actor contributes additional generative capacity to the field, and whether the resulting structure alters the possibilities of those whose resources supported the process.

Let R denote a public knowledge resource and a an actor incorporating that resource into a later productive structure S_a . A minimal appropriation relation can be represented as

$$R \longrightarrow S_a. \quad (44)$$

The political-economic question is incomplete until the downstream relations of S_a are examined. Several possibilities can follow:

$$R \longrightarrow S_a \longrightarrow R', \quad (45)$$

where new outputs return to a broadly accessible field, or

$$R \longrightarrow S_a \longrightarrow X_a, \quad (46)$$

where the resulting productive structure or output becomes substantially exclusive.

Neither configuration supplies a complete ethical conclusion. The distinction identifies different relational consequences of incorporation.

Appropriation therefore becomes especially significant when public inputs are converted into assets or infrastructures governed through access conditions substantially different from those applying to the original resources. Recent work on the assetization of academic content illustrates how scholarly materials can enter databases, platforms, and generative-AI infrastructures whose legal and economic organization differs substantially from the institutional conditions under which the source materials were produced [11].

7.3 Control Concentration

Knowledge-capital expansion can increase an actor's control over conditions that affect the generativity of others. Control can concern access, distribution, visibility, evaluation, technical standards, computational resources, identity infrastructure, licensing, or other relational conditions.

Let $X_a(t)$ denote the set of analytically relevant control relations exercised by actor a at time t . Control concentration can occur when

$$X_a(t) \subset X_a(t+1), \quad (47)$$

especially when the added control relations concern functions previously distributed among several actors.

A stronger structural transformation occurs when several independent paths become mediated through one actor:

$$A_i \longrightarrow R \quad \longrightarrow \quad A_i \longrightarrow P \longrightarrow R. \quad (48)$$

The introduction of P can improve coordination, reliability, search, safety, or accessibility. It can also increase the field's dependence upon the conditions imposed by P .

Control concentration is therefore analytically distinct from domination. The former describes a distribution of decision capacity. The latter requires a thicker interpretation involving constraint, dependency, contestability, alternatives, and the effects of the relation upon affected actors.

This distinction also prevents decentralization from becoming an automatic ethical ideal. A highly fragmented infrastructure can impose substantial coordination costs, reduce reliability, or undermine safety. The political-economic concern is how concentrated control operates within the field and whether alternative generative paths remain available.

7.4 Enclosure

Enclosure refers to a transformation in which access to, use of, or productive relations with a previously shared resource become more dependent upon exclusive or conditional control. In information and knowledge contexts, enclosure has been used to describe legal and institutional processes through which resources in or near the public domain become subject to stronger forms of exclusion [5].

The relational form of enclosure can be represented as a transition from relatively direct access

$$A_i \longrightarrow K_{\text{public}} \quad (49)$$

toward mediated or conditional access

$$A_i \longrightarrow P \longrightarrow K, \quad (50)$$

where P controls a condition necessary for continued access or use.

Enclosure need not require complete exclusion. It can occur through licensing conditions, technical interfaces, contractual restrictions, paywalls, proprietary formats, identity requirements, restricted computational access, or other mechanisms that reshape the practical possibilities of reuse.

The historical dimension is essential. A resource that was proprietary from its creation and a resource that moved from broad public accessibility into a restricted downstream structure can have similar present access conditions while exhibiting different relational histories.

The concept of re-enclosure is particularly useful for public knowledge. It describes a process in which resources generated or maintained under broadly accessible conditions contribute to a later structure whose productive benefits become increasingly governed through exclusive control.

A schematic sequence is

$$K_{\text{public}} \longrightarrow S_{\text{private}} \longrightarrow D_{\text{public} \rightarrow \text{private}}, \quad (51)$$

where the final term denotes a dependency of the public field upon a privately controlled downstream structure.

The ethical significance of such a transition cannot be inferred merely from the word *enclosure*. The downstream infrastructure can create important new value, require substantial investment, or provide capacities unavailable in the original commons. The normative question concerns how the resulting control relates to the generative conditions of the wider field.

7.5 Dispossession

Dispossession differs from enclosure by emphasizing loss of an actor's prior capacity, claim, or practical relation to a productive condition.

A simplified transformation can be represented as

$$a \xrightarrow{\text{access/control}} R \quad (52)$$

at t_1 , followed by

$$a \nrightarrow R \quad (53)$$

at t_2 , when a previously meaningful relation has been removed or rendered practically unusable.

In knowledge systems, dispossession need not involve physical deprivation. An actor can retain nominal access while losing effective control over the conditions needed to use a resource. A community can retain copies of data while losing the computational infrastructure required to process them. An author can retain nominal rights while losing practical visibility or distribution. An institution can retain formal participation while becoming dependent upon technical standards controlled elsewhere.

The political-economic object is therefore effective generative capacity rather than formal possession alone.

Dispossession can also concern collective conditions. A community can lose the ability to govern knowledge practices that previously depended upon locally controlled infrastructure. A public institution can outsource a critical knowledge function and later discover that reconstructing an alternative has become prohibitively costly.

The concept should nevertheless be used carefully. Not every change in access constitutes dispossession. The term is most useful when a previously operative generative relation is materially weakened or removed in a manner that alters the actor's capacity for continued participation.

7.6 Dependency Formation

Dependency formation occurs when one actor's continued generative activity becomes increasingly conditional upon a relation controlled by another actor.

Let a depend upon a set of generative paths

$$\mathcal{P}_a = \{p_1, p_2, \dots, p_n\}. \quad (54)$$

If several independent paths remain available, failure or withdrawal of one relation may have limited consequences. Dependency intensifies when the number of viable alternatives declines or when their substitution costs become prohibitive.

A simplified transition is

$$|\mathcal{P}_a(t+1)| < |\mathcal{P}_a(t)|. \quad (55)$$

Equation 55 is only a structural indicator. The number of paths does not by itself measure their quality, feasibility, or independence. One robust open alternative can be more meaningful than several nominal but unusable alternatives.

Dependency is especially relevant to digital knowledge infrastructure. Repositories, search systems, scholarly databases, model providers, authentication systems, cloud infrastructure, and standards can become deeply embedded in downstream practices. Their value can increase precisely because many actors coordinate around them.

The political-economic problem appears when the same coordination that creates value also raises the cost of exit. A service can move from optional convenience to infrastructural necessity without a discrete moment at which dependency is intentionally created.

Dependency formation therefore often has a cumulative history. Repeated adoption, network effects, data concentration, institutional integration, and role expansion can gradually transform the topology of the field.

7.7 Rent Formation

Rent formation concerns the capacity to derive continuing benefits from control over a scarce, exclusive, or difficult-to-bypass relational position. In public knowledge, rent can arise from control over access routes, infrastructure, databases, standards, visibility, evaluation systems, or other bottlenecks.

The relevant distinction is between value generated through continuing productive contribution and benefits derived primarily from control over the conditions through which others must pass.

Suppose an intermediary P occupies a relation

$$A_i \longrightarrow P \longrightarrow K. \quad (56)$$

If alternative paths remain costly or unavailable, P can potentially extract continuing returns because access to K has become dependent upon its position.

Rent formation need not imply that the intermediary creates no value. Infrastructure requires maintenance, coordination, security, preservation, and investment. The political-economic question concerns whether returns remain tied to productive contribution or increasingly arise from control over a position whose alternatives have been eliminated or made prohibitively costly.

Knowledge capital can contribute to rent formation when accumulated expertise, data, recognition, or infrastructure enables an actor to establish a bottleneck that later generates returns independently of proportional continuing contribution.

This possibility is particularly important in platform economies, where control over interfaces and network access can become as consequential as ownership of the underlying informational resources [23].

7.8 Extraction

Extraction describes a relational flow in which resources, value, knowledge, data, labour, attention, or other generative inputs move from one part of a system toward another under conditions that can reproduce substantial asymmetry.

In knowledge systems, extraction can involve public research, user-generated content, scholarly labour, community data, cultural resources, or accumulated public infrastructures entering downstream commercial or institutional processes.

A generic extractive structure can be represented as

$$\mathcal{R}_C \longrightarrow A \longrightarrow \mathcal{B}_A, \quad (57)$$

where $\mathcal{R}_C$ denotes resources generated within a commons or community and $\mathcal{B}_A$ denotes benefits concentrated around actor A .

This structure is insufficient to establish exploitation. Public knowledge is often intentionally made available for others to use, including commercially. The political-economic question concerns the wider relational history: whether benefits circulate back into the field, whether contributors remain capable

of participation, whether the downstream structure changes access conditions, and whether the process generates dependencies that alter future bargaining or governance positions.

Extraction therefore becomes more consequential when it participates in a closed recursive cycle:

$$\text{public inputs} \rightarrow \text{private capacity} \rightarrow \text{infrastructural control} \rightarrow \text{further public inputs.} \quad (58)$$

The issue is then no longer a single transfer. It is a relational mechanism through which resources from one field contribute to the increasing capacity of another actor to structure future transfers.

7.9 Externalization

Knowledge-capital expansion can generate costs that are not borne by the actor receiving the principal benefits. Externalization occurs when some of the burdens created by a process are displaced onto other actors, communities, institutions, or future states of the relational system.

Relevant burdens can include verification costs, misinformation correction, privacy risks, environmental costs of computation, archival burdens, institutional dependency, cultural harms, labour displacement, or the costs of maintaining infrastructures upon which private services depend.

A simplified relation can be represented as

$$B_A \not\geq C_{\text{total}}, \quad (59)$$

where actor A receives a substantial share of the benefit while some portion of the total cost C_{total} is borne elsewhere.

Equation 59 is schematic. It does not require benefits and costs to be reduced to a common quantitative metric. Externalization can be qualitative, institutionally distributed, delayed, or difficult to measure.

The ethical significance of externalization can be substantial because actors with greater knowledge capital can become increasingly capable of producing effects at scales beyond their own immediate relational environment. The capacity to generate widely distributed consequences can therefore expand faster than the institutional mechanisms through which responsibility is allocated.

7.10 Institutional Capture

Institutional capture occurs when an actor or concentrated group acquires sufficient influence over governance structures that rules increasingly reflect its interests, dependencies, or interpretive framework.

Capture is analytically different from ordinary participation in governance. Institutions frequently depend upon expert actors, infrastructure providers, publishers, funders, or technical communities. Their participation can improve knowledge and coordination.

The political-economic concern arises when an actor's accumulated resources alter the conditions under which governance decisions are made. Relevant resources can include expertise, funding, technical infrastructure, control over data, agenda-setting capacity, or the ability to threaten withdrawal of services upon which the institution depends.

A recursive relation can emerge:

$$K_A \uparrow \rightarrow P_A \uparrow \rightarrow G_A \uparrow \rightarrow K_A \uparrow, \quad (60)$$

where P_A denotes relational position and G_A denotes influence over governance conditions.

Institutional capture is therefore important to knowledge-capital expansion because accumulated epistemic resources can become institutional resources. An actor capable of defining standards, evaluation criteria, technical interfaces, or permissible forms of participation can influence the field in ways that support further accumulation.

The existence of influence does not establish capture. The concept becomes appropriate when governance loses meaningful independence, contestability, or capacity to incorporate perspectives outside the influential actor's relational position.

7.11 Recursive Accumulation

The political-economic significance of knowledge capital becomes clearest when accumulation changes the conditions of subsequent accumulation.

Let the actor's knowledge-capital state be $K_a(t)$, and let $\mathcal{G}_t$ represent the surrounding relational field. A recursive process can be expressed schematically as

$$K_a(t) \rightarrow P_a(t) \rightarrow \mathcal{G}_{t+1} \rightarrow K_a(t+1), \quad (61)$$

where accumulated capacity changes the actor's relational position, that position alters the surrounding field, and the altered field creates new conditions for further accumulation.

This formulation distinguishes recursive accumulation from simple repeated learning. The important transformation is endogenous modification of the field from which future accumulation occurs.

For example, accumulated knowledge can enable a platform to build better infrastructure. Better infrastructure attracts more users and resources. Greater participation produces additional data, recognition, and dependency. These changes further improve the platform's capacity for accumulation.

The cycle can be generatively productive for many participants. It can also reduce the number of independent pathways through which similar capacities can develop.

Recursive accumulation therefore introduces a feedback problem:

$$\text{capacity} \rightarrow \text{relational advantage} \rightarrow \text{field transformation} \rightarrow \text{further capacity}. \quad (62)$$

The ethical significance of this cycle depends upon the resulting generative conditions, the availability of alternatives, the distribution of benefits and burdens, and the capacity of the field to revise relations that become harmful.

7.12 Re-Enclosure

Re-enclosure describes a particular recursive configuration in which public or commons-based knowledge contributes to the creation of a downstream productive capacity that subsequently restricts, mediates, or conditions the generative possibilities of the field from which its inputs were drawn.

A minimal sequence is

$$K_{\text{public}} \rightarrow C_A \rightarrow P_A \rightarrow X_A \rightarrow D_{\text{commons}}, \quad (63)$$

where public knowledge contributes to actor A 's productive capacity C_A , that capacity improves its relational position P_A , the improved position enables greater control X_A , and the wider commons becomes increasingly dependent upon the resulting infrastructure.

The concept does not require the original public knowledge itself to disappear. The source materials can remain publicly accessible while the most practically important downstream capacities become concentrated elsewhere. Re-enclosure can therefore concern control over generative conditions rather than literal removal of the original resource from the public domain.

This distinction is particularly relevant to contemporary AI-mediated knowledge production. Publicly accessible scholarly, cultural, technical, and user-generated materials can contribute to model capabilities that are later accessible only through privately governed infrastructures. Recent political-economic research on AI and academic-content assetization illustrates this possibility [23, 11].

Re-enclosure also need not be complete. A public field can retain alternative paths while becoming increasingly dependent upon a dominant intermediary. The relevant political-economic question concerns whether public generative resources contribute to a transformation that progressively reduces the field's practical autonomy or diversity of productive pathways.

7.13 Political-Economic Interpretation and Ethical Openness

The concepts developed in this section identify different relational transformations. They should not be collapsed into a single category of political-economic harm.

Accumulation concerns increasing productive capacity. Appropriation concerns incorporation of resources into another productive organization. Control concentration concerns the distribution of decision capacity. Enclosure concerns changing access relations. Dispossession concerns loss of previously operative generative relations. Dependency concerns reliance upon controlled conditions. Rent formation concerns benefits derived from bottleneck positions. Extraction concerns directional resource flows. Externalization concerns displaced burdens. Capture concerns alteration of governance relations. Recursive accumulation concerns feedback through which accumulated capacity modifies the conditions of further accumulation. Re-enclosure concerns the conversion of public generative inputs into downstream structures that increasingly mediate the commons itself.

These transformations can overlap within the same relational history without being analytically identical. A process can involve accumulation without enclosure, concentration without dispossession, dependency without extraction, or commercialization without capture.

The distinction is necessary because ethical interpretation depends upon the specific structure of the case. The political-economic vocabulary provides a means of reconstructing that structure before normative judgment begins.

The resulting analytical sequence can be represented as

$$\mathcal{F} \longrightarrow \mathcal{P}(\mathcal{F}) \rightsquigarrow \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t}}, \quad (64)$$

where $\mathcal{P}(\mathcal{F})$ denotes a political-economic interpretation of relational history $\mathcal{F}$.

The map

$$\mathcal{F} \longrightarrow \mathcal{P}(\mathcal{F})$$

identifies transformations such as dependency, enclosure, accumulation, or capture. The subsequent relation to normative interpretation remains non-deterministic.

A diagnosis of enclosure therefore does not mechanically imply an ethical verdict. A finding of concentration does not establish domination. A finding of accumulation does not establish exploitation. Conversely, the absence of a familiar political-economic label does not establish ethical acceptability.

The political-economic layer serves instead as a structured intermediary between relational syntax and Generative Relational Ethics. The next section returns these concepts to the 2-complex representation and examines how access, control, dependency, path reduction, gatekeeper formation, role transformation, knowledge-capital concentration, and recursive advantage appear as transformations of relational histories.

8 Relational Transformations in Public Knowledge

Section 7 identified a set of political-economic transformations relevant to knowledge-capital expansion. The present section returns these concepts to the formal representation developed in Sections 4 and 5. Its objective is to specify how changes in access, control, dependency, generative pathways, roles, and knowledge capital can appear within relational graph configurations and the 2-complex histories connecting them.

The analysis remains descriptive and interpretive. A transformation can be represented formally and classified politically without receiving an ethical verdict. The same structural change can operate differently when embedded in different generative-relational systems.

For two successive relational configurations,

$$\Gamma_t = (V_t, E_t, \tau_V, \tau_E, \lambda_t) \quad (65)$$

and

$$\Gamma_{t+1} = (V_{t+1}, E_{t+1}, \tau_V, \tau_E, \lambda_{t+1}), \quad (66)$$

a relational transformation can involve changes in vertices, edges, types, labels, or the paths generated by their combination. The 2-complex $\mathcal{F} : \Gamma_t \rightarrow \Gamma_{t+1}$ records the history through which those changes occurred.

8.1 Access Transformations

Access is represented through typed relations connecting actors or role-instances to knowledge resources, infrastructures, or intermediaries. An access transformation occurs when the existence, conditions, direction, or mediation of such a relation changes.

A simple expansion of access can be written as

$$e_{iK}^A \notin E_t, \quad e_{iK}^A \in E_{t+1}, \quad (67)$$

where e_{iK}^A denotes an access relation between actor-role instance i and knowledge resource K .

Restriction can occur without complete removal of the relation. Instead, the relation label can change:

$$\lambda_t(e_{iK}^A) = \text{open} \quad \longrightarrow \quad \lambda_{t+1}(e_{iK}^A) = \text{conditional}. \quad (68)$$

Conditional access can include authentication, payment, licensing, institutional membership, technical restrictions, geographic limitations, rate limits, or other conditions.

Access can also become mediated. A direct relation

$$i \longrightarrow K \quad (69)$$

can be replaced by

$$i \longrightarrow P \longrightarrow K, \quad (70)$$

where P becomes an intermediary.

Mediation does not necessarily reduce effective access. A repository, search service, library, index, or platform can make knowledge substantially easier to reach. The transformation becomes politically important when continued access increasingly depends upon conditions controlled by the intermediary.

Access should therefore be represented through more than binary presence or absence. Relevant labels can include accessibility, cost, substitutability, scope of permissible use, technical requirements, temporal duration, and institutional conditions.

A history can also contain several access regimes. A resource can begin under restricted access, become publicly available, enter a commercially mediated distribution system, and later return to broad public availability. The 2-complex preserves these transitions rather than treating the final access state as the complete history.

8.2 Control Transformations

Control concerns an actor's capacity to alter conditions governing resources, relations, infrastructures, or other actors' participation. A control transformation occurs when such capacities are created, removed, transferred, expanded, or consolidated.

Suppose actor a initially controls a set of relations

$$X_a(t) = \{x_1, \dots, x_m\}. \quad (71)$$

A change to

$$X_a(t+1) = X_a(t) \cup \{x_{m+1}, \dots, x_{m+k}\} \quad (72)$$

represents expansion of the actor's control domain.

The significance of such expansion depends upon the functions represented by the added relations. Control over metadata formatting differs from control over admission to a repository. Control over one optional distribution channel differs from control over a channel through which most participants must pass.

Control concentration can also occur through consolidation. Suppose control over search, distribution, access governance, and evaluation is initially distributed across actors $P_1, \dots, P_n$. A later relational state can assign several of these functions to the same underlying actor P .

The graph representation records this through changes in actor-role instantiation and control edges. The 2-complex records the events through which consolidation occurred, including acquisition, institutional reorganization, platform expansion, contractual change, or gradual adoption.

Control should therefore be analyzed functionally. The important question is which generative conditions an actor can modify and how consequential those conditions are for other participants.

8.3 Dependency Transformations

Dependency concerns the extent to which an actor's continued generative activity relies upon relations maintained or controlled elsewhere. Section 7.6 introduced the set of viable generative paths $\mathcal{P}_a(t)$. A dependency transformation occurs when the composition or substitutability of that set changes.

A simple increase in dependency can be represented by a reduction in viable alternatives:

$$\mathcal{P}_a(t+1) \subset \mathcal{P}_a(t). \quad (73)$$

This expression is more informative than cardinality alone because the remaining paths themselves can differ qualitatively.

Dependency can also increase when a path remains formally available but becomes increasingly difficult to use. Let $c(p, t)$ denote the practical cost or difficulty associated with path p . Then

$$c(p, t+1) > c(p, t) \quad (74)$$

can indicate growing dependency upon an alternative path whose effective substitution cost has increased.

The quantity c need not be monetary. It can represent technical, institutional, legal, cognitive, linguistic, temporal, or organizational difficulty.

A field can therefore become dependent without any access edge disappearing. An alternative repository can remain online while becoming technologically incompatible. A competing platform can remain available while lacking the data, users, standards, or institutional recognition required for practical substitution.

The relational history is essential because dependency often emerges gradually. Repeated adoption, accumulated data, standardization, institutional integration, and investment can progressively increase the cost of changing paths.

Dependency can also decrease. Interoperability, open standards, public infrastructure, portability, mirrors, or newly developed local capacities can create additional viable paths. The representation therefore supports both dependency formation and dependency dissolution.

8.4 Generative Path Reduction

Dependency concerns an actor's reliance upon particular relations. Generative path reduction concerns the wider loss of possible routes through which future knowledge production can occur.

Let $\Pi_t(u, v)$ denote a selected set of viable relational paths connecting two relevant parts of the knowledge field. A reduction occurs when

$$\Pi_{t+1}(u, v) \subset \Pi_t(u, v). \quad (75)$$

The removed paths can represent alternative repositories, methods, publication routes, technical infrastructures, interpretive traditions, funding sources, or other relational possibilities.

Path reduction is broader than formal network connectivity. Two vertices can remain connected while the diversity of meaningful routes between them declines. Several technically distinct paths can also depend upon the same underlying provider and therefore offer little genuine relational independence.

For this reason, generative path diversity should be interpreted in relation to functional independence. A useful qualitative distinction is between

$$\Pi_t^{\text{nominal}} \quad (76)$$

and

$$\Pi_t^{\text{viable}}, \quad (77)$$

where the latter contains paths that remain practically usable under the conditions relevant to the actor or community.

Generative path reduction can occur through enclosure, standard consolidation, disappearance of local expertise, platform dependence, institutional closure, loss of linguistic diversity, or other transformations that reduce the range of possible future trajectories.

The concept is important because an ethical problem can arise before complete exclusion occurs. A field whose available pathways become progressively narrower can remain formally open while becoming less generatively plural.

8.5 Gatekeeper Formation

A gatekeeper emerges when an actor occupies a position through which a substantial set of relevant relational paths must pass and possesses some capacity to alter the conditions of passage.

Suppose a set of actors $A_1, \dots, A_n$ initially possesses multiple paths to resource or function K . A later state can contain a dominant intermediary P :

$$A_i \longrightarrow P \longrightarrow K, \quad i = 1, \dots, n. \quad (78)$$

Gatekeeper formation involves more than high graph centrality. An actor can occupy a structurally central position while possessing little discretionary control. Conversely, an actor with moderate topological centrality can possess decisive authority over a particularly important function.

A gatekeeping relation therefore combines at least three components:

$$\text{intermediation} + \text{dependency} + \text{decision capacity}. \quad (79)$$

The components need not be numerical or equally weighted. The expression identifies the relational dimensions that distinguish gatekeeping from simple centrality.

Gatekeeper formation can be temporary or persistent. A coordinating institution can occupy a central role during an emergency and later relinquish it. A platform can gradually become indispensable and maintain its position through network effects, data concentration, standards, or contractual relations.

The political-economic significance therefore depends upon the history through which the position was acquired, the alternatives that remain, and the procedures through which its control can be contested or revised.

8.6 Role Transformation

Role transformation was introduced conceptually in Section 3.6 and represented through actor-role trajectories in Section 5.3. The present subsection emphasizes its political-economic significance.

Let actor a occupy role r_1 before event q and role r_2 after the event:

$$(a, r_1) \xrightarrow{q} (a, r_2). \quad (80)$$

The transformation can also involve role accumulation:

$$(a, r_1) \longrightarrow \{(a, r_1), (a, r_2)\}. \quad (81)$$

Role accumulation is important when control obtained through one role becomes operative in another. A distributor that becomes an access governor can use information acquired through distribution to shape future access. A repository operator that becomes a commercializer can use infrastructural dependence in downstream contracting. A platform that becomes an evaluator can influence recognition while also controlling distribution.

The transformation

$$\text{participant} \rightarrow \text{aggregator} \rightarrow \text{platform} \rightarrow \text{gatekeeper} \quad (82)$$

therefore represents more than an increase in organizational size. Each transition can alter the actor's relation to the generative conditions of other participants.

Role transformation can also proceed in the opposite direction. A gatekeeping function can be separated from a platform, delegated to an independent institution, distributed across several actors, or constrained by interoperability requirements. Political-economic analysis should therefore represent role decomposition together with role accumulation.

8.7 Knowledge-Capital Concentration

Knowledge-capital concentration concerns the distribution of epistemic and productive capacities across actors in the relational field.

Let

$$\mathcal{K}_t = \{K_1(t), K_2(t), \dots, K_n(t)\} \quad (83)$$

denote the heterogeneous knowledge-capital conditions of relevant actors.

The concept of concentration does not require these values to be reduced to a single comparable scalar. In many cases, knowledge capital is multidimensional. One actor can possess greater computational capacity while another possesses deeper contextual knowledge or institutional legitimacy.

Political-economic concentration becomes especially important when different forms of knowledge capital become bundled within the same actor and are convertible into additional relational advantages.

A platform can simultaneously accumulate:

$$(K_{\text{data}}, K_{\text{model}}, K_{\text{infrastructure}}, K_{\text{users}}, K_{\text{recognition}}). \quad (84)$$

The combination can generate capacities that exceed the effects of any one component considered separately.

Knowledge-capital concentration also interacts with role concentration. An actor possessing extensive knowledge resources can remain politically peripheral if it lacks control over relevant infrastructures. Another actor can convert concentrated knowledge capital into standard-setting, evaluation, distribution, or governance capacities.

The relational model therefore treats concentration as a property of the distribution and conversion of capacities rather than as a simple ranking of how much knowledge each actor possesses.

8.8 Public-to-Private Relational Transitions

A central process in knowledge political economy concerns the movement of publicly generated resources into downstream structures governed through different access and control relations.

The transition can be represented schematically as

$$K_{\text{public}} \longrightarrow S_A^{\text{controlled}}, \quad (85)$$

where public knowledge contributes to a productive structure controlled by actor A .

This transition does not imply that the original knowledge ceases to be public. The public resource and the downstream controlled structure can coexist.

The politically relevant transformation concerns the relation between them. A public dataset can remain accessible while a highly valuable model trained upon it becomes proprietary. Open scholarly literature can remain available while a private platform becomes the principal infrastructure through which that literature is searched, synthesized, or evaluated.

A further transformation occurs when the downstream system returns as a condition of participation in the original field:

$$K_{\text{public}} \longrightarrow S_A \longrightarrow D_{\text{public},A}. \quad (86)$$

The resulting configuration contains a feedback relation. Public resources contribute to the private system, while public actors become increasingly dependent upon the capacity created from those resources.

Recent analyses of AI capitalism and academic-content assetization provide examples of how public or academic resources can enter privately controlled infrastructures and asset structures [23, 11].

The relational representation permits the analyst to distinguish several possibilities. A downstream private system can return substantial generative capacity to the public field. It can coexist with viable alternatives. It can become a dominant intermediary. It can later open its infrastructure. It can also progressively restrict access. These histories should remain analytically distinct.

8.9 Recursive Advantage Amplification

The transformations examined above can combine into feedback cycles. An initial advantage can improve an actor's capacity to acquire further resources, which can alter its position and increase the probability of subsequent advantage.

Let the state of actor a include knowledge capital K_a , relational position P_a , and control capacity X_a . A recursive trajectory can be represented schematically as

$$K_a(t) \rightarrow P_a(t) \rightarrow X_a(t) \rightarrow \mathcal{G}_{t+1} \rightarrow K_a(t+1). \quad (87)$$

The important feature of Equation 87 is that the actor's advantage modifies the field in which its later advantage is generated.

A platform with greater knowledge capital can provide a more useful service. Greater usefulness can attract more users. More users can generate more data, recognition, and institutional integration. Those resources can improve the platform's knowledge capital and increase the difficulty of substitution.

The feedback can therefore include several coupled processes:

$$\begin{aligned} K_a \uparrow &\rightarrow \text{service capacity} \uparrow, \\ \text{service capacity} \uparrow &\rightarrow \text{participation} \uparrow, \\ \text{participation} \uparrow &\rightarrow \text{data and recognition} \uparrow, \\ \text{data and recognition} \uparrow &\rightarrow K_a \uparrow. \end{aligned} \quad (88)$$

The same cycle can change dependency and path diversity:

$$K_a \uparrow \rightarrow P_a \uparrow \rightarrow \left| \Pi_{\text{others}}^{\text{viable}} \right| \downarrow. \quad (89)$$

Equation 89 represents one possible trajectory, not a universal law of knowledge-capital expansion. Accumulation can also create new pathways for other participants.

The 2-complex representation is especially useful here because recursive advantage cannot be located in a single edge or event. It is a property of an extended relational history in which outputs from earlier stages modify the conditions governing later stages.

8.10 Transformation Signatures

The preceding transformations can be summarized through a relational transformation signature. For a history

$$\mathcal{F} : \Gamma_t \longrightarrow \Gamma_{t+1}, \quad (90)$$

define provisionally

$$\Delta_{\mathcal{F}} = (\Delta A, \Delta X, \Delta D, \Delta \Pi, \Delta R, \Delta K, \Delta C), \quad (91)$$

where the components denote changes in access A , control X , dependency D , viable generative paths Π , role structure R , knowledge capital K , and concentration C .

The components of Equation 91 need not be numerical. A transformation signature can contain qualitative, categorical, topological, interval-valued, or empirically measured changes.

Its purpose is to summarize which dimensions of the relational field changed during the history. It does not combine those changes into a common score.

Two histories can therefore have similar transformation signatures while receiving different political-economic or normative interpretations. For example, both histories can exhibit

$$\Delta A < 0, \quad \Delta X > 0, \quad \Delta D > 0, \quad (92)$$

in a qualitative sense, while one concerns temporary emergency coordination and another concerns long-term commercial enclosure.

The transformation signature therefore remains part of relational syntax. Its interpretation depends upon the history and the generative-relational system in which that history is embedded.

8.11 Relational Transformation and Normative Transition

The formal and political-economic analyses developed in Sections 4–8 now permit three levels to be distinguished.

The first is the relational history:

$$\mathcal{F} : \Gamma_t \longrightarrow \Gamma_{t+1}. \quad (93)$$

The second is its transformation signature and political-economic interpretation:

$$\mathcal{F} \longrightarrow \Delta_{\mathcal{F}} \longrightarrow \mathcal{P}(\mathcal{F}). \quad (94)$$

The third is normative interpretation:

$$\mathcal{P}(\mathcal{F}) \rightsquigarrow \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t}}. \quad (95)$$

The final transition remains interpretive. A reduction in access can be protective, exclusionary, precautionary, extractive, or otherwise normatively significant according to its embedding. Greater concentration can support coordination under one institutional arrangement and rigidify dependency under

another. Role accumulation can improve integration or create conflicts of interest. Recursive advantage can produce public infrastructure or progressively narrow the field's generative alternatives.

The formal analysis therefore makes the object of ethical inquiry more precise while preserving the central methodological boundary of the paper. Structural transformation is neither ethically invisible nor ethically self-interpreting.

The next section develops the normative framework required for this final interpretive stage. It introduces Generative Relational Ethics through generative-relational systems, historically generated hermeneutic conditions, relational responsibility, re-cognizability, epistemic humility, and revisability.

9 Generative Relational Normativity

The preceding sections developed the relational and political-economic object of ethical inquiry. They identified actors, roles, dependencies, access relations, control transformations, knowledge-capital accumulation, enclosure, and recursive advantage without assigning these structures an invariant moral value. The present section develops the normative framework through which such histories can be interpreted.

Generative Relational Ethics begins from the proposition that ethical meaning emerges within historically evolving relational systems. Subjects, responsibilities, vulnerabilities, expectations, and values are formed within relations rather than appearing as fully constituted elements outside them. The ethical significance of an action therefore depends upon the generative conditions through which actors and their possibilities have emerged and through which they can continue to develop.

This orientation does not identify generativity with a universal quantity to be maximized. Different forms of generation can conflict. An increase in one actor's capacities can diminish another actor's possibilities. Restriction can sometimes preserve conditions needed for future generation, while expansion can sometimes destroy them. Generativity consequently functions as an object of relational inquiry rather than as a scalar objective.

The normative task is to interpret how a relational history affects the conditions through which heterogeneous actors can continue to recognize, revise, and develop their possible trajectories within an evolving field.

9.1 Generative-Relational Systems

Let $\mathcal{G}_{x,t}$ denote a generative-relational system situated at a selected spatiotemporal position x, t . The notation does not identify a closed social totality. It marks the wider relational field considered relevant to a particular inquiry.

A generative-relational system can include material, institutional, linguistic, cultural, technological, legal, ecological, interpersonal, epistemic, and political-economic relations. These relations condition what actors can perceive, understand, produce, communicate, contest, preserve, or become.

The term *generative* refers to the capacity of relations to participate in the formation of subsequent states. A relation can modify knowledge, identity, expectations, available paths, dependencies, institutional structures, or other conditions from which later relations emerge. The generative significance of a relation therefore lies in its participation in ongoing transformation.

This conception does not require every relation to generate desirable outcomes. A relation can generate dependency, exclusion, domination, epistemic closure, or institutional rigidity. Generativity describes a dynamical property before it becomes an ethical evaluation.

Likewise, an actor's generative capacity should not be understood as an isolated possession. It depends upon relations with knowledge, other actors, institutions, infrastructures, cultural resources, languages, environments, and historical conditions. The generativity of actor a can therefore be represented schematically as

$$G_a(t) = G(a, \mathcal{R}_a(t), \mathcal{G}_{x,t}), \quad (96)$$

where $\mathcal{R}_a(t)$ denotes the relations through which actor a participates in the relevant system.

Equation 96 is conceptual rather than computational. It states that generativity is relationally conditioned. It does not define a measurable utility function.

The ethical inquiry therefore concerns transformations of generative conditions rather than the maximization of G_a . A relation can enlarge one dimension of generativity while narrowing another. Increased technical capacity can reduce interpretive plurality. Greater openness can reduce privacy or safety. Increased coordination can reduce institutional independence. Ethical interpretation must retain these heterogeneous effects.

9.2 Historical Formation of Normative Interpretation

Normative interpretation emerges within historically formed relational systems. Concepts such as fairness, responsibility, privacy, exploitation, care, autonomy, publicness, authorship, and legitimate restriction do not operate independently of the histories through which they acquired meaning.

The relevant relation can be written as

$$\mathcal{G}_{x,t} \rightsquigarrow \mathcal{H}_{x,t}, \quad (97)$$

where $\mathcal{H}_{x,t}$ denotes the hermeneutic-normative system through which relational events become ethically intelligible.

The arrow in Equation 97 does not denote deterministic production. Historical systems do not generate one inevitable ethical interpretation. Multiple and conflicting normative traditions can emerge within the same society, institution, or community. Actors can also participate simultaneously in several interpretive systems.

The claim is instead that normative interpretation has conditions of formation. A society with a particular history of surveillance can interpret informational openness differently from one in which the central historical problem has been state secrecy. A community whose knowledge has repeatedly been appropriated without meaningful participation can interpret unrestricted reuse differently from a community whose principal difficulty has been systematic exclusion from scientific resources.

Historical formation therefore changes the field of reasons.

The same formal act can activate different historical relations, expectations, and vulnerabilities. Ethical inquiry requires attention to those relations because they contribute to what the act means for the affected participants.

Historical explanation remains distinct from normative justification. The fact that a norm emerged under particular historical conditions does not establish that the norm should continue. Historically generated norms can preserve relations whose original justification has disappeared or whose effects have become destructive.

Generative Relational Ethics therefore treats history as a condition of interpretation and as an object of criticism.

9.3 Hermeneutic Systems

The term *hermeneutic system* refers to the historically generated structure through which actors identify ethically relevant features, classify relations, articulate reasons, and interpret the significance of events.

A hermeneutic system can contain concepts, narratives, institutional categories, legal expectations, cultural meanings, habitual distinctions, historical memories, epistemic standards, and practical vocabularies. It is therefore broader than an explicit moral theory.

The normative interpretation of relational history $\mathcal{F}$ is written as

$$\llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t}}. \quad (98)$$

This notation makes three claims.

First, the object being interpreted is a relational history rather than an isolated act.

Second, interpretation occurs within a historically situated hermeneutic system.

Third, the interpretation can change when the hermeneutic system or the relational field changes.

A hermeneutic system is itself relationally generated and internally plural. Different actors can occupy different positions within it and can recognize different aspects of the same event. A platform operator can interpret a restriction through safety and operational risk. A contributor can interpret the same restriction through autonomy or access. A historically marginalized community can interpret the same infrastructure through prior experiences of appropriation or exclusion.

Generative Relational Ethics does not require these interpretations to remain irreconcilable. It requires that ethical inquiry reconstruct the relations through which they become meaningful before attempting to adjudicate among them.

The hermeneutic system is also reflexive. Its own categories can become objects of criticism. A vocabulary that recognizes only individual property rights can fail to perceive collective generative relations. A vocabulary centered exclusively on openness can fail to recognize protective closure. A framework centered only on safety can make excessive restriction appear self-justifying.

Normative interpretation therefore requires continuing examination of the interpretive tools through which ethical problems become visible.

9.4 Normativity under Relational Evolution

Generative-relational systems evolve. Technologies change, institutions reorganize, actors acquire new roles, dependencies emerge, knowledge expands, risks become visible, and previously unavailable alternatives become possible. Ethical interpretation must consequently remain responsive to relational evolution.

Suppose an interpretation at time t_1 is

$$J_{t_1} = \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t_1}}. \quad (99)$$

After relevant changes in the relational field,

$$\mathcal{G}_{x,t_1} \longrightarrow \mathcal{G}_{x,t_2}, \quad (100)$$

the same formal relation can be interpreted differently:

$$J_{t_2} = \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t_2}}, \quad J_{t_2} \neq J_{t_1}. \quad (101)$$

Normative change need not indicate inconsistency. If relevant relational conditions have changed, continuing to apply the earlier judgment without revision can itself represent a failure of ethical responsiveness.

A restriction imposed because no effective safeguard existed can require reconsideration after reliable safeguards become available. A centralized infrastructure justified by temporary coordination needs can require redistribution of authority after the emergency ends. A previously benign platform can acquire new ethical responsibilities after becoming an indispensable intermediary.

Normativity under relational evolution therefore contains a temporal requirement: reasons must be reconsidered when the relations that gave those reasons their force materially change.

This principle also applies to permissions. An arrangement previously judged acceptable can become problematic after accumulated dependency changes the consequences of withdrawal, pricing, access, or exclusion.

Ethical judgment is therefore historically indexed without becoming arbitrary.

9.5 Cultural and Historical Plurality

Generative-relational systems are heterogeneous across communities, cultures, institutions, and historical periods. The same relational configuration can therefore enter different hermeneutic systems.

Let $\mathcal{H}_A$ and $\mathcal{H}_B$ denote two historically generated interpretive systems. It can be the case that

$$[\mathcal{F}]_{\mathcal{H}_A} \neq [\mathcal{F}]_{\mathcal{H}_B}. \quad (102)$$

This plurality should not be reduced to a claim that different cultures simply possess different immutable values. Cultural systems contain internal variation, disagreement, institutional asymmetry, historical transformation, and relations with other systems.

The relevant unit is therefore not a homogeneous culture but a historically situated relational field.

Normative plurality can arise because actors have experienced different histories of deprivation, extraction, domination, secrecy, exclusion, colonization, technological dependence, or communal protection. These histories alter which risks and relations become ethically salient.

Ethical interpretation must therefore preserve the possibility that one framework does not initially recognize the reasons operative in another.

This requirement contributes to what the present paper later describes as re-cognizability. Ethical inquiry should avoid transformations that make alternative normative worlds impossible to encounter or understand before their claims have been adequately recognized.

Plurality nevertheless does not imply normative immunity. A historically generated system can be criticized for suppressing some of its own participants, denying relevant evidence, destroying alternative generative paths, or rendering itself incapable of revision.

Generative Relational Ethics therefore combines historical plurality with cross-relational criticism.

9.6 Generative Conditions

The ethical object of GREthic is not generativity considered as an abstract quantity. It is the set of conditions through which actors and relational systems can continue to generate viable future possibilities.

Generative conditions can include access to knowledge, physical security, epistemic resources, institutional recognition, privacy, interpretive capacity, cultural continuity, material infrastructure, autonomy, social trust, alternative pathways, and the ability to contest or revise governing relations.

These conditions are heterogeneous. Their importance varies according to the actor and relational field under examination.

A useful conceptual representation is

$$\mathcal{C}_a^G(t) = \{c_1, c_2, \dots, c_n\}, \quad (103)$$

where $\mathcal{C}_a^G(t)$ denotes the set of generatively relevant conditions for actor a at time t .

The set is neither complete nor universal. Different actors can require different conditions, and the same actor's relevant conditions can change through time.

Ethical analysis asks how relational history $\mathcal{F}$ transforms these conditions:

$$\mathcal{C}_a^G(t) \xrightarrow{\mathcal{F}} \mathcal{C}_a^G(t+1). \quad (104)$$

The transformation can enlarge some conditions and reduce others.

For example, a platform can dramatically increase access to knowledge while reducing privacy. A licensing regime can reduce immediate openness while protecting the institutional continuity of a vulnerable knowledge community. An AI system can increase cognitive assistance while contributing to dependency upon privately controlled infrastructure.

No fixed arithmetic determines how such heterogeneous transformations should be combined.

This is why GREthic rejects

$$\max_a \sum_a G_a \quad (105)$$

as a general ethical principle.

Equation 105 is included precisely as a formulation the framework does not adopt. Generative conditions cannot in general be represented as commensurable utilities, and maximizing aggregate capacity can destroy the conditions of particular actors, communities, or future possibilities.

The relevant normative inquiry concerns whether relational development preserves and sustains the conditions required for continued, heterogeneous, and revisable generation.

9.7 Relational Responsibility

Responsibility in Generative Relational Ethics arises from an actor's position within a relational field. It depends upon what the actor can affect, what it can reasonably recognize, which roles it occupies, and how its actions enter the generative conditions of others.

Relational responsibility therefore differs from a model that assigns the same obligation to every participant exposed to the same knowledge.

A platform operator capable of changing an access rule occupies a different position from a user constrained by that rule. A reviewer capable of shaping institutional recognition occupies a different position from an ordinary reader. A funder capable of changing the conditions of an entire research field can bear responsibilities unavailable to a single contributor.

Responsibility can be represented conceptually through the relation

$$\mathcal{R}_a^{\text{resp}} = \mathcal{R}(P_a, C_a, F_a, E_a), \quad (106)$$

where P_a denotes relational position, C_a relevant capacities, F_a foreseeable effects, and E_a epistemically accessible information.

Equation 106 is again non-computational. It identifies dimensions relevant to responsibility rather than defining a formula for assigning blame.

Relational responsibility also changes through role transformation. An actor that becomes an infrastructural gatekeeper acquires responsibilities that did not arise when it was merely one optional participant.

The same applies to knowledge-capital expansion. Increased epistemic capacity can increase the range of consequences an actor can foresee or influence. A greater ability to act can therefore alter the actor's normative position even when its institutional identity remains unchanged.

Responsibility is also reciprocal without being symmetrical. Different actors can bear different responsibilities within the same relation because their capacities and positions differ.

9.8 Re-Cognizability

Re-cognizability concerns the continuing capacity to encounter, recognize, and reinterpret alternative conceptual, cultural, epistemic, or normative worlds after a generative transformation has occurred.

Learning and institutional development are themselves generative processes. They alter the categories through which actors subsequently perceive the world. Such transformation can be beneficial, but it can also become irreversible in ways that make previously intelligible forms of experience unrecognizable.

The ethical concern is especially important in heterogeneous knowledge systems. A dominant technical or institutional framework can increase efficiency while progressively displacing alternative vocabularies, epistemologies, local knowledge practices, or interpretive traditions.

A transformation can therefore enlarge productive capacity while reducing the ability to recognize another possible organization of knowledge.

Let $\mathcal{W}_a(t)$ denote provisionally the set of conceptual or interpretive worlds that actor a remains capable of meaningfully recognizing. Re-cognizability concerns whether

$$\mathcal{W}_a(t+1) \quad (107)$$

remains sufficiently open to the reconstruction or encounter of alternatives that were available, or could reasonably become available, before the transformation.

The framework does not require preservation of every prior belief or interpretive system. Learning necessarily changes understanding, and some claims should be abandoned when evidence no longer supports them.

The ethical concern arises when a generative process closes the conditions of recognition themselves. A participant can become unable to perceive that another conceptual organization is possible, or an institution can make alternative epistemic practices impossible to express within its categories.

Re-cognizability therefore contributes a second-order ethical consideration. GREthic asks not only what a system enables actors to know, but also whether the system preserves their capacity to know differently.

This principle is especially relevant to AI-mediated knowledge systems, standardization, ranking infrastructures, and educational environments in which a dominant representational grammar can become increasingly difficult to perceive from outside.

9.9 Epistemic Humility

Ethical judgment operates under incomplete knowledge. Generative-relational systems can contain delayed effects, nonlinear interactions, hidden dependencies, unrepresented actors, uncertain risks, and transformations whose meaning becomes visible only after the system has evolved.

Epistemic humility is therefore a normative requirement rather than merely a description of limited knowledge.

A decision-maker should recognize that

$$\hat{\mathcal{G}}_{x,t} \neq \mathcal{G}_{x,t}, \quad (108)$$

where $\hat{\mathcal{G}}_{x,t}$ denotes the decision-maker's available representation of the relevant generative-relational system.

The difference can include unknown actors, uncertain causal relations, unrecognized cultural meanings, delayed effects, or future technologies that change the consequences of present choices.

Epistemic humility therefore discourages irreversible interventions when the relevant system is poorly understood and when less destructive alternatives remain available.

This does not generate a universal principle of nonintervention. Some situations require action precisely because delay can produce irreversible harm. The relevant ethical requirement is to recognize uncertainty as part of the relational condition rather than silently treating an incomplete model as the system itself.

Epistemic humility also applies to normative frameworks. GREthic does not assume that its current categories exhaust every ethically relevant relation. New experiences can expose missing concepts. Historically excluded actors can reveal relations that the prevailing framework did not recognize.

An ethically generative system should therefore retain institutional and conceptual mechanisms through which its own judgments can be challenged.

9.10 Revisability of Normative Interpretation

Revisability follows from the historical, relational, and epistemically limited character of normative judgment.

If the relevant system changes,

$$\mathcal{G}_{x,t} \longrightarrow \mathcal{G}_{x,t+1}, \quad (109)$$

or if previously unavailable information becomes accessible,

$$\hat{\mathcal{G}}_{x,t} \longrightarrow \hat{\mathcal{G}}'_{x,t}, \quad (110)$$

the reasons supporting an earlier interpretation can require reconsideration.
A normative judgment should therefore be represented as historically provisional:

$$J_t = \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t}}, \quad (111)$$

with the possibility that

$$J_{t+1} \neq J_t. \quad (112)$$

Revisability does not imply indecision or the absence of commitment. Ethical actors can make firm decisions under current conditions while acknowledging that the reasons supporting those decisions remain answerable to future evidence and relational change.

The requirement is stronger when an intervention substantially alters the future conditions of judgment itself. A governance system that removes every alternative institution, a knowledge infrastructure that makes exit impossible, or an educational system that destroys re-cognizability can make later revision practically unavailable.

Revisability therefore concerns both judgments and structures. A relational arrangement should, where ethically and practically possible, preserve conditions under which future correction remains possible.

This principle creates an important connection among generative conditions, epistemic humility, and re-cognizability. A system remains ethically revisable when affected actors can continue to produce new knowledge, express alternative interpretations, recognize different conceptual possibilities, and modify institutions in response to changing reasons.

The normative architecture developed in this section can therefore be summarized as

$$\mathcal{F} \hookrightarrow \mathcal{G}_{x,t} \rightsquigarrow \mathcal{H}_{x,t} \rightsquigarrow J_t, \quad J_t \text{ remains revisable.} \quad (113)$$

The interpretation J_t is constrained by relational history, informed by political-economic analysis, generated within a historically situated hermeneutic system, and subject to revision as generative conditions, knowledge, and relations change.

Generative Relational Ethics therefore does not seek a final ranking of openness, equality, autonomy, safety, efficiency, or generativity. It asks how these and other reasons operate within the particular relational history under consideration and whether the resulting arrangement sustains the possibility of continued, heterogeneous, recognizable, and revisable generation.

The next section examines the historicist background of this position more directly. It considers the relation between Generative Relational Ethics and historical materialism, the role of material and productive relations, the extension toward heterogeneous generative systems, and the distinction between historical contingency and normative arbitrariness.

10 Historical Materialism and Generative Relational Ethics

The historicist orientation developed in Section 9 has an important affinity with historical materialism. Both approaches resist treating normative consciousness as independent of the social and historical relations through which human life is organized. Concepts, values, institutions, and forms of judgment emerge within historically specific conditions rather than from a position external to history.

The affinity should nevertheless be stated carefully. Generative Relational Ethics does not identify itself with a complete Marxian theory of history, nor does it reduce normative interpretation to economic determination. Material production, property, labour, productive dependence, and accumulation remain important components of the relational field. The generative system examined by GREthic also includes cultural, linguistic, technological, institutional, legal, epistemic, symbolic, interpersonal, and ecological relations whose interaction cannot always be represented through a single causal hierarchy.

The purpose of this section is therefore comparative and constructive. It identifies the historical-materialist intuition incorporated into GREthic, clarifies the extension introduced by a generative-relational account, and addresses the normative problem created by historical situatedness.

10.1 Historical Formation of Normative Consciousness

A central insight associated with historical materialism is that consciousness must be examined in relation to the historically specific conditions of social life. In *The German Ideology*, Marx and Engels reject an account in which ideas possess an autonomous history detached from material activity, social intercourse, and the organization of production [15]. Forms of consciousness, including morality, are situated within the practical relations through which social life is reproduced.

This orientation is directly relevant to the present inquiry. Normative concepts used in public-knowledge governance have histories. Authorship, ownership, privacy, public access, scientific responsibility, intellectual freedom, institutional authority, and legitimate restriction have developed within changing technological, economic, legal, and cultural arrangements.

The normative meaning of knowledge circulation therefore cannot be fully understood by treating these concepts as timeless categories. A conception of authorship formed around scarce manuscript production differs from one operating under industrial printing, digital reproduction, or generative AI. A conception of public access formed under conditions of high distribution cost differs from one operating where copying is inexpensive but computational processing is highly concentrated.

Historical formation also affects which ethical problems become visible. A society can develop strong norms against state secrecy after a history of authoritarian control. Another community can develop strong norms concerning restriction and custodianship after repeated extraction of culturally significant knowledge. The normative salience of openness is therefore historically generated through different relational experiences.

GREthic preserves this insight. The hermeneutic system $\mathcal{H}_{x,t}$ through which relational history is interpreted is itself a historical formation within $\mathcal{G}_{x,t}$.

10.2 Material and Productive Relations

The relation to historical materialism is strongest where public knowledge is embedded in productive structures. Knowledge does not circulate independently of material infrastructures. Servers, laboratories, energy, communication networks, educational systems, archives, computational resources, labour, funding, and institutional organization all condition what can be produced and who can participate in production.

Marx’s analysis of capital emphasizes the relational organization of productive conditions and the historical processes through which control over those conditions becomes concentrated [14]. The relevance to knowledge capital lies less in a literal equation between knowledge and industrial capital than in the relational question of who controls conditions required for continued production.

A participant can possess formal access to public knowledge while lacking the material resources required to make that access generatively effective. Computational capacity, institutional affiliation, time, laboratory access, financial support, and technical infrastructure can substantially alter the productive consequences of nominally equal informational access.

The political economy of public knowledge is therefore inseparable from material conditions. A model trained on publicly available data can require computational resources unavailable to most contributors to that public field. An openly available scientific literature can remain difficult to use where education, language, infrastructure, or research time are unequally distributed.

GREthic consequently treats material and productive relations as central components of the generative system:

$$\mathcal{G}_{x,t} \supset \mathcal{G}_{x,t}^M, \quad (114)$$

where $\mathcal{G}_{x,t}^M$ denotes the material and productive relations relevant to the inquiry.

Equation 114 does not assign those relations exclusive causal priority. It states that ethical interpretation that ignores them would omit conditions through which knowledge-capital expansion becomes politically consequential.

10.3 Heterogeneous Generative Relations

Generative Relational Ethics extends the relevant field beyond material and productive relations. The extension follows from the observation that many conditions affecting future generativity operate through heterogeneous relations whose effects cannot always be reduced directly to property or production.

A useful decomposition is

$$\mathcal{G}_{x,t} = \{\mathcal{G}^M, \mathcal{G}^I, \mathcal{G}^L, \mathcal{G}^C, \mathcal{G}^T, \mathcal{G}^E, \mathcal{G}^S, \mathcal{G}^R, \dots\}_{x,t}, \quad (115)$$

where the superscripts refer provisionally to material, institutional, legal, cultural, technological, epistemic, symbolic, and interpersonal relational dimensions.

The decomposition is analytical rather than ontological. These dimensions are not independent layers. A technological infrastructure can alter legal relations, institutional roles, epistemic practices, and cultural expectations. A legal rule can change market incentives and thereby reshape technical architecture. A symbolic classification can affect recognition, funding, and institutional access.

The relevant system is therefore coupled.

This coupling is especially important in public knowledge. A licensing rule can affect commercial incentives. A platform interface can affect citation practices. A ranking algorithm can alter academic visibility. A linguistic standard can determine which knowledge is machine-readable. A cultural category can affect whether a community regards publication as legitimate.

The generative-relational account therefore asks which heterogeneous relations participate in producing the later state rather than presuming in advance that one class of relations exhausts the explanation.

This extension does not require rejection of material analysis. It instead places material relations within a wider system in which causal and interpretive influence can operate across several relational domains.

10.4 Symbolic and Cultural Relations

Symbolic and cultural relations require particular attention because public knowledge is constituted partly through representation. Classification, naming, citation, disciplinary boundaries, prestige, authorship conventions, and institutional recognition affect which objects become visible as knowledge and which actors become visible as legitimate producers.

A resource can therefore be publicly accessible while remaining culturally or epistemically marginal. Conversely, a resource can acquire substantial influence because an institution, platform, discipline, or symbolic authority recognizes it as canonical.

These processes can have material consequences. Recognition can affect employment, funding, publication, access to infrastructure, and the ability to participate in later knowledge production. Symbolic relations can therefore enter processes of knowledge-capital accumulation and conversion.

Bourdieu's analysis of symbolic and cultural capital is useful here because it shows how resources acquire effects within relational fields and how one form of capital can become convertible into another [4]. The present framework adopts a related sensitivity while emphasizing the generative consequences of these conversions.

Cultural relations also affect normative interpretation. A public-knowledge practice can appear as sharing under one hermeneutic system and as appropriation under another. A norm of individual attribution can preserve important forms of recognition in one institutional field while inadequately representing collective knowledge production in another.

These differences cannot be resolved by syntax alone. The relational history must be embedded within the symbolic and cultural systems through which its participants understand authorship, responsibility, ownership, community, publicness, and legitimate reuse.

10.5 Institutional and Technological Relations

Institutions and technologies occupy an intermediate position between material conditions and normative interpretation. They organize recurring relations through which knowledge is produced, stored, evaluated, distributed, and governed.

Institutional arrangements can stabilize roles and expectations. Peer review, repositories, universities, journals, archives, licensing institutions, funding systems, professional associations, and regulatory bodies create relatively durable structures within which knowledge relations take place.

Technologies likewise configure possibilities. Search systems determine what can be found. Interfaces determine what can be queried. File formats affect interoperability. Models affect what can be synthesized. Ranking systems affect visibility. Authentication systems affect who can enter.

These infrastructures can become historically sedimented. Once widely adopted, they influence later institutions and practices. A technical decision initially made for convenience can become an institutional standard. A platform introduced as an optional service can become infrastructural.

The direction of influence is therefore recursive:

$$\text{institution} \rightarrow \text{technology} \rightarrow \text{practice} \rightarrow \text{institution}. \quad (116)$$

Political-economic power can enter at each stage. Actors capable of shaping technical standards or institutional procedures can influence the future conditions of participation.

Historical materialist sensitivity remains relevant because these infrastructures are produced, financed, owned, maintained, and governed under specific material relations. GREthic adds that the resulting institutional and technological structures also become generative relations in their own right.

10.6 Normative Feedback into Relational Systems

A further extension concerns the direction of influence between relational systems and normative interpretation. The relation is not exhausted by

$$\mathcal{G}_t \rightarrow \mathcal{H}_t.$$

Normative interpretation can itself affect later relational development.

A judgment that unrestricted publication is irresponsible can generate new access rules. A judgment that a platform's control is excessive can generate interoperability requirements. A conception of open science can alter funding conditions. A new understanding of community consent can change archival practice.

The resulting recursive structure can be represented as

$$\mathcal{G}_t \rightsquigarrow \mathcal{H}_t \rightsquigarrow J_t \longrightarrow A_t \longrightarrow \mathcal{G}_{t+1}, \quad (117)$$

where J_t denotes normative judgment and A_t the actions or institutional interventions informed by that judgment.

Equation 117 expresses an important feature of GREthic. Normativity is historically generated, yet once generated it becomes one of the relations through which subsequent history develops.

The resulting system therefore contains feedback:

$$\mathcal{G}_t \rightsquigarrow \mathcal{H}_t \rightsquigarrow J_t \rightarrow \mathcal{G}_{t+1} \rightsquigarrow \mathcal{H}_{t+1}. \quad (118)$$

An ethical interpretation can alter the field that later becomes the object of ethical interpretation.

This recursive relation also explains why normative institutions can become rigid. A judgment can be encoded into law, infrastructure, organizational procedure, or technical standards. The resulting structure can persist after the conditions that originally supported the judgment have changed.

Normative revisability must therefore concern institutionalized judgments as well as explicit moral beliefs.

10.7 Historical Contingency and Ethical Arbitrariness

A historically generated account of normativity faces an immediate objection. If ethical interpretation depends upon historically specific relational systems, does the framework imply that any historically established norm is valid within its own context?

GREthic rejects this conclusion.

The distinction can be stated directly:

$$\text{historical contingency} \neq \text{normative arbitrariness.} \quad (119)$$

Historical contingency means that normative concepts and reasons have conditions of emergence and can change when those conditions change. Normative arbitrariness would mean that no reasoned criticism across or within historical systems is possible.

The first proposition does not entail the second.

A historically generated hermeneutic system can fail to recognize actors who are affected by its judgments. It can systematically exclude relevant experience. It can preserve dependency whose original justification no longer exists. It can destroy alternative generative paths. It can prevent affected participants from contesting its categories. It can become epistemically insulated from new evidence.

These failures can themselves be examined relationally.

Let $\mathcal{H}_t$ be the prevailing hermeneutic system. Ethical reflection can ask whether

$$\mathcal{H}_t \rightsquigarrow \{\text{recognition, contestability, revisability, continued generative conditions}\} \quad (120)$$

remains possible for the affected field.

Equation 120 is not a checklist whose components can be mechanically scored. It identifies dimensions through which the interpretive system itself can become an object of normative inquiry.

Cross-relational criticism is therefore possible because systems interact, participants move among them, consequences cross boundaries, excluded perspectives become visible, and new relations generate reasons unavailable within an earlier interpretive horizon.

Normative disagreement need not be resolved by appealing to a transcendent viewpoint outside all relations. Criticism can emerge through encounters among relations and through the consequences that existing systems generate.

This position preserves historical situatedness while avoiding a doctrine of ethical immunity.

10.8 Generative Relational Historicity

The preceding analysis permits the historical orientation of GREthic to be stated more precisely.

Historical materialism contributes the indispensable insight that social and normative consciousness must be interpreted through historically specific relations of material life, production, and social organization [15, 14]. The political economy of knowledge-capital expansion examined in this paper remains deeply dependent upon that insight.

Generative Relational Ethics develops a broader account in which material relations interact with heterogeneous cultural, symbolic, technological, institutional, legal, epistemic, and interpersonal systems. None of these domains is assumed to remain autonomous, and no single domain is treated here as an invariant explanatory base for every normative transformation.

The resulting historicity is relational and recursive.

At time t ,

$$\mathcal{G}_t \rightsquigarrow \mathcal{H}_t \rightsquigarrow J_t. \quad (121)$$

Judgment informs action:

$$J_t \rightarrow A_t. \quad (122)$$

Action alters the relational system:

$$A_t : \mathcal{G}_t \longrightarrow \mathcal{G}_{t+1}. \quad (123)$$

The transformed system contributes to a later interpretive horizon:

$$\mathcal{G}_{t+1} \rightsquigarrow \mathcal{H}_{t+1}. \quad (124)$$

The combined process can therefore be summarized as

$$\mathcal{G}_t \rightsquigarrow \mathcal{H}_t \rightsquigarrow J_t \rightarrow A_t \rightarrow \mathcal{G}_{t+1} \rightsquigarrow \mathcal{H}_{t+1}. \quad (125)$$

Equation 125 expresses what this paper calls *generative relational historicity*. Normative interpretation is historically formed, enters practical relations, and contributes to the conditions from which later normative interpretations emerge.

This model also clarifies the distinction between genealogy and justification:

$$\text{Gen}(J_t) \neq \text{Just}(J_t), \quad (126)$$

where $\text{Gen}(J_t)$ denotes the historical generation of a judgment and $\text{Just}(J_t)$ denotes the reasons through which that judgment is defended under ethical inquiry.

A genealogy can explain why a norm emerged without vindicating it. Ethical criticism can therefore remain historically situated while examining whether a judgment still responds adequately to the relational system in which it now operates.

This distinction is particularly important for public knowledge. Historical norms of authorship, secrecy, access, institutional authority, ownership, and scientific responsibility can all outlive the technological and relational conditions through which they originally acquired their force. Conversely, new technological capabilities can emerge faster than the interpretive systems needed to govern them.

Generative Relational Ethics therefore treats ethical judgment as occurring within history while preserving the possibility that history can generate the conditions for its own criticism.

The next section applies this historicist and relational framework to one of the central normative tensions in public knowledge: openness and closure. It examines why neither relation possesses a fixed ethical value and how protective restriction can transform into enclosure, or restrictive structures can become unnecessary, as the generative-relational system changes.

11 Openness and Closure under Generative Relational Ethics

Openness and closure provide a useful test of the framework developed in the preceding sections. Public-knowledge ethics is often organized around an implicit normative hierarchy in which openness is treated as presumptively good and restriction as a deviation requiring justification. Such a hierarchy captures important historical concerns concerning secrecy, exclusion, and informational enclosure, but it becomes insufficient when unrestricted circulation can itself damage the generative conditions of affected actors.

Generative Relational Ethics begins from a different analytical position. Openness and closure are relational configurations whose ethical meanings depend upon the systems in which they operate. Openness can enlarge learning, participation, criticism, and reuse. It can also expose vulnerable actors, accelerate harmful use, or enable forms of appropriation that alter the generative field. Closure can protect

privacy, safety, cultural continuity, or future generative possibilities. It can also preserve dependency, rent extraction, gatekeeping, and avoidable enclosure.

The ethical task is therefore to reconstruct what a particular access regime does within its relational history and whether the reasons supporting that regime remain responsive to changing generative conditions.

11.1 Openness as a Relational Configuration

Openness is frequently described as a property of a knowledge object. A paper, dataset, repository, or model is said to be open when relevant actors can gain access to it under sufficiently permissive conditions. For the purposes of this paper, openness is better represented as a set of relations.

Let K denote a knowledge resource and A_i a set of relevant actors. An open configuration can contain access relations

$$A_i \longrightarrow K, \quad i = 1, \dots, n, \quad (127)$$

together with labels concerning cost, permitted reuse, technical accessibility, attribution, modification, redistribution, or other relevant conditions.

Openness therefore has several dimensions. A resource can be free to read but difficult to reuse. It can be legally reusable but technically inaccessible. It can be publicly downloadable while intelligible only to actors possessing specialized knowledge or infrastructure. Formal openness and generative accessibility should consequently remain distinguishable.

A useful distinction is

$$A^{\text{formal}} \neq A^{\text{generative}}, \quad (128)$$

where the first denotes formal permission or availability and the second denotes practical capacity to enter a productive relation with the resource.

This distinction prevents public availability from being mistaken for equal generative opportunity. Open knowledge can remain embedded in substantial differences of language, education, computation, institutional support, recognition, or material infrastructure.

The ethical significance of openness therefore depends upon the wider relations through which access becomes operative. Open-science and open-access traditions establish strong reasons for widening scholarly participation and reuse [21, 22]. GREthic retains those reasons while treating them as part of a wider relational field.

11.2 Closure as a Relational Configuration

Closure is likewise relational rather than binary. A knowledge resource can remain available to some actors, uses, or institutions while access is restricted for others. Restrictions can concern reading, copying, redistribution, commercial use, automated processing, temporal release, identity, geographic location, or institutional membership.

A transition from openness to closure can therefore be represented as a change in the labels or topology of access relations:

$$\lambda_t(e_{iK}^A) = \text{open} \longrightarrow \lambda_{t+1}(e_{iK}^A) = \text{restricted}. \quad (129)$$

The ethical meaning of Equation 129 is not contained in the transition itself.

Restriction can be introduced by a community attempting to prevent harmful extraction of culturally significant knowledge. It can be introduced by a medical institution protecting identifiable participants. It can be imposed by a corporation attempting to preserve a commercial bottleneck. It can also arise unintentionally through technical incompatibility, institutional neglect, or disappearance of infrastructure.

Closure therefore includes heterogeneous relational forms. The analysis should reconstruct who controls the restriction, whom it affects, what purpose it serves, whether alternatives exist, how long it persists, and how its consequences enter the surrounding generative system.

11.3 Protective Closure

Protective closure occurs when restricting access serves to preserve generative conditions that would face significant threat under immediate openness.

The relevant conditions can include privacy, safety, institutional trust, cultural continuity, protected experimentation, confidentiality, or the future capacity of vulnerable participants to remain in the knowledge field.

Knowledge-commons research provides established examples in which privacy and confidentiality can support knowledge production by creating conditions of trust needed for disclosure and cooperation [7]. This relation shows why closure and generativity should not be treated as opposites.

A protective configuration can be represented schematically as

$$\text{restriction} \longrightarrow \text{preservation of vulnerable generative conditions.} \quad (130)$$

The arrow is interpretive rather than mechanically causal. Whether a restriction actually performs this protective function requires factual and relational inquiry.

Protective closure can be especially relevant when harm is difficult to reverse. Publication of sensitive personal information, release of material that enables severe misuse, or circulation of culturally restricted knowledge can alter the field in ways that later withdrawal cannot undo.

The ethical reason for restriction is therefore sometimes connected to irreversibility. Where dissemination is effectively irreversible while the consequences remain uncertain and potentially severe, temporary restraint can preserve future options that unrestricted release would eliminate.

Protective closure nevertheless requires continuing scrutiny. A protective purpose at t_1 does not guarantee that the same restriction remains protective at t_2 .

11.4 Extractive Closure

Closure can acquire a different political-economic function when restrictions primarily preserve an actor's ability to extract benefits from a relational bottleneck.

Consider a field in which public or collectively generated resources contribute to the formation of a downstream infrastructure P . If access to the resulting capacity becomes increasingly conditional upon terms controlled by P , the restriction can participate in a re-enclosure process:

$$K_{\text{public}} \longrightarrow P \longrightarrow X_P \longrightarrow D_{\text{others}}. \quad (131)$$

Here, X_P denotes increasing control and D_{others} denotes increasing dependency of other participants upon the controlled infrastructure.

The restrictive relation can then contribute to rent formation or recursive accumulation even when the original knowledge remains formally public.

Extractive closure is not defined merely by commercial activity. A commercial service can impose access restrictions while providing substantial new infrastructure, maintaining viable alternatives, and avoiding dependency. Conversely, a nonprofit or public institution can maintain restrictive control that produces severe gatekeeping.

The relevant distinction concerns the relational operation of closure rather than the institutional identity of the controlling actor.

A restriction becomes more plausibly extractive when the controlling position allows continuing benefit from dependencies that the actor itself has helped create or maintain, while affected participants possess few meaningful alternatives.

Even here, political-economic diagnosis remains distinct from the final ethical judgment. The reasons supporting the restriction, the investment required to maintain the infrastructure, and the generative benefits returned to the wider field remain relevant.

11.5 Safety and Misuse

Misuse presents one of the clearest cases in which maximum openness can conflict with continued generativity. Knowledge can increase capacities for beneficial action and harmful action simultaneously. The same technical, scientific, or institutional insight can support several downstream trajectories.

Let a knowledge release create a set of possible downstream paths

$$\Pi(K) = \{p_1, p_2, \dots, p_n\}, \quad (132)$$

where some paths contribute to beneficial generation and others create severe risks.

An ethical decision cannot generally isolate one trajectory in advance. Openness changes the field by making several downstream relations possible at once.

The relevant question is therefore not whether knowledge is intrinsically dangerous. It concerns the structure of foreseeable use, the severity and reversibility of possible harm, the availability of safeguards, the capacities of affected actors, and whether less restrictive alternatives can preserve valuable generative paths.

An organization can consequently have ethical reasons to delay or limit release when it cannot adequately protect actors whose generative conditions would be threatened by foreseeable misuse.

Such restriction should not acquire a permanent presumption merely because the initial uncertainty was substantial. Safety mechanisms can improve. Knowledge about the risk can increase. Alternative modes of access can become available. Normative interpretation must therefore track the evolution of the risk environment.

11.6 Knowledge Re-Enclosure

The openness-closure problem also appears at a longer temporal scale through knowledge re-enclosure.

An initially open configuration can generate a downstream system:

$$K_{\text{open}} \longrightarrow S_A. \quad (133)$$

If S_A becomes highly valuable, participants in the original knowledge field can begin to rely upon it:

$$K_{\text{open}} \longrightarrow S_A \longrightarrow D_{\text{commons},A}. \quad (134)$$

If actor A subsequently restricts access to S_A , the complete history can be written schematically as

$$K_{\text{open}} \rightarrow S_A \rightarrow D_{\text{commons},A} \rightarrow X_A. \quad (135)$$

The final restriction cannot be interpreted adequately without the earlier dependency-forming history.

This is why the ethical object is the 2-complex history rather than the last access event. A restriction imposed on an infrastructure that no one depends upon differs relationally from the same restriction imposed after the field has reorganized around that infrastructure.

Re-enclosure can therefore occur without withdrawing the original public knowledge. The political-economic object is control over downstream generative conditions.

This pattern is increasingly relevant where public scholarly or cultural resources contribute to privately controlled computational infrastructures [23, 11].

11.7 Temporary Restriction

Temporariness can materially change the normative structure of closure. A restriction introduced for a specific risk, transition, or institutional need can preserve future openness if it contains conditions for reconsideration.

Let a restriction begin at t_0 under conditions C_0 . Its continued justification at time t should not be inferred solely from the earlier judgment:

$$J_{t_0} \not\Rightarrow J_t. \quad (136)$$

Instead, the relevant system should be reassessed:

$$\mathcal{G}_{x,t_0} \longrightarrow \mathcal{G}_{x,t}. \quad (137)$$

If the risk, available safeguards, institutional capacity, or downstream relations have changed, the normative interpretation can also change.

Temporary restriction is therefore stronger ethically when the governance arrangement preserves mechanisms for review. These can include sunset conditions, periodic reassessment, staged access, independent review, or explicit criteria for modification.

These mechanisms should not be treated as universally mandatory procedural forms. Their significance lies in preserving the possibility that an earlier restriction can be reconsidered as the relational field evolves.

A restriction without any mechanism of reconsideration can more easily become detached from the reasons that originally supported it.

11.8 Institutional Control

Access regimes are rarely maintained by abstract principles alone. Institutions decide who can enter, which permissions apply, how disputes are resolved, and when restrictions can change.

The ethical meaning of closure therefore depends partly upon the institutional structure controlling it.

A restrictive regime governed through transparent procedures, affected-party participation, review, and meaningful appeal occupies a different relational configuration from one governed unilaterally by an actor that also derives substantial economic or political benefits from continued restriction.

Relevant relations include

$$\text{control} + \text{accountability} + \text{contestability} + \text{dependency}. \quad (138)$$

The expression is not an additive ethical formula. It identifies several institutional dimensions that change the meaning of the same formal access rule.

Control can also be distributed. A community can maintain restrictive access through collective governance. An independent fiduciary institution can hold sensitive material. Several institutions can share authority. Technical architecture can separate storage, authorization, and oversight.

The ethics of closure therefore concerns who controls the boundary and how that control is embedded within the larger relational system.

Institutional design also affects epistemic humility. A single actor can fail to recognize harms that are visible from another position. Governance structures capable of receiving alternative interpretations can therefore improve the system's capacity for revision.

11.9 Revisability of Closure

Closure becomes particularly problematic when it removes the conditions through which its own justification could later be challenged.

Suppose a restrictive regime controls not only access to knowledge but also the evidence, expertise, infrastructure, or institutional channels needed to contest the restriction. The regime then affects both the substantive object of judgment and the future conditions of normative reconsideration.

This relation can be represented schematically as

$$X_A(K) \longrightarrow X_A(\text{conditions of contestation}). \quad (139)$$

Such a structure can create normative rigidification.

GREthic therefore gives special attention to whether a restrictive relation preserves future possibilities for review, alternative knowledge production, and recognition of perspectives excluded by the current regime.

Revisability does not imply that every restriction must be easily reversible. Some protective decisions concern risks whose mitigation requires durable institutional boundaries. The normative issue is whether the system remains capable of recognizing reasons that could justify modification.

Re-cognizability is important here. A closed system can become so internally self-confirming that alternative interpretations disappear from its hermeneutic horizon. Closure can then reproduce itself because the conceptual resources needed to imagine another arrangement have been excluded.

The preservation of contestability and alternative epistemic paths therefore has ethical importance beyond immediate access.

11.10 Conditions for Reopening

If the ethical meaning of closure is historically generated, reopening cannot be governed by a timeless threshold. The reasons for reopening emerge when the relations supporting continued restriction change.

Consider a restriction initially supported by conditions

$$C_{t_0} = \{\text{high risk, limited safeguards, high irreversibility, limited institutional capacity}\}. \quad (140)$$

At a later time, the system can evolve toward

$$C_{t_1} = \{\text{reduced risk, effective safeguards, greater institutional capacity, less restrictive alternatives}\}. \quad (141)$$

The relational basis of the earlier judgment has then changed.

Reopening need not mean immediate unrestricted release. It can involve staged access, revised licensing, distributed governance, controlled research access, partial disclosure, interoperability, or another transformation that enlarges generative possibilities while responding to residual risks.

The relevant ethical movement is therefore from a rigid binary

open versus closed

toward an evolving configuration of relational possibilities.

A useful normative question is whether the current degree and form of restriction remain responsive to the reasons presently operative in the field.

This question differs from asking whether closure was originally justified. A historically justified restriction can become unjustified through relational change.

11.11 Generative Interpretation of Openness and Closure

The analysis of this section can now be summarized through two formally similar transitions:

$$\mathcal{F}_1 : \text{open} \longrightarrow \text{restricted} \quad (142)$$

and

$$\mathcal{F}_2 : \text{open} \longrightarrow \text{restricted}. \quad (143)$$

At the level of local syntax,

$$\mathcal{F}_1 \cong \mathcal{F}_2 \quad (144)$$

can hold.

Suppose, however, that

$$\mathcal{F}_1 \hookrightarrow \mathcal{G}_{x,t_1} \quad (145)$$

occurs under severe misuse risk, limited safeguards, and substantial irreversibility, while

$$\mathcal{F}_2 \hookrightarrow \mathcal{G}_{x,t_2} \quad (146)$$

occurs under manageable risk, viable alternatives, mature safeguards, and an established dependency structure benefiting the actor maintaining restriction.

Then

$$\llbracket \mathcal{F}_1 \rrbracket_{\mathcal{H}_{x,t_1}} \neq \llbracket \mathcal{F}_2 \rrbracket_{\mathcal{H}_{x,t_2}} \quad (147)$$

can follow despite the formal similarity of the local transition.

The example illustrates the central proposition of the paper. Openness and closure possess no invariant ethical value independent of their relational history.

This does not eliminate presumptions, principles, or institutional commitments in favor of openness. Such commitments can be historically and normatively well supported, particularly where secrecy, exclusion, monopoly, or informational inequality have constrained knowledge production. GREthic asks that their application remain responsive to the relations through which openness becomes generatively operative.

The same applies to closure. Protective reasons can be compelling, but they do not create permanent authority. Restrictions must remain interpretable within the changing field that gives them ethical significance.

The relevant normative object is therefore neither openness nor closure in isolation. It is the evolving relation between access, protection, dependency, control, risk, generative possibility, and revisability.

The following section extends this relational analysis from access regimes to the positions occupied by different participants. It examines how ethical reasons and responsibilities vary across contributors, publishers, readers, reusers, distributors, platforms, commercializers, reviewers, commons members, and governance institutions.

12 Role-Dependent Ethical Interpretation

The preceding sections examined relational histories primarily through transformations in access, control, dependency, enclosure, and generative conditions. Ethical interpretation also depends upon the position from which an actor participates in those histories. Public knowledge is produced and governed through heterogeneous roles whose capacities, responsibilities, and exposure to consequences differ substantially.

Role dependence does not imply that each role carries a fixed list of duties. A contributor can also be a commercializer, a platform can also be a repository, and a reviewer can also participate in governance. Responsibilities arise from the actor's actual relations, capacities, knowledge, and ability to affect the generative conditions of others.

The relevant principle is therefore

$$\text{ethical responsibility} \neq \text{institutional identity}. \quad (148)$$

Responsibility is interpreted through relational position.

12.1 Contributors

Contributors introduce knowledge, data, interpretations, software, methods, creative works, or other resources into a public-knowledge field. Their ethical position is shaped by both the act of contribution and the foreseeable relations that contribution can generate.

Relevant concerns can include accuracy, provenance, disclosure of uncertainty, respect for affected participants, and the consequences of making particular knowledge available. Contributors can also possess reasons to preserve access, facilitate criticism, and enable reuse where these practices sustain the generative field.

These considerations do not produce a universal obligation to publish. Section 11 showed that restriction can be ethically relevant where release would threaten important generative conditions. A contributor can therefore face competing reasons concerning openness, safety, privacy, cultural responsibility, or downstream misuse.

The contributor's responsibility depends partly upon epistemic position. An actor cannot reasonably respond to every consequence that becomes visible only after long and indirect relational development. Responsibility increases, however, where relevant harms are foreseeable or where the contributor possesses specialized knowledge that makes those consequences more recognizable.

Knowledge-capital expansion can also alter contributor responsibility. An actor with extensive expertise, institutional resources, or influence can shape downstream interpretation in ways unavailable to a novice contributor. The same formal act of publication can therefore carry different relational consequences according to the position from which it occurs.

12.2 Publishers

Publishers mediate the transition between knowledge production and public circulation. Their role can include selection, editing, formatting, distribution, preservation, licensing, correction, metadata production, and the maintenance of infrastructures through which knowledge becomes visible.

The publisher's ethical position therefore differs from that of the original contributor. A publisher can possess control over access, visibility, presentation, and persistence even when it did not create the underlying knowledge.

This position creates responsibilities concerning faithful representation, preservation of provenance, intelligibility of modifications, correction of material errors, and the conditions under which access is governed.

Publishers can also participate directly in knowledge-capital accumulation. Control over archives, citation infrastructures, metadata, usage data, or distribution channels can create capacities that exceed the traditional function of dissemination.

The role can therefore transform from

publisher $\longrightarrow$ infrastructure operator $\longrightarrow$ platform governor. (149)

Ethical responsibility changes accordingly. The more the publisher controls conditions required for downstream participation, the less adequate it becomes to interpret its obligations solely through the original act of publication.

12.3 Readers

Readers occupy one of the most basic positions in public knowledge. Reading creates relations through which public resources enter an actor's generative organization. The reader can learn, reinterpret, combine, reject, or later transform what has been encountered.

Ordinary reading generally imposes limited responsibility upon the surrounding field. The ethical position changes when reading becomes one stage in a larger relational process. A reader can become a contributor, classifier, commercializer, model developer, or institutional decision-maker.

The distinction between access and downstream power is therefore important. A person who reads a public document and a platform that processes millions of public documents can instantiate formally related access relations while possessing radically different capacities for transformation.

A reader also bears epistemic responsibilities concerning interpretation. Public accessibility does not guarantee that a resource has been understood within the historical or relational conditions in which it was generated. Misrepresentation can arise when knowledge is detached from context, provenance, uncertainty, or the limitations of the original claim.

Such responsibilities remain proportional to role and consequence. GREthic does not convert ordinary reading into a highly regulated moral activity. It asks how the reader's relation changes when acquired knowledge becomes generatively consequential for others.

12.4 Reusers and Modifiers

Reusers and modifiers transform existing knowledge into new configurations. Their activities can include translation, adaptation, synthesis, software implementation, dataset construction, model training, educational reuse, or conceptual recombination.

Reuse is central to the generativity of public knowledge. An ethical framework that treated incorporation of prior knowledge as presumptively suspect would undermine the recursive production that makes a knowledge commons valuable.

The relevant ethical questions concern the relations generated through reuse. Modification can obscure provenance, alter meaning, remove contextual limitations, introduce error, or create new downstream risks. It can also make knowledge intelligible to new communities, expose hidden assumptions, and create substantial new generative capacity.

A useful distinction is between transformation and attribution:

$$K \xrightarrow{\text{modification}} K' \quad (150)$$

does not determine whether the relation between K' and K remains sufficiently legible.

Preserving provenance can therefore contribute to the ability of later actors to understand how a transformed resource emerged. The requirement is especially important where modifications affect factual claims, risk interpretation, or institutional authority.

Reusers can also become politically consequential when scale transforms the nature of reuse. Automated aggregation and model training can convert many individually accessible resources into a productive infrastructure whose relational position differs substantially from that of an ordinary downstream user.

12.5 Distributors

Distributors shape the routes through which knowledge reaches subsequent participants. Their role includes transmission, indexing, recommendation, aggregation, syndication, search, and other functions that affect circulation.

Distribution can expand generativity by connecting knowledge with actors who would otherwise fail to encounter it. It can also shape visibility asymmetrically.

A distributor that merely transmits requested material occupies a different position from one whose ranking or recommendation systems strongly affect which knowledge becomes visible. Distribution can therefore acquire an interpretive and gatekeeping dimension.

The relational transformation can be written as

$$\text{distribution} \longrightarrow \text{visibility control} \longrightarrow \text{attention mediation.} \quad (151)$$

As this transformation proceeds, responsibilities concerning transparency, plurality, provenance, and the effects of ranking can become more salient.

A distributor can also affect re-cognizability. If repeated filtering makes some intellectual traditions, languages, or interpretive frameworks systematically difficult to encounter, the infrastructure can narrow the future conceptual field even without formally excluding those resources.

12.6 Platform Operators

Platform operators occupy a particularly complex relational position because they can mediate access, distribution, identity, computation, ranking, interaction, monetization, and governance simultaneously.

Their ethical significance arises from this combination of roles rather than from the category of platform itself.

A platform can increase generative capacity by reducing search costs, providing infrastructure, connecting participants, enabling collaboration, or making computational tools broadly available. The same infrastructure can generate dependency when downstream actors become unable to participate effectively without it.

A platform's relational position can therefore be represented through the intersection

$$\mathcal{R}_P = \{\text{access, distribution, control, dependency, governance, data}\}. \quad (152)$$

The significance of this set lies in the coupling among its components. Data obtained through distribution can improve the platform's productive capacity. Improved capacity can increase adoption. Adoption can increase dependency. Dependency can strengthen governance power.

Platform responsibility therefore concerns both individual decisions and the recursive structure produced by the platform's position.

GREthic does not infer that concentrated platform power is necessarily unethical. The relevant inquiry concerns alternatives, contestability, interoperability, dependency, use of accumulated knowledge capital, and the platform's effects upon the continued generativity of the surrounding field.

12.7 Commercializers

Commercializers convert knowledge-related capacities into monetary or market relations. Commercialization can finance infrastructure, reward productive activity, support maintenance, and provide services unavailable through public institutions alone.

The ethical issue is therefore not commercial use as such.

A commercial actor can create substantial new capacity from public knowledge while leaving the underlying commons accessible and contributing new resources to the field. Another can use public inputs to construct an indispensable downstream system and later impose conditions that substantially reduce the generative alternatives of others.

The difference concerns relational consequences.

Commercialization becomes especially relevant when revenue depends upon control over an access bottleneck, dependency, or exclusive downstream infrastructure. The distinction developed in Section 7.7 between productive contribution and rent formation is therefore important.

The commercializer's ethical position also depends upon the provenance of the resources being commercialized. Public funding, communal contributions, volunteer labour, cultural knowledge, or publicly maintained infrastructure can create reasons that would be absent in a purely private production history.

These reasons do not mechanically determine a required distribution of benefits. They establish relational facts that should remain visible in the normative interpretation.

12.8 Reviewers

Reviewers occupy an evaluative role. Their judgments can affect publication, recognition, funding, institutional standing, access to opportunities, or the subsequent visibility of knowledge.

Review therefore generates ethical responsibilities that differ from those of ordinary readers. A reviewer can convert an epistemic judgment into institutional consequences.

The relevant relation can be represented schematically as

$$\text{epistemic assessment} \longrightarrow \text{institutional consequence.} \quad (153)$$

This conversion requires evidentiary restraint. A judgment supported within a limited assessment context should not automatically be generalized into a broader characterization of the person, institution, or future generative capacity of the contributor.

Review responsibility therefore includes attention to the scope of evidence, procedural independence, conflict of interest, transparency of criteria where appropriate, and the possibility of correction or contestation.

The reviewer can also contribute to generative conditions by identifying problems without unnecessarily foreclosing future development. Critical assessment and generativity are compatible when criticism preserves the possibility of learning, revision, and renewed evaluation.

This does not require reviewers to weaken substantive standards. It requires that evaluative authority remain proportionate to the object and evidence actually under review.

12.9 Commons Members

Commons members occupy a dual position. They are beneficiaries of shared resources and participants in the social relations through which those resources remain usable.

Their responsibilities can therefore concern contribution, maintenance, reciprocity, governance participation, norm formation, preservation, and respect for the conditions enabling other members to participate.

Knowledge commons are institutionally heterogeneous [8]. Membership can be formal, informal, temporary, open, selective, or distributed across overlapping communities.

GREthic consequently does not impose one model of commons membership. It asks how membership relations affect the generative field.

A community can sustain norms of attribution, confidentiality, contribution, or restricted circulation because those norms make continued generation possible. The same norms can later become exclusionary if they rigidify into barriers unrelated to their original generative function.

Commons members therefore participate in the historical production of the hermeneutic system through which governance is interpreted. Their normative role is constitutive rather than merely consumptive.

12.10 Governance Institutions

Governance institutions possess capacities to create, interpret, modify, and enforce rules governing knowledge relations. Their decisions can affect access, licensing, privacy, safety, standards, dispute resolution, and the distribution of authority across the field.

Governance responsibility is therefore second-order. The institution does not only participate in particular relations; it shapes the conditions under which many other relations occur.

A governance intervention can be represented as

$$A_t^G : \mathcal{G}_t \longrightarrow \mathcal{G}_{t+1}, \quad (154)$$

where A_t^G alters rules, roles, permissions, or infrastructures within the relational system.

This position requires particular attention to epistemic humility. Governance institutions can easily overestimate their knowledge of heterogeneous participants and delayed consequences.

Revisability is therefore especially important. Rules should remain capable of responding to changes in technology, risk, dependency, cultural interpretation, and newly visible forms of harm.

Governance institutions also bear responsibility for preserving contestability. An institution that controls the terms of knowledge access and the channels through which those terms can be challenged risks creating a self-reinforcing normative structure.

A generative governance arrangement should therefore remain capable of receiving new information and alternative interpretations from the field it governs.

12.11 Multi-Role Actors

Many of the most consequential actors in contemporary public knowledge occupy several roles simultaneously.

Let actor a instantiate a role set

$$R_a(t) = \{r_1, r_2, \dots, r_n\}. \quad (155)$$

The ethical significance of a 's position cannot be reconstructed by evaluating each role independently if capacities acquired through one role affect another.

A platform can be simultaneously a distributor, commercializer, repository, model developer, access governor, and standards participant. A university can be contributor, funder, employer, licensor, repository operator, evaluator, and commercial partner.

The resulting interactions can produce conflicts of interest and recursive power.

For example,

$$\text{distribution data} \rightarrow \text{model capacity} \rightarrow \text{commercial advantage} \rightarrow \text{governance influence} \quad (156)$$

can occur within one organizational actor.

Multi-role analysis therefore requires attention to the conversion of relations across roles. The relevant question is not merely which roles the actor possesses, but how powers, information, dependencies, and resources obtained in one role become operative in another.

Role separation can sometimes reduce these problems. In other cases, integration can improve efficiency, accountability, or continuity. GREthic does not presume that separation is always preferable.

The ethical inquiry concerns the generative consequences of the actual configuration.

12.12 Conflicting Relational Responsibilities

Role-dependent ethics inevitably produces conflicts. A publisher can have reasons to maximize access and reasons to protect confidential material. A platform can have reasons to preserve open participation and reasons to restrict severe misuse. A governance institution can have reasons to support innovation and reasons to prevent dependency. A commercializer can have legitimate interests in sustaining investment while also benefiting from publicly generated resources.

GREthic does not resolve these conflicts through a fixed ordering of values.

Let actor a face a set of normatively relevant reasons

$$Q_a(t) = \{q_1, q_2, \dots, q_m\}. \quad (157)$$

These reasons can concern safety, openness, privacy, generative continuity, recognition, autonomy, reciprocity, institutional sustainability, or other relations.

The framework does not assume the existence of weights

$$w_1, \dots, w_m$$

through which

$$\sum_i w_i q_i$$

would produce a universal ethical score.

Reasons can be heterogeneous and partially incommensurable. Their force depends upon the relational history, affected actors, institutional conditions, foreseeable consequences, uncertainty, and available alternatives.

Ethical judgment therefore requires interpretation rather than optimization.

A useful object of inquiry is a relational normative dossier,

$$\mathcal{D}_a = \{\text{roles, capacities, dependencies, affected actors, history, alternatives, foreseeable effects, uncertainties, relevant re}\} \quad (158)$$

Equation 158 does not define a classifier. It identifies the kinds of information needed for situated normative judgment.

The resulting interpretation remains historically provisional:

$$J_a(t) = \llbracket \mathcal{D}_a \rrbracket_{\mathcal{H}_{x,t}}. \quad (159)$$

A change in role, capacity, dependency, knowledge, or the wider relational system can require

$$J_a(t+1) \neq J_a(t). \quad (160)$$

Role-dependent ethical interpretation is therefore compatible with the larger architecture developed in this paper. Relational roles help identify who can affect which conditions. Political economy identifies how those conditions are structured. Generative Relational Ethics interprets the resulting reasons within historically evolving systems.

The role analysis also reinforces a broader methodological conclusion: ethical responsibility should follow relational capacity rather than nominal status. Greater control, greater knowledge, greater ability to shape infrastructure, or greater capacity to foresee consequences can create reasons that do not arise for actors occupying less consequential positions.

The following section turns from role differentiation to the limits of the formal framework itself. It examines why the representation developed in this paper can structure ethical inquiry without supplying an algorithm for moral judgment, and why uncertainty, incommensurability, interpretive dependence, and revisability must remain explicit features of the analysis.

13 Limits of Formal Ethical Representation

The preceding sections have used graph configurations, labelled 2-complexes, transformation signatures, political-economic categories, and relational normative dossiers to make the object of ethical inquiry more explicit. These representations clarify who participates in a relational history, how roles change, where dependencies emerge, which access paths disappear, and how knowledge-capital accumulation alters the surrounding field.

Their usefulness depends upon maintaining a strict methodological boundary. The formal apparatus represents ethically relevant relations and preserves their histories. Ethical judgment remains an interpretive practice situated within an evolving generative-relational system.

This section states the consequences of that boundary. It examines the scope of formalization, the limits of optimization, the heterogeneity of normative reasons, contextual interpretation, hermeneutic uncertainty, ethical indeterminacy, and the institutional humility required when governance acts under incomplete knowledge.

13.1 Formalization of Ethical Objects

Formal representation is useful when an ethical problem contains relational structure that ordinary prose can leave implicit. The graph configuration Γ_t makes actors, role-instances, and typed relations identifiable. The history

$$\mathcal{F} : \Gamma_t \longrightarrow \Gamma_{t+1} \quad (161)$$

preserves the events and relational continuities through which one state develops into another.
The transformation signature

$$\Delta_{\mathcal{F}} = (\Delta A, \Delta X, \Delta D, \Delta \Pi, \Delta R, \Delta K, \Delta C) \quad (162)$$

summarizes selected changes in access, control, dependency, viable generative paths, role structure, knowledge capital, and concentration.

Likewise, the relational normative dossier

$$\mathcal{D}_a = \{\text{roles, capacities, dependencies, history, alternatives, effects, uncertainties, reasons}\} \quad (163)$$

organizes information relevant to the responsibility of an actor occupying a particular relational position.

These structures improve ethical inquiry by preventing important relations from disappearing into an undifferentiated narrative. They can reveal that a restriction followed a long dependency-forming history, that control acquired through one role became operative in another, or that formal openness coexisted with severe practical barriers.

Formalization therefore contributes to ethical intelligibility.

Its adequacy remains conditional upon representation choices. A model can omit affected actors, treat two distinct roles as one, choose an inappropriate temporal scale, or represent nominal access while overlooking effective inaccessibility. Formal clarity does not guarantee ontological completeness.

The ethical object constructed by the model should consequently remain open to revision when previously invisible relations become relevant.

13.2 Non-Formalization of Ethical Judgment

The framework does not define a mapping of the form

$$\Phi : \mathcal{F} \longrightarrow \{\text{ethical, unethical}\}. \quad (164)$$

Nor does it assume that sufficiently detailed relational data would eventually make such a mapping possible.

Ethical meaning arises through interpretation of relational history within a historically generated hermeneutic system:

$$J_t = \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t}}. \quad (165)$$

The notation records the dependence of judgment upon the interpretive system without making that system computational.

This distinction is substantive rather than merely practical. A political- economic structure such as concentration can participate in several ethically different configurations. A restriction can preserve vulnerable generative conditions or sustain an avoidable bottleneck. A dependency can support productive coordination or expose actors to unilateral control.

Additional data can improve the interpretation of these relations, yet the ethical problem still requires judgment concerning which reasons matter, how they apply, and how competing claims should be understood.

Formal analysis can therefore constrain ethical interpretation. It can show that a claim depends upon a relation that is absent from the history, or that an interpretation ignores actors clearly affected by the transformation. Formal structure cannot independently determine the final normative meaning.

13.3 Limits of Ethical Optimization

The strongest methodological restriction concerns optimization. GREthic does not treat ethical judgment as the maximization of a single objective.

A formulation such as

$$\max \sum_a G_a \quad (166)$$

would require heterogeneous generative conditions to be converted into a common scale and aggregated across actors. The framework does not assume that such a scale exists.

The same problem appears in multi-objective formulations such as

$$U = w_G G + w_A A + w_S S + w_R R, \quad (167)$$

where generativity, access, safety, and revisability would be assigned commensurable weights.

Such a representation can be useful within a narrow decision model when the variables and trade-offs have been institutionally defined. It does not provide a general account of ethical judgment.

The difficulty is conceptual. Greater openness can increase access while increasing severe misuse risk. Greater privacy can protect some actors while reducing accountability. Greater institutional stability can preserve continuity while reducing exit possibilities. Expanded generative capacity for one actor can narrow the future conceptual space available to another.

These relations cannot always be represented faithfully through marginal changes in one common quantity.

Optimization also risks converting historically generated reasons into fixed parameters. If the relational field changes, the relevance of a reason can change. A weight assigned under one institutional configuration can become misleading after new actors, technologies, dependencies, or harms emerge.

GREthic therefore uses formalization to make trade-offs and relational transformations visible while retaining interpretive judgment over their normative significance.

13.4 Incommensurable Normative Reasons

Normative reasons in public knowledge are heterogeneous. They can concern safety, autonomy, privacy, access, recognition, cultural continuity, public benefit, reciprocity, institutional sustainability, epistemic freedom, re-cognizability, and preservation of future generative possibilities.

Let

$$\mathcal{Q}_t = \{q_1, q_2, \dots, q_n\} \quad (168)$$

denote the set of reasons identified as relevant to a particular relational history.

The framework does not require an ordering

$$q_1 > q_2 > \dots > q_n \quad (169)$$

that remains valid across cases.

Some reasons can be comparable within a particular institutional setting. Others can remain only partially comparable. A severe threat to physical safety and a reduction in scholarly accessibility do not necessarily become more intelligible by assigning both a common numerical unit.

Incommensurability does not eliminate reasoned judgment. Ethical reasoning can distinguish relevance, urgency, reversibility, affected positions, foreseeability, and available alternatives without reducing every reason to one metric.

The relational normative dossier developed in Section 12.12 serves precisely this purpose. It preserves heterogeneous reasons so that their relations can be interpreted rather than aggregated prematurely.

Reasoning can therefore remain structured while resisting scalar reduction.

13.5 Contextual Interpretation

The interpretation of relational history depends upon its embedding within $\mathcal{G}_{x,t}$. The term *context* should therefore be used with care.

Context is not a residual variable appended after the main structure has been analyzed. Relevant contextual conditions can be distributed throughout the relational system: prior histories, legal arrangements, technological capacities, cultural meanings, institutional procedures, political-economic dependencies, and available alternatives.

This distributed structure was one motivation for attaching labels to different cells of the 2-complex rather than compressing context into a single vector.

Two locally similar histories can therefore satisfy

$$\mathcal{N}_k(q_1; \mathcal{F}_1) \cong \mathcal{N}_k(q_2; \mathcal{F}_2), \quad (170)$$

while their wider embeddings satisfy

$$\mathcal{G}_1 \not\cong \mathcal{G}_2. \quad (171)$$

Normative divergence can then arise from relations invisible in the selected local neighborhood.

Contextual interpretation therefore requires control over analytical scale. Expanding the relational neighborhood can reveal previously hidden dependencies or histories. Excessive expansion can also make analysis unmanageable and introduce relations with little bearing on the case.

The boundary of the relevant context is itself an interpretive judgment. GREthic therefore requires the analyst to justify why particular relations are included and to remain open to extending the representation when affected actors reveal omitted dependencies or meanings.

13.6 Hermeneutic Uncertainty

Ethical uncertainty can arise even when the relevant factual relations are reasonably well understood. Actors can disagree over how those relations should be interpreted, which historical analogies are relevant, or which concepts adequately describe the transformation.

This form of uncertainty is hermeneutic.

Suppose the relational facts establish that a community restricts access to a knowledge resource. One interpretation can understand the restriction as protective custodianship. Another can understand it as exclusionary control. The disagreement can persist even after both parties agree on the formal access structure.

Hermeneutic uncertainty can arise because actors occupy different relational positions, inherit different historical experiences, or use different conceptual vocabularies.

The appropriate response is not always immediate resolution. Ethical inquiry can first reconstruct the interpretive systems through which the disagreement has become possible.

Let

$$J_A = \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_A}, \quad J_B = \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_B}. \quad (172)$$

The divergence

$$J_A \neq J_B \quad (173)$$

can identify a substantive difference in normative interpretation rather than a simple factual error.

This does not imply that both interpretations must be accepted. Further inquiry can expose internal inconsistency, missing actors, inaccurate historical claims, or consequences that one hermeneutic system fails to recognize.

Hermeneutic uncertainty therefore becomes a legitimate object of ethical analysis.

13.7 Ethical Indeterminacy

Some relational histories can remain ethically indeterminate under the available evidence and interpretive conditions.

Indeterminacy can arise when consequences remain deeply uncertain, when relevant actors cannot yet be identified, when several reasons remain genuinely in tension, or when institutional alternatives have not developed far enough to permit meaningful comparison.

A responsible ethical framework should permit the conclusion

$$J_t = \text{underdetermined} \quad (174)$$

when the current relational field does not support a more determinate judgment.

This possibility is important because formal systems can create pressure for classification even where the underlying ethical object remains unresolved. A scoring system typically produces an output once its inputs are supplied. Ethical inquiry sometimes has stronger reasons to preserve uncertainty.

Indeterminacy does not prevent action. Governance can require provisional decisions under conditions in which the ethical interpretation remains incomplete.

The decision should then preserve the distinction between

$$\text{provisional action} \quad (175)$$

and

$$\text{settled normative judgment.} \quad (176)$$

An institution can restrict access temporarily because the potential harm is severe while explicitly acknowledging uncertainty concerning the long-term ethical arrangement.

This distinction supports revisability. Provisional decisions should preserve, where feasible, the conditions through which additional evidence and alternative interpretations can later become available.

13.8 Revisability and Institutional Humility

The limits of formal representation culminate in a requirement of institutional humility.

Institutions frequently govern systems they can only partially observe. Their models omit relations, their categories inherit historical assumptions, and their interventions can generate consequences that become visible only after the field has changed.

Let

$$\hat{\mathcal{G}}_{x,t} \quad (177)$$

denote the institution's working representation of the generative-relational system. In general,

$$\hat{\mathcal{G}}_{x,t} \subsetneq \mathcal{G}_{x,t} \quad (178)$$

should be treated as a persistent possibility.

Institutional humility therefore requires awareness that governance acts upon a system richer than its current representation.

This has practical consequences for the form of intervention. Where several responses remain plausible, institutions should attend to reversibility, contestability, preservation of alternatives, and the possibility of learning from subsequent effects.

A governance action can be represented as

$$A_t : \mathcal{G}_t \longrightarrow \mathcal{G}_{t+1}. \quad (179)$$

The action also changes the conditions under which later judgment will occur. An intervention that removes alternative institutions, eliminates relevant records, suppresses dissenting interpretations, or creates irreversible dependency can reduce the system's capacity to correct itself.

Institutional humility therefore concerns preservation of future ethical agency.

The relation among epistemic limitation, intervention, and revision can be written schematically as

$$\hat{\mathcal{G}}_t \rightsquigarrow J_t \rightarrow A_t \rightarrow \mathcal{G}_{t+1} \rightarrow \hat{\mathcal{G}}_{t+1} \rightsquigarrow J_{t+1}. \quad (180)$$

A generative governance system should allow the later representation $\hat{\mathcal{G}}_{t+1}$ to correct the assumptions embedded in $\hat{\mathcal{G}}_t$.

This requirement also applies to the formalism proposed in this paper. The graph vocabulary, 2-complex representation, political-economic categories, and GREthic concepts should remain revisable when they fail to represent ethically relevant structures.

The framework therefore does not claim formal closure over its own object.

Its methodological position can be summarized as follows:

Formal representation can discipline ethical inquiry by preserving relational structure, history, roles, and uncertainty. Political economy can identify consequential transformations within that structure. Normative judgment remains historically situated, interpretive, reason-responsive, and revisable.

The limits examined in this section are therefore integral to the framework rather than defects to be eliminated through increasingly extensive formalization.

The following section turns to the broader implications of the argument. It considers what the combined framework contributes to the ethics of knowledge-capital accumulation, commons governance, historical normativity, formal relational analysis, and AI-mediated public knowledge.

14 Discussion

The framework developed in this paper combines three analytical operations that are often performed separately. Relational syntax reconstructs the structure and history of knowledge processes. Political economy identifies transformations in accumulation, control, dependency, enclosure, extraction, and institutional position. Generative Relational Ethics interprets the normative significance of those transformations within historically evolving relational systems.

The resulting architecture does not provide a universal answer to whether knowledge-capital expansion, openness, concentration, commercialization, or restriction is ethically permissible. Its contribution lies instead in clarifying the object and conditions of such judgments.

Several broader implications follow. Knowledge-capital accumulation should be distinguished from domination; commons governance should be distinguished from maximum openness; historical normativity should be distinguished from arbitrary relativism; and formal representation should be distinguished from ethical computation. These distinctions become increasingly important where artificial intelligence accelerates the conversion of public knowledge into new epistemic capacities and infrastructural positions.

14.1 Knowledge Capital and Ethical Accumulation

The analysis developed in this paper does not treat knowledge-capital accumulation as intrinsically ethically problematic. This point is important because cumulative epistemic development is one of the central generative functions of public knowledge.

Learning itself is cumulative. Prior knowledge enables later inquiry, and institutional memory allows communities to preserve capacities that would otherwise need to be reconstructed repeatedly. Scientific

specialization, education, archives, libraries, and research infrastructures all depend upon forms of accumulation.

A framework that equated accumulation with domination would therefore condemn precisely the recursive generativity that makes public knowledge socially valuable.

The ethical object is instead the relational transformation through which accumulation becomes effective. Knowledge capital can remain primarily an increase in an actor's ability to understand and produce. It can also become convertible into infrastructural control, gatekeeping, dependency, or institutional authority.

A useful distinction is therefore

$$\text{knowledge-capital accumulation} \neq \text{relational domination.} \quad (181)$$

The first can contribute to the second under particular conditions, but the relationship is contingent.

This distinction also prevents asymmetry from becoming an ethical wrong in itself. Differences in expertise, recognition, capacity, and institutional position are unavoidable in generative systems. An actor that has studied a subject for many years will ordinarily possess capacities unavailable to a new participant. Eliminating this asymmetry would neither be possible nor desirable.

The relevant ethical question concerns what asymmetry becomes capable of doing within the relational field.

If accumulated knowledge enables an actor to contribute new resources, educate others, expand available pathways, or create useful infrastructure, the resulting asymmetry can participate in wider generativity. If the same capacity is converted into control over indispensable conditions while viable alternatives progressively disappear, a different ethical problem emerges.

GREthic therefore shifts attention from the possession of advantage toward its relational operation.

14.2 Commons and Re-Enclosure

The distinction between public availability and generative control has important consequences for knowledge-commons analysis.

A resource can remain technically public while the most consequential downstream capacities generated from it become concentrated within controlled infrastructures. Re-enclosure therefore need not take the simple form

$$\text{public resource} \longrightarrow \text{private resource.}$$

A more consequential trajectory can be

$$\text{public knowledge} \rightarrow \text{private productive capacity} \rightarrow \text{public dependency.} \quad (182)$$

The original knowledge remains available, yet the field becomes dependent upon a downstream system whose governance differs substantially from the conditions of the original commons.

This structure suggests that commons governance should attend not only to the legal status of resources but also to the generative infrastructure through which those resources remain socially effective.

A knowledge commons can therefore be weakened without formal privatization. Alternative pathways can disappear, local capacities can atrophy, technical standards can become concentrated, or the cost of independent participation can increase.

Conversely, private infrastructure need not constitute re-enclosure merely because it builds upon public knowledge. A privately operated service can increase the number of viable generative paths, remain interoperable, support public institutions, and coexist with meaningful alternatives.

The normative distinction again depends upon relational history.

This analysis also complicates the language of appropriation. Public knowledge is ordinarily created so that later actors can learn from and reuse it. An ethics of the commons therefore cannot protect generativity by preventing generative reuse.

The relevant problem arises when reuse contributes to a relational transformation through which the commons loses effective control over conditions increasingly necessary for its own continuation.

14.3 Openness and Generativity

The analysis of Section 11 supports a broader reconsideration of the relationship between openness and generativity.

Openness is often generatively powerful because it creates new relational possibilities. More actors can encounter a resource, develop knowledge from it, test existing claims, and generate unanticipated combinations.

The value of openness nevertheless arises through these relations. It is therefore possible for a formally open system to become generatively narrow. A field can provide universal technical access while ranking, standardization, linguistic barriers, computational requirements, or infrastructural concentration make only a small range of knowledge practically visible or usable.

Likewise, a partially closed system can preserve forms of generativity that unrestricted circulation would destroy.

The relation should consequently be represented as

$$\text{openness} \neq \text{generativity.} \quad (183)$$

Openness is one condition that can support generativity under many relational configurations. It is neither sufficient nor universally necessary.

This conclusion should not be interpreted as weakening the historical and institutional importance of open knowledge. Strong presumptions favoring openness can remain justified where secrecy, monopoly, exclusion, and informational inequality constitute persistent threats.

GREthic instead makes those presumptions revisable and relationally interpretable.

The resulting governance question is richer than whether a resource should be open. It concerns which configuration of access, protection, interoperability, plurality, provenance, safety, and institutional control best sustains the relevant generative field under present conditions.

14.4 Historical Normativity

The historicist account developed in Sections 9 and 10 has consequences beyond the specific problem of public knowledge.

If normative interpretation is historically generated, an ethical judgment is always made within an interpretive horizon that has itself emerged from prior relations.

This does not imply that ethical judgment is merely the expression of its historical environment.

The distinction

$$\text{Gen}(J_t) \neq \text{Just}(J_t) \quad (184)$$

remains fundamental.

Historical genealogy explains the conditions through which a judgment and its reasons became intelligible. Ethical justification asks whether those reasons remain defensible when the relevant relations, consequences, excluded perspectives, and alternative interpretations are considered.

This approach suggests a form of normativity that is neither ahistorical nor closed within historical relativism.

A normative interpretation can be situated without being immune from criticism. Historical systems can generate resources for criticizing their own institutions. Encounters among different systems can reveal previously unrecognized relations. New technologies can expose inadequacies in older ethical vocabularies. Affected actors can articulate experiences that the prevailing hermeneutic system did not previously represent.

Normative development can therefore itself be generative.

The resulting ethical task is partly reconstructive. Instead of asking only which timeless rule applies, inquiry asks how the present field was generated, which reasons remain operative, which have become historically detached from their original conditions, and which new relations require interpretation.

14.5 Relational Ethics and Political Economy

The connection between relational ethics and political economy is one of the central contributions of the framework.

Relational ethics can identify dependence, vulnerability, responsibility, and the constitution of subjects through relationships. Political economy can identify accumulation, control, productive conditions, extraction, enclosure, and structural asymmetry.

Neither level is sufficient alone for the present problem.

A purely interpersonal relational ethics can overlook infrastructures and capital processes whose effects occur beyond immediate encounters. A purely structural political economy can identify concentration or enclosure while leaving underdeveloped the historically situated interpretation of why a particular relation matters ethically to heterogeneous subjects.

GREthic places the two into a common sequence:

relational history $\rightarrow$ political-economic structure $\rightsquigarrow$ generative-relational interpretation. (185)

Political economy makes consequential structures visible. Generative Relational Ethics asks what those structures do to the conditions through which affected actors can continue to generate, recognize alternatives, contest relations, and revise their trajectories.

This connection also prevents political-economic categories from becoming automatic ethical verdicts.

Enclosure can describe a relational transformation whose justification still requires inquiry. Concentration can describe a structural condition without establishing domination. Extraction can identify a directional flow without settling whether the relation is exploitative.

At the same time, ethical interpretation should not use contextual complexity to dissolve structural criticism. A historically situated framework still needs political economy precisely because actors embedded within a relation can normalize dependencies and asymmetries that become visible only at a larger scale.

The two analytical layers therefore constrain one another.

14.6 Formal Structure and Hermeneutic Judgment

The formal apparatus developed in this paper is intended to address a recurring weakness in ethical discussion: relational histories are often compressed into isolated actions or simplified actor categories.

The 2-complex representation preserves temporal development. It allows ethical inquiry to distinguish a restriction imposed before dependency formed from the same restriction imposed after a field has reorganized around an intermediary. It can distinguish an actor that has always possessed a role from one that acquired the role through accumulation of capacities generated in other positions.

Formal structure therefore contributes to ethical explanation.

The framework nevertheless rejects the proposition

more formal detail $\longrightarrow$ automatic moral truth. (186)

No amount of graph resolution eliminates the need to interpret historical meaning, affected subjects, reasons, cultural significance, uncertainty, and the legitimacy of competing claims.

The formalism is consequently closer to a grammar for describing the object of ethical inquiry than to a calculus for resolving it.

This distinction is especially important where computational ethics is tempting. Once a relational history has been represented in machine-readable form, it becomes technically possible to calculate centrality, path diversity, concentration, accessibility, or other structural indicators.

Such indicators can reveal ethically relevant transformations.

A high dependency measure can identify a relation requiring attention. A decline in path diversity can reveal emerging infrastructural fragility. A rapid increase in role concentration can indicate a governance problem.

None of these quantities contains its own normative interpretation.

The proper relation is therefore

$$\text{measurement} \rightarrow \text{improved ethical inquiry}, \quad (187)$$

rather than

$$\text{measurement} \rightarrow \text{ethical verdict}. \quad (188)$$

14.7 Plurality and Relativism

The framework's acceptance of heterogeneous hermeneutic systems raises the question of relativism.

GREthic allows

$$\llbracket \mathcal{F} \rrbracket_{\mathcal{H}_A} \neq \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_B}. \quad (189)$$

It does not follow that every interpretation is equally defensible.

An interpretation can fail because it rests upon inaccurate relational facts. It can omit affected actors. It can make a dependency invisible. It can rely upon a historical justification whose conditions no longer exist. It can exclude evidence generated outside its prevailing categories. It can suppress the means through which alternative interpretations could be expressed.

Cross-relational criticism therefore remains possible.

Such criticism does not require an imaginary position outside every historical and relational system. It can proceed through comparison, encounter, consequences, internal inconsistency, newly generated evidence, and the perspectives of actors previously excluded from the dominant interpretation.

Re-cognizability becomes especially important here. A normative system is more capable of relational criticism when it preserves the conceptual possibility of encountering another system as something more than error or noise.

The relevant contrast is consequently

$$\text{normative plurality} \neq \text{normative immunity}. \quad (190)$$

Historically generated ethical worlds can remain open to transformation through relation with other worlds.

14.8 Governance Implications

Although the present paper does not propose a complete governance system, its framework suggests several implications for institutions governing public knowledge.

First, governance should preserve relational history. Decisions concerning access, restriction, licensing, infrastructure, and standards can be difficult to interpret ethically when the processes through which present dependencies emerged are forgotten.

Second, institutions should distinguish formal access from effective generative access. A resource can satisfy an openness requirement while remaining unusable to many relevant participants.

Third, governance should attend to path diversity. The existence of multiple viable routes can reduce destructive dependency and preserve future institutional choice.

Fourth, role accumulation deserves scrutiny where powers acquired through one function become operative in another. Distribution, evaluation, governance, commercialization, and infrastructure control can generate different responsibilities even when instantiated by one actor.

Fifth, restrictions should remain responsive to the reasons that sustain them. Protective closure becomes ethically fragile when its institutional structure prevents reassessment after the underlying risk environment changes.

Sixth, institutions should preserve contestability and re-cognizability. Governance becomes less revisable when affected actors lose the practical or conceptual means to formulate alternatives.

These considerations should not be converted into a universal governance scorecard. Their relevance varies across relational systems.

They instead indicate dimensions that a generatively oriented governance process should remain capable of recognizing.

14.9 AI-Mediated Knowledge Capital

Artificial intelligence provides a particularly important contemporary field for the framework because it changes the scale, velocity, and recursive capacity of knowledge-capital expansion.

AI systems can reduce the cost of searching, translating, synthesizing, classifying, recombining, and generating representations from large bodies of public knowledge. Actors who previously lacked the time or disciplinary background required to traverse several fields can gain new epistemic capacities through model-mediated interaction.

This can substantially increase individual and collective generativity.

The same process can intensify several political-economic transformations identified earlier. Large-scale processing can require concentrated computational infrastructure. Public knowledge can become input to privately controlled models. Model usefulness can attract users whose interactions improve the system further. Institutions can reorganize workflows around the resulting infrastructure.

A recursive cycle can therefore emerge:

$$K_{\text{public}} \rightarrow M_A \rightarrow C_A \rightarrow U_A \rightarrow D_A \rightarrow C'_A, \quad (191)$$

where M_A denotes an AI-mediated system, C_A its productive capacity, U_A increasing use, and D_A downstream dependency.

This cycle can be socially productive while simultaneously concentrating control.

AI also complicates attribution and epistemic capital. Generated outputs can draw upon very large bodies of prior public knowledge whose individual contributions are difficult to reconstruct in ordinary interaction. The resulting epistemic capacity can therefore have highly distributed generative origins while appearing through a concentrated interface.

This makes provenance, relational history, and institutional structure more important rather than less important.

The GREthic perspective also raises a distinctive concern with re-cognizability. AI systems can dramatically expand exposure to unfamiliar concepts, languages, and traditions. They can also mediate knowledge through dominant representational structures that progressively shape which distinctions users learn to make.

An AI-mediated knowledge environment is therefore ethically significant both for what it enables users to generate and for how it changes the generative grammar through which later knowledge becomes recognizable.

The framework does not support a categorical judgment that AI-mediated knowledge-capital expansion is liberating or enclosing. Both trajectories can occur, sometimes within the same system.

The relevant inquiry concerns how AI changes relational positions, infrastructural dependence, available paths, epistemic capacities, and the conditions under which alternative knowledge systems remain recognizable and generatively viable.

14.10 The Scope of the Proposed Framework

The combined framework should finally be understood as an analytical architecture rather than as a completed ethical system.

Its formal layer represents relational states and histories:

$$\Gamma_t, \quad \mathcal{F} : \Gamma_t \rightarrow \Gamma_{t+1}. \quad (192)$$

Its political-economic layer reconstructs consequential transformations:

$$\mathcal{F} \rightarrow \Delta_{\mathcal{F}} \rightarrow \mathcal{P}(\mathcal{F}). \quad (193)$$

Its normative layer embeds those histories in evolving generative-relational systems:

$$\mathcal{F} \hookrightarrow \mathcal{G}_{x,t} \rightsquigarrow \mathcal{H}_{x,t} \rightsquigarrow J_t. \quad (194)$$

The judgment remains revisable:

$$J_t \rightsquigarrow J_{t+1}. \quad (195)$$

These layers should remain distinguishable because each can fail in a different way. The formal representation can omit relevant relations. The political-economic interpretation can apply inappropriate categories. The hermeneutic system can fail to recognize affected subjects. The normative judgment can become detached from changing conditions.

No layer therefore guarantees the adequacy of the next.

The framework is strongest when these layers operate recursively. Normative disagreement can reveal missing formal relations. Political-economic analysis can expose dependencies that the prevailing hermeneutic system normalized. New historical evidence can alter both the relational representation and the ethical interpretation.

The framework should consequently remain capable of revising its own objects, categories, and representations.

The principal claim of the paper is therefore methodological as much as normative. The ethics of knowledge-capital expansion should be approached as the interpretation of evolving relational histories whose political-economic structure and normative meaning cannot be reduced to one another.

The final section returns to this claim and summarizes the resulting account of Generative Relational Ethics in public knowledge.

15 Conclusion

This paper has developed a Generative Relational Ethics of knowledge-capital expansion in public knowledge. Its starting problem was a normative tension internal to public knowledge itself. Public accessibility can support learning, criticism, recombination, circulation, and cumulative epistemic development. The same generative processes can also contribute to concentration, dependency, enclosure, extraction, institutional capture, and the formation of downstream infrastructures whose control differs substantially from that of the public resources from which they developed.

The paper has argued that these processes cannot be evaluated adequately by assigning fixed ethical values to visible relational forms. Openness is not identical with generativity. Closure is not identical with enclosure. Knowledge-capital accumulation is not identical with domination. Concentration does not by itself establish exploitation, and asymmetry does not by itself establish injustice.

The first contribution of the paper has therefore been to distinguish relational syntax from normative meaning. Public-knowledge processes can be represented through actors, roles, relations, events, dependencies, and transformations without assuming that their ethical interpretation is already contained in their formal structure.

The second contribution has been to represent this relational object through typed graph configurations and labelled 2-complexes. A relational state is represented by

$$\Gamma_t, \quad (196)$$

while a relational history connecting successive states is represented by

$$\mathcal{F} : \Gamma_t \longrightarrow \Gamma_{t+1}. \quad (197)$$

The 2-complex preserves actor-role trajectories, relational faces, higher-order events, and the historical development of dependencies and control. Its purpose is to formalize the object of ethical inquiry rather than ethical judgment itself.

The third contribution has been to insert political-economic interpretation between formal relational description and normative judgment. Accumulation, appropriation, concentration, enclosure, dependency, rent formation, extraction, externalization, capture, recursive advantage, and re-enclosure identify distinct transformations of the knowledge field. These categories can overlap, but none functions as an automatic ethical verdict.

The resulting architecture can be expressed schematically as

$$\mathcal{F} \longrightarrow \Delta_{\mathcal{F}} \longrightarrow \mathcal{P}(\mathcal{F}) \rightsquigarrow \llbracket \mathcal{F} \rrbracket_{\mathcal{H}_{x,t}}, \quad (198)$$

where $\Delta_{\mathcal{F}}$ summarizes relevant relational transformations, $\mathcal{P}(\mathcal{F})$ denotes their political-economic interpretation, and $\mathcal{H}_{x,t}$ denotes the historically generated hermeneutic system within which normative interpretation occurs.

Generative Relational Ethics therefore treats ethical meaning as historically generated and relationally situated. The same local relational syntax can receive different normative interpretations when embedded in different historical, cultural, institutional, technological, and political-economic systems:

$$\mathcal{F}_1 \cong \mathcal{F}_2 \not\Rightarrow \llbracket \mathcal{F}_1 \rrbracket = \llbracket \mathcal{F}_2 \rrbracket. \quad (199)$$

Historical situatedness does not remove the possibility of criticism. A central distinction developed throughout the paper is

$$\text{Gen}(J_t) \neq \text{Just}(J_t), \quad (200)$$

where the historical generation of a normative judgment remains distinct from its justification. Historically generated hermeneutic systems can themselves become ethically problematic when they erase affected actors, rigidify dependency, suppress alternative generative paths, prevent contestation, or become incapable of recognizing new evidence and changing relations.

This distinction supports a conception of normativity that is historically situated without becoming normatively arbitrary.

The paper has further argued that generativity should not be transformed into a scalar objective. GREthic does not seek to maximize aggregate generativity, openness, access, or another universal quantity. Generative conditions are heterogeneous and can conflict. Ethical inquiry must therefore remain responsive to relational position, affected actors, dependency, alternatives, foreseeable consequences, uncertainty, re-cognizability, and the capacity for future revision.

The central normative commitments of the framework are consequently expressed through the preservation and interpretation of generative conditions, relational responsibility, epistemic humility, re-cognizability, and revisability. These commitments do not constitute a fixed optimization rule. They orient inquiry toward the conditions through which heterogeneous actors and relational systems can continue to generate, recognize alternatives, contest governing relations, and revise earlier judgments.

The analysis of openness and closure illustrates the resulting approach. Restriction can be protective when severe risks, limited safeguards, and irreversible consequences threaten important generative conditions. The same restriction can acquire a different ethical meaning after those conditions change,

particularly when it begins to preserve dependency, exclusion, or an avoidable bottleneck. Ethical interpretation must therefore follow the history of the relation rather than attach a timeless moral value to its present syntax.

Role-dependent analysis leads to the same conclusion. Contributors, readers, reusers, publishers, distributors, platforms, commercializers, reviewers, commons members, and governance institutions occupy different positions within the relational field. Responsibility follows these positions and the capacities through which actors can affect the future generativity of others. Institutional identity alone does not determine ethical status.

The framework also has particular relevance to AI-mediated knowledge production. Artificial intelligence can radically expand the ability of individuals and institutions to traverse, synthesize, and recombine public knowledge. It can therefore broaden epistemic generativity while simultaneously accelerating recursive accumulation and concentrating computational, infrastructural, or platform control. The ethical interpretation of these processes depends upon how AI-mediated capacity alters the relational field, the viable paths available to other actors, and the conditions under which alternative forms of knowledge remain recognizable and generatively viable.

The paper has remained deliberately foundational. It does not provide a complete theory of justice, a universal taxonomy of political-economic wrongs, or a decision procedure for public-knowledge governance. The proposed graph and 2-complex representation also remains a working formal syntax whose adequacy should be evaluated according to the structures it preserves and the questions it enables.

The framework itself should therefore remain revisable.

Its central proposition is narrower. Ethical inquiry into knowledge-capital expansion should treat public knowledge as an evolving generative-relational field. The object of judgment is a relational history. Political economy clarifies how that history transforms access, capacity, control, dependency, and generative pathways. Normative interpretation emerges within historically generated systems of meaning and remains answerable to changing reasons, relations, and evidence.

The ethics of knowledge-capital expansion is consequently neither an ethics of maximum openness nor an ethics of opposition to accumulation. It is an inquiry into how knowledge-capital expansion enters relational histories, how those histories reshape the generative conditions of heterogeneous actors, and how their ethical meaning should remain open to recognition, criticism, and revision as the relational field continues to change.

References

- [1] Federico Battiston, Enrico Amico, Alain Barrat, Ginestra Bianconi, Guilherme Ferraz de Arruda, Benedetta Franceschiello, Iacopo Iacopini, Sonia Kéfi, Vito Latora, Yamir Moreno, Micah M. Murray, Tiago P. Peixoto, Francesco Vaccarino, and Giovanni Petri. The physics of higher-order interactions in complex systems. *Nature Physics*, 17:1093–1098, 2021.
- [2] Yochai Benkler. *The Wealth of Networks: How Social Production Transforms Markets and Freedom*. Yale University Press, New Haven, CT, 2006.
- [3] Vangie Bergum and John B. Dossetor. *Relational Ethics: The Full Meaning of Respect*. University Publishing Group, Hagerstown, MD, 2005.
- [4] Pierre Bourdieu. The forms of capital. In John G. Richardson, editor, *Handbook of Theory and Research for the Sociology of Education*, pages 241–258. Greenwood Press, New York, 1986.
- [5] James Boyle. *The Public Domain: Enclosing the Commons of the Mind*. Yale University Press, New Haven, CT, 2008.
- [6] Creative Commons. Attribution 4.0 international. Creative Commons Public License, 2013. CC BY 4.0.

- [7] Brett M. Frischmann, Katherine Haenschen, and Ari Ezra Waldman. Privacy and knowledge production across contexts. In Madelyn Rose Sanfilippo, Brett M. Frischmann, and Katherine J. Strandburg, editors, *Governing Privacy in Knowledge Commons*, pages 185–200. Cambridge University Press, 2021.
- [8] Brett M. Frischmann, Michael J. Madison, and Katherine J. Strandburg, editors. *Governing Knowledge Commons*. Oxford University Press, 2014.
- [9] Charlotte Hess and Elinor Ostrom, editors. *Understanding Knowledge as a Commons: From Theory to Practice*. MIT Press, Cambridge, MA, 2007.
- [10] Philip J. Kain. *Marx and Ethics*. Clarendon Press, Oxford, 1991.
- [11] Janja Komljenovic, Ben Williamson, Kean Birch, and Klaus D. Beiter. Assetizing academic content and the emergence of the ‘assetizen’: Education platforms, publisher databases, and ai model training. *Higher Education*, 2026. Advance online publication, 9 February 2026.
- [12] Timothy Lebo, Satya Sahoo, and Deborah McGuinness. PROV-O: The PROV ontology. W3c recommendation, World Wide Web Consortium, April 2013. W3C Recommendation, 30 April 2013.
- [13] Catriona Mackenzie and Natalie Stoljar, editors. *Relational Autonomy: Feminist Perspectives on Autonomy, Agency, and the Social Self*. Oxford University Press, 2000.
- [14] Karl Marx. *Capital: A Critique of Political Economy*, volume 1. Penguin Books, 1976.
- [15] Karl Marx and Friedrich Engels. *The German Ideology*. International Publishers, New York, 1970.
- [16] Robert K. Merton. Priorities in scientific discovery: A chapter in the sociology of science. *American Sociological Review*, 22(6):635–659, 1957.
- [17] Robert K. Merton. The matthew effect in science. *Science*, 159(3810):56–63, 1968.
- [18] Helen Nissenbaum. *Privacy in Context: Technology, Policy, and the Integrity of Social Life*. Stanford University Press, 2010.
- [19] Alejandro Perez. The spin-foam approach to quantum gravity. *Living Reviews in Relativity*, 16(1):3, 2013.
- [20] Yan Shvartzshnaider, Madelyn Rose Sanfilippo, and Noah Apthorpe. Contextual integrity as a gauge for governing knowledge commons. In Madelyn Rose Sanfilippo, Brett M. Frischmann, and Katherine J. Strandburg, editors, *Governing Privacy in Knowledge Commons*, pages 220–244. Cambridge University Press, 2021.
- [21] Peter Suber. *Open Access*. MIT Press, Cambridge, MA, 2012.
- [22] UNESCO. Recommendation on open science. Adopted by the General Conference of UNESCO at its 41st session, November 2021. Adopted 23 November 2021; accessed September 6, 2026.
- [23] Pieter Verdegem. Dismantling ai capitalism: The commons as an alternative to the power concentration of big tech. *AI & Society*, 39:727–737, 2024. First published online 9 April 2022.
- [24] Yuanzhao Zhang, Maxime Lucas, and Federico Battiston. Higher-order interactions shape collective dynamics differently in hypergraphs and simplicial complexes. *Nature Communications*, 14:1605, 2023.