

Sustaining Generativity under Epistemic Capitalism: A Praxis for the Epistemic Proletariat

Wanhong HUANG
huangwanhong@serendip.ngo

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Abstract

This paper develops a praxis for sustaining inquiry under unequal control of its material and institutional conditions. It defines the epistemic proletariat relationally through the dependence of inquiry-capable people and collectives on externally governed means of production and reproduction. Historical materialist diagnosis is joined to a differentiated account of ocean–atmosphere dynamics and to conditional models of viable action. Oceanic transport, water-property transformation, air–sea exchange, topographic mediation, waves, and moving coastal boundaries supply distinct causal roles for conceptual construction. An explicit translation procedure connects these roles to social hypotheses. Process I, generative upwelling, concerns viable changes in access, capabilities, relations, and constraints. Process II concerns adaptive intervention under changing conditions, combining a revisable local model with supervision of action windows, controllability, uncertainty, and continuation. The analysis distinguishes field-mediated cost reduction, stable transient amplification, critical slowing, and actual transition. Worked derivations establish how limited action depends on control channels, target geometry, response delay, and resource reserves. Generative layers are represented as overlapping regimes of constraint, with control and return operating across them. Reproduction and recirculation connect immediate outcomes to the possibility of subsequent inquiry and to collective changes in governing institutions. A constructed research-association case and bounded historical contrasts clarify the scope of the framework. The contribution is an integrated theoretical account of viable access, timed intervention, and governed continuation. Physical laws and mathematical results remain distinct from empirical social explanation and situated normative judgment.

Keywords: generativity; epistemic capitalism; epistemic proletariat; historical materialism; generative justice; ocean–atmosphere dynamics; viability; adaptive governance; collective praxis; reproduction

深处借势而升，临界借扰而变

*In depth, rise with available forces; near a transition, change through
perturbation.*

DRAFT

Authorial formulation developed in the exploratory dialogue.
The analytical distinctions and conditions are developed in the paper.

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This paper circulates as a discussion paper for reflection, discussion, and concept development. It makes no claim to have originated any of the concepts it presents. Similar or related concepts may already exist in other works or traditions. To the best of the author's knowledge, the paper identifies relevant theories, concepts, and precedents, while acknowledging that its account may be incomplete. Objections, criticism, corrections, references to overlooked work, and further discussion are welcome as contributions to its continuing development.

This discussion paper examines the conditions under which people and collectives can sustain meaningful inquiry while depending on infrastructures, institutions, and resources governed by others. It develops a praxis of material reproduction, changing access, adaptive intervention, and collectively governed return. The subject includes employed researchers, independent inquirers, and research associations wherever the relevant relation of dependence can be demonstrated.

The argument brings historical materialist diagnosis into conversation with generative justice, ocean-atmosphere dynamics, and mathematical control. These contributions perform different tasks. Political economy identifies relations of production and control. Ocean dynamics supplies differentiated mechanisms for conceptual construction. Mathematics establishes consequences of declared models. Historical and institutional investigation tests their social interpretation. Ethical evaluation concerns the purposes, rights, burdens, and relations involved in a particular practice.

The paper organizes its praxis through two recurrent processes. Generative upwelling changes the conditions that make inquiry and participation feasible. Adaptive transition identifies and realizes a bounded intervention under changing circumstances. Reproduction and recirculation operate throughout both processes, connecting present activity to continued inquiry. A transition has practical significance only in relation to the conditions and possibilities that follow it.

The formal results are conditional. Several elementary models are solved explicitly and checked numerically, while the social state variables and objectives remain proposals requiring empirical and participant justification. The historical materials are used as bounded contrasts. The framework's adequacy for a particular institution depends on evidence concerning its actual action channels, resource costs, observation limits, decision rights, and reproductive consequences.

The draft preserves a distinction between formal representation and situated normative interpretation. Its models can clarify a constraint or reveal an inconsistency in a proposed action. They cannot decide the value of an inquiry, the justice of an allocation, or the acceptability of a burden independently of historical and relational judgment.

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Statement on the use of language models. The development of this draft involved OpenAI’s ChatGPT and Codex for exploratory dialogue, literature discovery and verification, mathematical reconstruction, criticism, drafting, and document preparation. The human author directs the research programme and retains responsibility for reviewing the draft’s arguments, sources, calculations, and conclusions. Language-model assistance does not confer authorship. The present text remains subject to the author’s substantive review.

Research materials. The accompanying preparation package contains the conceptual refinement, derivation notebook, source ledger, verified bibliography, and reproducible numerical checks. The manuscript develops these materials into a continuous argument. Its historical contrasts have the evidentiary limits stated in the text.

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1 Introduction

This paper examines the practical conditions under which inquiry can continue when the means of producing and sustaining knowledge are unequally controlled. It develops a praxis connecting material reproduction, changes in access, adaptive intervention, and the governance of returns. The argument proceeds through political economy, a differentiated ocean–atmosphere account, and explicit models of viable action. These components establish a framework for investigation and practice under conditions that remain historically and institutionally specific.

1.1 Conditions of epistemic production

Publicly available knowledge can expand the possibilities of inquiry while leaving the conditions of effective participation unequal. A researcher may obtain an article yet lack the instrument needed to test its result. A community may contribute data while possessing little authority over the models constructed from it. A research association may gain access to a computational service whose price, availability, and renewal remain externally determined. Such situations bring knowledge circulation into relation with livelihood, infrastructure, time, institutional rules, and control.

The political-economic problem concerns the organization of these relations. An increase in available information can coexist with a widening difference between those able to convert it into further inquiry and those dependent on externally governed conditions. Academic-capitalism research and work on AI concentration identify institutional contexts for examining this difference [34, 39]. The 2026 AI Index reports that industry produced more than 90% of its category of notable models in 2025 [35]. That indicator concerns a specified category of model development. It provides a bounded illustration of infrastructure asymmetry, without measuring the whole field of knowledge production.

The consequences appear in the organization of ordinary research. A project can be intellectually promising and materially unsustainable. Access can arrive after the relevant occasion has passed. A contribution can attract attention while increasing unpaid maintenance work. Conversely, cooperation can change the available instruments, provide protected time, or establish a more durable form of participation. A theory of praxis must distinguish these mechanisms and examine how they interact.

1.2 Generativity and the epistemic proletariat

Generativity refers here to the situated capacity to initiate, sustain, revise, and connect meaningful inquiries, including the reproduction of their enabling conditions. Its exercise can produce publications, artifacts, methods, relationships, or clarified problems. No single output type exhausts the capacity. Periods of learning, reflection, maintenance, and recovery can contribute to its continuity even when they produce few immediately visible results.

The epistemic proletariat is defined through a relation of dependence: inquiry-capable people and collectives rely on indispensable conditions governed by others, under arrangements that confer consequential power over access, direction, or return. This definition concerns relations of production rather than credentials or an income category alone. Salaried and independent researchers can occupy different forms of the position. A collective can reduce dependence at one scale while encountering it at another.

The central problem is the preservation and transformation of generative conditions within these relations. Individual ingenuity can matter, but the available actions depend on institutions and cooperation. A shared facility, a maintenance agreement, a bargaining process, or a public provision can change what individuals are able to do. Collective agency therefore enters the framework as a possible change to the surrounding field.

1.3 Processes of praxis

The paper distinguishes two recurrent processes. Process I, generative upwelling, concerns viable changes in access, capabilities, relations, and constraints. It includes learning and repositioning as well

as organized changes to the institutions that govern inquiry. Process II concerns adaptive intervention under changing conditions. It includes identifying a feasible direction, fitting action to a temporal opening, and establishing a continuation after entry into a desired arrangement.

Reproduction and recirculation connect both processes to subsequent inquiry. Returns may include resources, learning, access, relationships, and decision rights. Their consequences depend on who receives them, whether they can be converted into usable conditions, and which maintenance costs follow. Entry into a desirable arrangement is therefore evaluated together with the ability to continue within or beyond it.

Ocean dynamics provides a disciplined source of distinctions for this construction. Transport, property transformation, wave propagation, air–sea exchange, and moving coastal boundaries involve different mechanisms. The corresponding social analysis must likewise distinguish movement through an existing field, changes in productive capacity, coordination, and institutional transformation. Section 5 states an explicit translation procedure linking physical mechanisms to abstract roles and then to social hypotheses.

1.4 Contribution and organization

The contribution is the integration of viable access, timed and controllable intervention, and reproductive continuation within a relational account of epistemic production. Generative justice, including Eglash and Garvey’s basin framework, is a direct predecessor [8]. The present analysis adds explicit distinctions concerning resource constraints, action channels, response delays, partial observation, and the persistence of outcomes. Its mathematical results concern specified models; the social applications remain hypotheses requiring evidence and situated judgment.

Section 2 reviews the relevant literature, and Section 3 establishes the philosophical and methodological commitments. Sections 4–7 develop the physical foundation, conceptual mapping, generative layers, and contradiction-guided diagnosis. Sections 8–12 formalize the processes and their integration with reproduction. A constructed case and bounded historical contrasts follow in Section 13. The final sections specify evidence, limitations, and institutional implications. The appendices provide derivations and a protocol for examining applications.

2 Literature Review

This section locates the paper within research on capitalist knowledge production, collective organization, generative justice, hydrosocial relations, ocean dynamics, and adaptive control. The review compares the explanatory work of these traditions and identifies the connections developed here. Its purpose is a theoretically directed synthesis. The source record accompanying the manuscript distinguishes inspected texts, abstracts, and bibliographic records; detailed historical claims are confined to the material examined.

2.1 Labor, knowledge, and accumulation

Political economy directs attention to the relation between productive capabilities and command over their conditions of exercise. Marx’s 1859 preface provides a formulation of the historical relation between productive forces and relations of production [20]. For epistemic production, this orientation requires examining the institutions through which knowledge-bearing people obtain instruments, time, cooperation, and the means of subsistence. The possession of a productive capacity and authority over its deployment are distinct questions. An analysis restricted to the quantity of knowledge an individual possesses therefore leaves the relevant relations of production incompletely specified.

Labor-process research supplies a neighboring set of questions. Braverman’s study concerns the organization and degradation of work under monopoly capital; Burawoy examines the production of consent within the labor process [3, 4]. These works identify an established field in which control, work

organization, and participation require explanation. Their relevance here lies in that problem orientation. A direct transfer of an industrial workplace analysis to every form of research would require additional argument concerning employment, ownership, professional authority, and the organization of inquiry.

The present analysis distinguishes two processes that can accompany one another. Epistemic development concerns changes in the capacity to understand, investigate, criticize, and generate further inquiry. Capital accumulation concerns historically organized claims over assets, labor, revenues, and future returns. A research result can contribute to both processes through different relations. The distinction permits examination of cases in which public circulation expands knowledge while the infrastructure required to act upon that knowledge becomes more concentrated. It also permits recognition of inquiry whose contribution to collective understanding carries little exchange value.

2.2 Academic capitalism and artificial intelligence

Academic-capitalism research addresses connections among higher education, markets, the state, and the commercialization of knowledge. Slaughter and Rhoades organize their study around policies, institutional practices, and organizational relations connecting universities and markets [34]. This provides an established context for examining how the conditions of inquiry change through funding, intellectual-property arrangements, managerial organization, and the treatment of students and researchers. The relevant unit extends beyond an individual scholar's motivations.

Contemporary AI infrastructures intensify the importance of this distinction between available artifacts and productive control. Verdegem analyzes concentrated corporate power in AI and develops a commons-oriented alternative [39]. The analysis makes ownership and governance relevant to debates frequently organized around the capabilities of individual systems. Publicly usable interfaces can coexist with unilateral authority over prices, withdrawal, access priorities, and technical changes. Conversely, a collectively governed infrastructure may still require concentrated expertise and continuing external support. Institutional form and effective capability consequently need joint examination.

These literatures support the present problem while leaving room for a more explicit account of situated action. A diagnosis of concentration does not by itself identify how a particular research association should allocate its next month of work. Equally, a practical arrangement that improves one group's access need not alter the underlying distribution of authority. The framework developed below connects those scales through a distinction between trajectory changes within a field and organized changes to the field's rules, resources, and control channels.

2.3 Cooperation, organization, and reproduction

Historical arguments about cooperation already connect immediate productive practices to wider political conditions. Marx's 1864 address discusses cooperative production alongside the limitations of isolated initiatives and the significance of broader political organization [21]. Gramsci's account of factory-council formation in 1919 records an effort to create workplace representation through workers' own organizational activity [13]. Both sources make collective organization part of the object of praxis. They are primary political texts whose descriptions and judgments require historically situated interpretation.

The contribution of these materials to the present inquiry concerns mechanisms of association. Shared work can produce capacities for representation, coordination, learning, and mutual provision. Such capacities can subsequently alter the conditions under which individual work occurs. The sequence is potentially recursive: an association enables action; action changes the association's resources and authority; the changed organization conditions later action. Its persistence depends on maintenance and on relations with institutions outside the association.

Institutional evidence also cautions against treating cooperative organization as a sufficient explanation of durability. Mondragon's historical account describes linked cooperative institutions, while its 2013 report records a major enterprise crisis and employment-support responses [22, 23]. These materials justify examining productive organization together with supporting institutions and exposure to

failure. Their corporate provenance limits the conclusions available from them alone. Section 13 uses them as bounded contrasts concerning infrastructure and reproduction.

2.4 Generative justice

Generative justice supplies a direct predecessor for the connection between productive contributors, the conditions of production, and the circulation of returns. Eglash and Garvey explicitly employ basins of attraction to discuss generative arrangements, including relationships among cooperation, participation, and supporting conditions [8]. Their contribution matters to the genealogy of the present project: a dynamical vocabulary already exists within this literature.

Eglash’s historical discussion places generative justice in a critical relation to his interpretation of Marxist centralization [7]. The argument should be treated as a substantive position within the debate. Historical materialist diagnosis and decentralized generative organization cannot simply be declared identical. Their relationship requires examination of the institutions that exercise control, the scales at which coordination is necessary, and the forms through which participants can contest decisions.

Computational reparations extends this concern to computational support for value generators and the restoration of circular value flows [9]. This perspective makes the organization of return central to evaluating a technical intervention. A useful computational artifact can participate in extractive relations if the people maintaining its conditions receive insufficient support or authority.

The extension proposed in this paper concerns the relation among constrained access, identifiable action channels, limited response time, and reproductive continuation. These are additional specifications of a praxis problem. They permit examination of cases in which an opening exists but remains unactionable, or an intervention succeeds initially while its consequences cannot be sustained. The formal construction is intended to make those distinctions inspectable. Its evaluative interpretation remains accountable to participants and to the historical relations that give the outcomes their meaning.

2.5 Ocean circulation and transformation

Oceanographic research distinguishes circulation pathways, energetic maintenance, and transformations of water properties. Cessi’s review organizes the global overturning circulation, while Marshall and Speer examine closure through Southern Ocean upwelling [5, 19]. This literature replaces an undifferentiated image of upward travel with a question about linked pathways and the mechanisms that maintain them.

The distinction becomes especially consequential near boundaries. Ferrari and colleagues analyze the relationship among mixing, interior transformation, and boundary processes [10]. Observations within a sloping submarine canyon provide evidence of localized diapycnal upwelling [42]. Together, these contributions motivate explicit attention to geometry and flux divergence. A large local mixing coefficient does not determine the direction of vertical motion independently of the surrounding budget.

Wave research connects large-scale forcing to spatially distributed transformation. Internal tides arise through the interaction of tidal currents with topography; wave propagation and subsequent instability can distribute energy beyond the generation site [11, 32]. Reviews of internal-wave mixing and upper-ocean turbulence identify the need to consider multiple forcing and dissipation pathways [6, 41]. Wind, wave, and current interactions also involve feedback among components [12]. These mechanisms support a differentiated account of external forcing, local coupling, and delayed effects.

Water-mass transformation provides an integrative framework for connecting property budgets to circulation and biogeochemistry [14, 40]. The object being transformed is a class defined by properties; its changing membership differs from the history of a single tagged parcel. This distinction will matter to the conceptual translation. A change in collective classification, an individual’s movement, and a transformation of productive capability are likewise different empirical objects, although they may interact.

2.6 Hydrosocial relations

Hydrosocial research already examines the relation between water, infrastructure, authority, and social organization. Linton and Budds develop a relational-dialectical account of the hydrosocial cycle, while the hydrosocial-territories literature emphasizes political and spatial relations [2, 17]. These contributions establish a relevant precedent for treating material flows and social power together.

The present use of ocean dynamics has a different immediate object: the construction of a praxis for people dependent on externally governed epistemic conditions. Nevertheless, the hydrosocial literature disciplines that construction. An infrastructure's physical operation and its institutional organization enter the same historical situation. A laboratory, data repository, or computing facility possesses technical properties while also embedding rules of admission, maintenance, and command. Describing only the flow of information would leave those relations unspecified.

The conceptual translation therefore includes a distinct intermediate level. A physical mechanism identifies an abstract causal role, such as transport through an existing field, transformation of a carried property, or access through a moving boundary. The proposed epistemic counterpart then requires evidence of a social mechanism. This procedure provides a route from analogy to researchable claims while preserving the differences between fluid motion and purposive collective action.

2.7 Control, transient dynamics, and tipping

Control theory separates the evolution a system would undergo from the interventions available to an actor. Its relevance here concerns that distinction and the effects of limited resources, incomplete observation, and finite horizons. Optimization-based control and model-predictive control provide explicit architectures for comparing actions, representing constraints, and revising decisions as observations arrive [24, 31]. Their engineering results apply under mathematical assumptions that a social application must examine independently.

Transient-dynamics research further distinguishes stability from finite-time response. Trefethen and colleagues show the significance of nonnormal dynamics for hydrodynamic stability analysis [38]. A stable linear system can amplify particular perturbations before their eventual decay. This supplies a direct counterexample to the claim that every large response indicates nonlinear transition.

Tipping research distinguishes changes associated with bifurcation, noise, and the rate of environmental change [1]. Research on early-warning signals also identifies circumstances in which recovery slows as a transition approaches [33]. Consequently, rapid environmental variation, high susceptibility, slow local relaxation, and rapid institutional response require separate descriptions. Their combination in a particular case must be demonstrated.

These distinctions are useful because practical narratives often compress them. A successful action may exploit favorable drift without amplification; an amplified response may leave the governing regime intact; a stable arrangement may fail to track rapidly changing conditions. Sections 9 and 10 develop elementary models that separate these possibilities.

2.8 Integrative contribution

The proposed contribution concerns the organization of a sequence of problems. An inquirer must remain able to continue, obtain or transform access, identify an actionable opening, intervene through effective channels, and secure a viable continuation. Different literatures illuminate different relations within this sequence. Table 1 records their principal roles and the additional connection developed here.

This synthesis supports a bounded theoretical claim. The paper develops a common interface among these concerns and derives several consequences of specified models. Establishing the framework's empirical adequacy requires investigation of actual projects, associations, and institutions. Establishing its political and ethical value requires argument about the relations it helps to preserve or change.

Table 1: Literature contributions and the integration developed in this paper

Tradition	Existing analytical contribution	Connection developed here
Political economy and labor process	Productive conditions, control, appropriation, and work organization	Relations between situated intervention and collective changes to field conditions
Generative justice	Generators, governed return, and generative arrangements	Entry cost, action channels, timing, and continuation
Ocean dynamics	Coupled transport, property transformation, forcing, and boundaries	A differentiated source of causal roles for conceptual construction
Hydrosocial analysis	Material flows and historically organized social power	An explicit translation procedure for epistemic praxis
Control and transition theory	Reachability, transient response, constraints, and adaptation	A conditional operational account joined to reproduction and situated judgment

3 Philosophical and Methodological Framework

This section establishes the material, relational, and historical commitments governing the argument. It first defines the conditions and positions represented by the framework, then develops the role of dialectical diagnosis and collective agency. It concludes by distinguishing mathematical representation, empirical explanation, and normative judgment.

3.1 Material conditions of inquiry

Inquiry requires organized conditions of activity. An embodied researcher needs subsistence, care, rest, and usable time. A research practice also depends on inherited languages, techniques, instruments, archives, and relations of cooperation. These conditions vary with the object and method of inquiry. Some projects require specialized equipment; others depend principally on access to people, places, or a community's trust. Their heterogeneity prevents a complete account through a single stock of information.

The material character of these conditions does not imply that every relevant relation is a physical possession. A permission, a reliable commitment, or recognized authority to participate can determine whether an instrument is usable. Material analysis therefore includes the institutions through which possibilities become effective. A public database that cannot be interpreted, processed, or questioned within available time represents a different condition from a usable research resource.

The distinction between possession and effective use also clarifies the reproduction of epistemic capacity. A researcher may retain remembered knowledge while losing the conditions needed to employ it. Exhaustion, exclusion, discontinued software support, or the withdrawal of an indispensable collaborator can make an otherwise familiar method impracticable. Conversely, a modest addition to shared infrastructure can render existing abilities usable. Generativity concerns the continuing relation between capacities and their conditions of exercise.

Definition 3.1 (Generative capacity). Generative capacity is the situated ability of a person or collective to initiate, sustain, revise, and connect meaningful inquiries, including the ability to reproduce the conditions upon which subsequent inquiry depends.

The definition identifies an object of analysis while leaving meaningfulness open to situated justification. Different communities may disagree about a project's significance, appropriate methods, or acceptable burdens. Such disagreement enters the governance of inquiry. It should remain visible when a model selects a target or evaluates a continuation.

3.2 Epistemic capitalism and productive control

Epistemic capitalism denotes, in this paper, an organization of knowledge production in which capacities, infrastructures, and outputs become objects and means of capitalist accumulation. Its analysis concerns the institutional relations connecting productive activity to ownership, investment, command over labor, appropriation, and claims on future returns. The term identifies a political-economic configuration whose operation must be demonstrated in particular settings.

The distinction from epistemic development is consequential. An increase in reusable knowledge or competence can expand productive possibilities without establishing a corresponding claim to profit or control. Capitalist accumulation involves further relations through which these possibilities are owned, governed, financed, or appropriated. Conversely, an institution can expand the value of its assets while restricting the inquiry that particular contributors are able to pursue.

Epistemic capitalism can operate through public and cooperative settings as well as private firms. The relevant question is how the setting connects to accumulation and control. Publicly financed work can enter arrangements that concentrate downstream authority; a cooperative can depend on commercially governed infrastructure. Identifying such a connection requires evidence about contracts, financing, asset control, work organization, or return allocation. The presence of hierarchy or scarcity alone is insufficient to establish a capitalist relation.

This qualification also governs the class concept. Ordinary institutional dependence includes many relations that cannot be classified through ownership alone. A publicly accountable allocation rule, a community's stewardship obligation, and an investor's power over a productive platform have different histories and consequences. The analysis should specify which relation grants control, how that control is reproduced, and how it connects to the surrounding political economy.

Generative capacity and capitalist command can therefore develop unevenly. A contributor can acquire substantial competence while remaining unable to determine the conditions of its use. A collective can increase its shared capacity while its dependence on an indispensable external service intensifies. These configurations motivate the relational definition that follows and the distinction between local access gains and changes to governing institutions.

3.3 Relational position and epistemic proletarianization

The concept of an epistemic proletariat identifies a relation between productive capability and control over indispensable conditions. Ordinary interdependence becomes a question of class when dependence grants others consequential powers to direct activity, exclude participants, appropriate returns, or determine continuation. The degree and form of these powers require empirical specification.

Definition 3.2 (Epistemic proletarian position). An epistemic proletarian position is a relation in which a person or collective possesses capacities for inquiry while depending substantially on conditions of epistemic production and reproduction governed by others, within arrangements connected to capitalist accumulation that confer consequential authority over access, direction, or return.

The definition includes several possible contractual and organizational situations. Salaried employment may provide stable resources while subordinating research direction. Independent inquiry may preserve agenda choice while leaving access precarious. A small organization can exercise internal autonomy while remaining dependent on a platform, funder, or public authority. These differences matter because they imply different avenues of action.

A person may occupy different positions across projects. Ownership of a tool for one inquiry does not confer control over the infrastructure of another. A collective can also reduce its members' dependence while becoming vulnerable at a larger scale. The analysis therefore records the relation, indispensable condition, counterpart, and temporal horizon. Proletarianization names a process through which the separation between productive capacities and effective command over their conditions is extended or intensified.

This formulation permits examination of intermediate and contradictory positions. A researcher may be subordinated to a funding institution while exercising exclusionary authority over students or assistants. An association may defend open inquiry while transferring maintenance costs to unpaid contributors. Class analysis must trace these differentiated relations rather than assign an exhaustive moral identity to each person.

3.4 Historical materialism and contradiction

Historical materialism provides a method for examining the conditions under which productive capacities and institutions develop together. Marx's account of the relation between productive forces and relations of production establishes a point of departure [20]. The present inquiry uses that orientation to examine historically specific configurations of knowledge, infrastructure, livelihood, and control. A diagnosis must identify the institutions and practices through which its claimed tendencies are reproduced.

The term contradiction concerns relations that generate opposed tendencies while binding those tendencies together. Public research may depend on wide circulation while the institutions financing it seek exclusive appropriation. A platform may require contributions from a broad community while limiting that community's authority over maintenance and access. These formulations identify possible relations for investigation. Demonstrating a contradiction requires explaining how the tendencies arise from the same organized configuration.

Mao's discussion of principal contradictions and principal aspects provides a more specific vocabulary for strategic diagnosis [18]. Its use here is methodological and historically attributed. A principal-relation diagnosis proposes that a particular relation organizes the present configuration of obstacles and possibilities. It must be supported through investigation of causation, mediation, and feasible change.

The diagnosis remains revisable because interventions can transform the configuration they address. Access to an instrument can expose a previously secondary shortage of interpretive competence. A successful collaboration can make control over renewal more consequential. The same practical obstruction can also arise from different relations. An inability to finish a study might reflect a training need, a care burden, an exclusionary evaluation system, or a combination. Section 7 develops the corresponding discipline of diagnosis.

3.5 Collective agency and changes to the field

The subject of praxis can be an individual, association, cooperative, network, or public institution. These subjects possess different action channels. An individual can change a method, negotiate a commitment, or preserve time. An association can pool resources, maintain a shared record, and represent demands. Public institutions can provide infrastructure and change rules at scales inaccessible to smaller actors.

Collective action changes more than the amount of available effort. It can create new kinds of intervention. A pooled instrument changes the resource constraint; a maintenance agreement changes the expected duration of access; a representation rule changes who can decide. These changes belong within the dynamics of the field. Treating the field as permanently external would exclude an essential aspect of political praxis.

The formation of a collective is itself a material process. Coordination consumes time, conflict requires institutions of resolution, and delegated roles can become concentrated powers. Participation may impose unequal burdens when some members have less discretionary time or greater exposure to retaliation. A collective's formal openness therefore needs examination alongside effective voice, exit, representation, and support.

The framework admits both local improvement and wider transformation. A researcher who secures access has achieved a consequential change in the conditions of inquiry. Whether the action changes the relation of subordination at a broader scale is a further question. The distinction permits practical gains to be assessed without making them stand for an entire transformation of the political economy.

3.6 Abstraction, evidence, and normative interpretation

The argument operates at several levels. Physical equations describe a declared approximation to material processes. Mathematical derivations establish consequences of specified assumptions. Social models propose variables and mechanisms for a particular institutional setting. Normative interpretation evaluates the purposes, burdens, rights, and consequences involved. Movement between these levels requires explicit justification.

A target set, for example, can specify continued access to a laboratory. Mathematics may establish the minimum intervention cost under a model of admission and resource use. Empirical inquiry must determine whether the assumed controls and costs correspond to the institution. Normative inquiry must assess whose projects receive access, whose work maintains the laboratory, and which forms of authority the arrangement creates. The cost calculation cannot settle those questions by itself.

The same distinction applies to success. A transition can satisfy a modeled target while imposing new dependencies on contributors elsewhere. A project can remain productive by drawing down unpaid care or ecological resources outside the modeled boundary. Adequate interpretation therefore includes the choice of boundary and the people whose activities sustain it. The model should support this inquiry by making exclusions and dependencies inspectable.

This methodological arrangement preserves a role for formal reasoning without assigning it authority over the whole practical situation. A useful model can reveal an inconsistency, distinguish causal mechanisms, or show that a proposed action cannot fit the available time. Participants can then revise the model, reject its target, or change the institution. Reflexive revision is part of the praxis being modeled.

4 Ocean–Atmosphere Foundations

This section develops the physical foundation of the framework through conservation laws, constitutive relations, and boundary conditions. It distinguishes circulation from property transformation, then connects deep pathways to waves, atmosphere, chemistry, biology, and coasts. The purpose is to identify compatible mechanisms whose abstract roles can subsequently be examined in epistemic production.

4.1 State, geometry, and the tracked object

An oceanic state includes velocity, pressure, temperature, salinity, composition, and the geometry of its boundaries. These variables occupy different roles in the equations. Pressure gradients and buoyancy enter momentum; temperature and salinity determine density through a thermodynamic relation; topography constrains boundary motion; mixing transports properties; reactions transform chemical species. A comprehensive account must connect these roles through compatible budgets.

For a local rotating, incompressible Boussinesq approximation, let $\mathbf{v}$ be velocity, z increase upward, b denote buoyancy relative to a reference density ρ_0 , and π denote pressure divided by reference density after removal of a reference hydrostatic component. With vertical Coriolis parameter f , molecular viscosity ν , and tide-generating potential Ψ_T , the momentum and mass balances are Equation 4.1.

$$\begin{aligned} \frac{D\mathbf{v}}{Dt} + f\mathbf{e}_z \times \mathbf{v} &= -\nabla\pi + b\mathbf{e}_z - \nabla\Psi_T + \nu\nabla^2\mathbf{v}, \\ \nabla \cdot \mathbf{v} &= 0, \quad \frac{D}{Dt} = \partial_t + \mathbf{v} \cdot \nabla. \end{aligned} \tag{4.1}$$

Each acceleration term has dimensions of length per time squared. Surface stress supplies a momentum boundary condition; it should be represented consistently if the surface layer is instead integrated into a reduced model. Coriolis acceleration changes direction while its scalar product with velocity is zero. Its role concerns the organization of motion rather than a direct supply of mechanical energy. The local rotating-frame approximation has a defined range of applicability [30].

The tracked object also requires specification. A tagged parcel follows the velocity field and may exchange heat and dissolved substances. A tracer cloud spreads and can lose a compact identity. A water

mass is a class defined by properties, so its membership changes when those properties change. A statement that deep water reaches the surface can refer to different aspects of these objects. Distinguishing them avoids assigning one trajectory to an entire property class.

Density is pressure dependent. TEOS-10 provides the thermodynamic reference for Absolute Salinity, Conservative Temperature, pressure, and density [36, 37]. For local stability calculations, a pressure-referenced buoyancy approximation is necessary: a vertical gradient of raw in-situ density at great depth includes compression. In a locally stable reference state, $N^2 = \partial_z \bar{b} > 0$ defines the squared buoyancy frequency. A small adiabatic parcel displacement ζ produces restoring buoyancy $-N^2 \zeta$, with local available potential energy $N^2 \zeta^2 / 2$ per unit mass. Appendix A states the approximation and its derivation.

4.2 Deep pathways and boundary transformation

The overturning circulation connects pathways that differ in geometry, property change, and energetic maintenance [5, 19]. Motion along a sloping density surface can change geometric height while largely retaining the same locally referenced density class. Cross-density motion requires a corresponding change in the parcel's relation to surrounding buoyancy. Consequently, a universal account of ascent through successive fixed gravitational levels would obscure the governing dynamics.

A useful local identity makes this distinction explicit. Let a buoyancy surface be $z = Z_b(\mathbf{r}_h, t)$, with $\partial_z b \neq 0$, and write the material buoyancy tendency as $Db/Dt = Q_b$. Differentiating the surface condition and combining it with the material budget yields Equation 4.2.

$$w = \partial_t Z_b + \mathbf{v}_h \cdot \nabla_h Z_b + \frac{Q_b}{\partial_z b}. \quad (4.2)$$

The terms distinguish motion of the buoyancy surface, advection along its slope, and a vertical component of motion relative to the surface. The corresponding normal relative speed is $Q_b/|\nabla b|$. A parcel's upward velocity can therefore combine several mechanisms. Its interpretation depends on the reference surface and the property budget.

In a steady one-dimensional interior approximation with vertical diffusivity K , the buoyancy equation gives $wN^2 = \partial_z(KN^2)$. With constant N and $K = K_0 e^{-z/\ell}$, it gives $w = -K/\ell < 0$. This calculation is an interior sign example, not a closed global circulation. Its significance is that mixing magnitude alone is insufficient: the relevant derivative and boundary geometry determine the local transformation. Ferrari and colleagues' analysis and observations of canyon upwelling motivate precisely this attention to boundary processes [10, 42].

Ridges, sills, slopes, and canyons can redirect flow, alter exchange, and concentrate wave conversion or turbulent processes. A stationary topographic boundary does not provide an unlimited energy source. It mediates interactions with maintained currents and waves. The energy supplied by tides or winds can be transformed at one location and dissipated elsewhere, while property transformation and circulation close through a broader spatial pattern.

4.3 Waves, shear, and irreversible mixing

Internal gravity waves arise in stratified water, with rotation modifying their propagation. Tidal currents moving over topography can generate internal tides, and the resulting waves can transmit energy away from their source [11]. Their interaction with shear, boundaries, and other waves can produce instability and turbulence [32, 41]. This connects external forcing to local transformation through a sequence whose stages remain physically distinct.

For a uniformly stratified, inviscid rotating fluid, a plane wave with horizontal wavenumber k_h and vertical wavenumber m has intrinsic frequency specified by Equation 4.3.

$$\omega^2 = \frac{N^2 k_h^2 + f^2 m^2}{k_h^2 + m^2}. \quad (4.3)$$

The amplitude equations and elimination are given in Appendix A. Energy propagation follows the group velocity, whereas the leading parcel displacement oscillates. A propagating disturbance can therefore transmit an influence without transporting the same mass over the same distance.

Turbulence introduces fluxes and dissipation. Under a locally stationary kinetic-energy balance and a downgradient buoyancy-flux closure, the diffusivity relation is $K_\rho = \Gamma \epsilon_{\text{diss}} / N^2$, where ϵ_{diss} is the kinetic-energy dissipation rate and Γ is a flux coefficient [28]. This closure makes its assumptions visible. The coefficient depends on the process, and intermittent boundary events can violate the stationary approximation. Dissipation, irreversible mixing, and a signed transformation rate remain different quantities.

Shear and nonlinear interaction also perform different energetic tasks. Perturbations can extract energy from a maintained mean flow through linear coupling, while nonlinear advection redistributes energy among perturbation scales. The distinction is derived in Appendix B. It will later support an account of small interventions whose subsequent effects draw upon an existing field. The source of the response and the size of the initiating action need separate budgets.

4.4 Air–sea exchange and response time

The atmosphere supplies momentum through wind stress and exchanges heat and water with the ocean. A bulk stress depends on wind relative to the surface current, atmospheric density, and a transfer coefficient. Heat exchange combines radiation, sensible heat, latent heat, and, where relevant, precipitation-related terms. Evaporation, rainfall, runoff, and ice processes affect freshwater and salt budgets. Official flux documentation provides the context for a validated calculation; the compact expressions used here are stated approximations [27].

Let Q_{in} be net heat flux into the ocean and F_{fw} net freshwater addition, both positive inward. With thermal expansion coefficient α , salinity contraction coefficient β , specific heat c_p , and a consistent salinity unit, the corresponding local buoyancy input is Equation 4.4.

$$B_0 \simeq \frac{g\alpha Q_{\text{in}}}{\rho_0 c_p} + g\beta S_A F_{\text{fw}}. \quad (4.4)$$

The buoyancy flux has units of length squared per time cubed. Ice salt exchange and penetrative short-wave radiation require consistent additional treatment. In particular, the heat entering the sea need not all be absorbed within the mixed layer.

Mixed-layer depth supplies a qualified reason for relatively rapid thermal response. Consider a homogeneous layer of fixed depth h , neglect entrainment and advection, and linearize heat loss from a temperature anomaly θ as $\Lambda\theta$, with $\Lambda > 0$. Conservation of heat gives Equation 4.5.

$$\rho_0 c_p h \dot{\theta} + \Lambda \theta = Q'(t), \quad \tau_\theta = \frac{\rho_0 c_p h}{\Lambda}. \quad (4.5)$$

Under comparable damping, a shallower layer has a shorter relaxation time. The response depends on thermal storage as well as forcing. With zero damping, constant forcing produces linear warming in this model and supplies no finite relaxation time. Upper-ocean turbulence, entrainment, and horizontal exchange complicate the complete budget [6].

The coupling also operates from ocean to atmosphere. Currents alter relative wind; waves modify surface conditions; temperature affects exchanges. Research on wind, waves, and surface currents emphasizes these interactions [12]. Externality is therefore relative to a chosen subsystem and timescale. A reduced model that eliminates a changing environmental component can acquire memory, as the elementary calculation in Appendix A demonstrates.

4.5 Astronomical forcing and phase

Tides originate in differential gravitational forcing by the Moon and Sun. Expanding the gravitational potential in an Earth-centered frame removes a spatially constant term and the uniform acceleration of

the frame. The remaining leading potential is quadrupolar, with a force scale proportional to $GM|\mathbf{r}|/R^3$ for a body at separation R [26]. This forcing differs from wind stress and belongs in the potential term of Equation 4.1.

A harmonic representation expresses local tidal elevation as a sum of constituents with location-dependent amplitudes and phases [25]. The astronomical frequencies do not determine the local response by themselves. Depth, rotation, geometry, and dissipation shape the amplitudes, phases, and currents. Tidal influence also extends into the deep ocean through interaction with topography.

Periodic elevation creates a temporal structure, but cumulative transport requires additional dynamics. Rectification, asymmetric boundaries, mixing, or spatially varying currents can generate a residual effect. The distinction between oscillation and accumulated displacement matters to the later concept of an action window. A periodic opening provides an occasion for a specified action; repetition alone does not guarantee progress.

4.6 Chemistry, biology, and property budgets

Chemical and biological processes enter through composition, reaction, settling, and feedback on properties such as density or optical absorption. Temperature and salinity transport can also interact through unequal diffusivities. Nonlinear thermodynamics permits a mixture to differ from a linear interpolation of its components. Appendix A derives the curvature correction and distinguishes arithmetic density comparison from the mass-consistent specific-volume budget.

A dissolved or particulate tracer requires a transport equation with diffusion, reaction, and any relative settling flux. Uptake and remineralization transfer material among forms; a consistent reaction network respects the relevant elemental budgets. These mechanisms can change water properties and ecological conditions. Their contribution cannot be represented by adding a generic upward biological force to the momentum equation. Reviews of biologically generated mixing also qualify the contribution of organism-driven turbulence to ocean-wide mechanical mixing [15].

Property-class inventories provide a common interface. In a fixed impermeable volume Ω , let $V_{<\beta}$ denote the volume with buoyancy below a threshold β . The Heaviside function H and Dirac distribution δ express the inventory and its transformation through Equation 4.6.

$$V_{<\beta} = \int_{\Omega} H(\beta - b) dV, \quad \frac{dV_{<\beta}}{dt} = - \int_{\Omega} \delta(\beta - b) Q_b dV. \quad (4.6)$$

The right side has dimensions of volume per time. Its derivation uses incompressibility and the boundary condition; open boundaries add inventory transport. This framework connects circulation with thermodynamic and biogeochemical transformations without treating all contributions as interchangeable forces [14, 40].

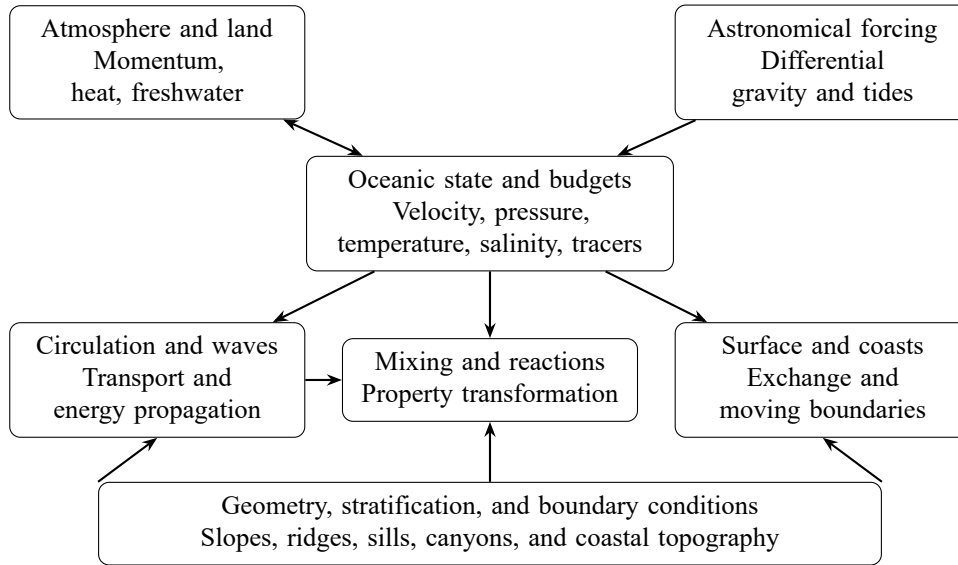
4.7 Coasts, shorelines, and coupled pathways

The sea surface and the shoreline are different boundaries. Surface arrival concerns a parcel or property class reaching the upper ocean. Shoreline crossing concerns a moving wet-dry boundary where sea elevation meets topography. Shelf currents, waves, runoff, wind stress, and atmospheric pressure can affect the approach. Inner-shelf circulation has its own coupled wind- and wave-driven mechanisms [16].

At a shoreline defined by $s(x, t) = \eta(x, t) - z_b(x) = 0$, a regular boundary satisfies $\dot{x}_{\Sigma} = -s_t/s_x$. The boundary can move even when the position of a tracked object changes little. A physical crossing therefore depends on relative motion. Surface gravity waves and a depth-integrated momentum budget are derived in Appendix A, with the restrictions of the shallow-water approximation stated explicitly.

Figure 1 integrates the physical architecture. Its arrows indicate specified causal couplings, and its branches distinguish transport from property transformation. The diagram supplies an organized physical foundation for the next section's translation. It does not imply a universal trajectory from trench to land or a universal ordering of timescales by depth.

Figure 1: Ocean–atmosphere mechanisms and transport pathways



5 Conceptual Mapping

This section specifies the method by which the physical account informs a theory of epistemic praxis. It introduces an intermediate level of causal roles, applies it to several mechanism families, and identifies the evidence needed for social interpretation. The procedure makes the analogy a source of explicit hypotheses rather than a substitute for institutional explanation.

5.1 Levels of translation

A physical mechanism can be abstracted with respect to a particular causal relation. Advection describes movement conditioned by an existing field. Property transformation changes what the moving object can subsequently do within that field. A boundary condition limits admissible motion. Coupling permits a change in one component to affect another. These abstractions retain selected relations while discarding most of the physical specification.

An epistemic application supplies a further interpretation. Existing field dynamics might correspond to the changing availability of public infrastructure. Property transformation might correspond to learning that makes an instrument usable. A boundary might correspond to an admission or renewal rule. Each proposal requires evidence connecting actions, relations, and outcomes. The same physical role may have several social realizations, and the same institution may perform several roles.

The intermediate level prevents ambiguous substitution. A qualification can function as evidence of competence, an admission condition, a status signal, or a contractual requirement. Treating it as a generic potential would conceal the mechanism through which it affects a particular project. Its modeled role should depend on what the qualification changes and who has authority to recognize it.

Table 2 gives a set of translations used in the paper. The final column states the evidence needed to move from a useful analogy to a supported social claim.

5.2 Mechanism families and institutional specificity

Transport and transformation identify different practical tasks. Obtaining access to a public archive changes the resources within reach. Learning to interpret its records changes the capabilities brought to those resources. A workshop can accomplish both, but the distinction remains useful when diagnosing a failure. Repeatedly expanding access will have limited effect when the actual obstruction concerns interpretation, while repeated training cannot remove a binding exclusion rule.

Table 2: Physical mechanisms, abstract roles, and epistemic interpretations

Physical mechanism	Abstract role	Epistemic interpretation	Required evidence
Advection in a maintained circulation	Field-conditioned movement	An external institutional change lowers a project's intervention requirements	Matched target, horizon, resources, and action channels
Water-property transformation	Change in subsequent possibilities	Learning or methodological collaboration makes existing access usable	Demonstrated capability and an identified change in feasible inquiry
Topographic and boundary constraints	Geometry of admissible paths	Permissions and infrastructure rules condition participation	Rules, effective enforcement, and feasible alternatives
Wave propagation and coupling	Mediated influence	A demonstration or association changes another institution's response	Identified transmission channel, direction, delay, and consequence
Mixed-layer thermal storage	Response time under stated damping	Prepared capacity affects responsiveness to a specified event	Preparation costs, decision process, and observed response times
Moving shoreline	Relative boundary motion	Eligibility changes while the applicant's situation also evolves	Time-resolved rules, state changes, and the relevant target
Flux and maintenance budgets	Continued reproduction	Returns replenish inquiry and shared infrastructure	Recipients, conversion conditions, maintenance costs, and persistence

Coupling introduces a further distinction. Public visibility can create encounters without establishing reciprocal work. A contribution affects future possibilities only through a process connecting it to interpretation, use, collaboration, resource allocation, or authority. The relevant input–output relation may be highly selective. A large response in an irrelevant channel can consume resources while leaving the chosen inquiry target unchanged.

Temporal access concerns the relationship between changing conditions and the time required for action. An opening can close during the interval needed to discover it, understand its conditions, deliberate, prepare materials, and obtain a response. Preparedness changes that interval, but maintaining preparedness also uses resources. The analysis therefore joins timing to reproduction rather than treating rapid response as an unconditional objective.

Storage and memory concern the persistence of prior conditions. A relationship can remain useful after the event that initiated it; a resource commitment can carry delayed obligations; a previous exclusion can affect present trust. If these effects matter, a memoryless model of the present state needs augmentation. The mathematical treatment can use additional state variables or a declared approximation, while institutional inquiry determines what has actually persisted.

5.3 Reflexivity and the limits of correspondence

People and institutions interpret the situations in which they act. They can revise a target, contest an admission rule, organize a new facility, or reject a modeled definition of success. These capacities require an environment that can respond to collective action. The distinction between subject and field is therefore analytical and revisable.

Knowledge also differs from a conserved fluid. Its communication can reproduce an accessible expression without preserving interpretation, competence, authority, or material access in equal measure. Learning can create possibilities that a fixed state catalogue did not contain. The framework represents selected variables for a specified inquiry; it does not postulate a conservation law for knowledge or an exhaustive space of future discoveries.

The physical analogy remains productive when it exposes distinctions and directs investigation. It becomes misleading when the prestige of a physical equation substitutes for evidence about institutions. The paper consequently uses formal results in a conditional form: given the specified dynamics, inputs, target, resources, and horizon, a conclusion follows. The correspondence between those specifications and a social situation must be established separately.

This method also permits the analogy to fail locally. A proposed phase effect may disappear once resource differences are accounted for. An apparent threshold may be a discretionary judgment with changing criteria. A seemingly stable regime may be maintained through continuous negotiation. Such findings improve the analysis by identifying a more appropriate mechanism and revising the corresponding praxis.

6 Generative Layers

This section constructs generative layers as relatively persistent configurations of constraints and mediating relations. It begins with the conditions required for continued inquiry, distinguishes recurrent regime types, and then examines overlap, reversal, and nested positions. The resulting structure supports diagnosis while leaving its empirical granularity open.

6.1 Construction of the regime model

A layer identifies a configuration in which certain relations organize the practical work required to continue. The concept concerns the form of the problem rather than a universal rank. A research practice must reproduce its contributors, obtain usable conditions, develop relevant competence, become communicable to appropriate others, and sustain some form of coordination. Authority over these processes and the allocation of returns operates across them.

The functions are distinguishable because one can be present while another remains obstructed. Equipment can be available without the competence or time needed to use it. Competence can persist while permission is withdrawn. A contribution can be understood locally while excluded from a wider channel of evaluation. A highly visible project can remain dependent on revocable infrastructure. These configurations require different interventions.

A regime description should therefore include the project, relevant community, indispensable condition, responsible actors, and horizon. The same individual can occupy several regimes at once. A layer is useful when it groups situations that require a sufficiently similar diagnosis and response. The number and boundaries of these groups should be revised when the empirical material demands it.

6.2 Reproduction and productive access

The reproduction regime concerns the continuity of the people and relationships sustaining inquiry. Livelihood, care, rest, health, and time enter this regime as conditions of activity. A project that can be completed only through repeated depletion has a different temporal structure from one supported through realistic cycles of work and recovery. A viability analysis should be able to represent both the activity and the recovery needed to repeat it.

Productive access concerns effective use of indispensable means. Formal availability is one component, alongside affordability, permissions, compatibility, reliability, and the competence needed to engage with a resource. Revocation and renewal matter because inquiry unfolds over time. A temporary allocation can enable an experiment while leaving verification, maintenance, or follow-up impossible.

These regimes often interact. A free facility may be inaccessible because its opening hours conflict with paid work or care. A paid access arrangement may save enough time to make a project feasible. An institution can also transfer access costs into invisible preparation and administrative labor. The diagnosis should record the complete relation rather than classify a resource by price alone.

Table 3: Generative regimes and practical changes

Regime	Characteristic obstruction	Evidence of a consequential change
R: Reproduction	An inquiry cycle depletes indispensable conditions	Repeated cycles become possible with realistic maintenance and recovery
A: Productive access	Required means are unavailable, unusable, or insecure	Effective access with a credible continuation or alternative
E: Epistemic transformation	Available resources exceed current usable competence	Demonstrated capability and a newly feasible line of inquiry
L: Communicability	Relevant others cannot interpret or evaluate the contribution	Actual understanding, scrutiny, or reuse
C: Reciprocal coupling	Encounters fail to establish sustained joint work	Commitments change subsequent productive possibilities
G: Control and return	Authority or replenishment remains insufficient for continuation	Consequential changes in decision rights, allocation, or maintenance

6.3 Epistemic transformation and communicability

Epistemic transformation concerns the development of the ability to use resources critically and productively. Reading, experimentation, apprenticeship, methodological collaboration, and translation can change the inquiries an actor is able to pursue. Such transformation includes the capacity to recognize limitations, revise a question, and distinguish a productive direction from a misleading one.

An accumulation of materials can coexist with an unresolved transformation problem. The immediate task may be to develop an interpretation or method that connects available resources to a specific question. This can require extended attention and uncertain exploration. Treating every interval without a visible output as inefficiency would misidentify the process.

Communicability concerns the forms through which others can encounter, understand, scrutinize, and use a contribution. The relevant form depends on a community and purpose. A demonstration, oral explanation, technical record, translation, or reproducible procedure may be more appropriate than a conventional publication in a particular setting. The criterion is an actual relation of interpretation or scrutiny.

Communicability can also become a site of appropriation or exclusion. The channels that confer recognition may impose costly forms, privilege certain languages, or transfer rights. A contribution's increased visibility consequently requires examination of the relations through which visibility becomes access, authority, or return.

6.4 Reciprocal coupling, control, and return

Reciprocal coupling concerns durable connections among actors, tools, institutions, and projects. Contact becomes productive coordination when participants establish a shared problem, workable responsibilities, and conditions for continued contribution. Complementarity can create possibilities unavailable to isolated actors. It can also produce dependencies when an indispensable role lacks a viable replacement or adequate support.

Control and return concern authority over direction, allocation, maintenance, and continuation. These questions arise in every regime. A shared instrument can improve access while leaving its renewal under unilateral control. A successful collaboration can produce resources whose allocation excludes the people maintaining the work. Conversely, an enforceable participation right can improve the durability of access even before output increases.

Table 3 summarizes the initial regime typology. Its codes identify diagnostic categories for case analysis. They should not be treated as a universal developmental scale.

6.5 Overlap, reversals, and nested positions

The regimes overlap because inquiry depends on several conditions simultaneously. A peer association may address access, learning, and communicability in one arrangement. Its success can also expose a new maintenance burden. Movement among regimes is therefore recurrent and can include regression. A publication, credential, or invitation is evidence of a transition only when it changes the relevant configuration.

Layer membership also depends on scale. A collective can provide secure access to its members while remaining vulnerable to an external platform. An individual can participate effectively in a local community while encountering exclusion elsewhere. These nested positions require a relational description that distinguishes internal provision from external dependence.

Transitions can be continuous or discrete. Growing competence changes some capabilities gradually. An account closure or a funding decision can abruptly alter permissions and reserves. A revised diagnosis may change the regime label while leaving the material state continuous. The formal distinction between a diagnostic change and an institutional event prevents the model from manufacturing a transition whenever its classification changes.

Response speed and transition sensitivity are additional properties of a regime. They can vary independently of its place in the diagnostic typology. A reproduction crisis can develop rapidly; an access arrangement can remain stable for years; a communicability opportunity can have a short deadline without any dynamical instability. The architecture of Process II therefore monitors these properties separately.

7 Contradiction-Guided Praxis

This section develops a method for selecting and revising interventions within the generative regimes. It distinguishes structural contradictions from project constraints, examines the diagnosis of principal relations, and connects investigation to individual and collective action. The method concerns historically situated judgment supported by causal evidence.

7.1 Structural relations and binding constraints

A structural contradiction concerns opposed tendencies reproduced through a relation. A binding constraint concerns a specific limit on an action or trajectory under stated conditions. The two objects can be connected, but they answer different analytical questions. A shortage of usable time may be the immediate constraint on inquiry, while the organization of employment, care, or access produces that shortage.

The distinction matters to intervention. Rescheduling a task can alleviate a local shortage without changing its institutional source. Shared care or protected research time can alter the relation through which the shortage recurs. Both changes may be consequential. Their scope should be specified so that a practical improvement is neither dismissed nor mistaken for a transformation of the wider configuration.

A constraint is also relative to a project and horizon. The absence of a particular instrument may block one method while leaving another feasible. A deadline can bind a short-term application while having little relevance to a longer collective campaign. An analysis of praxis should therefore identify the chosen target before ranking obstacles to it.

The target itself can be questioned. An institution may define success in a way that imposes unsustainable work or inappropriate forms of evaluation. Participants can respond by changing a method, negotiating conditions, or organizing an alternative venue. Such actions transform the problem definition and belong within the analysis.

7.2 Principal relations and causal diagnosis

A principal-relation diagnosis proposes that a particular relation organizes the current configuration of obstacles and possibilities. The vocabulary draws on Mao's account of principal contradictions and prin-

pical aspects, while the material and historical orientation is broader [18, 20]. Its practical use requires investigation of the mechanisms through which the proposed relation conditions other activities.

A defensible diagnosis specifies actors, indispensable conditions, authority, opposed tendencies, and mediating processes. It compares plausible alternatives and traces what an intervention would change. For a computational research project, lack of equipment, inadequate interpretation, unstable livelihood, and exclusionary renewal rules may produce similar visible symptoms. The alternatives imply different action channels and different expectations.

Evidence for strategic priority can take several forms. A constraint may recur across otherwise different projects. An intervention may remove several subordinate obstacles together. A supposed skill deficit may persist despite successful training because an institution continues to withhold authorization. These observations support a causal argument; they do not automatically identify a principal contradiction.

The effects of a diagnosis also require scrutiny. An organization may characterize overwork as an individual failure of responsiveness because that account preserves its control of staffing or deadlines. A participant may attribute every difficulty to infrastructure because training would expose an uncomfortable limitation. Investigation should examine how each explanation distributes responsibility and which evidence could revise it.

7.3 Mediation and indirect intervention

An indirect action can alter a consequential relation through a sequence of mediations. A reading group may develop shared competence, then produce a demonstration, then use the demonstration to obtain institutional access. A maintenance cooperative may make a facility more reliable, then gain a recognized role in decisions about its continuation. These sequences require explicit causal connections between stages.

Complementarity is especially relevant. Equipment and competence can jointly make a study feasible even when neither intervention suffices alone. For a declared outcome V , the finite contrast $\Delta_{ij}V = V_{ij} - V_i - V_j + V_0$ records whether the joint change exceeds the sum of separate changes. Positive complementarity supports a bounded claim about those interventions and that outcome. It does not calculate the ethical value or historical priority of the relation.

Indirect action also carries risk of displacement. A strategy intended to improve access through increased visibility may consume the time needed for the research itself. A partnership intended to secure infrastructure may produce a new dependence on a single intermediary. The relevant comparison includes both the intended mediation and its effects on reproduction and control.

Strategic attention to secondary relations is therefore compatible with an analysis of principal relations. The practical route to a wider change can pass through a more accessible relation. The justification depends on whether the sequence can be traced and whether the intermediate arrangements preserve the capacity to continue.

7.4 Investigation, action, and revision

The method begins with a description of the actual inquiry cycle: its purposes, work, resources, participants, dependencies, and expected continuation. The next step formulates rival diagnoses of the binding configuration. Candidate actions are then evaluated for their direct and mediated effects, resource costs, timing, and implications for others. Observation after intervention tests both the action and the diagnosis.

This sequence includes qualitative evidence. Participants may know that a decision channel is ineffective even when numerical records are unavailable. Records of access withdrawal, administrative delay, maintenance work, or excluded proposals can reveal a mechanism that aggregate output measures miss. Quantification is useful where it clarifies a well-defined relation and should be withheld where it would conceal uncertainty.

Revision can concern the state estimate, the causal model, the chosen target, or the collective's organization. A failed action may indicate insufficient effort, an incorrect mechanism, a changed institution,

or an unacceptable cost. These possibilities should be distinguished because repeated application of the same intervention can deepen depletion.

The inquiry cycle also requires intervals for deliberation and reflection. Rapid response is valuable only relative to a justified opening and a feasible action. A group that reduces every decision to immediate reaction may lose the interpretive capacity needed to recognize changes in the governing relation. Reproduction includes the conditions for judgment.

7.5 Collective transformation of conditions

Collective praxis can alter action channels, resources, and rules. Bargaining can establish protected time. Shared infrastructure can change the cost of an experiment. Contributor representation can affect renewal and maintenance. Public provision can make access less dependent on an individual's ability to purchase or negotiate it.

These changes can be evaluated through their distribution and durability. A facility that admits a few exceptional participants may improve their trajectories while leaving the general access relation intact. A publicly accountable allocation process can change who is entitled to participate and how exclusion is contested. The difference concerns the institution's operation over subsequent cases.

Collective transformation also requires internal safeguards against renewed concentration of authority. The people who administer a shared resource can acquire discretionary powers through their technical knowledge or control of records. Governance must therefore support intelligible procedures, replacement of roles, maintenance resources, and means of contestation. These are productive conditions of the collective, not merely external constraints on its efficiency.

Contradiction-guided praxis consequently joins immediate action to the history and reproduction of governing relations. It provides the diagnostic orientation for Process I and the supervisory interpretation for Process II. The mathematical models that follow specify consequences within this orientation while leaving its historical judgments open to evidence.

8 Generative Upwelling

This section formalizes Process I as viable change in the conditions and possibilities of inquiry. It defines the joint state of subject, field, and resources, then develops target access, intervention cost, and meaningful options. An exact elementary example isolates the contribution of a changing field, and a final discussion connects the model to path dependence.

8.1 Joint dynamics and observation

Let x describe the capabilities and project state of a person or collective, y describe the relevant institutional field, and r describe resource reserves. Their concatenation is $Z = (x, y, r)$. The variables may have different units; any norm or cost must specify a normalization. Distinguish immediate project actions u_i from collective interventions u_c that can alter field conditions. A proposed model is Equation 8.1.

$$\begin{aligned}\dot{x} &= f_x(x, y, r, t) + B_i(x, y, r, t)u_i, \\ \dot{y} &= f_y(x, y, r, t) + B_c(x, y, r, t)u_c, \\ \dot{r}_j &= s_j(x, y, r, t) - m_j(x, y, r, t) - c_j(u_i, u_c, t), \\ o_k &= h(Z(t_k), t_k) + \nu_k.\end{aligned}\tag{8.1}$$

Supply s_j , reproduction and maintenance m_j , and intervention use c_j are measured in the units of resource j per time. The observation o_k can be incomplete, with error ν_k . The model permits the field to respond to the subject and to organized intervention. Returns and depreciation are made explicit in Section 12.

The decomposition is a modeling choice rather than an assertion that project action and institutional action are always separable. A negotiation can affect both. A richer full dynamics can include both controls in both equations. The distinction identifies causal roles that should be specified in an application.

8.2 Viability and inquiry cycles

Define a time-dependent viable region through conditions $g_j(Z, t) \geq 0$. These can represent minimum reserves, valid permissions, workload limits, or other practical requirements. The finite-horizon viability kernel consists of states from which an admissible causal policy can keep the trajectory within that region. Equation 8.2 states the deterministic definition.

$$\begin{aligned} \mathcal{V}(t) &= \{Z : g_j(Z, t) \geq 0 \text{ for every } j\}, \\ \text{Viab}_{[t, T]}(\mathcal{V}) &= \{Z_0 : \exists \pi_c, Z_t = Z_0, Z_s \in \mathcal{V}(s) \text{ for all } s \in [t, T]\}. \end{aligned} \quad (8.2)$$

The admissible policy π_c uses the information available at decision time. Under bounded uncertainty, robust viability requires one policy that works for every disturbance in a declared class. Under unbounded diffusion, a probabilistic formulation is generally needed. These are different problem specifications.

An inquiry cycle can contain concentrated effort and planned recovery. Viability need not mean a constant instantaneous level of productivity. It can include schedules and cumulative constraints that preserve the ability to resume. A relevant state description must record the reserves and commitments needed to make that assessment.

Viability is also distinct from desirability. An arrangement may preserve a project's minimum conditions while maintaining an objectionable distribution of authority or burdens. The viable region expresses specified practical limits. Its normative adequacy remains part of the wider evaluation.

8.3 Target access and intervention cost

Choose a target $\mathcal{T}$, start time t , and horizon H , with $T = t + H$. The target might specify a renewable access arrangement, demonstrated methodological capability, or another condition of inquiry. With a positive-definite cost matrix R_u , define the minimum intervention cost through Equation 8.3.

$$\begin{aligned} J^*(Z, t; \mathcal{T}, H) &= \inf_{u \in \mathcal{U}_{\text{adm}}} \frac{1}{2} \int_t^T u(s)^T R_u(s) u(s) ds, \\ Z_t &= Z, \quad Z_T \in \mathcal{T}, \quad Z_s \in \mathcal{V}(s) \quad (t \leq s \leq T). \end{aligned} \quad (8.3)$$

Permissions, input bounds, and cumulative resource limits belong to the admissible set. An unreachable target has cost $+\infty$. Quadratic effort is an analytically convenient objective with declared units. It should be distinguished from the separate money, time, and maintenance constraints in the state.

For budget E , the reachable set $\mathcal{R}_E^H(Z, t)$ consists of endpoints realized by admissible viable controls with cost at most E . If that set intersects the target, then $J^* \leq E$. The converse is assured when $J^* < E$; equality requires attainment of the infimum. Compactness, continuity, and appropriate closedness conditions can support attainment, but they must be established or assumed. A positive budget margin is useful where such conditions or cost estimates remain uncertain.

Equation 8.3 describes viable entry. Durable continuation requires a subsequent residence interval or a terminal set with a demonstrated continuation policy. The associated resource use must be included. Access whose renewal cannot be sustained is a different outcome from access supported through subsequent inquiry cycles.

8.4 Changing fields and meaningful options

Process I can change the state, available controls, resource limits, and institutional conditions. To isolate a field-mediated contribution to a particular transition, compare two specified field scenarios with the

same initial state, target, calendar interval, control conventions, information assumptions, and viability requirements. When both costs are finite, Equation 8.4 defines the contrast.

$$\Delta J_{\text{field}} = J_{\text{ref}}^*(Z, t; \mathcal{T}, H) - J_{\text{evo}}^*(Z, t; \mathcal{T}, H). \quad (8.4)$$

A positive difference identifies a reduction under that comparison. If a target becomes feasible from an unreachable reference state, the result should be reported as newly established feasibility. Subtracting infinite costs is undefined. A frozen reference field is an analytical benchmark whose causal interpretation requires justification.

The contrast also differs from comparing costs at unrelated dates. A later opportunity may arrive after reserves have declined or the remaining horizon has shortened. Waiting can improve an external condition while making the full inquiry cycle less viable. A coherent comparison includes those changes.

Access to a chosen target and the range of meaningful options are separate quantities. For a fixed catalogue of targets $\mathcal{T}_k$ and declared weights w_k , one possible option measure is $M_E^H = \sum_k w_k \mathbf{1}\{\mathcal{R}_E^H \cap \mathcal{T}_k \neq \emptyset\}$. This measure records access to the selected options. A raw volume of a reachable set would depend on coordinates and would not distinguish their significance. Neither measure supplies a universal index of generativity.

8.5 An exact model of field-mediated access

A scalar model isolates the logical content of borrowed potential. Let the normalized dynamics be $\dot{x} = v(t) + u(t)$, with initial state x_0 , target $x(H) \geq L$, unrestricted square-integrable signed control, and cost $\frac{1}{2} \int_0^H u^2 dt$. Assume that additional path constraints do not bind. Integrating the dynamics and applying the Cauchy–Schwarz inequality yields Equation 8.5.

$$\Delta = L - x_0 - \int_0^H v(t) dt, \quad u^* = \frac{\max(\Delta, 0)}{H}, \quad J^* = \frac{\max(\Delta, 0)^2}{2H}. \quad (8.5)$$

Proposition 8.1 (Field-mediated cost reduction). *Under the scalar model above, an increase in integrated favorable drift weakly decreases the minimum intervention cost for the upper-half-line target. It decreases the cost strictly while the required controlled displacement remains positive.*

Proof. Endpoint feasibility requires $\int_0^H u dt \geq \Delta$. If $\Delta \leq 0$, zero control is feasible and has minimum cost zero. If $\Delta > 0$, Cauchy–Schwarz gives $\int_0^H u^2 dt \geq \Delta^2/H$, with equality for constant $u = \Delta/H$. The expression in Equation 8.5 has the stated dependence on integrated drift. $\square$

For a unit horizon, $x_0 = 0$, and $L = 1$, the zero-drift reference costs 0.5. A constant drift $v = 0.75$ reduces cost to 0.03125. A budget of 0.05 reaches the target in the second case. The calculation uses linear dynamics and requires no amplification or critical transition.

The target convention matters. Exact equality $x(H) = L$ requires cost $\Delta^2/(2H)$, including compensating negative control when the field would overshoot. Input bounds and viability constraints can also remove the proposed optimum from the admissible set. The example establishes a conditional mechanism that an institutional application must specify anew.

8.6 Path dependence and recurrent upwelling

The order of interventions can change their consequences. Training before access may prepare a group to use a short opening; access before training may provide the setting in which competence develops. A public demonstration may precede a negotiation, while a negotiated permission may be necessary before a demonstration can be produced. These are institutionally specified sequences.

For smooth vector fields f and g , the difference between opposite orders of small flows is $h^2(Dg f - Df g) + O(h^3)$. Appendix B derives the relation and distinguishes an actual sequence of actions from a numerical splitting approximation. The expression supports the possibility of path dependence; it does not identify which institutional ordering is preferable.

Generative upwelling is consequently recurrent. An intervention changes the configuration from which the next inquiry proceeds. Successful access can expose a transformation need, and a new capability can make collective action possible. The process preserves continued inquiry while revising its conditions and possibilities.

9 Perturbation and Transition Mechanisms

This section distinguishes the dynamical mechanisms through which bounded interventions can produce consequential effects. It connects perturbation energy to local response, separates stable transient amplification from transition, and derives the contrast between susceptibility and relaxation near a fold. These distinctions provide the diagnostic basis for Process II.

9.1 Perturbation energy and maintained fields

A small initiating action can draw on a field whose maintenance requires resources supplied elsewhere. In fluid mechanics, perturbations around a maintained mean flow can extract energy through the mean velocity gradient. For compatible incompressible boundary conditions, their energy balance contains the production term $-\int v'_i v'_j \partial_j U_i dV$, viscous dissipation, and any perturbing force. Coriolis acceleration performs zero work. Appendix B derives the balance.

This analysis distinguishes the initiating input from the energy subsequently redistributed through the system. Nonlinear advection redistributes perturbation energy among modes under the stated boundary conditions, while linear coupling can already extract energy from the mean. Hydrodynamic stability research provides the relevant precedent for examining transient response independently of eigenvalue stability [38].

The epistemic interpretation is conditional. A demonstration may initiate a response in an institution whose resources and coordination already exist. The demonstrator's effort and the resources sustaining the response belong to different budgets. The causal channel, direction of benefit, and distribution of costs must be identified before such a case can be described as borrowing from a field.

9.2 Local directions and finite-time evolution

Let $Z_0(t), u_0(t)$ be a nominal trajectory and intervention. Linearization of a twice-differentiable full dynamics gives Equation 9.1.

$$\delta \dot{Z} = J(t)\delta Z + B(t)\delta u + G(t)\delta w + \mathcal{E}_2, \quad (9.1)$$

where J and B are state and input derivatives evaluated along the trajectory, $G\delta w$ represents uncertain disturbances, and $\mathcal{E}_2$ collects second-order terms. A tangent space supplies local directions; the Jacobian describes a linearized evolution of perturbations. Updating the latter does not necessarily change the tangent space itself.

Define the transition matrix through $\partial_s \Phi(s, t) = J(s)\Phi(s, t)$ and $\Phi(t, t) = I$. In the linear disturbance-free case, variation of constants yields Equation 9.2.

$$\delta Z(T) = \Phi(T, t)\delta Z(t) + \int_t^T \Phi(T, s)B(s)\delta u(s) ds. \quad (9.2)$$

The effect of an input depends on its timing and on the subsequent dynamics. For time-varying non-commuting Jacobians, the transition matrix generally differs from $\exp(\int_t^T J(s) ds)$. An instantaneous eigenvector therefore need not identify a useful finite-time action direction.

9.3 Stable transient amplification

A transparent linear example separates large response from regime change. The matrix and exact transition matrix in Equation 9.3 follow by solving the second component and substituting into the first.

$$J = \begin{pmatrix} -1 & K \\ 0 & -2 \end{pmatrix}, \quad e^{Jt} = \begin{pmatrix} e^{-t} & K(e^{-t} - e^{-2t}) \\ 0 & e^{-2t} \end{pmatrix}. \quad (9.3)$$

The eigenvalues are -1 and -2 . Starting from $(0, 1)^T$, the displacement at $t = \log 2$ is $(K/4, 1/4)^T$, with norm $\sqrt{K^2 + 1}/4$. For $K = 10$, the norm exceeds 2.5 before eventually decaying.

The example demonstrates stable transient amplification. It does not supply a different attractor or a durable change. An institutional analogue would require an identified transient channel and evidence that its output affects the desired target. Increased attention alone would leave that interpretation incomplete.

Input and output selection are consequential. A permitted action may fail to excite an amplifying direction. An amplified state component may be irrelevant to access or may impose additional maintenance costs. A mathematical measure of overall response must therefore be connected to the chosen outcome and the actual control channels.

9.4 Fold geometry, susceptibility, and relaxation

The local fold model provides a distinct mechanism. Consider $\dot{q} = \mu - q^2 + p$, with $\mu > 0$ and a small constant input p . At $p = 0$, equilibria are $q_s = \sqrt{\mu}$ and $q_u = -\sqrt{\mu}$. Linearization and differentiation of $q_s(p) = \sqrt{\mu + p}$ yield Equation 9.4.

$$\lambda_s = -2\sqrt{\mu}, \quad \tau_{\text{relax}} = \frac{1}{2\sqrt{\mu}}, \quad \chi_{\text{static}} = \frac{1}{2\sqrt{\mu}}, \quad d_{\text{boundary}} = 2\sqrt{\mu}. \quad (9.4)$$

As μ approaches zero, the stable and unstable equilibria approach one another, static susceptibility increases, and relaxation slows. Research on early-warning signals situates this kind of slowing within particular transition mechanisms [33]. The calculation supplies no general rule that everything near criticality responds faster.

The distinction also appears in a periodic response. Linearization around q_s gives frequency-dependent susceptibility magnitude $1/\sqrt{4\mu + \omega^2}$. High static sensitivity does not imply unlimited response to rapid forcing. The timescale of the intervention and the timescale of local relaxation must be compared.

The local potential $U(q) = q^3/3 - \mu q$ gives a barrier $4\mu^{3/2}/3$ between the equilibria. This potential barrier is a property of the one-dimensional model. It differs from a chosen quadratic intervention budget, and the local normal form alone supplies no desirable destination after escape.

9.5 Environmental rate and transition mechanisms

A system can lose tracking because its environment changes too rapidly even when each frozen configuration retains a stable state. Consider $\dot{q} = (q - a) - (q - a)^3$ with $a(t) = vt$. The moving coordinate $y = q - a$ obeys $\dot{y} = y - y^3 - v$. Its positive tracking branch disappears at $v_c = 2/(3\sqrt{3})$, while the upper equilibrium of every frozen system remains stable. Appendix B derives the threshold.

This example expresses a rate-induced mechanism, distinct from a frozen-parameter bifurcation or noise-induced escape [1]. It is relevant to the problem of adaptation because maintaining a locally favorable configuration can depend on how rapidly its conditions move. It remains an illustrative dynamical model rather than evidence that an institution follows this particular equation.

Table 4 consolidates the diagnostic distinctions. The next section uses them to define an architecture that can choose among preparation, adaptation, transition, stabilization, and withdrawal.

Table 4: Dynamical properties and their diagnostic objects

Property	Diagnostic object	Practical interpretation
Field-mediated access	Matched target cost or feasibility contrast	Existing changes can reduce a required intervention
Transient amplification	Finite-time input–output gain	A permitted perturbation can produce a large temporary response
Local relaxation	Linearized decay or recovery time	A displaced configuration can recover quickly or slowly
Transition sensitivity	Boundary geometry and specified mechanism	A small change may alter the continuation regime
Environmental rate	Forcing rate relative to tracking dynamics	A locally stable arrangement can fail to keep pace
Institutional responsiveness	Observation-to-effect latency	A feasible action can arrive within or outside an opening
Persistence	Viable continuation after entry	An initially attained outcome can be maintained

10 Adaptive Governance

This section develops Process II as an architecture for choosing, timing, and revising interventions under changing and partially observed conditions. It connects a local model of response to supervision of transition mechanisms, remaining time, uncertainty, and reproduction. The architecture supports adaptation within an arrangement as well as an attempted transition to a different one.

10.1 Local identification and action channels

Local identification concerns the relationship among an available action, a relevant outcome, and a specified horizon. Where quantitative data are available, the practitioner can estimate a local state and input model. Where they are limited, a qualitative model can identify plausible signs, delays, dependencies, and boundaries of uncertainty. Both approaches require distinguishing observed association from an intervention’s causal effect.

The local model must include actual channels. An invitation to comment, a negotiated meeting, a formal application, and a collective representation process may reach different decision points. Their efficacy depends on authority, timing, and information. A model that treats all visible responses as equivalent controls would conceal these differences.

For an instantaneous action parameter a , let the induced state displacement be $B_a a$, the cost be $a^T R_a a/2$, and the chosen outcome be measured by C with weight Q_o . With R_a positive definite and Q_o positive semidefinite, the normalized maximum linear response is Equation 10.1.

$$\sup_{a \neq 0} \frac{\|Q_o^{1/2} C \Phi(T, t) B_a a\|_2}{\sqrt{a^T R_a a}} = \sigma_{\max} \left(Q_o^{1/2} C \Phi(T, t) B_a R_a^{-1/2} \right). \quad (10.1)$$

The change of variables $v = R_a^{1/2} a$ reduces the expression to an induced Euclidean norm. Under budget E , the maximum magnitude is $\sqrt{2E}$ times the displayed singular value. Outcome weights and normalization are explicit choices. A large magnitude still requires evaluation of direction, feasibility, and consequences.

Local identification consumes resources and may alter the field. A demonstration can both reveal and influence an institution’s response. The information gained from it may depend on how participants interpreted its purpose. Any proposed probe should therefore have an explicit practical rationale and be evaluated for its effects on trust, workload, and future cooperation.

10.2 Controllability and target geometry

For action distributed over time, the relevant object is the controllability Gramian. In the linear model of Equation 9.2, let d be the desired terminal displacement relative to the uncontrolled trajectory. Minimizing the quadratic cost subject to this displacement gives Equation 10.2.

$$\begin{aligned} W(t, T) &= \int_t^T \Phi(T, s) B(s) R_u(s)^{-1} B(s)^T \Phi(T, s)^T ds, \\ J_{\text{lin}}^*(d) &= \frac{1}{2} d^T W^\dagger d, \quad d \in \text{Range}(W). \end{aligned} \quad (10.2)$$

Appendix B derives the minimizing input by a Lagrange multiplier. The pseudoinverse applies only to displacements in the Gramian's range. A target outside that range is unreachable through the available channels.

Approximate a desired terminal region by $n^T d \geq \delta$. When $q = n^T W n > 0$, minimizing over this half-space gives Equation 10.3.

$$J_{\text{lin, half}}^* = \frac{\max(\delta, 0)^2}{2n^T W n}, \quad d^* = \frac{\max(\delta, 0) W n}{n^T W n}. \quad (10.3)$$

If $q = 0$ and $\delta > 0$, the target is inaccessible in this approximation. A large response elsewhere in state space cannot compensate for this absence of a relevant channel.

These formulas omit state and input bounds. Removing bounds produces a cost lower bound when the dynamics and other problem data remain identical. If the linear model approximates nonlinear institutional dynamics, the result is a local estimate with no general lower-bound guarantee for the original problem. Optimization-based control supplies the formal method, while an application must justify its model and admissible controls [24].

10.3 Moving boundaries and temporal openings

An opportunity can change through both the subject's trajectory and movement of an institutional boundary. Let a desired region satisfy $s(Z, t) \geq 0$, with a nonzero boundary gradient. The chain rule and the boundary condition give Equation 10.4.

$$\frac{ds(Z(t), t)}{dt} = \partial_t s + \nabla s \cdot F + \nabla s \cdot B u, \quad v_\Sigma^{(n)} = -\frac{\partial_t s}{\|\nabla s\|}. \quad (10.4)$$

The normal boundary speed is measured along $\nabla s / \|\nabla s\|$. A change in eligibility can move the boundary toward a group without changing its competence or reserves. The meaning of crossing must consequently be assessed against the material target.

A periodic example makes the timing relation explicit. Let the terminal shortfall be $\delta(t) = d_0 - a \cos(\omega t)$, with $a, \omega > 0$, and hold $q = n^T W n > 0$ constant across candidate start phases. Under budget E , access is feasible when $\delta(t) \leq \sqrt{2Eq}$. If $c = (d_0 - \sqrt{2Eq})/a$ lies between -1 and 1 , Equation 10.5 gives the available time per period.

$$\mathcal{W}_E = \{t : \cos(\omega t) \geq c\}, \quad |\mathcal{W}_E|_{\text{period}} = \frac{2 \arccos c}{\omega}. \quad (10.5)$$

For $c > 1$, no opening exists; equality at $c = 1$ gives isolated times; $c \leq -1$ gives the whole period. Each phase comparison uses the same planning horizon. Changes in the Gramian, reserves, or persistence requirements require recalculation.

The periodic form is an analytical example of timed access. Institutional openings need not repeat regularly or have astronomical causes. The transferable relation concerns the fit among a changing shortfall, available control, and the time at which an intervention can take effect.

10.4 Latency, observation, and model validity

A practical response includes discovery, interpretation, deliberation, execution, and propagation to the relevant outcome. For a serial process, a necessary timing condition is Equation 10.6.

$$\tau_{\text{loop}} = \tau_{\text{obs}} + \tau_{\text{id}} + \tau_{\text{decision}} + \tau_{\text{execution}} + \tau_{\text{propagation}} \leq \tau_{\text{remaining}}. \quad (10.6)$$

Parallel preparation can shorten the actual critical path, so an application should measure that path rather than automatically add overlapping intervals. The relevant comparison is with the remaining usable window, which may be much shorter than its original duration.

Preparation can reduce latency through reusable records, shared knowledge, delegated roles, and prior deliberation. Maintaining such preparation also uses time and resources. Its value depends on the opportunities it makes actionable and on its contribution to the broader inquiry cycle. Continuous alertness that undermines recovery can reduce viability while increasing nominal responsiveness.

A local prediction also has a validity horizon. Suppose the true dynamics is Lipschitz with constant $L > 0$ in a normalized norm, model mismatch is bounded by ϵ_m within a valid tube, and initial estimation error is e_0 . Comparing trajectories under the same applied control gives Equation 10.7.

$$\|Z(t+h) - \hat{Z}(t+h)\| \leq e^{Lh}e_0 + \frac{\epsilon_m}{L}(e^{Lh} - 1). \quad (10.7)$$

For $L = 0$, the bound is $e_0 + \epsilon_m h$. Appendix B derives the estimate. A planning horizon should keep uncertainty within the chosen model-validity and viability margins.

Frequent updates cannot compensate for an uninformative observation channel. A publicly visible response may reveal little about an institution's renewal policy. An estimated correlation may change when the institution recognizes the intervention. Adequate identification requires observations relevant to the mechanism and a willingness to revise the model when those observations cease to support it.

10.5 Transition supervision

The supervisory function evaluates whether a local control problem remains an appropriate description of the situation. Its diagnostic vector includes viable margins, target cost, controllable directions, transient gain, evidence about stability or basin structure, remaining time, uncertainty, and prospects of maintenance. Different components have different units and meanings. Combining them into one universal criticality score would conceal their distinct causal roles.

The expression criticality governance refers here to supervision of a specified transition mechanism. Where the opening is an ordinary rule change or favorable drift, the supervisor should describe that mechanism directly. A transition-sensitive situation calls for closer attention to local model validity and the consequences of crossing. The objective is a justified continuation, not instability as an end in itself.

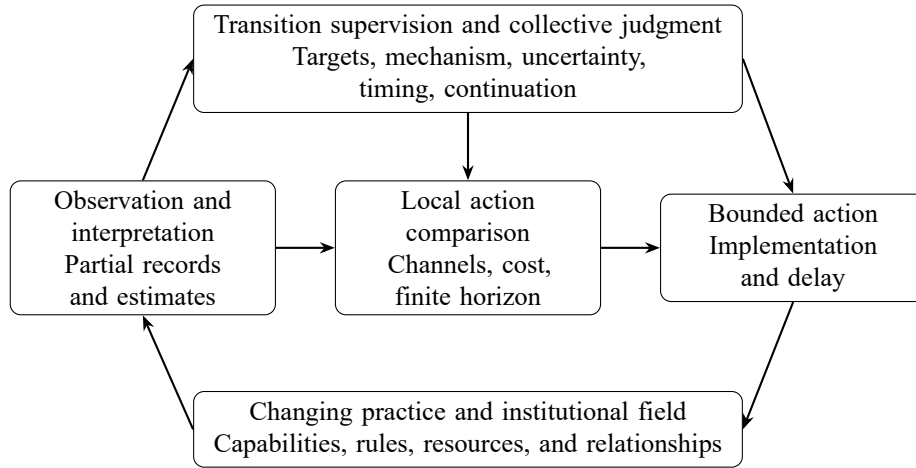
The supervisor can authorize preparation, a limited probe, immediate action, stabilization, waiting, or withdrawal. These modes are practical responses to a diagnosis. They need not correspond to a slower timescale than the local controller; supervision must update quickly enough when the mechanism itself changes. Collective judgment enters through authority to select targets, impose constraints, or reject an intervention whose burdens are unacceptable.

Process II-A concerns continued adaptation within an arrangement. Process II-B concerns an attempted transition followed by stabilization or a planned exit. A change of target, a loss of access, or unexpected depletion can return the process to the diagnostic work of Process I. The two processes therefore share observations and resources.

10.6 Receding-horizon organization

A receding-horizon procedure estimates the present situation, compares actions over a bounded interval, implements the first action, observes its effects, and revises the plan. Model-predictive control supplies

Figure 2: Adaptive governance under partial observation



an established architecture for this sequence [31]. The present application can use a small set of qualitative alternatives or a quantitatively specified optimization, depending on the evidence.

Figure 2 represents the relation among observation, local comparison, supervision, and action. Reproductive constraints and collective judgment shape the admissible problem. An engineering proof of recursive feasibility requires compatible terminal sets, continuation policies, and disturbance assumptions. Repeated replanning in an uncalibrated social model supplies a disciplined comparison rather than such a proof.

This organization gives responsiveness a bounded purpose. The interval of action is selected in relation to the opening, uncertainty, and reproductive conditions. It preserves the capacity to revise the target and to change the institutions that define available actions.

11 Integration of Upwelling and Transition

This section joins Processes I and II through their common state, resource, and continuation requirements. It identifies how preparation changes a later intervention problem, states a conditional compatibility result, and examines failures that separate access from durable transition. The integration concerns a recurrent organization of praxis.

11.1 Preparation and the location of intervention

Process I changes the situation from which an intervention becomes possible. Learning can alter the capability state; an association can create an input channel; a maintenance agreement can change the viable region; a public resource can enlarge the available budget. These changes affect both the minimum target cost and the ability to observe or respond.

Process II uses a current configuration to realize a chosen intervention. Its effective location is relational as well as spatial or informational. A person may be near a decision in the sense of possessing a recognized channel, prepared evidence, and a credible response path. Mere awareness of the decision does not provide the same position.

The distinction between preparation and intervention is analytical. A public demonstration can develop competence, create a relationship, and influence an allocation at once. An attempted transition can also reveal the need for additional preparation. The integration must admit such overlap while retaining separate accounts of what changed, what resources were used, and what continuation became possible.

11.2 Compatibility of access, timing, and continuation

The combined process requires compatible trajectories. A viable preparation path must lead to a state from which the proposed action is feasible. The action must arrive within the relevant opening and remain within acceptable model uncertainty. Its endpoint must permit continued inquiry under the resources and commitments that remain.

A simple deterministic result makes the compatibility requirement explicit. Let $t_0 < t_1 < t_2 < t_3$. Consider a preparation trajectory on $[t_0, t_1]$, an intervention trajectory on $[t_1, t_2]$, and a continuation trajectory on $[t_2, t_3]$. All state variables, including resources, are represented in the joint state. The cost of the concatenation is Equation 11.1.

$$J_{\text{total}} = J_{\text{preparation}} + J_{\text{intervention}} + J_{\text{continuation}} \leq E_{\text{total}}. \quad (11.1)$$

Proposition 11.1 (Compatible viable continuation). *Suppose the controlled deterministic dynamics admits unique trajectories under the chosen piecewise admissible controls. Assume that the three trajectories share matching endpoint states, remain in the same specified viable region, satisfy their time-dependent permissions and constraints, and obey Equation 11.1. If the intervention ends in a target subset from which the continuation is feasible, their concatenation is a viable realization of preparation, target entry, and continuation over $[t_0, t_3]$.*

Proof. Define the control piecewise on the three intervals. Matching endpoint states and uniqueness join the trajectory segments. Each segment satisfies the relevant constraints, and the resource state is passed unchanged from the endpoint of one segment to the start of the next. Additivity of the integral cost gives Equation 11.1. The target and continuation properties follow from the assumptions on the latter two segments. $\square$

The proposition is a composition result, with substantive requirements in its assumptions. It prevents a preparation plan from spending resources that a transition plan independently assumes are still available. It also prevents a terminal entry condition from standing for a demonstrated continuation. Under uncertainty, the deterministic construction must be replaced by a justified robust or probabilistic policy statement; favorable sample paths are insufficient.

The resulting integration uses a conjunction of conditions. Access, controllability, latency, uncertainty, and reproduction have different roles. Multiplying them into a single index would require additional assumptions about units, compensation, and value. A feasible path and its resource account provide a more transparent object for review.

11.3 Recurrence and changes to the field

The endpoint of one inquiry becomes part of the initial condition of another. A new relationship can support later learning; a resource commitment can create maintenance obligations; an intervention can alter an institution's subsequent response. The field is changed by practice and can change the meaning of later actions.

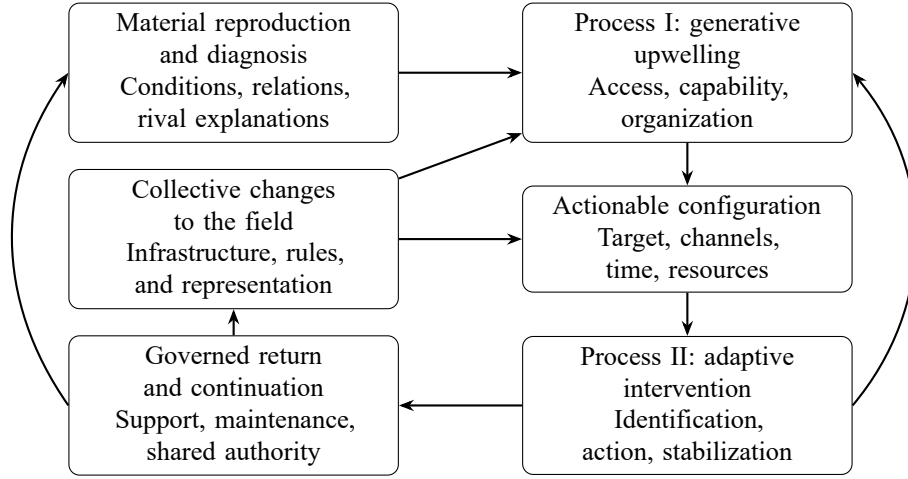
Reproduction consequently operates throughout the sequence. Some returns arrive before a target is reached, as in mutual teaching or shared maintenance. Some costs emerge after visible success, as in support demands or renewal obligations. The time of each flow matters to viability. A future reward cannot automatically cover a present shortfall.

Figure 3 represents the recurrent architecture. Its feedback paths include renewed diagnosis, collective institutional change, and the allocation of returns. The diagram should be read as a set of possible relations. The actual sequence depends on the project and historical configuration.

11.4 Failure configurations and strategic implications

An accessible opening can fail through insufficient continuation resources. A group may obtain a facility allocation and complete a demonstration while lacking the time to maintain data, software, or participa-

Figure 3: Integration of generative upwelling, adaptive transition, and reproduction



tion. The entry target has been reached, but the reproductive condition has not. A revised plan may need a smaller project, an explicit support commitment, or a different institutional arrangement.

A second failure concerns direction. High transient gain can occur in a channel that does not affect the target. A widely circulated contribution may generate attention while the authority controlling access remains unresponsive. The relevant diagnosis concerns the input map and target geometry, not the overall intensity of public reaction.

A third failure concerns timing. Prepared competence and adequate resources may arrive after the decision window has closed. Conversely, an immediate opportunity can be refused because the necessary deliberation cannot be completed responsibly within it. Timing is part of feasibility, and a missed occasion does not by itself diagnose deficient generativity.

A fourth failure concerns a changing mechanism. An intervention modeled as a routine application can become a negotiation about governance. The assumptions supporting a local cost estimate then cease to organize the situation. Supervision should revise the problem or return to diagnosis, rather than continue optimizing against the earlier model.

These configurations clarify the practical thesis. Sustaining generativity involves maintaining and transforming the relations through which action can be prepared, directed, timed, and continued. Each process addresses a different part of that organization, while collective praxis can alter the conditions connecting them.

12 Reproduction and Recirculation

This section examines how the consequences of inquiry become conditions for subsequent inquiry. It distinguishes return flows by resource, connects allocation to governance, and derives a simple model of continued capacity. The analysis evaluates sustainability through reproduction and maintenance rather than an assumed requirement of indefinite expansion.

12.1 Resource-specific return

Returns can include money, protected time, renewed access, competence, relationships, and authority. These forms differ in their conversion conditions. Recognition can lead to a funded opportunity, but it can also impose unpaid obligations. Access to an instrument can save time in one activity while increasing maintenance work in another. A useful return account records both the recipient and the practical transformation through which the return supports inquiry.

Let Y_i denote different return rates, and let A_{ji} represent their allocation or conversion into resource j . With external supply s_j , maintenance m_j , intervention use c_j , and depreciation rate δ_j , Equation 12.1

extends the resource budget.

$$\dot{r}_j = s_j + \sum_i A_{ji} Y_i - m_j - c_j - \delta_j r_j. \quad (12.1)$$

Each row has the units of its own resource per time. Conversion coefficients carry the necessary units. External supply and return categories must be defined without double counting. Knowledge, money, care, and decision rights are not assumed mutually convertible.

For a scalar resource with constant terms and $\delta_j > 0$, a fixed point is $r_j^* = (s_j + \sum_i A_{ji} Y_i - m_j - c_j) / \delta_j$. Preserving a minimum $r_{j,\min}$ requires nonnegative drift at that boundary, namely $s_j + \sum_i A_{ji} Y_i - m_j - c_j \geq \delta_j r_{j,\min}$. Each indispensable resource requires its own condition. A surplus in one row cannot automatically compensate for a binding deficit in another.

Timing is part of the balance. A promised payment after completion cannot finance an indispensable purchase before work begins unless an additional credit or support arrangement exists. A renewal decision can arrive after the current access expires. Delays and commitments therefore belong in a sufficiently complete resource state.

12.2 Allocation, authority, and maintenance

Generative justice directs attention to contributors and the organization of return [9]. The present framework connects that concern to the conditions of continuation. The distribution of returns matters because contributors occupy different positions in the production and maintenance of an outcome. A visible author, a technical maintainer, a community providing data, and a caregiver may enable the same project through different activities.

Control over allocation also shapes future possibilities. A grant to a principal investigator, an enforceable resource commitment to a collective, and a discretionary invitation to an individual can have different reproductive consequences even when their immediate monetary values coincide. Authority over renewal, agenda, and maintenance influences the reliability of the return.

A commons arrangement therefore requires an account of its supporting labor and institutions. Public availability can expand use while maintenance remains concentrated among a few contributors. A collectively governed project can also develop unequal voice when administrative and technical roles become difficult to replace. Institutional analysis should examine how participation, responsibility, support, and decision rights are connected. Ostrom's differentiated social-ecological framework provides a relevant precedent for attending to institutional configurations [29].

Reproduction includes uses sometimes categorized as consumption. Food, housing, rest, care, and recovery preserve the people and relations that make inquiry possible. Treating them only as deductions from productive return would distort the material account. A sustainable arrangement can support a modest level of output while reproducing substantial capacity for future inquiry.

12.3 Continued capacity across inquiry cycles

A simplified recurrence illustrates the distinction between reproduction and indefinite growth. Let c_n be a chosen normalized capacity measure for a specified practice. Suppose a fraction d is lost per cycle, potential return is ηc_n , an effective fraction α returns to support the generator, and external support minus reproduction requirements is $s - m$. Adding retained capacity and replenishment gives Equation 12.2.

$$c_{n+1} = g_c c_n + s - m, \quad g_c = 1 - d + \alpha \eta, \quad c^* = \frac{s - m}{1 - g_c} \quad (0 \leq g_c < 1). \quad (12.2)$$

The fixed point follows by setting $c_{n+1} = c_n$. Deviations satisfy $c_n - c^* = g_c^n (c_0 - c^*)$. The region $c \geq c_{\min}$ is invariant under this monotone recurrence when $g_c c_{\min} + s - m \geq c_{\min}$.

The calculation shows that external support can sustain capacity even when internal returns alone do not replace losses. It also shows why a short-term gain is insufficient evidence of sustainable reproduction. A project can increase capacity during an unusually favorable interval and then deplete it when support or return changes. The relevant object is the sequence of conditions and flows.

The scalar capacity is an illustrative model choice. Its coefficients would require justification for a particular practice, and a multidimensional description is preferable when resources cannot be substituted. A multiplier above one predicts growth only within the linear approximation. It supplies no conclusion about distribution, ecological burden, or the value of the inquiry.

12.4 Collective reproduction and externalized burdens

An arrangement can maintain its immediate participants by shifting costs elsewhere. Unpaid support work, ecological damage, or dependence on a precarious supplier can remain outside a narrowly chosen budget. The framework's resource boundary must therefore be scrutinized alongside its apparent viability. Continued output within the boundary can coexist with depletion of its supporting conditions.

Collective governance can make these relations more visible by recording maintenance, care, access conditions, and contested allocations. It can also establish commitments that allow contributors to plan a realistic inquiry cycle. Such organization requires resources of its own and should be evaluated through actual participation rather than formal procedure alone.

Reproduction is consequently both a material condition and an object of political contestation. Participants can disagree about what should be maintained, whose capacities should receive support, and which dependencies should be transformed. The formal budget clarifies the consequences of an allocation; the justification of that allocation requires situated judgment.

Recirculation completes the recurrent architecture of praxis. Returns support the next cycle, can alter the field through shared infrastructure or authority, and can revise the subject's available actions. Generativity is sustained when these processes preserve a capacity for continued and revisable inquiry under conditions that remain open to collective evaluation and change.

13 Individual and Collective Praxis

This section applies the framework to a constructed research association and then develops bounded historical contrasts. The constructed case follows the same participants through diagnosis, access, a timed intervention, and continuation. The historical materials identify organizational mechanisms and evidentiary limits. Neither component is presented as an empirical validation of the complete model.

13.1 A constructed research association

Consider six independent researchers developing an environmental-data study. They possess relevant experience and access to public data, but require dependable computing, methodological review, and time for documentation. Their initial target is a renewable arrangement for computation and peer scrutiny with a recognized role in decisions affecting their participation. All quantities and institutional events in this case are illustrative.

Each member initially has twenty hours per month of usable inquiry time after accounting for paid work, care, and recovery. The aggregate is 120 hours, although tasks remain subject to individual availability and competence. The proposed monthly work totals 138 hours: 84 for research and analysis, 24 for documentation, 18 for coordination and administration, and 12 for maintenance. The initial plan therefore exceeds available time before uncertainty or interruption is included.

The immediate diagnosis identifies coupled reproduction and access constraints. Buying equipment would leave the time deficit and add maintenance obligations. Abandoning documentation would make the result difficult to scrutinize and reproduce. A strategy focused only on increased individual effort would weaken the very conditions the project needs to maintain.

The association reorganizes work through shared records and explicit responsibilities. In the constructed plan, documentation falls to 12 hours and coordination to 10, while research and maintenance remain at 84 and 12. A support commitment supplies 20 additional protected hours, taking total available time to 140. Planned use is now 118 hours, leaving a 22-hour aggregate margin. The group must still

Table 5: Illustrative monthly inquiry-time budget

Activity or resource	Initial plan, hours	Revised plan, hours
Research and analysis	84	84
Documentation	24	12
Coordination and administration	18	10
Maintenance	12	12
Total planned use	138	118
Available protected time	120	140
Unallocated time margin	−18	22

check that specialized tasks fit the particular members' availability. Aggregate feasibility alone cannot allocate expertise.

Table 5 records the time account. The reductions are stipulated effects of the constructed reorganization, not estimates of typical collective efficiency. Their purpose is to demonstrate how the viability comparison should be made.

The group also arranges shared computing through a public facility and develops a reproducible demonstration using a modest initial allocation. This is Process I: access, competence, communicability, and reproduction change together. The group records the facility's renewal rules and identifies which decisions can be negotiated collectively.

13.2 An opening and a bounded intervention

Suppose the facility announces a ten-day period for proposals concerning a renewable participation programme. The association learns of it after two days, leaving eight. Without preparation, its remaining interpretation, deliberation, preparation, and propagation stages would take two, one, four, and two days respectively. The nine-day chain exceeds the remaining opening.

Prepared records and established roles reduce those remaining stages to one day each in the constructed scenario. The four-day chain fits within the eight days left. The original discovery delay remains part of the history; it is not counted a second time in the comparison of remaining work. The example distinguishes preparation that reduces latency from an institutional change that creates the opening.

The action target also requires precision. An increased number of public responses to the demonstration would not necessarily affect the facility's allocation decision. The association therefore identifies an authorized proposal channel and a decision-maker able to establish the relevant commitment. Its local model concerns the connection between the proposal, the allocation process, and the requested governance terms.

A viable intervention includes its documentation and follow-up costs. If the facility requests additional work that removes the time margin, the association must revise the proposal or obtain further support. The supervisory judgment can also reject an offer that provides computation while assigning indefinite unpaid maintenance obligations. A formally successful admission would otherwise conceal a deterioration in reproduction.

The normalized scalar and Gramian examples developed earlier can guide the structure of comparison. Their numerical coefficients are not estimated from this association. A real application would require records of interventions, decisions, resource use, and relevant alternatives before assigning quantitative cost or probability values.

13.3 Continuation and institutional consequences

Assume that the association obtains a six-month access arrangement with a stated renewal procedure and contributor representation in a maintenance discussion. Entry is followed by observation across

successive inquiry cycles. The group records actual research time, support work, interruptions, access reliability, and participation in decisions. The stipulated outcome becomes durable only to the extent that these conditions support continuation.

Returns include demonstrated capability, a reusable method, renewed access, and relationships with reviewers. Their value depends on their use in subsequent inquiries. A public result can also generate additional requests. The association should record whether these requests replenish capacity, consume the time margin, or create new dependencies.

The governance terms distinguish a trajectory improvement from a wider institutional change. An exceptional allocation to this association improves its access. A transparent process through which other eligible groups can obtain comparable access changes the rule governing subsequent cases. Contributor representation may similarly range from a consultative occasion to a consequential decision right. The empirical assessment should specify which change occurred.

The case therefore yields a set of observations rather than a single success score. These include the initial constraint configuration, actual changes in time and access, the latency of the intervention, the authority of its channel, and the persistence and distribution of returns. A project can improve on some dimensions while remaining vulnerable on others.

13.4 Historical contrasts in organization

Historical materials supply contrasting forms of organization. Marx's 1864 address treats cooperative production as consequential while connecting its limitations to wider political conditions [21]. The relevant comparison concerns the relation between local productive organization and institutions that shape its reach. A contemporary association's effective internal cooperation may still depend on externally governed access, finance, or permissions.

Gramsci's 1919 account of the Brevetti-Fiat council records workplace representation organized through sections and trades [13]. Its relevance concerns the construction of collective channels and the relation between productive activity and representation. The account expresses a participant's political interpretation. It cannot by itself establish the long-term effectiveness or wider consequences of council organization.

Mondragon's history links cooperative development with supporting institutions, while its 2013 report describes the Fagor crisis and responses involving employment support [22, 23]. The contrast concerns reproduction under vulnerability. Productive success, supporting infrastructure, and exposure to enterprise failure can coexist. The corporate sources provide bounded evidence of reported arrangements and responses; independent analysis is required for a general explanation of outcomes.

These comparisons identify questions for a praxis framework: which capacities association creates, which external dependencies persist, how representation becomes effective, and which institutions support contributors when a productive arrangement fails. They do not establish that historical organizations followed an oceanic mechanism or a specified control law.

13.5 Individual action and collective scale

Individual praxis remains consequential within this account. A person can preserve a feasible inquiry cycle, develop competence, maintain a reliable record, or negotiate a workable commitment. Such actions can prepare conditions for association. Their evaluation should include the resources and relations that make them possible.

Collective praxis can change the action set. Shared infrastructure, protected time, representation, and public provision create possibilities that additional individual effort alone may not provide. Yet collective scale does not automatically remove dependency or unequal authority. The organization must reproduce its contributors and maintain accountable control over its own conditions.

The relation between scales is therefore recursive. Individual actions can sustain a collective; collective institutions can change individual possibilities; external institutions can constrain or support both.

A comprehensive account of generativity follows these relations across successive cycles and examines where productive capacity remains separated from effective control.

14 Scope and Evidence

This section specifies the claims established by the framework and the evidence required for its social applications. It distinguishes analytical verification from empirical identification, formulates possible counterevidence, and describes a research design suited to relational and temporal mechanisms.

14.1 Status of the formal results

The scalar cost formula, the stable linear amplification example, the Gramian solution, and the elementary transition models are mathematical results under explicit assumptions. Numerical checks compare selected consequences with direct substitution, quadrature, finite differences, and independent differential-equation integration. The accompanying package reports twenty-five successful numerical and structural checks. Appendix C describes their scope.

These checks do not estimate a real institution's dynamics. An accurate calculation can still be based on an inappropriate target, absent control channel, or unsupported parameter. A local linear approximation can fail when a decision process changes its rules. A scalar resource representation can conceal non-substitutable requirements. The mathematical and empirical questions therefore require separate evaluation.

Several results also depend on existence or regularity conditions. An infimum at a budget boundary need not be attained. A constrained controller requires admissible trajectories. A state-dependent model needs a sufficiently informative observation process. A viability claim under diffusion differs from an inward deterministic drift condition. These restrictions are retained because they affect the meaning of practical success.

14.2 Identification of social mechanisms

An empirical application should begin with an actual inquiry or institutional relation rather than an abstract score. The record should identify participants, targets, indispensable resources, permissions, action channels, timing, and continuation. It should distinguish formal rules from their effective operation and document how participants interpret the arrangement.

A field-mediated access claim requires a meaningful comparison. Relevant alternatives should share a target, horizon, and resource convention, or the differences should be modeled explicitly. If groups facing different opportunities also have different reserves, the observed outcome cannot isolate a timing effect without further evidence. Selection into the opportunity may itself depend on unobserved competence or institutional connections.

A controllability claim concerns interventions and outcomes. Correlations among publicly visible variables may provide little information about an institution's response to a new action. Evidence can include decision records, changes in permissions, interrupted sequences, comparable rejected proposals, and participant accounts. Where direct experiments are inappropriate, process tracing can examine the sequence linking an action to its claimed effect.

A reproduction claim requires follow-up. Immediate output, attention, or admission is insufficient evidence of continued generativity. Subsequent workloads, maintenance, access renewal, learning, and participation in decisions should be observed across realistic cycles. The record should include people whose support work lies outside the most visible project boundary.

14.3 Propositions and counterevidence

Table 6 connects the framework's conditional propositions to evidence and possible counterevidence. The propositions concern mechanisms that can be examined independently. A finding may support one

Table 6: Praxis propositions, evidence, and counterevidence

Proposition	Supporting observations	Counterevidence or rival explanation
Field changes can lower a specified access cost	Comparable targets require less intervention after an identified rule or resource change	Different reserves, targets, or selection explain the outcome
Preparation can improve use of a short opening	Recorded stages shorten while the target and judgment requirements remain comparable	Apparent speed comes from omitted work or weaker evaluation
Effective channels condition intervention	Identified authority links an action to the desired decision	Public response increases without changing the target condition
Regime diagnosis can improve action selection	Different constraint configurations require different successful interventions	A generic resource difference explains all cases
Entry and continuation are distinct	Initial admission coexists with divergent later maintenance and access	The target already included the full observed continuation
Collective organization can change field conditions	Rules, resources, or decision rights change beyond an isolated case	Only exceptional access changes, or burdens move to excluded contributors
Returns can reproduce inquiry	Resource and authority changes support subsequent cycles	Output is sustained through depletion or externalized maintenance

component while requiring revision of another.

Counterevidence should include failed attempts, abandoned projects, and regression. Restricting analysis to visible successes would conceal the resources needed to survive unsuccessful intervention. It could also mistake retrospective narratives of timing for evidence of an identifiable opening.

14.4 Comparative and participatory inquiry

A suitable initial design combines comparative process tracing with participatory institutional analysis. Cases should vary in access conditions, resource security, collective organization, and the temporal structure of opportunities. The unit can be a project sequence, an association, or an access relation, provided the boundary is explicit.

Participants should be able to challenge the diagnosis, target, and resource account. Their disagreement can identify omitted labor, unequal burdens, or an institutional relation obscured by aggregate measures. Participation in interpretation does not remove the need to evaluate evidence; it expands the record of what must be explained.

Quantitative calibration should follow specification of observable variables and plausible mechanisms. A useful first model may be a bounded decision record rather than a fitted high-dimensional dynamical system. Model complexity should reflect the information available and the practical distinctions required.

The framework is therefore open to revision at several levels. Particular mappings can fail; a regime typology can require different categories; a local control description can prove inappropriate; a target can be rejected on normative grounds. These possibilities are part of the research programme rather than exceptions to be hidden by the formalism.

15 Discussion

This section develops the institutional and theoretical implications of the integrated framework. It connects the formal distinctions to infrastructure, commons governance, temporal organization, and the relation between generativity and political-economic transformation.

15.1 Infrastructure and durable participation

The framework directs attention to the duration and governability of access. A resource can be technically available while its renewal, maintenance, or terms remain too uncertain for a sustained inquiry. Institutional design should therefore consider the complete cycle through which participants obtain access, develop competence, produce a contribution, and continue or transfer the work.

Protected time, reliable infrastructure, intelligible procedures, and supported maintenance can change the viable action set. Their effects differ from increasing the number of opportunities advertised. An opening whose requirements exceed available resources remains inaccessible, while a modest commitment can make an existing opportunity actionable.

Durability also depends on authority. Participants who can contest allocation, understand renewal conditions, and influence maintenance possess different possibilities from those dependent on discretionary favor. These arrangements can be evaluated through their actual effects on continuation and participation. A formal right without a usable channel may have limited practical force.

Collective institutions can also preserve alternatives. Shared records, interoperable tools, and transferable competence can reduce the consequences of a single access withdrawal. Maintaining alternatives consumes resources, so their value should be considered in relation to the vulnerabilities they address and the inquiry they support.

15.2 Commons, appropriation, and governed return

Public availability and generative control are distinct institutional achievements. An artifact can circulate widely while the means of updating, evaluating, or applying it remain concentrated. A commons can expand access while relying on unacknowledged maintenance. Conversely, a temporary boundary can protect the time needed to develop a contribution or support a community's authority over its conditions.

The framework evaluates these arrangements through their relations and consequences. It asks which capacities are enabled, which dependencies persist, who governs continuation, and how returns are allocated. Generative justice provides a relevant orientation toward contributors and return, while the models clarify particular constraints and effects [7, 9]. Neither a nominally open form nor a positive resource balance determines the whole normative assessment.

A practical implication is that dissemination should be considered alongside support for reproduction. An institution that funds an initial artifact while leaving its maintenance unresourced creates a different trajectory from one that supports continuing stewardship. A project that receives attention can require governance of requests and obligations to prevent depletion of its contributors.

15.3 Temporal organization and the conditions of judgment

The analysis gives response speed a specific role. An intervention must fit an opening, but the time required for interpretation and deliberation belongs within that condition. Speed can be improved through preparation and shared organization. It can also be purchased by weakening scrutiny or shifting costs onto participants with less power.

Generative praxis should therefore preserve differentiated timescales. Some tasks benefit from rapid coordination; others require extended learning, careful observation, or recovery. An institution that demands the same tempo from all activities can undermine the transformations upon which later responsiveness depends.

The distinction between critical slowing and rapid external change further cautions against a general acceleration imperative. A situation can become more sensitive while recovering more slowly. The appropriate response may involve narrower action, greater reserves, a shorter prediction horizon, or withdrawal. The model should identify the relevant mechanism before assigning a temporal strategy.

15.4 Generativity and political-economic transformation

The immediate objective is continued meaningful inquiry under unequal conditions. Achieving that objective can produce local gains without transforming the class relation at a wider scale. The framework preserves this distinction while locating possible connections through collective field change.

A group that secures access changes its trajectory. A rule that makes access available to subsequent groups changes an institutional relation. A supported association can build capacities for representation and maintenance that alter later possibilities. These processes may connect local praxis to wider political-economic change, but the connection requires a historical account of organization, conflict, and scale.

The paper's mathematical contribution is to clarify some conditions of such processes. It distinguishes attainable targets from assumed opportunities, temporary response from persistent change, and return from reproductive sufficiency. Its philosophical contribution is to place those distinctions within a material and relational analysis of inquiry.

The framework consequently remains answerable to the purposes and judgments of those whose activity it represents. Sustaining generativity includes the capacity to revise a method, contest a target, refuse an extractive arrangement, and organize different conditions of inquiry. Formal representation supports that capacity when it makes constraints and consequences more intelligible.

16 Conclusion

This paper has developed a praxis for sustaining generativity under unequal control of epistemic production and reproduction. The argument defines the epistemic proletariat relationally, constructs overlapping regimes of generative constraint, and connects historical diagnosis to individual and collective action.

Process I concerns viable changes in access, capabilities, relations, and institutions. Process II concerns the identification and realization of bounded interventions under changing conditions. Their integration requires compatible resources, effective action channels, sufficient time, acceptable uncertainty, and a feasible continuation. Reproduction and governed return connect both processes to subsequent inquiry and to possible changes in the surrounding field.

The ocean-atmosphere account supplies differentiated mechanisms of transport, transformation, coupling, and boundary motion. The mathematical models distinguish field-mediated cost reduction, stable transient amplification, transition sensitivity, and persistence. These results establish conditional relations and expose several ways in which a seemingly favorable opportunity can remain unactionable or unsustainable.

The social framework requires empirical identification and situated normative judgment. Its practical value lies in making the conditions of action and continuation explicit, while preserving the capacity to revise targets and organize different institutions. Generativity is sustained through the reproduction and transformation of the relations that allow inquiry to continue.

A Physical Derivations

This appendix supplies the physical calculations supporting Section 4. It fixes thermodynamic and sign conventions, derives the forcing and wave relations, and records the assumptions behind transformation and boundary models. The equations describe selected compatible approximations; a global ocean simulation would require additional closures, geometry, forcing data, and numerical treatment.

A.1 Thermodynamic closure and mixing

In a local Boussinesq region at a common reference pressure, density is $\rho(S_A, \Theta, p)$. Linearization gives $b \simeq g[\alpha(\Theta - \Theta_r) - \beta(S_A - S_{A,r})]$, with $\alpha = -\rho^{-1}\partial_\Theta\rho$ and $\beta = \rho^{-1}\partial_{S_A}\rho$ evaluated consistently. Approximate scalar budgets are $D\Theta/Dt = \nabla \cdot (K_\Theta \nabla \Theta) + s_\Theta$ and $DS_A/Dt = \nabla \cdot (K_S \nabla S_A) + s_S$. A complete thermodynamic model handles pressure, enthalpy, and any nonconservative corrections [36, 37].

Nonlinear mixing follows from the curvature of the equation of state. Let q_1, q_2 be approximately conservative composition coordinates at a common pressure, with mass fractions $a, 1 - a$. Define $q_m = aq_1 + (1 - a)q_2$, $\Delta q = q_1 - q_2$, and specific volume $v_\rho = 1/\rho$. Expanding both parcels about q_m , the first-order terms cancel in the weighted sum. Equation A.1 gives the second-order differences.

$$\begin{aligned} \rho(q_m) - a\rho(q_1) - (1 - a)\rho(q_2) &\simeq -\frac{a(1 - a)}{2}\Delta q^T H_\rho \Delta q, \\ v_\rho(q_m) - av_\rho(q_1) - (1 - a)v_\rho(q_2) &\simeq -\frac{a(1 - a)}{2}\Delta q^T H_{v_\rho} \Delta q. \end{aligned} \quad (\text{A.1})$$

The Hessians are evaluated at the mean. For mass fractions, the density corresponding to total unmixed volume is $[a/\rho(q_1) + (1 - a)/\rho(q_2)]^{-1}$. A negative change in specific volume indicates contraction. If the initial parcel densities are equal, the density benchmarks coincide and a denser mixture exhibits cabbeling. General mixtures require the volume distinction and consistent heat accounting.

For small adiabatic displacements in a resting stratified state, parcel buoyancy remains fixed while environmental buoyancy changes by $N^2\zeta$. The relative acceleration is therefore $-N^2\zeta$. Integrating the restoring work gives Equation A.2.

$$\delta b = -N^2\zeta, \quad \ddot{\zeta} + N^2\zeta = 0, \quad e_{\text{available}} = \frac{1}{2}N^2\zeta^2. \quad (\text{A.2})$$

The energy is per unit mass and has dimensions of length squared per time squared. The pressure-equilibrated parcel approximation is local. The complete internal-wave problem includes horizontal motion and pressure perturbations.

A.2 Air–sea exchange and mixed-layer budgets

Let $\mathbf{U}_r = \mathbf{U}_a - \mathbf{v}_s$ denote atmospheric wind relative to the surface current. With atmospheric density ρ_a , heat capacity c_{pa} , latent heat L_v , and bulk coefficients C_D, C_H, C_E , define upward sensible and latent heat fluxes H_s, H_l . The simplified exchange relations are Equation A.3.

$$\begin{aligned} \boldsymbol{\tau} &= \rho_a C_D |\mathbf{U}_r| \mathbf{U}_r, \\ H_s &= \rho_a c_{pa} C_H |\mathbf{U}_r| (T_s - T_a), \\ H_l &= \rho_a L_v C_E |\mathbf{U}_r| (q_s - q_a), \\ Q_{\text{in}} &= Q_{\text{sw}} + Q_{\text{lw}} - H_s - H_l + Q_{\text{rain}}, \\ F_{\text{fw}} &= P + R + M - E_v, \quad E_v = \frac{H_l}{\rho_{\text{fw}} L_v}. \end{aligned} \quad (\text{A.3})$$

Here q_s, q_a are humidity variables; P, R, M, E_v are precipitation, area-normalized runoff, effective ice freshwater exchange, and evaporation in length per time. Net radiation is positive into the ocean. The

evaporation relation ensures a consistent latent-heat and freshwater convention. Detailed algorithms include atmospheric stability and other corrections [27].

Differentiating the linear buoyancy relation and inserting heat and freshwater input gives Equation 4.4. Integrating the scalar budgets over a homogeneous mixed layer gives a further distinction between surface input and entrainment. With depth h , nonnegative entrainment rate w_e , base values Θ_b , S_b , and remaining integrated transport terms $\mathcal{D}_\Theta$, $\mathcal{D}_S$, the slab balances are Equation A.4.

$$\begin{aligned} h \frac{D_m \Theta_m}{Dt} &= \frac{Q_{\text{abs}}}{\rho_0 c_p} + w_e (\Theta_b - \Theta_m) + \mathcal{D}_\Theta, \\ h \frac{D_m S_m}{Dt} &= -S_m F_{\text{fw}} + w_e (S_b - S_m) + \mathcal{D}_S. \end{aligned} \quad (\text{A.4})$$

The entrainment terms follow by subtracting the mean property carried by the changing layer mass from the property entering at the base. Detrainment, large volume changes, and explicit ice salt fluxes require corresponding adjustments. Q_{abs} includes only the heat absorbed in the layer.

For the fixed-depth anomaly model in Equation 4.5, multiply by the integrating factor e^{t/τ_θ} . Integration gives Equation A.5.

$$\theta(t) = e^{-(t-t_0)/\tau_\theta} \theta(t_0) + \frac{1}{\rho_0 c_p h} \int_{t_0}^t e^{-(t-s)/\tau_\theta} Q'(s) ds. \quad (\text{A.5})$$

A constant input and zero initial anomaly give $\theta = (Q'/\Lambda)(1 - e^{-(t-t_0)/\tau_\theta})$. Setting $\Lambda = 0$ directly in the budget gives linear warming; taking a finite relaxation time in that case would be inconsistent.

A.3 Tidal potential and Ekman transport

For a celestial mass M_j at distance R_j in direction $\mathbf{n}_j$, expand $-GM_j/|R_j \mathbf{n}_j - \mathbf{r}|$ in $|\mathbf{r}|/R_j$. Remove the constant term and the uniform acceleration of the Earth-centered frame. The leading differential potential is Equation A.6.

$$\begin{aligned} \Psi_T(\mathbf{r}, t) &= - \sum_j \frac{GM_j}{2R_j(t)^3} [3(\mathbf{n}_j(t) \cdot \mathbf{r})^2 - |\mathbf{r}|^2] \\ &\quad + O\left(\sum_j \frac{GM_j |\mathbf{r}|^3}{R_j^4}\right). \end{aligned} \quad (\text{A.6})$$

The force is $-\nabla \Psi_T$. Its leading scale is $GM_j |\mathbf{r}|/R_j^3$, which differs from the uniform gravitational acceleration. A local harmonic elevation $\eta_T = \sum_j a_j(\mathbf{r}_h) \cos[\omega_j t + \varphi_j(\mathbf{r}_h)]$ describes the response through measured or modeled constituents [25, 26]. Residual transport requires additional dynamical structure.

For a steady integrated Ekman layer with negligible stress at its base, horizontal momentum gives $f \mathbf{e}_z \times \mathbf{M}_E = \boldsymbol{\tau}/\rho_0$. Inverting the rotation and integrating continuity under zero vertical velocity at the surface yields Equation A.7.

$$\mathbf{M}_E = \frac{\boldsymbol{\tau} \times \mathbf{e}_z}{\rho_0 f}, \quad w_E = \nabla_h \cdot \mathbf{M}_E = \frac{1}{\rho_0} \left[\partial_x \left(\frac{\tau_y}{f} \right) - \partial_y \left(\frac{\tau_x}{f} \right) \right]. \quad (\text{A.7})$$

Transport has units of area per time and w_E is upward at the layer base when positive. Near $f = 0$, or under strong unsteadiness and interacting boundary layers, this approximation requires replacement or modification.

A.4 Internal-wave elimination

Take constant N, f , align the horizontal wavenumber with x , and use amplitudes proportional to $e^{i(kx+mz-\omega t)}$. Linearized inviscid momentum, buoyancy, and continuity give Equation A.8.

$$\begin{aligned} -i\omega \hat{u} - f \hat{v} &= -ik \hat{\pi}, & -i\omega \hat{v} + f \hat{u} &= 0, \\ -i\omega \hat{w} &= -im \hat{\pi} + \hat{b}, & -i\omega \hat{b} + N^2 \hat{w} &= 0, \\ k \hat{u} + m \hat{w} &= 0. \end{aligned} \quad (\text{A.8})$$

Continuity gives $\hat{u} = -m\hat{w}/k$. The transverse momentum and buoyancy equations give $\hat{v} = f\hat{u}/(i\omega)$ and $\hat{b} = N^2\hat{w}/(i\omega)$. Eliminating pressure from the remaining equations yields $\omega^2(k^2 + m^2) = N^2k^2 + f^2m^2$, recovering Equation 4.3.

Differentiation gives vertical group velocity $\partial_m\omega = (f^2 - N^2)k_h^2m/[\omega(k_h^2 + m^2)^2]$. The sign depends on wavevector and stratification. The derivation assumes uniform coefficients and neglects strong shear, dissipation, and breaking. Slowly varying conditions can support a local propagation approximation; abrupt changes require additional analysis.

A.5 Turbulent budgets and water-mass transformation

Let P_s be turbulent production from shear and B_b the buoyancy-work contribution to turbulent kinetic energy. Under a locally stationary balance and downgradient buoyancy flux, Equation A.9 follows by defining the flux coefficient Γ .

$$0 \simeq P_s + B_b - \epsilon_{\text{diss}}, \quad B_b = -K_\rho N^2, \quad K_\rho = \frac{\Gamma \epsilon_{\text{diss}}}{N^2}, \quad R_f = \frac{\Gamma}{1 + \Gamma}. \quad (\text{A.9})$$

Here $\Gamma = K_\rho N^2/\epsilon_{\text{diss}}$ and $R_f = -B_b/P_s$. The coefficients are distinct. The often-used flux-coefficient approximation near 0.2 is conditional on the mixing regime [28]. This local closure does not determine the sign of the divergence of the buoyancy flux.

To derive Equation 4.2, differentiate $b(\mathbf{r}_h, Z_b, t) = \beta$. The surface derivatives satisfy $b_t + b_z Z_{b,t} = 0$ and $\nabla_h b + b_z \nabla_h Z_b = 0$. Substitution into $Db/Dt = Q_b$ yields the stated decomposition of w . For a steady one-dimensional diffusive budget, $Q_b = \partial_z(Kb_z)$, giving $wN^2 = \partial_z(KN^2)$.

The inventory identity in Equation 4.6 follows from differentiating $\int_\Omega H(\beta - b) dV$. Substitute $b_t = Q_b - \mathbf{v} \cdot \nabla b$. The advective term becomes a divergence of $\mathbf{v}H(\beta - b)$; incompressibility and an impermeable boundary remove its volume integral. If $\mathcal{G}_b(\beta) = \int_\Omega \delta(\beta - b) Q_b dV$, the volume in a class $\beta_1 < b < \beta_2$ changes at rate $\mathcal{G}_b(\beta_1) - \mathcal{G}_b(\beta_2)$. Open boundaries and surface transformations require consistent additional terms [14, 40].

A.6 Tracer reactions and relative settling

Let c denote a tracer concentration and w_s a signed vertical settling velocity relative to the water, with downward settling negative. Adding the relative particulate flux $w_s c \mathbf{e}_z$ to the tracer flux gives Equation A.10.

$$\partial_t c + \nabla \cdot (\mathbf{v}c) = \nabla \cdot (K \nabla c) + \mathcal{R} - \partial_z(w_s c). \quad (\text{A.10})$$

The reaction term $\mathcal{R}$ represents changes in the chosen tracer; a complete network must respect the relevant conserved elements. Dissolved tracers can have $w_s = 0$. Optical, density, and ecological feedbacks require explicit couplings to their respective budgets. This form locates biological effects without assigning them an unspecified mechanical force.

A.7 Surface waves and coastal momentum

For irrotational inviscid water of mean depth d_0 , solve Laplace's equation with an impermeable flat bottom. A Fourier velocity potential has vertical dependence $\cosh k(z + d_0)$. Combining the linear surface conditions $\eta_t = \phi_z$ and $\phi_t + g\eta = 0$ gives Equation A.11.

$$\omega^2 = gk \tanh(kd_0), \quad c_{\text{shallow}} = \sqrt{gd_0} \quad (kd_0 \ll 1). \quad (\text{A.11})$$

The relation neglects surface tension, rotation, breaking, and mean currents. It concerns a different wave family from the internal waves of Equation 4.3.

Let total depth be $d = \eta - z_b$ and depth-mean cross-shore velocity U . A one-dimensional shallow-water budget, omitting freshwater source terms for this local example, can include surface and bottom stresses, atmospheric pressure p_a , and wave radiation stress S_{xx} . Vertical integration gives Equation A.12.

$$\begin{aligned} \partial_t d + \partial_x(dU) &= 0, \\ \partial_t(dU) + \partial_x(dU^2 + \frac{1}{2}gd^2) &= -gd\partial_x z_b + \frac{\tau_x - \tau_b}{\rho_0} \\ &\quad - \frac{d}{\rho_0}\partial_x p_a - \frac{1}{\rho_0}\partial_x S_{xx}. \end{aligned} \tag{A.12}$$

The depth-integrated wave momentum flux S_{xx} has units of force per length; every momentum term has units of area per time squared. A wave-averaged closure must avoid double counting resolved waves. Breaking and the wet–dry front require suitable treatment, and adding mass sources requires consistent momentum terms [16].

The regular shoreline condition $s(x, t) = \eta - z_b = 0$ gives $\dot{x}_\Sigma = -s_t/s_x$ by direct differentiation. This calculation concerns local boundary geometry. It supplies no global guarantee of transport onto or beyond land.

A.8 Environmental memory

An eliminated environmental component can generate a memory term even when the enlarged model is Markovian. Consider $\dot{q} = -q/\tau + a\zeta(t)$, with q entering the resolved dynamics through a coupling cq . The integrating-factor solution is Equation A.13.

$$q(t) = e^{-(t-t_0)/\tau} q(t_0) + a \int_{t_0}^t e^{-(t-s)/\tau} \zeta(s) ds. \tag{A.13}$$

Substitution into the resolved equation produces the corresponding convolution. Several eliminated components can generate several memory scales. A memoryless reduced drift therefore requires a declared approximation, such as rapid relaxation relative to resolved motion. The elementary calculation clarifies a modeling issue shared by physical and institutional reductions without asserting a universal closure.

B Viability, Control, and Transition Derivations

This appendix derives the mathematical results supporting Processes I and II. It treats attainment, dynamic programming, ordered interventions, perturbation energy, optimal control, timing, stochastic residence, and continuation. Each result applies to its stated model and information assumptions.

B.1 Attainment and the information state

The distinction between an infimum and an attained minimum affects budget feasibility. Consider $\dot{x} = u$ on a unit horizon from zero, cost $\frac{1}{2} \int_0^1 u^2 dt$, and the open target $x(1) > 1$. Cauchy–Schwarz implies cost strictly greater than $1/2$ for every feasible control. Constant controls approaching one from above show that the infimum is $1/2$. Thus an inequality $J^* \leq E$ at $E = 1/2$ does not establish an available feasible action.

The main scalar example uses a closed half-line target and exhibits an attaining control explicitly. More general problems require conditions on targets, controls, dynamics, and compactness. Model uncertainty provides an additional reason to leave a positive margin when an intervention is evaluated against a resource budget.

The deterministic full-state value function also has a specific information interpretation. Under partial observation, an exact dynamic program generally requires an information state, such as a belief distribution under a justified probabilistic model. Using a point estimate in a full-state controller is an approximation. Resource reserves, remaining budgets, and relevant memory must be represented in the state when they affect future admissibility.

B.2 Dynamic programming and control dependence

Let the full deterministic dynamics be $\dot{Z} = F_{\text{full}}(Z, u, t)$ and the running cost be $u^T R_u u / 2$. Over a short interval dt , the dynamic programming principle equates present value to immediate cost plus future value. Taylor expansion and division by dt give Equation B.1.

$$0 = J_t + \min_{u \in U_{\text{adm}}(Z, t)} \left\{ \frac{1}{2} u^T R_u u + \nabla J \cdot F_{\text{full}}(Z, u, t) \right\},$$

$$J(Z, T) = \begin{cases} 0, & Z \in \mathcal{T}, \\ +\infty, & Z \notin \mathcal{T}. \end{cases} \quad (\text{B.1})$$

State constraints impose the corresponding viability boundary conditions. A nonsmooth value function requires an appropriate generalized solution concept.

If $F_{\text{full}} = F + Bu$ and controls are unconstrained, differentiation with respect to u gives $u^* = -R_u^{-1} B^T \nabla J$. Substitution gives the control Hamiltonian contribution $-\nabla J^T B R_u^{-1} B^T \nabla J / 2$. The explicit minimizer requires control-affine dynamics. Nonlinear resource-cost terms in Equation 8.1 can invalidate that specialization; the full minimization must then be retained [24].

The scalar cost proof in Proposition 8.1 is an exact alternative to solving the partial differential equation. Its simplicity makes the counterfactual assumptions visible. A more elaborate numerical value function would still need the same specification of state, target, information, resources, and horizon.

B.3 Ordered flows and institutional events

Let f and g be smooth vector fields with flows ϕ_f^h, ϕ_g^h . Taylor expansion of the second flow around the endpoint of the first yields Equation B.2.

$$\begin{aligned} \phi_g^h \circ \phi_f^h(Z) &= Z + h(f + g) + h^2 \left(\frac{1}{2} Df f + Dg f + \frac{1}{2} Dg g \right) + O(h^3), \\ \phi_g^h \circ \phi_f^h(Z) - \phi_f^h \circ \phi_g^h(Z) &= h^2 (Dg f - Df g) + O(h^3). \end{aligned} \quad (\text{B.2})$$

All fields and derivatives on the right are evaluated at Z . A Lie-split composition approximates the simultaneous flow of $f + g$ over h with local error $O(h^2)$. An actual sequence of institutional actions is a different object, specified by the times at which those actions occur.

Discrete changes can be represented through a hybrid model. Let a diagnostic regime m select a dynamics F_m , and let an identified guard or event permit a reset. Equation B.3 records this optional representation.

$$\dot{Z} = F_m(Z, u, t), \quad (m^+, Z^+) = \mathcal{H}_{mn}(m^-, Z^-, t) \quad \text{at an identified event.} \quad (\text{B.3})$$

A revised diagnosis often changes only the regime label, with $Z^+ = Z^-$. An actual account closure or contract change can alter state variables discretely. Overlapping regimes require explicit selection or combination rules. Numerical label changes should not be mistaken for observed institutional transitions.

B.4 Perturbation energy

Write an incompressible velocity as $\mathbf{U} + \mathbf{v}'$, where $\mathbf{U}$ is a maintained mean flow. Subtract its governing equation from the full momentum equation. In an unstratified perturbation calculation, take the scalar product with $\mathbf{v}'$ and integrate over a domain with periodic or compatible impermeable no-work boundaries. Integration by parts yields Equation B.4.

$$\frac{d}{dt} \frac{1}{2} \int |\mathbf{v}'|^2 dV = - \int v'_i v'_j \partial_j U_i dV - \nu \int |\nabla \mathbf{v}'|^2 dV + \int \mathbf{v}' \cdot \mathbf{f}' dV. \quad (\text{B.4})$$

Mean advection and nonlinear perturbation advection become boundary terms, pressure performs no net work under these conditions, and Coriolis work vanishes pointwise. Stratification adds a buoyancy-work term and the corresponding potential-energy account.

Projection onto energy-orthonormal divergence-free modes gives a system $\dot{a} = La + Q(a, a) + Fu$, with $a^T Q(a, a) = 0$ under compatible boundaries. Nonlinear advection redistributes energy among modes; the linear operator can exchange energy with the maintained background. The nonnormal example in Equation 9.3 illustrates finite-time amplification within a stable linear system.

B.5 Propagators and the Gramian optimum

For the time-varying linear equation, variation of constants gives Equation 9.2. The transition matrix depends on time ordering. Equality with the exponential of an integrated Jacobian holds under suitable commutation conditions; it should not be assumed for general changing coupled dynamics.

To obtain Equation 10.2, minimize $\frac{1}{2} \int_t^T u^T R_u u \, ds$ subject to $d = \int_t^T \Phi(T, s) B(s) u(s) \, ds$. Introduce a multiplier λ for the terminal displacement. Variation with respect to the control gives Equation B.5.

$$u^*(s) = R_u(s)^{-1} B(s)^T \Phi(T, s)^T \lambda, \quad W\lambda = d, \quad u^*(s) = R_u(s)^{-1} B(s)^T \Phi(T, s)^T W^\dagger d. \quad (\text{B.5})$$

The final expression applies when $d \in \text{Range}(W)$. Substitution gives cost $d^T W^\dagger d / 2$. For a positive-definite Gramian, the inverse is ordinary. With a singular Gramian, the range restriction remains indispensable: an inaccessible direction can have pseudoinverse quadratic form zero.

For the half-space $n^T d \geq \delta$, consider the active case $\delta > 0$. A scalar multiplier gives $d = \lambda Wn$, and the constraint gives $\lambda = \delta / (n^T Wn)$. Substitution yields Equation 10.3. If $\delta \leq 0$, zero control satisfies terminal membership. If $n^T Wn = 0$ and $\delta > 0$, the half-space is unreachable through the specified inputs.

B.6 Moving boundaries and model error

Differentiating $s(Z_\Sigma(t), t) = 0$ gives $\partial_t s + \nabla s \cdot \dot{Z}_\Sigma = 0$. Projection onto $n = \nabla s / \|\nabla s\|$ yields the normal speed in Equation 10.4. Differentiating the same function along the subject's trajectory separates field drift, explicit boundary change, and control.

For the periodic shortfall, budget feasibility from Equation 10.3 reduces to $\cos(\omega t) \geq c$. The interval within each period has angular width $2 \arccos c$, giving Equation 10.5. This result presumes the same directional Gramian and relative planning horizon across phases. It does not account for a changing reserve or an additional residence requirement unless those are included.

For the error bound, compare true and predicted trajectories under the same applied input within a valid tube. Lipschitz continuity and a bounded model discrepancy imply that the upper derivative of their distance obeys $\dot{e} \leq Le + \epsilon_m$. Multiplying by e^{-Lh} , integrating, and adding the initial error gives Equation 10.7. The bound is conditional on remaining within the tube where the assumptions hold.

B.7 Fold and rate-induced transitions

For $\dot{q} = \mu - q^2 + p$, the unforced equilibria satisfy $q^2 = \mu$. The derivative of the drift at $q_s = \sqrt{\mu}$ is $-2\sqrt{\mu}$, giving the relaxation time in Equation 9.4. Differentiating the forced equilibrium $q_s(p) = \sqrt{\mu + p}$ gives the static susceptibility. Linear harmonic forcing yields magnitude $1/\sqrt{4\mu + \omega^2}$. Integrating the negative drift gives $U(q) = q^3/3 - \mu q$, and evaluating the potential difference gives $4\mu^{3/2}/3$.

The translating bistable model separates tracking failure from loss of frozen stability. With $\dot{q} = (q - a) - (q - a)^3$ and $a = vt$, the moving coordinate $y = q - a$ gives Equation B.6.

$$\dot{y} = y - y^3 - v, \quad 1 - 3y_c^2 = 0, \quad y_c = \frac{1}{\sqrt{3}}, \quad v_c = y_c - y_c^3 = \frac{2}{3\sqrt{3}}. \quad (\text{B.6})$$

At the positive fold, the tracking equilibrium and the intervening unstable equilibrium merge. For $v > v_c$, a trajectory initially near the upper branch moves toward the remaining negative tracking branch. Each frozen upper equilibrium $q = a + 1$ still has derivative -2 . This is a rate-induced mechanism of the kind distinguished in tipping research [1].

B.8 Stochastic entry and residence

For a controlled diffusion $dZ = F(Z, u, t)dt + \sqrt{2\varepsilon_n}\Sigma(Z, t)dW_t$, define an entry set $\mathcal{K}_{\text{entry}}(s)$ strictly inside a broader acceptable target $\mathcal{T}(s)$. Let τ_K be its first hitting time after t . A causal budget-constrained policy can be evaluated through the entry-and-residence probability in Equation B.7.

$$p^*(Z, t) = \sup_{\pi_c} \Pr_{Z, t}^{\pi_c} [\tau_K \leq T, \quad Z_s \in \mathcal{V}(s) \text{ for } t \leq s \leq \tau_K + \tau_{\text{stab}}, \\ Z_s \in \mathcal{T}(s) \text{ for } \tau_K \leq s \leq \tau_K + \tau_{\text{stab}}]. \quad (\text{B.7})$$

The budget includes stabilization costs. The definition supplies a target for estimation or analysis, without asserting that the supremum is attained or that its probability is known.

The interior buffer has a mathematical purpose. For $X_s = d + \sqrt{2D}W_s$ on the positive half-line, subtracting the reflected Gaussian transition density at an absorbing boundary gives survival probability $\text{erf}(d/\sqrt{4Dh})$ over duration $h > 0$. It vanishes at $d = 0$. First hitting an outer boundary and immediately requiring uninterrupted residence on its inner side can therefore produce a zero-probability event under nondegenerate normal diffusion. Entry into an inner set followed by residence in a broader target avoids this particular defect.

An elementary committor calculation provides a separate exact result. For $dq = -U'(q)dt + \sqrt{2D}dW_t$, with $D > 0$, smooth potential, and finite boundaries $a < b$, the probability of reaching b before a solves $Dp'' - U'p' = 0$, $p(a) = 0$, and $p(b) = 1$. Setting $v = p'$ gives $v'/v = U'/D$. Integration and the boundary conditions yield Equation B.8.

$$p(q) = \frac{\int_a^q e^{U(y)/D} dy}{\int_a^b e^{U(y)/D} dy}. \quad (\text{B.8})$$

This probability depends on noise and geometry. It does not equate random forcing with available deliberate control, and the potential is not automatically an intervention-cost landscape.

B.9 Receding-horizon control and continuation

At observation time t_k , let $\hat{Z}(t_k)$ be a state estimate and $\hat{F}_k$ a current discrete model. A finite-horizon comparison with stage cost ℓ , terminal cost V_f , and terminal continuation set $\mathcal{K}_k$ is Equation B.9.

$$\begin{aligned} \min_{u_0, \dots, u_{N-1}} \quad & \sum_{j=0}^{N-1} \ell(\hat{Z}_j, u_j) + V_f(\hat{Z}_N), \\ \text{subject to} \quad & \hat{Z}_0 = \hat{Z}(t_k), \quad \hat{Z}_{j+1} = \hat{F}_k(\hat{Z}_j, u_j), \\ & \hat{Z}_j \in \hat{\mathcal{V}}_k, \quad u_j \in \hat{\mathcal{U}}_k \quad (0 \leq j < N), \\ & \hat{Z}_N \in \mathcal{K}_k \subseteq \hat{\mathcal{V}}_k. \end{aligned} \quad (\text{B.9})$$

Apply the first control, observe, and update. Resources and cumulative budgets must be included in the model or constraints. The supervisory process can change the target, horizon, uncertainty margins, or admissible actions when the diagnosed mechanism changes. Recursive feasibility requires additional terminal and disturbance conditions [31].

For a closed maintainable region with a regular smooth representation $k_j(Z, t) \geq 0$, a locally Lipschitz admissible feedback can establish deterministic forward invariance when its velocity lies in the time-dependent tangent cone at every boundary point. In the regular inequality representation, the same control must satisfy $\partial_t k_j + \nabla k_j \cdot F_{\text{full}}(Z, \pi_c, t) \geq 0$ for every active constraint. Existence of that feedback is part of the claim to be established. Inward deterministic drift alone does not establish the corresponding property under nondegenerate diffusion.

C Verification and Case Protocol

This appendix records the scope of mathematical verification and a protocol for subsequent institutional applications. The numerical examples support selected analytical derivations. The case protocol specifies evidence needed to interpret those derivations in relation to actual inquiry.

C.1 Numerical verification

The preparation package contains a reproducible script that performs twenty-five numerical and structural checks. The checks include a quadratic mixing identity, the mass-consistent volume comparison, mixed-layer relaxation, the tidal force expansion, Ekman sign conventions, internal-wave amplitude residuals, the sign of mixing-induced transformation, a property-class inventory, and the shallow-water wave limit.

Control checks cover the scalar cost optimum, ordered flows, noncommuting time evolution, stable transient amplification, Gramian control, the half-space target, and an unreachable Gramian direction. Further checks concern moving boundaries, periodic windows, a model-error bound, fold geometry, rate-induced transition, the one-dimensional committor, the stochastic residence buffer, and the reproductive recurrence. The structural check verifies the forty-eight stable equation identifiers in the preparation notebook.

The numerical methods include direct substitution, quadrature, finite differences, and fourth-order Runge–Kutta integration of stated ordinary differential equations. Examples and tolerances are recorded with the code. They contain no fitted social parameters. Their agreement with the analytical results supports those particular calculations and does not validate the whole coupled physical model or a social prediction.

Figure 4 compares three of the worked mechanisms. The variables are normalized. The first panel fixes a unit target and horizon, the second varies a coupling while preserving negative eigenvalues, and the third approaches a fold by reducing its parameter. Their separate responses are the reason for retaining distinct diagnostic quantities.

C.2 Institutional case record

An application should define its unit of analysis before assigning numerical variables. A project sequence, an access relation, and an organization have different boundaries. The record should state the initial situation, the target and its justification, the horizon, and the conditions required for continued inquiry.

Table 7 gives a minimal case record. Each item should include its evidence source and uncertainty. Participant disagreement should be retained where it affects the diagnosis or interpretation.

C.3 Reproduction of the draft materials

The source ledger and BibTeX file record verified source identities and the depth of inspection. Publisher descriptions and metadata are distinguished from inspected full texts. The manuscript limits detailed historical conclusions accordingly; expanded case analysis requires additional direct and independent evidence.

The accompanying draft is written in the supplied XeLaTeX template. Section files, appendices, figures, and references are kept separately so that substantive revision can proceed without reconstructing the document. The validation record reports compilation, citation, cross-reference, and layout checks for the generated PDF. These document checks are distinct from mathematical verification and from the empirical adequacy of the argument.

Figure 4: Cost reduction, stable transient amplification, and fold slowing in illustrative models

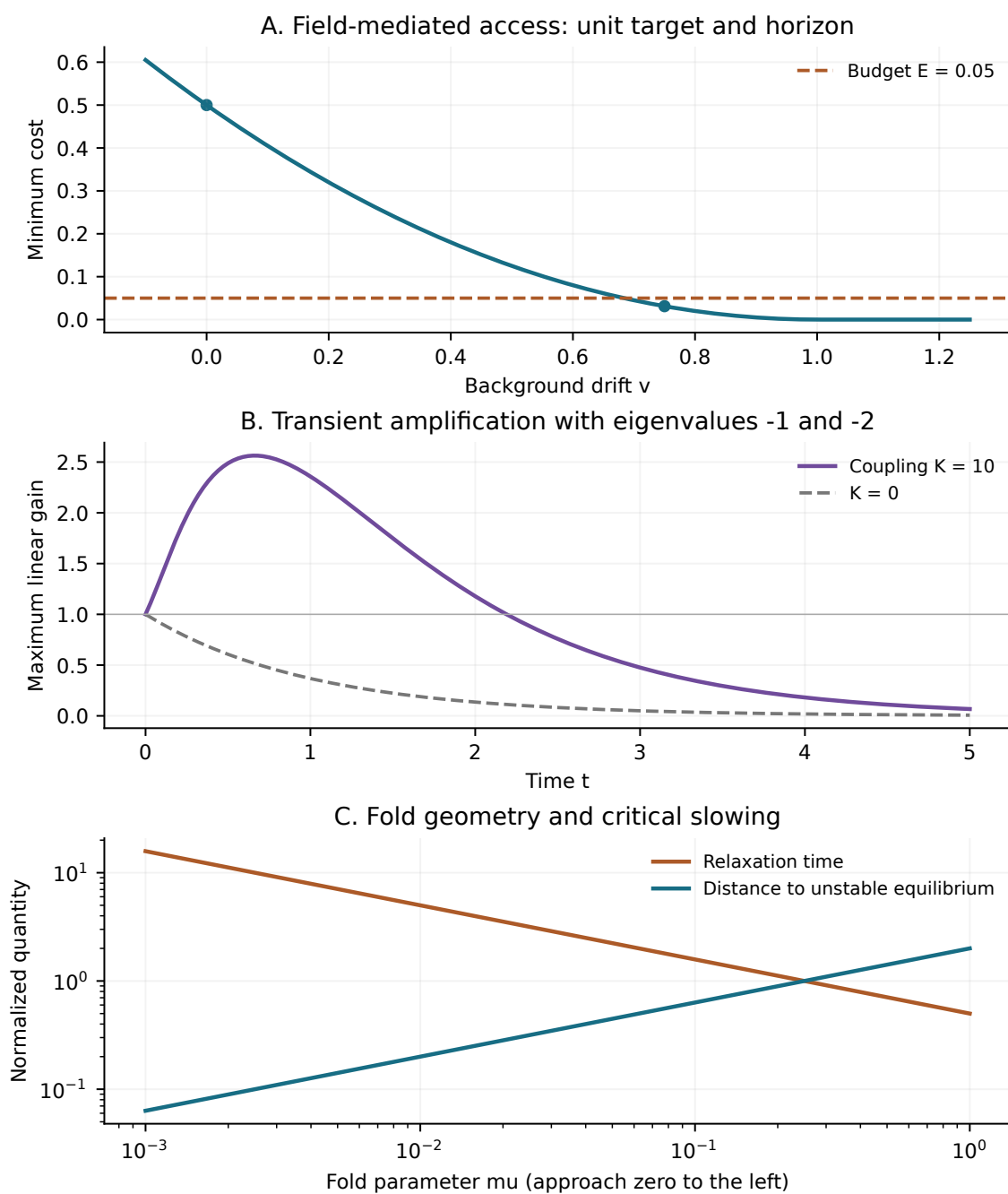


Table 7: Institutional case record for generative praxis

Record component	Required specification
Subject and boundary	Participants, supporting contributors, relevant institution, and scale
Inquiry and target	Practical purpose, desired condition, alternatives, and participant justification
Resources and reproduction	Money, time, care, infrastructure, permissions, maintenance, and recovery
Control relations	Decision authority, renewal, appropriation, representation, and contestation
Diagnostic configuration	Binding conditions, rival explanations, and proposed principal relation
Action channels	Permitted interventions, actual decision points, expected effects, and constraints
Temporal structure	Discovery, interpretation, decision, execution, propagation, and remaining window
Observation and uncertainty	Records available, omitted variables, identification limits, and model revisions
Outcome and continuation	Entry, subsequent cycles, distribution of returns, depletion, and institutional changes
Comparative evidence	Failed attempts, alternative trajectories, selection processes, and counterevidence

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