Towards a Generative-Relational Taxonomy of Governance

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Abstract

Governance is commonly classified through institutional forms, modes of coordination, jurisdictions, policy domains, or normative traditions. Such classifications illuminate important differences among governance arrangements, while providing a more limited vocabulary for distinguishing the structural objects upon which governance interventions operate. This paper develops a generative-relational taxonomy of governance organized around the layers through which relational systems generate, sustain, and transform their trajectories. The proposed framework distinguishes four analytically separable layers: state and explicit-rule governance, dynamical-process governance, relational-structural governance, and generative-background governance. Each layer contains multiple governance mechanisms. Dynamical-process governance includes event-based intervention, feedback governance, perturbative governance, tangent-space governance, and criticality governance. Relational-structural governance encompasses network, coupling, boundary, modular, distributed, and polycentric forms of coordination. Generative-background governance concerns structures that shape the conditions under which trajectories and relations become possible, accessible, stable, or costly, including generative conditions, structural flows on manifolds, background geometry, fields, symmetry structures, gauge-like connections, and emergent backgrounds. A formal representation is developed using dynamical systems, relational structures, differential geometry, and related mathematical languages. The taxonomy treats governance interventions as operators acting upon different components of a generative system and allows a single institutional intervention to be decomposed across multiple structural layers. This layered representation supports comparison among governance theories that employ different conceptual vocabularies and clarifies the relation between immediate intervention, trajectory regulation, relational reconfiguration, and modification of the conditions of generation. The paper presents the taxonomy as a foundational framework for subsequent theoretical and empirical development. Its broader objective is to provide a common analytical language for studying governance in heterogeneous, nonlinear, evolving, and partially observable relational systems while preserving the possibility of plural and revisable forms of order.

Keywords: generative-relational governance; governance taxonomy; dynamical systems; relational governance; criticality governance; generative conditions; emergent governance

Discussion Paper Note

This note specifies the analytical status, scope, formal vocabulary, and methodological commitments of the proposed Generative-Relational taxonomy of governance. It introduces the structural objects used throughout the paper, clarifies the meaning of the four governance layers, and establishes the role of mathematical representations drawn from dynamical systems, relational structures, geometry, and field-based formalisms. The note also defines the provisional and revisable status of the taxonomy before the literature review and layer-specific analysis begin.

The principal analytical orientation concerns the *object of governance intervention*. Governance may modify an observable state, an explicit rule, a dynamical process, a relational structure, or a generative background through which relations and trajectories acquire their effective conditions of formation. Several such objects may coexist within one institutional arrangement, and one intervention may transform several structural components simultaneously.

A preliminary decomposition of a governed generative-relational system is given by Equation 1.

$$\mathfrak{S} = (X, R, F, C, \mathcal{B}) \,. \tag{1}$$

In Equation 1, X denotes the state space, R denotes explicit rules and institutionally represented constraints, F denotes the dynamical structure governing system evolution, C denotes relational and coupling structures, and $\mathcal{B}$ denotes the generative background within which states, relations, and trajectories acquire their effective possibilities.

The transformation produced by governance is represented provisionally by Equation 2.

$$\mathcal{U} : \mathfrak{S} \longrightarrow \mathfrak{S}'. \tag{2}$$

Equation 2 directs the classificatory analysis toward the structural support of an intervention. The principal questions concern which components are transformed, how the transformation propagates, how long its effects persist, and how interventions operating at different structural depths interact.

The paper distinguishes four principal analytical layers: state-and-rule governance, dynamical-process governance, relational-structural governance, and generative-background governance. Their ordering indicates structural depth within the analytical representation. Normative desirability, institutional maturity, and practical effectiveness remain separate dimensions of evaluation. Different governance problems may therefore call for intervention at different layers, and many governance arrangements operate across several layers simultaneously.

State-and-rule governance concerns comparatively explicit objects of intervention. Its mechanisms include changes in observable states, permissions, prohibitions, entitlements, sanctions, formal rules, and institutionally codified constraints. Such interventions primarily act upon X, R, or the relation between them.

Dynamical-process governance concerns the evolution through which system states change over time. Its analytical vocabulary includes feedback governance, event-based governance, perturbative governance, tangent-space governance, criticality governance, bifurcation-sensitive intervention, and other trajectory-dependent mechanisms.

A generic continuous-time representation of this dynamical layer is provided by Equation 3.

$$\dot{x} = F(x, \theta, t), \qquad x \in M. \tag{3}$$

In Equation 3, M denotes an appropriate state manifold and θ collects parameters relevant to the selected model. Within this representation, a local intervention may transform the effective vector field from F to $F + \delta F$. Event-based governance may condition intervention upon the crossing of an event surface, tangent-space governance may act through locally available directions in $T_x M$, and criticality governance may respond to changing dynamical sensitivity near transition regions. The dynamical-process section develops these mechanisms separately.

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Relational-structural governance concerns the architecture through which system components interact. Its objects include network topology, coupling relations, interfaces, boundaries, modular organization, distributed coordination, polycentric arrangements, and relations among partially autonomous subsystems. Governance at this layer changes how generative effects are transmitted, amplified, filtered, redirected, or interrupted among components.

A schematic representation of the relational structure is given by Equation 4.

$$C = (V, E, W, \Gamma, \ldots) . \tag{4}$$

The components in Equation 4 may encode system elements, relations, coupling weights, interaction rules, or other domain-specific relational structures. The appropriate representation depends upon the institutional and empirical system under examination.

Generative-background governance concerns structures that condition the accessibility, stability, propagation, cost, direction, and effective possibility of subsequent relations and trajectories. The generative background $\mathcal{B}$ may therefore receive different formal representations according to the governance problem under examination.

A general family of background representations is summarized by Equation 5.

$$\mathcal{B} = (g, \Phi, A, G, J, \mathcal{E}, \ldots) . \tag{5}$$

In Equation 5, g may represent an effective metric or geometry, Φ a field-like structure, A a connection, G a symmetry structure, J a structural flow, and $\mathcal{E}$ a mechanism through which the effective background emerges. The components provide alternative or complementary mathematical languages for different classes of governance problems.

Mathematical concepts drawn from dynamical systems, differential geometry, network theory, field theory, and related areas enter the framework through explicit structural correspondences. Their use requires identification of the relevant governance objects, transformations, observables, relations, and domain-specific interpretation. This requirement separates formal modelling from loose metaphor and provides a criterion for deciding when a physics-derived mathematical language contributes analytical structure.

Metric governance, for example, concerns structures that modify effective distance, accessibility, cost, or compatibility within a relational space. Field governance concerns distributed quantities whose local values influence the evolution of actors or processes. Symmetry governance concerns transformations under which selected institutional or relational observables remain invariant. Gauge-like governance concerns local representations, transformations among such representations, preserved quantities, and connection structures governing translation or transport across local frames.

The term *gauge-like* is used deliberately. A meaningful gauge-like governance model requires an explicit correspondence among local representations, admissible transformations, invariants, and connections. Later sections develop these requirements before applying gauge-theoretic language to governance.

Structural Flows on Manifolds provide another formal language for generative-background processes. Within the present taxonomy, SFM governance concerns the generation, circulation, coupling, divergence, persistence, interruption, and reconstruction of structural flows within relational spaces whose effective geometry may evolve over time. SFM therefore provides a bridge between trajectory-level dynamics, relational organization, and historically generated background structures.

The generative background may itself arise endogenously from prior relational processes. This recursive relation is represented by Equation 6.

$$\mathcal{B}_t = \mathcal{E}\left(\mathfrak{R}_{\leq t}\right) . \tag{6}$$

In Equation 6, $\mathfrak{R}_{\leq t}$ denotes a relevant history of relational processes and $\mathcal{E}$ denotes a background-emergence operator. This formulation permits governance analysis to address both the effective background at a given time and the processes through which that background is reproduced and transformed.

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The endogenous formulation is particularly important for Generative Relational theory. Relations generate structures; generated structures subsequently condition relations; conditioned relations participate in further structural generation. Governance therefore participates within recursive generation and can influence both current trajectories and the conditions under which future trajectories become possible.

A concrete governance intervention may possess components operating at several structural layers. The corresponding multilayer decomposition is represented by Equation 7.

$$\mathcal{U} = \mathcal{U}_{\mathrm{S}} \oplus \mathcal{U}_{\mathrm{D}} \oplus \mathcal{U}_{\mathrm{R}} \oplus \mathcal{U}_{\mathrm{B}}. \tag{7}$$

In Equation 7, $\mathcal{U}_{\mathrm{S}}$, $\mathcal{U}_{\mathrm{D}}$, $\mathcal{U}_{\mathrm{R}}$, and $\mathcal{U}_{\mathrm{B}}$ denote state-and-rule, dynamical-process, relational-structural, and generative-background components, respectively. The operator $\oplus$ denotes analytical composition. Layer-specific components may interact, reinforce one another, generate countervailing effects, and operate across different temporal scales.

The multilayer representation separates institutional form from structural action. A law, administrative decision, international agreement, platform rule, community institution, technical architecture, or informal norm may operate through several structural layers. Comparable structural transformations may also be implemented through different institutional forms. The taxonomy therefore complements classifications organized around actors, institutions, jurisdictions, policy sectors, coordination modes, and distributions of authority.

The term *generative* refers to the capacity of relational configurations to produce subsequent states, relations, structures, meanings, possibilities, and transformations. Generativity describes a property of relational processes and their future-producing capacity. Questions of desirability, justice, sustainability, and legitimacy enter through a distinct normative analysis of how generative capacities are distributed, sustained, constrained, appropriated, damaged, or regenerated.

This distinction permits the descriptive taxonomy to support later Generative-Relational normative analysis. Such analysis can examine procedural conditions, relational asymmetries, participation, value circulation, revisability, heterogeneous generative capacities, and the preservation of future possibilities across interacting systems.

The framework also incorporates epistemic and operational limits. Governance takes place under partial observability, model uncertainty, heterogeneous timescales, evolving relational structures, and possible nonlinear transitions. Interventions directed toward deeper structural objects can produce effects across wider portions of a system and may simultaneously increase modelling uncertainty, implementation difficulty, and the temporal distance between intervention and observable consequence.

The word *Towards* in the title indicates the methodological status of the present paper. The taxonomy provides a foundational vocabulary and an initial formal architecture whose categories remain available for refinement, subdivision, recombination, empirical testing, and domain-specific reconstruction.

Generative Relational theory is subject to the same principle of revisability. The categories of state, rule, dynamics, relation, background, and generativity function as analytical instruments within the present framework. Their continued use depends upon their capacity to clarify governance processes across theoretical and empirical contexts.

The paper therefore treats the taxonomy itself as an evolving analytical structure. Its development can incorporate new governance mechanisms, revised formal distinctions, empirical anomalies, and alternative representations while preserving explicit records of conceptual change.

The remainder of the paper develops this framework through a systematic review of governance theory, a formal account of the Generative-Relational system, four layer-specific taxonomies, an analysis of cross-layer composition, and a discussion of epistemic, operational, and normative implications. Individual governance mechanisms are developed at the subsection level so that their formal structures, theoretical antecedents, practical domains, and analytical limits can be examined independently while remaining integrated within the common taxonomy.

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Statement on the use of language models. The exploratory discussions and preparation of this paper involved OpenAI's ChatGPT. ChatGPT supported exploratory dialogue, formal reconstruction, source discovery followed by website verification, exact calculation, argumentative criticism, and drafting in LaTeX. The author selected the research questions, directed and approved the theoretical commitments and epistemic status of the claims, and bears sole responsibility for the manuscript, including its definitions, formal constructions, taxonomy, calculations, arguments, conclusions, and errors. Authorship credit remains with the human author. The access level and claim limit for every cited source are recorded in the accompanying literature audit.

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1 Introduction

This section establishes the research problem, analytical orientation, scope, and contributions of the proposed Generative-Relational taxonomy of governance. It situates the taxonomy within established governance scholarship, identifies the classificatory dimension developed in this paper, and introduces the relation between governance intervention and the generative structure of evolving relational systems. The section concludes by specifying the role of formal modelling in the taxonomy and presenting the organization of the paper. A systematic examination of relevant governance traditions follows in the subsequent literature-review section.

Governance has become a broad analytical vocabulary for describing the organization, coordination, steering, and transformation of collective affairs across public, private, civic, transnational, and hybrid institutional settings. Its conceptual expansion has accompanied changes in the organization of governing activity itself. Authority may be distributed among governmental agencies, firms, communities, international organizations, networks, technical infrastructures, and other institutional actors. Coordination may operate through formal command, exchange, negotiation, collaboration, distributed decision making, institutional adaptation, and combinations among these mechanisms. Governance theory has consequently developed multiple conceptual traditions for describing the forms through which collective action is organized.

Several influential approaches illustrate the diversity of classificatory dimensions already available. Rhodes identifies multiple uses of governance and gives particular analytical importance to self-organizing interorganizational networks in relation to markets and hierarchies [106]. Stoker develops governance through propositions concerning institutional complexity, blurred organizational boundaries, power dependence, autonomous networks, and capacities for collective action [124]. Network-governance research further differentiates participant governance, lead-organization governance, and network administrative organizations according to their structural forms and conditions of effectiveness [104]. Polycentric governance directs attention toward systems containing multiple interacting centers of decision making [95]. Adaptive-governance scholarship emphasizes learning, self-organization, cross-scale relations, institutional renewal, and responses to changing social-ecological conditions [41]. Complexity-oriented governance research further examines nonlinear dynamics, thresholds, cascades, and limited predictability as conditions affecting governance capacity [35].

These traditions differentiate governance through several analytically productive dimensions, including modes of coordination, organizational form, distribution of authority, institutional scale, actor configuration, adaptive capacity, and relations among governing centers. Their coexistence reflects the multidimensional character of governance. A polycentric arrangement may contain hierarchical organizations and network relations. A network may incorporate formal legal authority, negotiated coordination, and market incentives. An adaptive governance arrangement may operate across several jurisdictions while combining centralized rules with decentralized learning. Multiple descriptions can therefore characterize the same governance system because each classification identifies a different structural or institutional property.

The present paper develops an additional classificatory dimension organized around the *structural object of governance intervention*. The central analytical concern is the component of an evolving relational system through which an intervention seeks to influence subsequent generation. A governance mechanism may act directly upon a represented state or formal rule. It may modify the process through which states evolve. It may reconfigure relations among system components. It may also alter the background conditions through which ranges of future relations, trajectories, and institutional forms become accessible, stable, costly, or sustainable. These forms of intervention can occur within the same institutional arrangement while operating through different structural mechanisms.

The distinction becomes important when governance is examined as a process within an evolving system. Collective systems frequently contain feedback, historical dependence, heterogeneous temporal scales, distributed information, nonlinear responses, changing network structures, and interactions among partially autonomous components. Duit and Galaz describe governance problems in complex

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adaptive systems in terms that include nonlinear dynamics, threshold effects, cascading processes, and limited predictability [35]. Adaptive-governance scholarship similarly gives central importance to learning, reorganization, cross-level interaction, and responses to periods of substantial change [41]. Such conditions make the location, timing, and propagation of governance interventions analytically significant.

An identical formal rule, incentive, or administrative action can generate different consequences across different system states and relational configurations. An intervention applied within a stable dynamical regime can have effects different from those of an intervention applied near a transition region. Modification of a highly connected relation can propagate differently from modification of a peripheral relation. Changes in access to resources, information, institutional recognition, or opportunities can reshape many future trajectories even when an immediate behavioral command remains unchanged. Governance analysis therefore benefits from distinguishing the structural pathways through which intervention enters system evolution.

The Generative-Relational orientation developed in this paper approaches these pathways through two connected commitments. *Generativity* concerns the capacity of relational configurations to produce subsequent states, relations, structures, meanings, possibilities, and transformations. *Relationality* concerns the dependence of effective properties and possibilities upon relations, couplings, institutional positions, histories, and contexts of interaction. An actor's available trajectories can depend upon legal status, network position, access to information, material resources, institutional recognition, and relations with other actors. The practical effect of a formal rule can likewise depend upon the relational and dynamical system within which the rule operates.

Governance can consequently be studied through the structures that condition ongoing generation. The preliminary system representation introduced in the Discussion Paper Note, $\mathfrak{S} = (X, R, F, C, \mathcal{B})$, distinguishes a state space X, explicit rules and constraints R, dynamical structure F, relational and coupling structure C, and generative background $\mathcal{B}$. This decomposition supplies the common analytical vocabulary for the taxonomy. The components are modelling abstractions whose empirical interpretation depends upon the governance domain under examination.

The proposed taxonomy distinguishes four principal layers of governance. *State-and-rule governance* concerns observable states, explicit rules, permissions, prohibitions, sanctions, entitlements, formal constraints, and related directly represented objects. *Dynamical-process governance* concerns the evolution of system states and includes mechanisms such as feedback governance, event-based governance, perturbative governance, tangent-space governance, attractor-sensitive governance, and criticality or bifurcation-sensitive intervention. *Relational-structural governance* concerns networks, couplings, interfaces, boundaries, modular structures, distributed organization, polycentric relations, and other architectures through which system components interact. *Generative-background governance* concerns conditions that structure the effective possibilities within which states, dynamics, and relations are generated.

The four layers describe structural depth within the proposed analytical model. Structural depth concerns the location of an intervention within the generative architecture and the pathways through which its effects can propagate. A state intervention acts close to a represented system configuration. A dynamical intervention modifies some aspect of evolution. A relational intervention changes the architecture through which interactions and effects propagate. A background intervention changes conditions under which families of relations or trajectories acquire their effective properties.

Structural depth forms one dimension of governance analysis alongside legitimacy, justice, effectiveness, cost, reversibility, observability, temporal scale, and institutional capacity. Interventions at different depths can therefore be appropriate under different conditions. A direct legal rule may provide a clear and rapidly implementable response. A local dynamical intervention may be useful when only short-horizon system behavior is sufficiently observable. Relational reconfiguration may address persistent patterns produced through interaction structures. Background intervention may affect a wider family of future processes while requiring greater knowledge of structural propagation and longer temporal horizons. The taxonomy provides the descriptive architecture through which these differences can

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later be evaluated.

The dynamical-process layer creates a particular connection between governance theory and dynamical-systems reasoning. Governance can depend upon feedback, event occurrence, local direction of change, stability, attractor structure, proximity to a transition, and sensitivity to perturbation. These mechanisms possess different informational requirements and intervention logics. An event-based mechanism can condition action on an observable trigger. Tangent-space governance can use locally available directions when global reconstruction of a high-dimensional system remains unavailable. Criticality governance can attend to changing sensitivity and transition risk near regions in which the existing dynamical regime becomes less stable. Their inclusion within one layer permits systematic comparison while preserving the distinctions among their mechanisms.

The relational-structural layer places established networked, distributed, and polycentric governance forms within a broader analysis of relational architecture. Polycentricity, for example, describes an important organization of decision centers [95], while network-governance typologies differentiate organizational structures within networks [104]. The present taxonomy preserves these established meanings and examines an additional property: how changes in relational architecture alter the generation and propagation of system behavior. This orientation permits analysis of coupling strength, connectivity, boundaries, interfaces, modularity, dependencies, and channels of circulation alongside institutional descriptions of networked governance.

The generative-background layer extends the analysis toward structures that shape the effective conditions of generation. These may include resource and information distributions, institutional accessibility, background structural flows, effective distances, field-like conditions, symmetry structures, connection structures, and mechanisms through which the background itself emerges from prior relational processes. Several mathematical languages can be used to represent such structures. Structural Flows on Manifolds can describe historically evolving flows within relational spaces. Metric or geometric models can represent effective distance, accessibility, and path structure. Field-like models can represent spatially or relationally distributed conditions affecting local dynamics. Symmetry and gauge-like constructions can be considered where transformations, invariants, local representations, and connections can be explicitly identified.

The use of mathematical concepts at this layer requires particular methodological discipline. Dynamical systems, network theory, differential geometry, field theory, symmetry, and gauge structures supply mathematical objects and relations whose usefulness depends upon an explicit correspondence with the governance system being modeled. A social or institutional process acquires a geometric, field-like, or gauge-like representation through a defined mapping among observables, transformations, relations, and formal objects. The taxonomy therefore treats mathematical physics as a source of formal languages whose applicability must be established within each model.

The proposed framework also allows one governance intervention to possess several layer-specific components. A legislative reform may alter a formal rule while changing incentives that affect trajectories, restructuring relations among organizations, and modifying access to resources or information. A digital-platform intervention may combine explicit content rules, event-triggered enforcement, changes in network visibility, and background modifications to recommendation or access conditions. A transnational governance mechanism may simultaneously modify procedural rules, institutional couplings, information flows, and cross-jurisdictional accessibility. Multilayer decomposition permits these effects to be separated analytically and subsequently recombined.

This decomposition also creates a distinction between *institutional form* and *structural action*. Similar structural mechanisms can occur through different institutional instruments, while similar institutional instruments can operate through different structural pathways. A law, treaty, administrative order, platform architecture, community arrangement, technical standard, or informal norm can therefore be examined according to both its institutional form and its location within the generative structure. The proposed taxonomy supplements established governance classifications through this additional axis.

The paper makes several connected contributions. First, it develops a classification of governance based on structural objects of intervention. Second, it integrates dynamical mechanisms including feed-

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back, event triggering, local perturbation, tangent-space intervention, attractor structure, criticality, and bifurcation sensitivity within a common governance layer. Third, it connects established relational governance traditions with a formal analysis of coupling, topology, boundaries, modularity, and distributed organization. Fourth, it develops generative-background governance as a family of interventions concerned with the conditions through which trajectories and relations are produced. Fifth, it provides a framework for analysing cross-layer composition and propagation. Sixth, it creates an analytical basis for comparing the epistemic and operational requirements associated with different intervention depths. Seventh, it provides a descriptive structure that can subsequently support Generative-Relational normative analysis of generative capacity, relational asymmetry, procedural conditions, value circulation, revisability, and sustainability.

The scope of the paper is foundational and programmatic. The taxonomy is designed to support comparison across public governance, international and transnational governance, social-ecological systems, regulatory institutions, organizational networks, digital platforms, and other evolving relational systems. Empirical application requires domain-specific identification of states, rules, observables, relations, dynamics, and background structures. Formal representations developed in the paper therefore specify analytical possibilities and modelling requirements that can be operationalized in subsequent domain-specific research.

The remainder of the paper develops the taxonomy in stages. The following section provides a systematic review of major governance theories and classification traditions, including hierarchical, market, network, collaborative, polycentric, adaptive, multilevel, metagovernance, and complexity-oriented approaches. The subsequent formal section establishes the Generative-Relational system representation, governance operators, structural depth, temporal evolution, and relations among analytical layers. Four major sections then develop state-and-rule governance, dynamical-process governance, relational-structural governance, and generative-background governance. Individual mechanisms receive separate subsections containing their conceptual definition, formal representation, relation to established theory, domains of application, and analytical limits. The later synthesis examines cross-layer composition, observability, temporal scale, reversibility, intervention depth, model uncertainty, and recursive background formation. The final discussion connects the descriptive taxonomy with Generative-Relational normative analysis and identifies directions for theoretical refinement and empirical development.

2 Philosophical Lineages of Governance

This section reconstructs selected philosophical lineages that bear upon the objects, mechanisms, and conditions of governance. Its role is to identify conceptual resources that precede contemporary governance theory and to clarify how different traditions locate governing activity in political authority, legal rules, institutional relations, processes of formation, conduct, communication, distributed order, and conditions of generation. The review is analytical and selective. It follows conceptual structures across Western and Asian philosophical traditions and preserves the historical specificity of each source. The section concludes by identifying the philosophical coordinates that later support the Generative-Relational taxonomy.

2.1 Political Order and Constitutional Authority

This subsection examines philosophical traditions in which governance is primarily organized around political order, constitutional form, legitimate authority, and the relation between rulers and members of a political community. Its objective is to identify the conceptual ancestry of governance directed toward explicit institutions, offices, laws, and authoritative decisions. The discussion proceeds from classical constitutional analysis to social-contract accounts of political authority.

Aristotle's *Politics* provides an early systematic analysis of political association through the constitution of the polis, the organization of offices, the distribution of ruling functions, and distinctions among forms of constitution [8]. Political order in this account is inseparable from the organization of relations

among citizens, offices, households, and institutions. A constitution concerns the arrangement through which political functions are distributed and collective life acquires an organized form.

The Aristotelian framework is relevant to governance taxonomy because it already distinguishes the political community from a mere aggregation of individual actions. Governing operates through an institutional arrangement that defines offices, participation, authority, and the purposes toward which political association is organized. The object of governance therefore includes both decisions and the constitutional structure through which decisions become authoritative.

Hobbes reorganizes the problem around the production of common authority. *Leviathan* develops an account of political order in which individuals authorize a sovereign capable of securing peace and providing a common power under conditions in which fragmented private judgment can generate persistent conflict [60]. Sovereignty provides a structure through which dispersed individual capacities are organized into a public authority with the capacity to establish and enforce common rules.

For the present taxonomy, the Hobbesian lineage is important because it gives analytical priority to the consolidation of authoritative capacity. Governance acts through a recognized center capable of issuing determinate decisions, defining obligations, and stabilizing expectations. This orientation supplies one important philosophical foundation for later command-oriented, state-centered, and rule-centered forms of governance.

Locke develops political authority through consent, political society, law, property, and the fiduciary character of governmental power [84]. Legislative and executive institutions possess authority within an organized political society, while the purposes and limits of those institutions remain connected to the rights and interests for whose protection political society is constituted. The resulting architecture places political power within an institutional structure whose legitimacy depends upon its relation to the persons subject to it.

This lineage adds an important dimension to governance analysis. Authority can be analyzed according to its source, institutional location, scope, and conditions of legitimate exercise. Governance therefore concerns both the capacity to act and the institutional relations that authorize, constrain, and evaluate that capacity.

Rousseau develops another form of collective self-constitution through the relation among sovereignty, law, citizenship, and the general will [110]. Political order acquires legitimacy through a form of association in which citizens participate in the constitution of the laws under which they live. The relation between the governed and the governing order thereby becomes internal to the constitution of political authority.

The social-contract tradition as a whole supplies several enduring analytical objects for governance: authority, consent, obligation, sovereignty, constitutional form, law, and the relation between collective order and individual agency. These concepts remain central to contemporary public governance. Within the Generative-Relational framework developed later, they correspond most directly to state-and-rule structures while also raising questions concerning the relations through which political authority is constituted and reproduced.

2.2 Law, Obligation, and Institutional Rule

This subsection examines philosophical approaches in which governance is organized through rules and through institutions that produce, identify, change, interpret, and apply rules. Its role is to establish the conceptual depth of rule-centered governance and to show that legal order already contains mechanisms governing the production and transformation of rules themselves. The discussion focuses on analytical jurisprudence and procedural conceptions of legality.

Hart's *The Concept of Law* provides a particularly influential account of legal order through the distinction between primary and secondary rules [56]. Primary rules regulate conduct, while secondary rules supply institutional mechanisms through which rules can be identified, changed, and adjudicated. A developed legal system consequently contains both conduct-regulating norms and structures for governing the legal order's own operation.

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This distinction is important for a structural taxonomy of governance. Rule-centered governance contains several different intervention objects. A prohibition may change the admissibility of conduct. A rule of change modifies the process through which future rules can be created or revised. A rule of adjudication structures the institutional determination of violations and disputes. Governance through law therefore contains recursive institutional capacities even before more explicitly dynamical concepts are introduced.

Fuller's *The Morality of Law* develops another structural dimension by examining conditions associated with the successful operation of legal order [46]. His account of legality directs attention to such properties as generality, promulgation, intelligibility, consistency, practicability, temporal orientation, relative stability, and congruence between official action and declared rules. The significance of these properties extends beyond the semantic content of individual legal commands.

This perspective provides an important bridge between explicit-rule governance and governance of the conditions under which rules can function. A formal rule can exist while its effective operation depends upon publicity, interpretability, institutional consistency, implementation, and relations between official conduct and normative formulation. Legal governance therefore already involves both represented rules and conditions of effective rule generation and application.

The jurisprudential lineage also clarifies a distinction that becomes important later in the paper. A rule constitutes one possible structural object of governance, while the institutions governing rule production, interpretation, revision, and implementation constitute additional objects. A taxonomy based solely on the visible legal instrument can consequently conceal several mechanisms operating beneath the same institutional form.

2.3 Relational Constitution and Ethical Life

This subsection examines philosophical traditions in which persons, social roles, and institutions acquire meaning through relations embedded within larger forms of ethical and social life. Its objective is to identify resources for a relational ontology of governance. The discussion considers Hegelian institutional ethical life and contemporary interpretations of Confucian relational personhood.

Hegel's *Elements of the Philosophy of Right* organizes modern ethical life through the differentiated institutions of family, civil society, and the state [59]. Individual freedom acquires institutional form through relations of property, contract, family membership, economic association, civil society, and political membership. The philosophical importance of this structure lies in the institutional mediation of agency: social freedom develops within organized relations and practices rather than through an abstractly isolated subject.

For governance analysis, the Hegelian lineage directs attention toward the institutional structures through which capacities and identities become socially effective. Governance can therefore concern the constitution of relations among family, civil society, organizations, and political institutions. Changes in one institutional domain can alter the conditions through which actors participate in others.

A comparable emphasis on relational constitution appears in important interpretive traditions of Confucian philosophy. The *Analects* presents ethical cultivation through roles, ritual practices, exemplary conduct, familial relations, learning, and forms of political leadership [31]. Governance and self-cultivation are closely connected within this tradition because political order is partly mediated through cultivated relations and patterned conduct.

Ames develops this relational dimension explicitly through the interpretive framework of Confucian role ethics [5]. Within this framework, persons are understood through lived relational roles and the ongoing cultivation of relationships. The account gives conceptual priority to relational personhood, situated conduct, and the processes through which ethical identities are formed.

The relevance to Generative-Relational governance lies in the possibility of treating actors as relationally constituted participants whose capacities depend upon historically and institutionally organized relations. A governance intervention can change an actor's effective position without changing the actor as an isolated unit. Alterations to recognition, role, institutional membership, dependency, obligation, or access can transform the possibilities available within a relational system.

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This relational lineage also provides a caution against reducing governance to interactions among fully constituted nodes. Networks and institutions can participate in the constitution of the actors who subsequently act through them. Later sections develop this point formally through relational structures whose states and couplings can co-evolve.

2.4 Process, Emergence, and Public Formation

This subsection examines philosophical traditions in which events, relations, and collective forms are understood through processes of becoming. Its role is to provide a philosophical basis for treating governance as participation in ongoing generation. The discussion uses process philosophy and pragmatist political thought as complementary resources.

Whitehead's *Process and Reality* develops a metaphysical framework in which process, relation, becoming, and event possess fundamental explanatory importance [132]. Whitehead's work is a metaphysical system rather than a theory of public governance. Its relevance to the present paper lies in its processual ontology, which offers a philosophical vocabulary for understanding entities through processes of formation and relation.

A processual orientation changes the temporal assumptions of governance analysis. Institutional objects can be treated as relatively stabilized patterns generated through continuing processes. Rules, organizations, identities, and relations can persist while remaining historically produced and capable of transformation. Governance then participates in processes that both reproduce and modify these forms.

Dewey's *The Public and Its Problems* provides a more directly political form of emergent analysis [33]. Dewey develops the public through the consequences of associated action. A public forms where indirect consequences become sufficiently important to require organized attention and regulation. Political organization therefore develops in relation to changing patterns of social consequences.

This account is particularly significant for Generative-Relational governance because the governed collective need not be assumed as a permanently fixed object. Relations and consequences can generate a public whose problems then generate institutional responses. Changes in technology, communication, economic organization, and social interdependence can transform both the relevant public and the capacities required for governance.

The process and pragmatist lineages thereby support an important move from governance of fixed objects toward governance within evolving relations. Institutional forms remain real and consequential, while their persistence is understood through processes that continually reproduce, reinterpret, and modify them. This orientation later supports the distinction among current states, dynamical evolution, relational architecture, and the conditions of further generation.

2.5 Power, Discipline, and Governmentality

This subsection examines philosophical approaches that relocate governance from sovereign command toward the organization of conduct, populations, security, knowledge, and institutional environments. Its objective is to identify a lineage in which power operates through distributed practices and conditions as well as through explicit legal authority. The discussion centers on Foucault's development of governmentality.

Foucault's lectures collected in *Security, Territory, Population* develop a history of governmental rationalities through the analysis of sovereignty, discipline, security, population, and governmentality [42]. The movement among these forms expands the analytical field of governing beyond the juridical act of command. Security mechanisms, for example, operate through the management of populations, circulations, probabilities, environments, and processes whose regularities become objects of governmental knowledge.

This shift is particularly important for the taxonomy developed in the present paper. Governance can operate by establishing a prohibition, by disciplining conduct within an institution, by monitoring a population, or by modifying the environment through which conduct takes shape. These mechanisms can coexist while acting upon different structural objects.

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Governmentality also connects governing with knowledge. The capacity to govern populations depends upon ways of rendering phenomena observable, measurable, classifiable, and administratively actionable. Statistics, political economy, security knowledge, and administrative practices participate in the constitution of governmental objects. Governance therefore involves an epistemic relation between an intervention and the representation through which its target becomes legible.

This point will later become central to the paper's treatment of observability and epistemic limits. A governance mechanism presupposes some representation of the system upon which it acts. Direct state intervention, event detection, criticality monitoring, network reconfiguration, and background governance each require different forms of observation and inference.

Foucault's analysis also complicates a simple correspondence between depth and coercion. Interventions operating through environments, incentives, security arrangements, or normalized practices may possess broad generative effects despite limited visible command. The structural location of intervention and its normative legitimacy therefore require separate analysis.

The governmentality lineage consequently provides one of the closest philosophical precursors to the later category of generative-background governance. The correspondence remains analytical. Foucault's historical and genealogical project retains its own conceptual aims, while the present taxonomy uses the distinction among governing conduct, processes, and conditions for a different formal purpose.

2.6 Communication, Procedure, and Public Reason

This subsection examines philosophical traditions in which legitimate collective order depends upon procedures of justification, communication, and public reasoning among participants. Its role is to establish the philosophical basis for governance mechanisms centered on procedure and communicative relations. The discussion focuses on Habermas and Rawls as influential representatives of procedural and public-reason traditions.

Habermas's *Between Facts and Norms* develops the relation among law, democratic legitimacy, communicative action, discourse, and constitutional institutions [54]. Legal legitimacy is connected to procedures through which citizens can understand themselves as participants in the formation of the norms governing collective life. The institutional architecture of law and democracy consequently depends upon communicative conditions as well as formal validity.

This perspective provides an important philosophical basis for procedural governance. The quality of a governance process can depend upon access to deliberation, opportunities for participation, reciprocal justification, information, institutionalized procedures, and relations among communicative actors. Governance therefore acts through procedures that structure how collective decisions are generated.

Rawls's later political philosophy addresses political order under conditions of enduring pluralism [105]. *Political Liberalism* develops an account of political justification among free and equal citizens who may affirm different comprehensive doctrines. Public reason, political conceptions of justice, and the institutional structure of a constitutional democracy become resources for sustaining cooperation across persistent normative heterogeneity.

This lineage is especially relevant to a Generative-Relational account because heterogeneity is treated as an enduring condition of political association. Governance cannot rely upon complete convergence of comprehensive worldviews as its ordinary operating condition. Institutions require procedures and relations through which cooperation remains possible across difference.

Procedural and deliberative approaches also clarify the distinction between a substantive output and the process generating that output. Similar decisions can possess different legitimacy when produced through different procedures. Governance analysis therefore requires attention to the generative process through which a rule or decision becomes institutionally valid.

The later dynamical and relational layers extend this procedural insight into additional formal domains. Event structures, feedback relations, coupling, information flow, and conditions of participation can all influence the process through which collective outcomes emerge. Procedural legitimacy remains a normative question whose formal location can span several structural layers.

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2.7 Distributed Order and Self-Organization

This subsection examines philosophical resources for understanding order generated through decentralized interactions and rule-governed coordination. Its objective is to identify conceptual precedents for governance systems in which global order depends upon dispersed knowledge and locally situated actions. The discussion focuses on Hayek's theory of spontaneous order while reserving contemporary polycentric governance for the following governance theory section.

Hayek's *Law, Legislation and Liberty* distinguishes forms of deliberately organized order from orders that develop through the interactions of multiple participants following general rules [57]. His analysis of spontaneous order emphasizes the epistemic limits facing centralized direction and the capacity of rule-governed decentralized processes to coordinate knowledge distributed across society.

This tradition contributes two important ideas to governance taxonomy. First, order can arise from patterns of interaction without requiring detailed central specification of each resulting state. Second, governance can operate through general rules that influence a process of decentralized coordination while leaving many concrete outcomes open.

The resulting governance object differs from a direct command to a particular actor. General institutional conditions can structure a space within which actors coordinate through dispersed decisions. The relation between the rule and the resulting order is consequently generative: the rule contributes to conditions under which a range of future configurations can develop.

Distributed order also introduces an epistemic argument for structural plurality in governance. Local actors can possess information unavailable to a central decision maker, while system-level institutions can provide coordination conditions unavailable to isolated participants. Governance can therefore require combinations of local knowledge, general rules, relational interfaces, and higher-order institutional safeguards.

The present paper does not adopt Hayek's normative political programme as a general theory of governance. The analytical contribution retained here concerns decentralized generation, dispersed knowledge, and the distinction between directing specific outcomes and structuring conditions under which order develops. These concepts provide philosophical resources for later analysis of polycentricity, self-organization, and generative-background intervention.

2.8 Conditionality, Non-Action, and Generative Order

This subsection examines Asian philosophical resources in which outcomes arise through relational conditions, cultivated environments, and processes whose development can be influenced without continuous direct command. Its role is comparative and conceptual. The discussion considers Daoist political philosophy, Buddhist dependent arising, and selected Yogācāra accounts of conditioning and dispositional "seeds." These traditions retain their own ethical, soteriological, cosmological, and political purposes throughout the comparison.

The *Daodejing* gives sustained attention to $wuwei$, commonly translated through forms of "non-action" or "non-coercive action," and to $ziran$, commonly rendered as naturalness or self-so [77]. Interpretations of these ideas vary substantially. Contemporary scholarship recognizes the political dimension of the text and its concern with sociopolitical order, while also locating its politics within a wider ethical and cosmological context [29].

For governance theory, $wuwei$ provides a philosophical resource for considering the relation between intervention intensity and conditions of self-development. Governing activity can include restraint, removal of distorting pressures, cultivation of enabling conditions, exemplary conduct, and the preservation of processes through which order develops. The governance problem thereby extends beyond the selection of an immediate terminal state.

This interpretation requires caution. $Wuwei$ belongs to a historically and philosophically specific Daoist discourse. Its significance cannot be reduced to a modern engineering concept such as minimal control. Its contribution to the present genealogy concerns a broader philosophical possibility: effective governing can sometimes be conceptualized through conditions and relational alignment rather than

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through continuous direct intervention.

Buddhist philosophy provides a distinct account of conditional generation through dependent arising. Phenomena arise through causes and conditions within processes of dependence, and their transformation is correspondingly connected to changes in those causal and conditional relations [85]. This doctrine is primarily a Buddhist account of causality, experience, suffering, and liberation. Its relevance here lies in the philosophical structure of conditioned emergence.

A conditional account of generation directs governance analysis toward the relations required for an event or pattern to arise. An undesirable outcome can be approached through the conditions that repeatedly generate or sustain it. A desirable capacity can similarly depend upon relations, resources, opportunities, knowledge, and institutional supports that permit its development. This reasoning is one philosophical source for the GR concept of generative conditions.

Yogācāra develops a particularly elaborate vocabulary of conditioning through theories of consciousness, dispositions, and the $\bar{a}$layavijñāna or store consciousness. Contemporary scholarship describes Yogācāra accounts in which dispositional "seeds" can be held within the $\bar{a}$layavijñāna and actualized under appropriate circumstances, with complex relations of conditioning among different forms of consciousness [125]. Lusthaus likewise emphasizes the importance of dependent arising, karma, transformation, and conditions within Yogācāra philosophical psychology [85].

The conceptual relevance to governance concerns the distinction among a latent capacity, the conditions of activation, and the resulting event. This distinction provides a philosophical analogy for governance that acts upon conditions under which patterns become likely to emerge. The analogy remains limited to structural reasoning. A social institution is not an $\bar{a}$layavijñāna, and institutional rules are not Buddhist karmic seeds.

The comparative value of the Daoist and Buddhist materials therefore lies in their attention to conditional generation. Direct intervention represents one possible relation to an evolving process. Changes in conditions, dependencies, relations, and environments provide additional modes through which subsequent generation can be influenced. This conceptual family becomes important in the later development of generative-background governance.

2.9 Philosophical Coordinates for Generative-Relational Governance

This subsection synthesizes the philosophical lineages reviewed above and specifies their analytical relevance to the Generative-Relational taxonomy. Its objective is to identify recurring governance objects across historically distinct traditions while preserving the distinctions among those traditions. The synthesis is organized around authority, rules, relations, processes, conduct, procedures, distributed order, and generative conditions.

Table 1 summarizes the principal philosophical coordinates developed in this section.

The comparison in Table 1 reveals several recurring shifts in the location of governance. Political philosophy often begins from authority, constitutions, laws, and collective self-organization. Jurisprudence adds institutional mechanisms through which rules themselves are generated and transformed. Relational philosophy directs attention toward the constitution of actors through roles and institutions. Process philosophy treats apparently stable entities as outcomes of continuing formation. Governmentality expands governing activity toward conduct, population, knowledge, circulation, and environmental conditions. Procedural theories locate legitimacy within processes of communication and justification. Distributed-order theories emphasize decentralized generation, while Daoist and Buddhist resources bring conditional formation into explicit philosophical view.

These lineages cannot be arranged as a historical sequence of progressively deeper governance. They provide distinct conceptual coordinates developed for different philosophical purposes. Sovereign authority remains indispensable in many contemporary governance contexts. Explicit legal rules continue to structure rights and obligations. Procedures remain essential to legitimacy. Relational and background conditions can shape the practical operation of those institutions. The relevant analytical problem concerns the relation among these governance objects.

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Table 1: Philosophical lineages and governance objects

Philosophical lineage	Primary object	Governance mechanism	GR relevance
Political order and constitutional authority	Authority, constitution, political membership	Institutional organization, legislation, authorization, collective decision	State-and-rule structures and institutional constitution
Jurisprudence and legality	Rules and legal institutions	Rule formation, recognition, change, adjudication, implementation	Explicit rules and recursive rule governance
Relational ethical life	Roles, institutions, social relations	Cultivation, recognition, institutional participation, relational obligation	Relational constitution and coupling structure
Process and pragmatist philosophy	Events, consequences, publics, evolving institutions	Adjustment, inquiry, institutional formation, response to consequences	Generativity, temporal evolution, endogenous collective formation
Governmentality	Conduct, population, security, governmental knowledge	Discipline, monitoring, environmental structuring, management of circulation	Dynamical processes, observability, generative backgrounds
Procedural and deliberative philosophy	Communication, justification, political procedure	Deliberation, participation, public justification, institutionalized discourse	Process governance, relational participation, procedural evaluation
Distributed order	Decentralized interaction and dispersed knowledge	General rules, local coordination, self-organization	Relational structure and decentralized generation
Daoist conditional order	Conduct, environment, relational alignment	Restraint, enabling conditions, cultivation, non-coercive intervention	Generative conditions and intervention depth
Buddhist conditionality	Causes, conditions, dispositions, dependent processes	Transformation of conditioning relations and activation conditions	Conditional generation and endogenous process formation

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The philosophical genealogy therefore supports a plural conception of governance intervention. Governance can act upon a represented condition, formal rule, procedure, relation, trajectory, institutional environment, or condition of generation. Several such objects can be implicated by one institutional action. Their differentiation provides the conceptual basis for the structural taxonomy developed later in the paper.

The genealogy also establishes three commitments that become central to the Generative-Relational framework. The first concerns relational constitution: the capacities and properties of governed actors can depend upon their relations and institutional positions. The second concerns temporal generation: governance operates within systems whose structures are reproduced and transformed through time. The third concerns conditionality: the appearance and persistence of an outcome can depend upon a wider set of relations and conditions than those represented by an immediate rule or decision.

These commitments prepare the transition from philosophical genealogy to modern governance theory. The following sections examine how contemporary governance scholarship institutionalizes and differentiates hierarchy, markets, networks, collaboration, polycentricity, multilevel organization, adaptation, experimentation, regulation, and other governance forms. The later Generative-Relational formalization then reorganizes these resources according to the structural objects through which governance acts.

3 Development of Modern Governance Theory

This section reconstructs the development of modern governance theory from administrative and managerial approaches toward networked, collaborative, polycentric, multilevel, adaptive, experimental, an-

ticipatory, and global forms of governance. Its role is to identify the principal theoretical dimensions through which contemporary scholarship has conceptualized governing arrangements and to distinguish those dimensions from the structural-object taxonomy developed later in the paper. The discussion proceeds through major theoretical families and concludes with a synthesis of their classificatory coordinates. Detailed regulatory, judicial, organizational, international, and technological practices are reserved for the following section on governance forms and institutional practice.

3.1 Administrative and Managerial Foundations

This subsection establishes the administrative and managerial background from which modern governance theory developed. Its objective is to clarify the transition from organization-centered accounts of public administration toward approaches emphasizing management, performance, decentralization, contractual relations, and increasingly heterogeneous arrangements for public action. The discussion focuses on New Public Management and its relationship to the later governance turn.

Classical public administration placed substantial analytical weight on formal organization, public authority, administrative responsibility, hierarchy, competence, and the implementation of collectively authorized decisions. Modern governance scholarship developed partly through attempts to understand institutional environments in which these administrative structures interacted with markets, private organizations, voluntary associations, and increasingly fragmented systems of service delivery.

New Public Management constituted an influential stage in this development. Hood identifies a recognizable group of doctrines associated with New Public Management and examines their intellectual provenance, administrative values, and claims concerning public-sector performance [63]. The reform vocabulary emphasized management, performance measurement, organizational disaggregation, competition, contracting, managerial discretion, and techniques influenced by private-sector management.

The significance of New Public Management for governance theory extends beyond the individual reforms associated with it. Contracting and organizational disaggregation redistribute activities across organizational boundaries. Performance systems introduce new informational relations between principals, providers, managers, and users. Competition changes the mechanisms through which public functions are coordinated. Public administration thereby becomes increasingly concerned with the management of relations among organizationally distinct actors.

Peters and Pierre examine this transformation in relation to the emerging language of "governance without government" and explicitly connect the governance debate with networks, partnerships, markets, and changes in public administration [100]. Their analysis also preserves the continuing significance of the state and public institutions within governance arrangements.

Osborne later develops the concept of New Public Governance as a framework for understanding plural and pluralist systems of public-service provision [92]. This perspective gives greater analytical prominence to interorganizational relations, service systems, networks, and continuing interactions among multiple providers and stakeholders.

The managerial lineage consequently introduces several dimensions that remain important throughout governance scholarship: organizational differentiation, performance, contracts, incentives, interdependence, and relations among providers. These dimensions provide part of the institutional setting within which governance theory increasingly shifted its attention from the internal operation of a single public organization toward relations among multiple organizations and governing actors.

3.2 Governance Turn and Institutional Interdependence

This subsection examines the consolidation of governance as a distinct analytical vocabulary during the late twentieth century. Its objective is to identify the conceptual expansion from governmental organization toward interdependence, steering, institutional plurality, and self-organizing relations. The discussion centers on influential formulations by Rhodes, Stoker, Pierre, Peters, and Kooiman.

Rhodes's analysis of the "new governance" identifies several established uses of the term and develops self-organizing interorganizational networks as a distinctive governance form [106]. Markets,

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hierarchies, and networks thereby become alternative and interacting structures through which resources can be allocated and collective activities coordinated.

The importance of this move lies in the analytical displacement of the individual public organization as the sole center of governing capacity. Organizations depend upon resources controlled by other organizations, participate in continuing exchanges, and operate within networks whose internal relations can constrain centralized direction. Governing capacity therefore becomes partly relational.

Stoker develops this governance perspective through propositions concerning institutions beyond government, blurred organizational boundaries, power dependence, autonomous self-governing networks, and capacities for collective action [124]. Governance in this formulation concerns institutional and relational structures through which collective purposes are pursued across organizational boundaries.

Pierre's edited volume *Debating Governance* further consolidates governance as a problem of authority, steering, democracy, and changing relations between states and societies [101]. The governance perspective consequently addresses both institutional change and the continuing role of political authority in coordinating heterogeneous actors.

Pierre and Peters similarly analyze governance through the problem of societal steering in environments characterized by increasing complexity and interaction among state and non-state institutions [102]. The state remains an important actor while its governing capacities are exercised through a wider range of institutional relations.

Kooiman develops one of the most systematic interaction-oriented accounts. His framework treats governing as interaction among societal and political actors under conditions of diversity, complexity, and dynamism and distinguishes modes and orders of governance [75]. Self-governance, co-governance, and hierarchical governance become different forms through which interactions can be organized, while higher orders concern institutional conditions and governability.

The governance turn therefore introduces a shift in analytical scale and object. Governing increasingly becomes a property of institutional configurations, relations, and processes extending across formal organizational boundaries. This theoretical development supplies a major foundation for the relational-structural component of the Generative-Relational taxonomy.

3.3 Network Governance and Network Management

This subsection examines the theoretical development of network governance as a distinct account of governing through interdependent organizational relations. Its objective is to distinguish network structure from network management and to identify the forms of authority and coordination operating within whole networks.

Policy-network and network-management scholarship treats interdependence among organizations as a durable feature of public decision making and implementation. Kickert, Klijn, and Koppenjan develop a network-management approach in which policy processes occur within networks of interdependent public and private actors and require strategies capable of managing complex interaction [71]. Governance within this setting involves coordination across actors whose resources, objectives, and institutional positions differ.

Network management directs attention toward processes including activation of participants, mediation, arrangement of interactions, development of common understandings, and institutional adjustment. The relevant governing problem concerns the configuration and management of an interaction system as well as the decisions of individual participants.

Provan and Kenis provide a complementary structural theory of whole-network governance [104]. Their framework distinguishes participant-governed networks, lead-organization governance, and network administrative organizations. The modes differ in the concentration of governance activities and in the institutional location through which network-level coordination is performed.

Their analysis demonstrates that "network" describes an organizational domain containing several possible governance architectures. The existence of interorganizational relations alone does not determine how collective decisions, coordination, administration, and accountability are organized within the network.

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Network governance contributes directly to the later distinction between institutional form and structural object. A network is a relational architecture, while governance within a network can operate through rules, feedback processes, modifications to connectivity, redistribution of resources, or changes in the conditions governing participation. Network theory therefore provides an important relational vocabulary while leaving room for finer classification of the mechanisms acting through that architecture.

3.4 Collaborative and Interactive Governance

This subsection examines theories centered on sustained interaction, deliberation, joint decision making, and collective action among public and non-state actors. Its objective is to distinguish collaboration as a governing process from network structure as an organizational architecture and to identify the contextual conditions incorporated into later collaborative frameworks.

Ansell and Gash develop collaborative governance through a model based on collective forums in which public agencies and non-state stakeholders participate directly in consensus-oriented decision making [7]. Their framework connects starting conditions, institutional design, facilitative leadership, and collaborative processes. Trust building, commitment, shared understanding, and intermediate outcomes participate in an iterative process of collaboration.

The framework is significant for governance theory because process becomes an explicit analytical object. Participant composition and institutional structure remain important, while the evolution of interaction through time also affects the capacity for collective action. Collaboration therefore contains both relational and dynamical properties.

Emerson, Nabatchi, and Balogh broaden collaborative governance through an integrative framework containing system context, collaborative governance regimes, collaborative dynamics, capacities for joint action, and resulting impacts [39]. This architecture places collaboration within a wider environment and emphasizes relations among principled engagement, shared motivation, and capacity for joint action.

Interactive governance extends this relational orientation beyond formal collaborative forums. Torfing, Peters, Pierre, and Sørensen conceptualize governance through interaction among state and societal actors and examine the institutional, managerial, democratic, and political dimensions of interactive governing [128]. Their account retains an active role for public authority within systems containing substantial interaction and interdependence.

Collaborative and interactive governance therefore contribute an analytical language of participation, interaction, joint action, trust, negotiation, institutional design, and enabling context. These concepts later intersect with both the dynamical-process and relational-structural layers of the Generative-Relational taxonomy.

3.5 Polycentric Governance

This subsection examines polycentric governance as a theory of institutional organization across multiple decision centers. Its objective is to identify the relational properties of polycentric systems and to clarify the distinction between polycentricity, decentralization, and particular coordination mechanisms.

Ostrom's analysis of polycentric governance develops an institutional alternative to simplified choices between centralized governmental provision and market allocation [95]. Complex collective-action problems can involve multiple decision centers operating at different scales, developing rules under heterogeneous local conditions, and interacting through patterns of cooperation, competition, learning, and institutional coordination.

Polycentric systems give analytical importance to partial autonomy. Decision centers possess meaningful capacities to act within particular domains while remaining connected to other centers. The resulting structure can support institutional diversity and experimentation across locations and scales.

The concept therefore concerns a relational architecture of governing centers. A polycentric system may contain hierarchical relations, network interaction, legal rules, market mechanisms, collaborative forums, and higher-order coordination. Polycentricity specifies the distribution and interaction of decision-

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making capacities across centers and leaves the internal governance mechanism of each center open to further analysis.

This property makes polycentric governance particularly compatible with a multidimensional taxonomy. Polycentric organization can be classified as a relational structure while the interventions occurring within it can simultaneously operate through state-and-rule, dynamical-process, or generative-background mechanisms.

3.6 Multilevel Governance

This subsection examines multilevel governance as a theory of authority distributed across jurisdictions and scales. Its objective is to distinguish vertical and overlapping institutional organization from polycentric decision-center structure and to identify scale as an independent dimension of governance classification.

Hooghe and Marks develop a widely used distinction between two types of multilevel governance [65]. One form is organized through relatively stable, general-purpose jurisdictions with memberships structured across a limited number of levels. Another form consists of task-specific jurisdictions whose memberships, territorial scales, and institutional boundaries can overlap.

Multilevel governance directs attention toward the movement and organization of authority across local, regional, national, supranational, and functional domains. Governing therefore occurs within a vertically and horizontally differentiated institutional space.

Scale becomes analytically significant because governance problems and capacities can possess different spatial, administrative, ecological, economic, and informational ranges. A governance mechanism effective within one jurisdictional level may depend upon coordination with processes operating at other levels.

Multilevel governance consequently supplies an additional coordinate for the present paper. Structural depth describes the component of a generative system upon which intervention operates, while institutional level describes the jurisdictional or functional scale at which governing authority is organized. An intervention can therefore be deep or shallow in the structural sense while operating at a local, national, transnational, or overlapping institutional scale.

3.7 Metagovernance and Governance Composition

This subsection examines the development of metagovernance as an account of the coordination and shaping of governance arrangements themselves. Its objective is to establish a theoretical predecessor for the later Generative-Relational analysis of governance composition while preserving the distinctive institutional meaning of metagovernance.

The proliferation of networks, partnerships, market instruments, and hybrid governance arrangements creates a higher-order problem concerning how these forms are coordinated. Metagovernance addresses this problem by examining the ways in which actors shape the institutional conditions, interaction processes, and combinations through which governance operates.

Sørensen and Torfing analyze metagovernance as a means of improving the effectiveness and democratic quality of governance networks [122]. Their account identifies forms of metagovernance through which public actors can influence network design, framing, management, and participation while retaining substantial self-regulation within the network.

Jessop's analysis of the rise of governance similarly emphasizes the possibility of governance failure and the institutional problems associated with the coordination of increasingly complex forms of economic and social governance [68]. Governance arrangements themselves thereby become objects requiring organization and reflexive adjustment.

Metagovernance introduces an important recursive feature into governance theory: governance can be directed toward the structures through which other governance mechanisms operate. The later Generative-Relational framework develops a related formal problem through cross-layer composition. The two concepts occupy different analytical registers. Metagovernance concerns the governance of governance

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arrangements, while cross-layer composition concerns the interaction of interventions acting upon different structural objects.

3.8 Adaptive, Experimentalist, and Anticipatory Governance

This subsection examines theoretical traditions that make temporal adaptation, learning, revision, experimentation, and engagement with emerging futures central properties of governance. Its objective is to identify temporal orientation as a major classification dimension and to prepare the later analysis of dynamically responsive governance.

Adaptive governance developed prominently within research on social-ecological systems. Folke et al. emphasize social networks, leadership, knowledge integration, bridging organizations, learning, and institutional reorganization during periods of change [41]. Governance capacity in this framework includes the ability to reorganize and develop responses as system conditions evolve.

Adaptive governance introduces a form of institutional plasticity. Rules, relations, organizational structures, and management practices can change in response to new information and altered system conditions. Adaptation can therefore operate through several structural objects while retaining temporal responsiveness as its defining analytical orientation.

Experimentalist governance develops a more explicitly recursive institutional architecture. Sabel and Zeitlin analyze arrangements in which broadly framed goals are combined with substantial local discretion, reporting and comparison of performance, peer review, and periodic revision of goals and procedures [111]. Local variation becomes a source of information for collective learning and subsequent institutional revision.

This recursive architecture is especially relevant to Generative-Relational theory because governance generates information that subsequently modifies the conditions of further governance. Institutional rules and evaluative standards can therefore evolve through repeated cycles of implementation, comparison, reflection, and revision.

Anticipatory governance adds a forward-oriented dimension. Guston describes anticipatory governance through societal capacities for foresight, engagement, and integration in relation to emerging technologies [53]. Its temporal logic concerns developing reflective capacity while technological and institutional trajectories remain open to influence.

Adaptive, experimentalist, and anticipatory theories consequently represent different temporal orientations. Adaptation emphasizes adjustment to evolving conditions, experimentalism institutionalizes recursive learning, and anticipation develops capacities for engagement with emerging possibilities. These orientations can crosscut institutional form and structural depth.

3.9 Global and Transnational Governance

This subsection examines the extension of governance theory beyond the territorial state and into international and transnational systems. Its objective is to identify governing order under conditions of dispersed authority, institutional heterogeneity, and cross-border interdependence. The discussion establishes global scope as another dimension that intersects with the structural taxonomy.

Rosenau and Czempiel's *Governance without Government* provided an influential formulation of governance in world politics under conditions without a centralized world government [109]. Rosenau's contribution distinguishes governance from formal government and examines the patterns, institutions, and processes through which order can be produced and sustained in world politics.

This perspective expands the conceptual space of governance beyond the organizational boundaries of sovereign states. International organizations, states, transnational actors, regimes, networks, norms, markets, and informal arrangements can participate in the production of governing order across borders.

Dingwerth and Pattberg subsequently examine global governance as a perspective on world politics and distinguish different ways in which the concept is used within international-relations scholarship [34]. Global governance thereby becomes both an empirical description of changing political arrange-

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ments and an analytical perspective for studying political authority and coordination beyond state-centric institutional structures.

The global-governance literature is important for the Generative-Relational taxonomy because heterogeneous institutional forms frequently coexist within the same governance system. Treaty rules, international organizations, transgovernmental interaction, private standards, expert networks, multistakeholder arrangements, markets, and civil-society processes can operate across overlapping scales and through different mechanisms.

Global scope therefore represents another independent coordinate of governance classification. A governance mechanism can be local or transnational, centralized or polycentric, hierarchical or networked, adaptive or stable, while simultaneously operating upon a particular state, process, relational structure, or generative background.

3.10 Theoretical Coordinates of Modern Governance

This subsection synthesizes the major theoretical traditions reviewed in this section. Its objective is to identify the classificatory dimensions carried by modern governance theory and to establish the conceptual position of the Generative-Relational taxonomy. The synthesis treats these dimensions as complementary analytical coordinates whose combinations can describe complex governance arrangements.

Table 2 summarizes the principal theoretical coordinates developed in the preceding subsections.

Table 2 demonstrates that modern governance theory has developed along several distinct analytical dimensions. Administrative theories emphasize organization and managerial capacity. Network and collaborative theories emphasize interdependence and interaction. Polycentric and multilevel theories emphasize the distribution of authority across centers and scales. Metagovernance emphasizes the composition of governance arrangements. Adaptive, experimentalist, and anticipatory theories introduce different temporal relationships between governing institutions and changing conditions. Global governance extends analysis across territorial and institutional boundaries.

These dimensions can coexist within one governance system. A transnational environmental regime may be multilevel and polycentric, contain network and hierarchical components, employ collaborative processes, support adaptive learning, and use metagovernance to coordinate heterogeneous institutional arrangements. Each theoretical vocabulary describes a particular property of the same broader governing system.

The Generative-Relational taxonomy therefore enters an already multidimensional theoretical field. Its distinctive classificatory coordinate is the structural object through which governance influences subsequent generation. The taxonomy asks whether an intervention acts primarily upon an explicit state or rule, a dynamical process, a relational architecture, a generative background, or a composition of these structures.

This coordinate also permits theories reviewed in this section to be related without collapsing their established meanings. Network governance remains a theory of networked organization. Polycentric governance remains a theory of multiple interacting decision centers. Adaptive governance remains concerned with institutional adaptation. Their concrete mechanisms can subsequently be decomposed according to the structural layers through which they act.

Modern governance theory consequently supplies the institutional and conceptual vocabulary upon which the later taxonomy builds. The following section moves from theoretical traditions to governance forms and institutional practice. It examines the instruments and arrangements through which governing activity is operationalized in legislation, administration, adjudication, regulation, markets, standards, organizations, networks, international institutions, digital platforms, infrastructures, and emergency settings. The subsequent systems and complexity section then develops the dynamical vocabulary required for the formal Generative-Relational model.

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Table 2: Theoretical coordinates in modern governance scholarship

Theoretical tradition	Classification dimension	Analytical object	GR relation
Public administration and New Public Management	Administrative and managerial organization	Authority, organization, performance, contracts, incentives	Institutional form across structural layers
Governance turn	Institutional interdependence	State–society relations, steering, organizational interdependence	Relational constitution of governing capacity
Network governance	Network architecture	Interorganizational relations, network coordination, network administration	Relational-structural layer
Collaborative and interactive governance	Interaction process	Participation, negotiation, trust, joint action, institutional context	Dynamical and relational layers
Polycentric governance	Decision-center structure	Partially autonomous centers, institutional diversity, inter-center relations	Relational-structural layer
Multilevel governance	Institutional scale	Jurisdictions, territorial levels, functional levels, overlapping authority	Scale dimension across structural layers
Metagovernance	Governance composition	Design, framing, coordination, and management of governance arrangements	Cross-layer and higher-order governance
Adaptive governance	Adaptive capacity	Learning, reorganization, institutional adjustment, cross-scale relations	Dynamical and relational layers
Experimentalist governance	Recursive learning	Local discretion, comparison, review, revision, institutional feedback	Dynamical processes and recursive rule formation
Anticipatory governance	Temporal orientation	Foresight, engagement, integration, emerging trajectories	Dynamical processes and generative conditions
Global and transnational governance	Political scope	Cross-border institutions, regimes, networks, norms, distributed authority	Scale and relational structure across layers
Generative-Relational taxonomy	Structural object	State and rule, dynamics, relational structure, generative background	Primary structural coordinate

4 Governance Forms and Institutional Practice

This section surveys the principal institutional forms and practical instruments through which governance is implemented. Its role is to complement the theoretical traditions reviewed in the preceding section with an instrument-oriented account of governing activity. The analysis proceeds from policy instruments, legislation, administration, and adjudication through regulatory, economic, informational, standard-setting, organizational, community, transnational, digital, and crisis-governance practices. The section concludes by separating institutional form, policy instrument, implementation mechanism, and structural object of intervention. This separation provides the practical foundation for the later Generative-Relational taxonomy.

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4.1 Policy Instruments and Implementation

This subsection establishes policy instruments as the practical link between governance objectives and implemented action. Its objective is to identify the range of techniques available to governing actors and to distinguish instrument choice from the institutional setting in which an instrument is used. The discussion draws on the policy-instruments literature and organizes the subsequent subsections around recurrent families of governing tools.

Policy instruments are mechanisms through which policy objectives are translated into concrete interventions. McDonnell and Elmore develop an instrument-oriented approach that connects problem definition, instrument choice, organizational context, implementation, and policy effects [88]. This orientation shifts attention from the declared objective of a policy toward the mechanism through which the objective is pursued.

Hood's *The Tools of Government* develops a broad account of governmental capacities through information, authority, financial resources, and organization [64]. These capacities can be mobilized both to act upon the world and to acquire information about the environment within which government operates. Governance practice consequently contains an intervention side and an observational side.

Howlett similarly treats policy instruments as techniques used to give effect to policy objectives and emphasizes the relation among instrument choice, policy formulation, and implementation [66]. Instrument analysis therefore provides a bridge between abstract governance theory and concrete institutional practice.

The practical importance of this perspective lies in the heterogeneity of the available instruments. Governments and other governing actors can command, prohibit, authorize, subsidize, tax, disclose information, organize services, establish standards, delegate authority, create markets, alter institutional procedures, redesign infrastructures, or coordinate other actors. Several instruments can also be combined within a single policy programme.

This plurality anticipates a central distinction of the Generative-Relational taxonomy. A policy instrument describes a technique of governing, while a structural layer describes the system component through which that technique produces its effects. One instrument can consequently possess several structural components.

4.2 Legislation and Formal Rule-Making

This subsection examines legislation, regulatory rules, permissions, prohibitions, rights, and formal standards as explicit forms of governance. Its objective is to identify the practical mechanisms through which institutionally recognized rules delimit conduct and structure future decision-making. The discussion focuses on rule production, specification, interpretation, and institutional implementation.

Legislation provides one of the most visible forms of governance. Statutes and other formally authorized rules can define rights, duties, competences, procedures, prohibitions, permissions, liabilities, and institutional mandates. Their practical effects depend upon both their normative content and the institutional arrangements through which they are interpreted and implemented.

Regulatory scholarship demonstrates substantial variation within formal rule-based governance. Black's study of rules and regulators examines the nature, formulation, interpretation, and use of regulatory rules within financial-services regulation [19]. Rule design can vary in precision, scope, interpretive openness, and the extent to which implementation requires judgment by regulatory actors.

Baldwin, Cave, and Lodge identify command-and-control regulation, rights and liabilities, incentives, market-based approaches, disclosure, direct action, and design-oriented intervention among major regulatory strategies [14]. Formal rule-making therefore constitutes one instrument family within a wider regulatory repertoire.

Rule-making also creates second-order institutional effects. A statute may define the powers of an agency, establish procedural requirements, allocate jurisdiction, create reporting duties, or authorize future delegated rule-making. The resulting governance structure can influence both immediate conduct and the processes through which later governance decisions are generated.

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Within the later Generative-Relational taxonomy, legislation provides a paradigmatic case of state-and-rule governance when its primary intervention changes explicit permissions, obligations, or institutional constraints. Its effects can also propagate into dynamical, relational, and background structures through implementation.

4.3 Administrative Implementation and Discretion

This subsection examines administration as the practical translation of general policies into situated decisions, services, classifications, and resource allocations. Its objective is to identify discretion, implementation conditions, organizational routines, and frontline judgment as distinct governance mechanisms. The discussion uses street-level bureaucracy to illustrate the difference between formally specified policy and enacted governance.

Administrative governance operates through agencies and officials who interpret legal mandates, allocate resources, process applications, inspect conduct, provide services, issue permits, maintain records, and make case-specific decisions. The implementation process therefore involves situated judgment as well as formal authorization.

Lipsky's analysis of street-level bureaucracy demonstrates the importance of discretion among public-service workers who interact directly with citizens and implement public programmes under conditions of limited resources, ambiguous goals, substantial workloads, and case-specific judgment [81]. Front-line officials can consequently participate in the practical formation of public policy through repeated implementation decisions.

Administrative routines also reshape policy through categorization, prioritization, eligibility decisions, procedural simplification, and resource rationing. The enacted form of governance can therefore diverge from the abstract specification contained in legislation while remaining embedded within the same institutional programme.

This practical domain is important for the later taxonomy because administrative implementation frequently spans several structural layers. An official can apply an explicit rule, respond to an evolving case, establish or modify relations between a citizen and an institution, and alter access to resources or opportunities. Administrative governance provides a clear example of multilayer intervention within a single institutional process.

4.4 Adjudication and Institutional Review

This subsection examines courts, administrative adjudication, and review procedures as governance practices concerned with disputes, rights, interpretation, authorization, and institutional accountability. Its objective is to identify adjudication as an intervention into both particular cases and the rule structures governing subsequent cases. The discussion considers judicial and bureaucratic forms of decision-making.

Courts govern through authoritative interpretation, dispute resolution, remedies, review of public action, and the development of legal doctrine. Shapiro's comparative analysis emphasizes variation in judicial organization and the multiple political and decision-making roles performed by courts across legal systems [117]. Adjudication therefore constitutes a distinctive institutional form whose effects extend from individual disputes to broader patterns of rule interpretation.

Administrative adjudication introduces a related form of governance within bureaucratic organizations. Mashaw's analysis of Social Security disability decision-making examines the organizational and procedural problems associated with producing consistent and legitimate administrative determinations [86]. Such systems combine rules, evidence, professional judgment, procedural safeguards, organizational routines, and large-scale case processing.

Review mechanisms add a recursive dimension. Courts, tribunals, internal review bodies, ombuds institutions, and appellate structures can evaluate earlier governance decisions and alter the standards governing subsequent practice. Adjudication can therefore modify both a current state and the institutional rules through which future states are determined.

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The later structural taxonomy can distinguish among these effects. A remedy may alter an immediate legal state; an interpretive precedent may alter the effective rule structure; procedural review may change the dynamics of decision-making; and institutional access to adjudication can alter the background conditions under which rights become practically exercisable.

4.5 Regulatory Instruments and Enforcement

This subsection surveys regulation as a practical field containing multiple instruments for influencing economic, organizational, environmental, and social activity. Its objective is to distinguish regulatory strategy from a single command model and to identify enforcement, monitoring, information, incentive, market, and design mechanisms within the regulatory repertoire.

Modern regulatory practice contains a wide range of instruments. Baldwin, Cave, and Lodge identify governmental capacities to command, deploy financial resources, use market structures, provide information, undertake direct action, and create protected rights and liabilities [14]. Regulatory strategy therefore involves the selection and combination of different mechanisms according to the regulated domain.

Gunningham, Grabosky, and Sinclair develop this plurality through *Smart Regulation*, which examines command regulation, economic instruments, self-regulation, informational strategies, and combinations of regulatory instruments [52]. Their account gives particular attention to complementary instrument mixes and to interactions among governmental, commercial, and third-party actors.

Monitoring and enforcement constitute additional dimensions. Rules acquire practical effects through inspection, information gathering, reporting, auditing, investigation, sanctions, remediation, licensing, and other mechanisms that connect normative standards with observed conduct. Enforcement architecture can consequently influence the effective behavior of a regulatory system independently of the textual content of its rules.

Regulatory governance therefore illustrates the distinction between institutional instrument and structural mechanism particularly clearly. Formal rules, monitoring systems, incentive structures, information requirements, third-party relations, and technological designs can coexist within one regulatory regime while acting through different structural pathways.

4.6 Responsive and Risk-Based Regulation

This subsection examines regulatory practices in which the intensity, timing, or allocation of intervention depends upon observed conduct or assessed risk. Its objective is to identify conditionality and prioritization as practical governance mechanisms. The discussion distinguishes responsive sequences from risk-based allocation while emphasizing their shared dependence on information about the regulated environment.

Ayres and Braithwaite's theory of responsive regulation develops a regulatory architecture in which intervention can escalate according to the behavior of regulated actors and the effectiveness of preceding regulatory responses [12]. The enforcement pyramid provides a widely recognized representation of graduated intervention, ranging from persuasion and cooperative measures toward increasingly stringent sanctions.

Responsive regulation introduces state dependence into practical regulatory action. The next intervention depends upon information produced through the preceding interaction. Regulatory practice therefore contains an iterative relationship among observation, assessment, intervention, and subsequent behavior.

Risk-based regulation uses assessments of risk to allocate regulatory attention and resources. Black analyzes risk as an organizing principle that can frame regulatory objects, organizations, processes, justifications, and accountability relations [20]. The OECD similarly emphasizes risk-based approaches to regulatory design and implementation as a means of allocating attention under conditions in which regulatory resources and risk reduction capacities are finite [91].

Risk-based practice can influence inspection frequency, supervisory intensity, reporting requirements, enforcement priorities, and the allocation of regulatory resources. Its operation depends upon

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methods for identifying, classifying, estimating, and comparing risks.

Responsive and risk-based regulation provide important predecessors for the later dynamical-process taxonomy. Responsive regulation contains behavior-conditioned intervention sequences, while risk-based regulation contains state assessment and differentiated allocation. Their formal development can subsequently be compared with feedback, event-based, and criticality-sensitive governance while preserving the established meanings of the regulatory concepts.

4.7 Economic, Informational, and Design Instruments

This subsection examines governance instruments that alter incentives, information environments, opportunities, or material architectures. Its objective is to identify practical forms of intervention whose effects arise through the conditions of choice and action. The discussion connects economic instruments, disclosure and information, and design-based governance.

Economic instruments influence conduct through financial consequences or market structures. Taxes, subsidies, tradable permits, grants, procurement, fees, competition rules, and other mechanisms can change the relative costs and benefits associated with available actions. Hood identifies financial resources as one of the major capacities available to government [64], while regulatory scholarship treats incentives and market-harnessing controls as important regulatory strategies [14].

Information constitutes another governance resource. Public information campaigns, mandatory disclosure, product labels, performance reporting, warnings, rankings, transparency obligations, and advisory systems can change the informational conditions within which actors make decisions. Information can also support subsequent regulatory intervention by rendering activities observable to regulators, markets, communities, or other organizations.

Design-based governance works through the architecture of available action. Lessig's analysis of cyberspace gives particular prominence to code and architecture as forms of regulation and situates them alongside law, markets, and social norms [80]. The insight extends beyond digital systems: physical and technical architectures can enable, impede, channel, or condition particular forms of conduct.

These instrument families become especially important for Generative-Relational analysis because their immediate governance object can differ from the eventual behavior of the governed actor. A subsidy alters an economic condition, disclosure changes an information environment, and architecture changes available paths of action. The behavior emerges through the actor's relation with these modified conditions.

4.8 Standards, Certification, and Soft Law

This subsection examines standards, certification systems, codes, guidelines, and soft-law instruments as governance practices operating through normative benchmarks with varying forms of legal and institutional authority. Its objective is to identify standardization as a mechanism that can coordinate heterogeneous actors across organizational and jurisdictional boundaries.

Standardization has become an important mechanism of contemporary governance. Brunsson and Jacobsson examine the production, organization, adoption, and effects of standards across organizations and markets [26]. Standards can coordinate expectations and practices across actors that remain organizationally independent.

Certification adds monitoring and recognition mechanisms to standard-setting. Certification systems may connect compliance with market access, reputation, procurement eligibility, professional recognition, or participation in supply chains. Cashore et al. examine non-state market-driven forest certification as a form of governance in which market incentives and private standards interact with public policy [28].

International governance also employs instruments whose degrees of legal obligation, precision, and delegation vary. Abbott and Snidal analyze hard and soft legalization and explain why actors may select institutional forms with different combinations of obligation, precision, and delegation [2]. Soft-law instruments can support flexibility, compromise, learning, and coordination under uncertainty.

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Standards and soft law demonstrate that normative influence can extend beyond formally binding legislation. Their practical effects can depend upon recognition, interoperability, professional practice, market access, reputation, certification, monitoring, and relations among organizations. These mechanisms can therefore operate through explicit norms and through the background conditions associated with participation in wider institutional systems.

4.9 Contractual, Organizational, and Partnership Governance

This subsection examines governance implemented through contracts, organizational arrangements, delegation, partnerships, and coordinated provision. Its objective is to identify practical forms in which governing capacity is distributed among actors through formal and relational arrangements. The discussion connects contracting with the broader organizational ecology of public and private governance.

Contracts can specify responsibilities, performance requirements, prices, quality standards, reporting duties, risk allocation, remedies, and termination conditions. Public contracting therefore allows governance to operate through legally structured relationships with service providers, firms, nonprofit organizations, and other institutional actors.

Organizational governance also occurs through delegation and the creation of specialized bodies. Agencies, public corporations, regulators, commissions, interorganizational boards, and administrative organizations can receive defined competences while remaining embedded within wider systems of oversight, finance, reporting, and accountability.

Partnership governance adds negotiated and collaborative relations among actors possessing distinct resources and institutional capacities. The collaborative-governance frameworks reviewed in Section 3 show how institutional design, leadership, trust, participation, and joint action affect such arrangements [7, 39].

These forms are significant for structural classification because a contract or partnership can operate simultaneously through rule, relational, and background mechanisms. Contractual clauses define explicit obligations; organizational arrangements establish coupling relations; financing and resource allocation affect future action capacities; reporting requirements alter informational conditions.

4.10 Community and Commons Governance

This subsection examines governance practices developed and maintained by communities managing shared resources and collective-action problems. Its objective is to identify rule formation, monitoring, sanctioning, participation, boundary definition, and local institutional adaptation outside a purely centralized administrative setting.

Ostrom's *Governing the Commons* documents diverse institutional arrangements through which users of common-pool resources develop and maintain rules for collective resource governance [93]. The empirical cases demonstrate substantial institutional variation and support analysis of the conditions under which self-organized arrangements persist or fail.

Commons governance can include definitions of resource and membership boundaries, rules concerning appropriation and contribution, monitoring, graduated sanctions, conflict-resolution mechanisms, and arrangements for collective choice. These mechanisms combine formalized rules with relational knowledge and locally situated monitoring.

Community governance is therefore relevant to several GR layers. Collective rules belong to the explicit-rule structure. Monitoring and sanctioning can form feedback processes. Membership and resource relations constitute relational structures. Local knowledge, trust, resource availability, and institutional recognition can contribute to generative conditions.

The practical significance of commons governance lies in the co-production of governance by participants whose actions are themselves governed by the resulting institutional arrangement. This recursive relation becomes important for the later analysis of endogenous governance structures.

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4.11 International, Transnational, and Indirect Governance

This subsection examines governance practices operating across borders and through heterogeneous combinations of states, international organizations, firms, intermediaries, civil-society organizations, and private standards. Its objective is to identify treaty-based, soft-law, delegated, orchestrated, and transnational-private mechanisms as distinct practical forms.

International governance includes treaties, institutional decisions, monitoring mechanisms, reporting systems, dispute settlement, technical assistance, conditional finance, standards, recommendations, and coordinated national implementation. The absence of a centralized global government creates institutional environments in which authority and implementation are distributed across multiple actors and scales [109].

The distinction between hard and soft law provides one important dimension of international practice. Abbott and Snidal show how varying combinations of obligation, precision, and delegation can provide different institutional solutions under different political conditions [2]. International governance therefore contains a continuum of normative instruments with different implementation architectures.

Indirect governance adds another mechanism. Abbott, Genschel, Snidal, and Zangl distinguish delegation from orchestration and conceptualize orchestration as governance through intermediaries supported through relatively soft forms of influence [1]. Governing capacity can therefore be extended through organizations possessing resources, expertise, legitimacy, access, or implementation capabilities unavailable to the initiating actor.

Transnational private regulation further distributes governance across firms, standards organizations, professional bodies, certification organizations, civil-society groups, and supply-chain actors. Public and private rules can interact through layered institutional environments, as Bartley demonstrates in his analysis of transnational standards and domestic rule systems [16].

These practices are particularly important for the GR framework because governance effects frequently travel through extended relational chains. An international organization may modify the resources or standards of an intermediary, which alters national or organizational practices, which then changes the conditions confronting local actors. Structural decomposition can make these propagation paths analytically visible.

4.12 Digital Platform and Algorithmic Governance

This subsection examines governance conducted through digital architectures, platform rules, automated monitoring, ranking, recommendation, and content moderation. Its objective is to identify computational systems as practical governance infrastructures whose operation can combine explicit rules, feedback, prediction, relational restructuring, and architectural conditioning.

Digital platforms govern through terms of service, community standards, account rules, access controls, ranking systems, recommendation algorithms, interface design, moderation practices, data collection, and enforcement mechanisms. Gillespie's study of content moderation demonstrates the institutional significance of platform decisions concerning the production, visibility, removal, and organization of user-generated content [47].

Algorithmic regulation introduces more explicitly computational governance loops. Yeung characterizes algorithmic regulation through systems that collect data from dynamic environments, generate knowledge computationally, and use that information to manage risk or alter behavior [134]. Her taxonomy distinguishes configurations of standard setting, information gathering, prediction, and execution or recommendation.

Automated content moderation provides a specific example. Gorwa, Binns, and Katzenbach analyze technical systems used for large-scale moderation and identify associated problems of transparency, accountability, fairness, and the political character of moderation decisions [49]. Computational implementation can therefore change both the scale and the structure of governance.

Lessig's architectural account remains relevant because software determines available actions and constraints within digital environments [80]. Platform governance can consequently operate through

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explicit policy rules and through the technical architecture in which those rules are enacted.

Digital governance is especially useful for demonstrating multilayer composition. A content policy can define a rule, an automated classifier can implement an event-sensitive decision process, a recommender can alter network visibility, and interface architecture can modify the background conditions under which interactions occur. The same platform can therefore contain multiple structural forms of governance simultaneously.

4.13 Crisis and Emergency Governance

This subsection examines governance under conditions of acute disruption, compressed decision time, uncertainty, institutional stress, and rapidly changing information. Its objective is to identify crisis governance as a practical domain in which timing, sense-making, coordination, temporary authority, communication, and institutional learning acquire heightened importance.

Crisis governance can involve emergency powers, rapid resource mobilization, temporary organizational structures, interagency coordination, public communication, evacuation, restrictions, emergency procurement, and accelerated decision procedures. Such practices operate under conditions in which ordinary governance processes may be too slow for the temporal demands of the event.

Boin, 't Hart, Stern, and Sundelius organize crisis management around major leadership tasks including sense-making, decision-making and coordination, meaning-making, crisis termination, accountability, and learning [24]. Their framework emphasizes the changing informational and institutional demands that arise as crises unfold.

Crisis conditions can change the relative importance of governance mechanisms. Direct intervention can become temporally necessary when harms are imminent. Event detection and threshold crossing can trigger emergency procedures. Coordination structures may be reconfigured rapidly. Information flows and public communication can become central to collective response.

The crisis domain therefore provides an important practical test for the later taxonomy. Governance depth, intervention speed, reversibility, observability, and uncertainty can trade off sharply during emergencies. The suitability of a governance mechanism depends upon both its structural reach and the time available for intervention.

4.14 Practical Instrument Families and Structural Correspondence

This subsection synthesizes the governance practices reviewed above into a comparative instrument map. Its objective is to separate four analytical properties: institutional form, practical instrument, immediate implementation mechanism, and preliminary Generative-Relational structural correspondence. The synthesis prepares the transition from institutional practice to the systems and complexity vocabulary developed in the following section.

Table 3 summarizes the principal instrument families examined in this section.

Table 3 demonstrates that practical governance instruments rarely map uniquely onto one structural layer. Legislation can create relationships and background capacities in addition to explicit rules. Economic instruments influence trajectories through altered conditions. Standards combine normative specification with organizational and market relations. Algorithmic governance can simultaneously encode rules, observe system states, trigger responses, alter relational visibility, and shape the architecture of available action.

The practical survey therefore supports a distinction among *institutional form*, *instrument*, *implementation mechanism*, and *structural object*. Institutional form identifies the organization or legal arrangement through which governance is authorized. Instrument identifies the technique selected for intervention. Implementation mechanism describes how that instrument produces an operational effect. Structural object identifies the component of the generative system whose transformation carries that effect into subsequent system evolution.

These properties can vary independently. A statute can operate through a direct prohibition, an incentive, a reporting requirement, institutional delegation, or architectural requirements. A digital platform

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can govern through explicit rules, economic incentives, ranking systems, network relations, or technical affordances. An international organization can use binding rules, soft standards, information, financial support, monitoring, or orchestration through intermediaries.

The distinction provides an empirical motivation for the Generative-Relational taxonomy. Governance practice contains a larger mechanism space than any single institutional classification captures. Structural decomposition offers a method for identifying where within an evolving system each mechanism initially acts and how its effects can subsequently propagate.

The following section develops the systems, cybernetic, and complexity concepts required to analyze this propagation. Feedback, state dependence, nonlinearity, self-organization, attractors, thresholds, critical transitions, network dynamics, partial observability, and model uncertainty provide the formal bridge between the institutional practices reviewed here and the Generative-Relational system developed in the subsequent formal sections.

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Table 3: Governance practices, implementation mechanisms, and structural correspondence

Institutional practice	**Instrument family**	**Implementation mechanism**	**Preliminary GR correspondence**
Legislation and formal rule-making	Statutes, rules, rights, duties, permissions, prohibitions	Norm specification, authorization, legal constraint	State-and-rule; relational effects through institutional competence
Administrative implementation	Licensing, eligibility, allocation, service delivery, discretionary decisions	Case processing, interpretation, resource allocation, situated judgment	State-and-rule; dynamical and background effects
Adjudication and review	Judgments, remedies, appeals, administrative review	Interpretation, dispute resolution, precedent, institutional correction	State-and-rule; recursive rule and process governance
Regulation and enforcement	Commands, monitoring, inspection, sanctions, disclosure, direct intervention	Compliance control, observation, deterrence, remediation	State-and-rule and dynamical process
Responsive regulation	Graduated enforcement and conditional escalation	Behavior-dependent regulatory response	Dynamical process
Risk-based regulation	Risk classification, supervisory prioritization, differentiated inspection	State assessment and resource prioritization	Dynamical process and information structure
Economic instruments	Taxes, subsidies, grants, permits, procurement, market mechanisms	Modification of costs, rewards, and resource access	Dynamical incentives and generative conditions
Informational instruments	Disclosure, warnings, labels, reporting, rankings, advice	Modification of information availability and observability	Dynamical process and generative background
Design and architecture	Physical, technical, and digital design	Modification of available actions and paths	Generative background; possible state-and-rule encoding
Standards and certification	Technical standards, codes, certification, accreditation	Benchmarking, recognition, monitoring, market access	State-and-rule, relational structure, generative background
Contracts and partnerships	Contracts, delegation, collaborative arrangements	Obligation, resource exchange, coordination, joint action	State-and-rule and relational structure
Commons and community governance	Locally generated rules, monitoring, sanctions, collective choice	Participant-based institutional production and maintenance	State-and-rule, dynamical, and relational structure
International and transnational governance	Treaties, soft law, orchestration, private standards, technical assistance	Cross-border rule transmission, intermediary mobilization, distributed implementation	Relational structure and multilayer propagation
Digital and algorithmic governance	Platform rules, ranking, recommendation, automated moderation, access control	Continuous data processing, automated response, architectural conditioning	State-and-rule, dynamical, relational, and background layers
Crisis and emergency governance	Emergency powers, rapid coordination, temporary procedures, resource mobilization	Time-sensitive intervention, event response, institutional reconfiguration	State-and-rule, dynamical, and relational layers

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5 Systems, Cybernetics, and Complexity in Governance

This section develops the systems-theoretical and dynamical foundations that connect established governance scholarship with the formal Generative-Relational taxonomy developed later in the paper. Its objective is to identify the conceptual transition from systems of political inputs and outputs toward feedback, regulation, adaptation, complex adaptive systems, resilience, nonlinear transitions, path dependence, network propagation, and partial observability. The discussion proceeds from political systems theory and classical cybernetics through organizational cybernetics and complexity science to contemporary work on critical transitions and network cascades. The final synthesis identifies the dynamical concepts that will subsequently be formalized as distinct governance mechanisms.

5.1 Systems Approaches to Political and Administrative Order

This subsection establishes the early application of systems concepts to political organization and governing processes. Its objective is to identify the shift from isolated institutional acts toward interconnected processes of input, transformation, output, environmental response, and system persistence. The discussion focuses on the systems approaches of Easton and Deutsch and their significance for later feedback-oriented governance analysis.

Systems analysis introduced a vocabulary in which political processes could be studied through relations among a system, its environment, incoming demands and support, political decision processes, and resulting outputs. Easton's *A Systems Analysis of Political Life* develops political life through a system-environment framework concerned with the persistence of political systems under changing conditions [36]. Political processes thereby become components of a continuing pattern of interaction through which demands, support, authoritative allocations, and environmental effects are related over time.

The systems perspective changes the unit of analysis. A governmental decision can be examined as part of an ongoing sequence in which environmental conditions generate inputs, institutions transform those inputs, decisions produce consequences, and subsequent conditions influence further political activity. Governance consequently acquires a temporal and recursive structure.

Deutsch develops a closely related political application of communication and control in *The Nerves of Government* [32]. His analysis gives information, communication, learning, memory, feedback, and control a central role in political capacity. Governmental effectiveness can consequently depend upon the ability of an institution to receive information concerning its environment and its own performance, process that information, and modify action in response.

The systems and communication perspectives provide a conceptual predecessor for later feedback governance. They also introduce an epistemic dimension. The capacity of a governing institution depends partly upon the signals that reach it, the delay and distortion associated with those signals, and the institutional processes through which information becomes actionable.

Peters later reviews this tradition explicitly through cybernetic models of governance and emphasizes information acquisition, feedback, adjustment, and the information-processing capacities of governing institutions [99]. Systems thinking therefore occupies an established position within governance scholarship and provides an important bridge toward the more detailed dynamical distinctions developed in the present paper.

5.2 Cybernetics, Feedback, and Requisite Variety

This subsection examines the conceptual foundations of cybernetic regulation. Its objective is to identify feedback, state information, control, environmental disturbance, and regulatory variety as distinct analytical objects. The discussion draws on Wiener and Ashby and then relates their concepts to governance under changing environmental conditions.

Wiener's *Cybernetics* develops a general language of control and communication across machines and living systems [133]. Feedback provides a mechanism through which the consequences of action

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can influence subsequent action. Regulation therefore depends upon a continuing relation among system state, desired or viable conditions, environmental disturbance, observation, and corrective response.

Feedback is important for governance because it introduces endogenous adjustment. A governing intervention can generate information about the system's response, and that information can subsequently modify the intervention. Regulation becomes a temporal process whose successive actions depend upon observed consequences.

Ashby's *An Introduction to Cybernetics* develops a systematic treatment of states, transformations, regulation, stability, information, and variety [9]. Ashby's law of requisite variety connects the variety of disturbances facing a system with the variety available to a regulator. The principle provides a conceptual language for analysing the capacity of a governing system to respond to heterogeneous environmental conditions.

The governance implication concerns regulatory repertoire. A system facing a wide range of disturbances may require correspondingly differentiated observational and response capacities. Institutional simplification can reduce administrative cost while also reducing the range of situations that can be distinguished or addressed. Increasing regulatory complexity can expand response capacity while imposing additional informational, organizational, and legitimacy burdens.

Requisite variety also illuminates the relation between decentralization and local knowledge. Regulatory variety can be distributed across multiple actors, levels, or modules. A system can therefore obtain response capacity through local differentiation, institutional diversity, or coordination among specialized components. This provides one systems-theoretical connection to network, polycentric, and multilevel governance.

Cybernetic governance consequently introduces several dimensions that later receive separate formal treatment: observation, feedback, response repertoire, control delay, state dependence, and the relation between environmental complexity and regulatory capacity.

5.3 Organizational Cybernetics and Viability

This subsection examines the extension of cybernetic reasoning to organizations and management. Its objective is to identify viability, recursion, autonomy, coordination, and environmental adaptation as organizational properties relevant to governance. The discussion focuses on Stafford Beer's management cybernetics and its relation to multi-level regulatory organization.

Beer develops the application of cybernetics to management in *Cybernetics and Management* [17] and later constructs a more elaborate organizational account in *Brain of the Firm* [18]. Organizational viability in this tradition depends upon a structure capable of coordinating operational units, managing internal interactions, relating present operations to changing environmental conditions, and maintaining higher-order organizational coherence.

The resulting perspective gives autonomy and coordination complementary roles. Operational components require sufficient autonomy to handle locally relevant variation, while the larger organization requires mechanisms through which interactions, conflicts, resources, and strategic adaptation can be coordinated.

This organizational logic is relevant to governance across several scales. Public agencies, international organizations, polycentric systems, and distributed administrative arrangements all confront questions concerning which disturbances can be handled locally, which require coordination across units, and which require transformation of higher-order institutional structures.

Organizational cybernetics also introduces recursion as a structural property. A subsystem can itself contain regulatory structures analogous to those operating at a larger organizational level. This provides a useful conceptual resource for governance systems containing nested organizations, jurisdictions, and semi-autonomous decision centers.

The present taxonomy later separates several mechanisms that organizational cybernetics frequently combines. Local feedback belongs primarily to the dynamical-process layer. Relations among operational units belong to the relational-structural layer. Conditions supporting the continued viability and

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adaptive range of organizational components can extend into the generative-background layer. The distinction allows cybernetic organizational concepts to be decomposed according to their structural object.

5.4 Complex Adaptive Systems and Emergent Organization

This subsection introduces complexity science as a framework for systems whose macroscopic behavior develops through interactions among adaptive components. Its objective is to establish adaptation, distributed interaction, emergence, and co-evolution as conceptual foundations for governance under conditions in which system organization changes through time. The discussion uses Holland, Simon, and contemporary complexity-oriented governance research.

Complex adaptive systems contain multiple interacting components whose behavior can change in response to experience and environmental conditions. Holland's *Hidden Order* develops a general account of adaptation and emergent complexity across systems composed of interacting adaptive agents [61]. Local adaptation can produce aggregate patterns whose properties exceed the behavior specified at the level of an individual component.

Emergence changes the governance problem because aggregate order can arise through interactions distributed across a system. Governing capacity can therefore involve relations among local rules, adaptive responses, interaction structures, and higher-order patterns generated through those interactions.

Simon provides an additional structural contribution through his analysis of complexity and hierarchical organization. His account of nearly decomposable systems emphasizes the importance of subsystems and the relative strength of interactions within and among them [119]. His broader work on artificial systems also treats design, organization, environment, and complexity as connected analytical problems [120].

Modularity becomes particularly important for governance. A modular structure can localize some disturbances, allow differentiated adaptation, and reduce the informational burden associated with global coordination. Couplings among modules remain important because sufficiently strong cross-module interaction can transmit disturbances or constrain local adaptation.

Duit and Galaz bring complex adaptive systems directly into governance theory. Their analysis considers nonlinear dynamics, threshold effects, cascades, limited predictability, and variation in adaptive governance capacity [35]. Complexity therefore enters governance scholarship as a property of the governed system as well as a property of institutional organization.

The Generative-Relational framework extends this orientation by distinguishing the components through which complex-system governance operates. Adaptive agents, local dynamics, coupling structures, and the conditions under which those structures reproduce themselves become analytically separable objects.

5.5 Self-Organization, Modularity, and Emergent Order

This subsection develops the structural implications of self-organization and modularity for governance. Its objective is to identify how system-level order can arise through local interactions and how the organization of interactions affects the propagation of change. The discussion connects systems theory with the relational architecture developed later in the paper.

Self-organization refers broadly to the generation of macroscopic organization through interactions among system components. The resulting pattern can depend upon local rules, feedback relations, resource flows, interaction topology, and environmental conditions. In governance settings, self-organization can appear in community institutions, markets, networks, professional practices, informal norms, and polycentric systems.

Self-organized order creates a governance problem concerning intervention scale. Direct specification of every local state can require extensive information and administrative capacity. Governance can also operate through rules, interfaces, incentives, boundaries, or resource conditions that shape the processes through which decentralized order develops.

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Simon's account of complex architecture provides one resource for understanding the importance of subsystem organization [119]. Modular or nearly decomposable systems can display strong interactions within subsystems and weaker interactions among them. This structural distinction can affect both system evolution and governance strategy.

The governance significance of modularity extends to institutional design. Boundaries can limit propagation while preserving local adaptation. Interfaces can permit coordination while retaining differentiated internal structures. Cross-module dependencies can create channels through which information, resources, and disturbances propagate.

Self-organization therefore connects the dynamical and relational dimensions of governance. Local processes generate global structures, while the emerging structures subsequently condition local action. This recursive relation will later become important for the GR account of endogenous generative backgrounds.

5.6 Resilience, Robustness, and Adaptive Cycles

This subsection examines system persistence and transformation under disturbance. Its objective is to distinguish resilience, stability, robustness, and adaptive reorganization as concepts relevant to governance. The discussion draws primarily on social-ecological systems research because that literature provides particularly explicit treatments of multiple regimes, institutional adaptation, and coupled human-environment systems.

Holling's foundational work distinguishes resilience from conceptions of stability focused on rapid return to equilibrium [62]. Resilience concerns the persistence of system relationships and the capacity to absorb changes while retaining important system properties. This distinction makes the structure of possible regimes and the magnitude of tolerable disturbance analytically significant.

The governance implication concerns the object of preservation. Maintaining a particular instantaneous state, maintaining the local stability of a regime, and maintaining a system's capacity to continue reorganizing under disturbance represent different objectives. A governance intervention designed for one can produce different consequences for the others.

The later panarchy framework develops adaptive cycles and cross-scale relations among processes of growth, accumulation, release, and reorganization [51]. This vocabulary emphasizes that persistence and transformation occur across multiple temporal and spatial scales.

Anderies, Janssen, and Ostrom connect robustness explicitly with institutional structures in social-ecological systems [6]. Their framework examines relations among resource users, public infrastructure providers, public infrastructure, and resource systems. Robustness therefore depends upon interactions among ecological and institutional components.

Resilience and robustness provide important distinctions for governance taxonomy. A rule can stabilize one system variable while weakening adaptive capacity elsewhere. Redundancy can increase robustness to one class of disturbance while increasing cost. Tight coupling can improve coordination during ordinary conditions while increasing exposure to cascading failure.

The GR framework later treats these properties as evaluative characteristics of system configurations and interventions. They do not constitute an additional structural layer. Their relevance spans states, dynamics, relations, and generative backgrounds.

5.7 Nonlinearity, Regime Structure, and Path Dependence

This subsection examines temporal processes in which intervention effects depend strongly upon system state, parameter configuration, historical sequence, and prior institutional development. Its objective is to establish nonlinearity, multiple dynamical regimes, and path dependence as reasons for distinguishing governance mechanisms according to their location in system evolution.

Nonlinear systems can respond disproportionately to changes in state or parameters. Comparable interventions can produce different effects under different conditions, and small changes can occasionally

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produce large consequences when system sensitivity is high. Dynamical systems theory provides a formal vocabulary of equilibria, stability, attractors, basins, and bifurcations for analysing these phenomena [76].

This vocabulary has important governance implications. The effectiveness of an intervention may depend upon the regime in which the system currently evolves. A policy that produces gradual adjustment within one regime may contribute to a qualitative transition under another parameter configuration. The timing of intervention can therefore matter independently of its nominal magnitude.

Historical institutionalism provides a complementary account of temporal dependence in political systems. Pierson develops path dependence through increasing returns and emphasizes the importance of timing, sequence, contingent events, and processes through which established institutional paths become progressively difficult to reverse [103]. Political development can consequently produce asymmetries between the process through which an institutional path is formed and the process required to alter it later.

Path dependence is particularly important for governance depth. Interventions can influence current behavior while also changing the conditions under which future institutional choices are made. Early institutional decisions can alter resources, expectations, expertise, organizational investments, and political coalitions in ways that shape subsequent trajectories.

This temporal asymmetry provides one bridge to generative-background governance. Historically generated structures can become effective conditions for later action. Governance can therefore participate in the production of the background that constrains subsequent governance.

5.8 Critical Transitions and Early-Warning Structures

This subsection examines systems that can undergo qualitative changes in dynamical regime as control conditions vary. Its objective is to establish the scientific basis and epistemic limits of critical-transition reasoning before the later formulation of criticality governance. The discussion distinguishes transition mechanisms from indicators proposed for detecting proximity to some classes of transitions.

Bifurcation theory studies qualitative changes in dynamical behavior associated with changes in system parameters [76]. In applied complex systems, related phenomena are often discussed through the vocabulary of critical transitions or tipping points.

Scheffer et al. review evidence that some systems approaching certain critical transitions can display generic early-warning properties associated with critical slowing down [113]. Proposed indicators include changes in recovery rates, autocorrelation, variance, and spatial patterning. The scientific significance of these indicators lies in their relation to changing local dynamical stability as a transition is approached.

The governance significance is considerable. If reliable information concerning changing dynamical sensitivity becomes available before a regime transition, intervention timing can be adjusted according to proximity to the transition region. Governance can then distinguish ordinary operating conditions from periods requiring heightened observation, reduced delay, greater coordination, or precautionary intervention.

Early-warning inference also contains important limitations. Boettiger and Hastings demonstrate that common warning statistics can produce false positives under some forms of conditional case selection and emphasize the need for careful model comparison and inference [23]. Abrupt transitions can also arise through mechanisms for which critical-slowing-down indicators provide limited information.

Criticality governance therefore requires an epistemically modest formulation. The relevant governance problem concerns changing evidence about system sensitivity, stability, and transition risk. The presence of a candidate early-warning statistic does not by itself establish a known bifurcation, a known destination regime, or a uniquely appropriate intervention.

This distinction will be preserved in the later formal taxonomy. Criticality-sensitive governance concerns governance under changing dynamical sensitivity and transition risk. Specific early-warning indicators remain model-dependent observational tools within that broader governance mechanism.

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5.9 Network Topology and Cascading Dynamics

This subsection examines how relational topology influences the transmission and amplification of local events. Its objective is to connect network structure with dynamical propagation and to establish cascades as phenomena requiring joint analysis of local response rules and relational architecture. The discussion uses foundational work on complex networks and cascade dynamics.

Complex networks can possess highly heterogeneous degree distributions and other structural properties with important consequences for system behavior. Barabási and Albert demonstrate how network growth and preferential attachment can generate scaling properties in network connectivity [15]. The broader significance for governance lies in the possibility that actors and institutions can occupy structurally very different positions within the same relational system.

Network position affects propagation. Highly connected nodes can transmit information, resources, failures, or behavioral influence across large parts of a system. Community structure, bridges, bottlenecks, redundancy, and dependency relations can similarly shape the path through which disturbances travel.

Watts demonstrates through a threshold model that small initial shocks can generate large cascades under particular combinations of network structure and local vulnerability [130]. Large collective effects therefore depend upon the interaction between node-level response conditions and relational topology.

This result is particularly important for the GR taxonomy because it demonstrates the analytical insufficiency of state variables considered in isolation. A local event acquires different systemic significance according to its relational position and the response properties of connected components.

Governance of cascading systems can consequently involve several mechanisms. Intervention can target vulnerable nodes, modify coupling relations, introduce buffers, alter thresholds, create redundancy, isolate modules, or change the conditions through which propagation occurs. These mechanisms belong to different structural layers even when they address the same systemic risk.

Network dynamics therefore provide one of the clearest cases in which dynamical-process governance and relational-structural governance must be distinguished and subsequently recombined.

5.10 Observability, Information, and Model Uncertainty

This subsection examines the epistemic conditions under which systems-oriented governance operates. Its objective is to distinguish the state of a governed system from the information available to governing actors and to identify partial observation, model uncertainty, delay, aggregation, and changing system structure as governance constraints.

Cybernetic regulation presupposes information concerning the regulated system. Wiener and Ashby treat information and communication as central components of regulatory processes [133, 9]. Political applications of cybernetic reasoning similarly connect governance capacity with the reception and processing of relevant information [32, 99].

Governance systems commonly observe proxies, reports, indicators, samples, administrative categories, network measurements, or delayed outcomes. The observed representation can therefore differ from the state space assumed in a theoretical model. Measurement itself can also aggregate heterogeneous conditions into a smaller set of administratively actionable categories.

Complexity intensifies this problem. Duit and Galaz explicitly identify limited predictability as a central governance challenge in complex adaptive systems [35]. Nonlinearity, adaptation, changing relations, and cross-scale interaction can reduce the reliability of long-horizon prediction.

Simon provides an additional design-oriented perspective by emphasizing the relation between bounded information-processing capacity and the structure of complex environments [120]. Governance strategies can therefore be designed around manageable representations, modular structures, local heuristics, and partial models.

The epistemic problem has direct implications for structural depth. A governance intervention based on a local observable may require relatively little knowledge of global system structure. An intervention intended to alter a large-scale relational topology requires more extensive structural information.

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Generative-background intervention can require knowledge of slowly changing conditions whose effects appear across long temporal horizons.

The later taxonomy therefore treats epistemic requirements as a separate dimension of governance mechanisms. Structural depth, observability, prediction horizon, model uncertainty, and intervention reversibility will be analysed jointly without assuming that deeper intervention provides greater knowledge or control.

5.11 Temporal Scale and Cross-Scale Dynamics

This subsection examines the coexistence of processes operating at different rates and scales. Its objective is to establish timescale separation, cross-scale coupling, and slow-variable accumulation as important conditions for governance. The discussion connects resilience research, institutional path dependence, and complex-system dynamics.

Governed systems often contain fast and slow processes. Market prices, information flows, public reactions, and operational decisions can change rapidly, while infrastructures, legal cultures, institutional capacities, ecosystems, demographic structures, and patterns of trust can evolve over much longer periods.

The panarchy framework emphasizes connections among processes operating across different spatial and temporal scales [51]. Slow variables can shape the conditions within which faster processes operate, while fast disturbances can occasionally reorganize slower structures.

Political path dependence provides an institutional analogue. Institutional investments and increasing returns can accumulate gradually and later constrain the range of feasible alternatives [103]. A governance system focused exclusively on short-term output indicators can therefore miss changes occurring in slower structural variables.

Cross-scale dynamics also complicate intervention evaluation. A policy can produce an immediate improvement in one observable while altering slower conditions in ways that affect future resilience or generative capacity. Conversely, background reforms can impose short-term adjustment costs while changing the conditions under which future trajectories develop.

The GR distinction between dynamical processes and generative backgrounds will later provide a formal language for this issue. Fast trajectory modification and slow structural formation can be represented separately while their coupling remains explicit.

5.12 Dynamical Vocabulary for Governance Analysis

This subsection synthesizes the systems, cybernetic, and complexity traditions reviewed above into the dynamical vocabulary required by the Generative-Relational taxonomy. Its objective is to identify the established conceptual resources inherited from these traditions and the finer distinctions introduced later in the paper. The synthesis organizes the literature according to information, dynamics, structure, transition, and epistemic conditions.

Table 4 summarizes the principal systems-theoretical concepts and their relevance to the later taxonomy.

Table 4 identifies a substantial systems-oriented lineage preceding the formal concepts developed in this paper. Feedback, adaptation, regulation, distributed information, resilience, nonlinear change, thresholds, networks, cascades, and uncertainty already have established theoretical histories. The Generative-Relational contribution lies in reorganizing these resources according to the structural object upon which governance acts and in distinguishing mechanisms that are frequently grouped together under broad labels such as adaptive, systems, or complexity governance.

Several distinctions become especially important for the later taxonomy. Feedback concerns the relation between observed consequences and subsequent intervention. Event-based governance concerns the condition under which an intervention is activated. Perturbative governance concerns a bounded change to an existing dynamical process. Tangent-space governance concerns locally available directions of evolution under limited global knowledge. Attractor-sensitive governance concerns the relation

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between trajectories and persistent dynamical regimes. Criticality governance concerns changing dynamical sensitivity near possible regime transitions. Relational governance concerns the coupling structures through which processes interact and propagate.

The systems literature also provides foundations for generative-background governance. Environmental conditions, slow variables, resource structures, information architectures, accumulated institutional paths, and cross-scale relations can shape a range of subsequent trajectories without specifying each trajectory individually. The later GR framework formalizes this family through generative conditions, structural flows, metrics, fields, symmetries, connections, and endogenous background formation.

The conceptual sequence developed across Sections 2, 3, 4, and 5 now provides three complementary foundations for the proposed taxonomy. Philosophical traditions identify different objects and conditions of governing. Modern governance theory classifies institutional arrangements, modes of coordination, and distributions of authority. Governance practice identifies concrete instruments and implementation mechanisms. Systems and complexity theory provides a language for the evolution and propagation of their effects.

The following section integrates these foundations into the formal Generative-Relational model. States, explicit rules, dynamical structures, relational couplings, and generative backgrounds are defined as analytically separable components of an evolving system. Governance is then represented through interventions whose structural support can occupy one or several of these components. This formalization establishes the taxonomic criterion used throughout the four layer-specific sections.

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Table 4: Systems, cybernetic, and complexity concepts in governance analysis

Conceptual tradition	**Primary analytical object**	**Governance relevance**	**Later GR development**
Political systems analysis	System–environment interaction	Inputs, outputs, persistence, environmental response	State evolution and system-level representation
Political communication and control	Information and communication	Learning, feedback, signal transmission, adjustment	Observation and feedback governance
Classical cybernetics	Regulation and feedback	State dependence, correction, disturbance response	Feedback and dynamical-process governance
Requisite variety	Regulatory repertoire	Capacity to respond to heterogeneous disturbances	Distributed and adaptive governance capacity
Organizational cybernetics	Viability and recursive organization	Autonomy, coordination, adaptation, organizational recursion	Cross-level dynamical and relational governance
Complex adaptive systems	Adaptive interacting components	Emergence, co-evolution, distributed adaptation	Generative and relational dynamics
Modularity and complex architecture	Subsystem organization	Localization, interfaces, coordination, propagation	Relational-structural governance
Resilience and robustness	Persistence under disturbance	Regime persistence, adaptive capacity, disturbance absorption	Evaluation of state, dynamics, and background conditions
Path dependence	Historical sequence	Increasing returns, institutional persistence, temporal asymmetry	Endogenous structural formation
Bifurcation and regime dynamics	Qualitative dynamical change	Stability, multiple regimes, parameter sensitivity	Attractor- and bifurcation-sensitive governance
Critical-transition research	Changing dynamical sensitivity	Transition risk, early-warning structures, response timing	Criticality governance
Complex network dynamics	Topology and propagation	Centrality, vulnerability, cascades, modularity	Relational and cascade governance
Partial observability	Information conditions	Measurement, delay, uncertainty, model limitation	Epistemic constraints on intervention depth
Cross-scale dynamics	Heterogeneous temporal and spatial scales	Slow variables, fast responses, inter-level propagation	Cross-layer and temporal governance composition

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6 Generative-Relational Foundations

This section establishes the formal architecture underlying the Generative-Relational taxonomy of governance. Its role is to integrate the philosophical, governance-theoretical, institutional, and systems-oriented foundations developed in the preceding sections into a common analytical language. The section defines relational constitution, generativity, system state, explicit rules, dynamical structures, relational couplings, generative backgrounds, governance operators, structural depth, and cross-layer propagation. The resulting framework supplies the notation and taxonomic criteria used throughout the four layer-specific sections.

6.1 Relational Constitution

This subsection establishes the relational ontology used throughout the formal framework. Its objective is to represent system components as historically situated elements whose effective properties can depend upon relations, institutional positions, and prior interaction. The formalization therefore permits both the states of system components and the relational structures among them to evolve.

A Generative-Relational system contains distinguishable components, while the effective properties of those components can depend upon the relational configuration in which they occur. A person, organization, jurisdiction, platform, regulatory body, or other institutional entity can possess capacities whose practical significance depends upon access, recognition, authority, resource relations, communication channels, dependencies, and positions within wider institutional structures.

The relational commitment can be represented through a component state $z_i(t)$ whose effective evolution depends upon both its local condition and its relational environment. A generic relational evolution law is represented by Equation 8.

$$\dot{z}_i = f_i\left(z_i, \{z_j\}_{j\in\mathcal{N}_i}, C_t, R_t, \mathcal{B}_t, t\right). \tag{8}$$

In Equation 8, $\mathcal{N}_i$ denotes the set of components relationally relevant to component i, C_t represents the relational structure, R_t represents explicit institutional rules, and $\mathcal{B}_t$ represents the generative background. The representation permits the effective dynamics of a component to change while its locally represented characteristics remain unchanged.

Relational constitution also permits relations themselves to evolve. Trust, dependency, authority, communication, contractual association, jurisdictional linkage, institutional recognition, and resource exchange can be generated, strengthened, weakened, redirected, or terminated through interaction. Consequently, C_t is treated as a dynamical component of the governed system.

This co-evolutionary assumption is important for governance analysis. An intervention directed toward one component can alter subsequent relations, while changes in relational architecture can transform the effective capacities of components. Governance therefore occurs within a relational system whose nodes and relations can participate jointly in processes of generation.

6.2 Generativity and Temporal Evolution

This subsection defines generativity as a property of temporally extended relational processes. Its objective is to distinguish generativity from a single observed output and from a scalar objective function. The formalization treats a present system configuration as capable of generating a family of subsequent configurations under admissible processes of evolution.

The term *generativity* refers to the capacity of a relational configuration to participate in the production of subsequent states, relations, structures, meanings, capacities, and possibilities. Generativity therefore concerns future-producing structure. Its analytical object extends beyond the immediate value of the state currently observed.

For a system configuration $\mathfrak{S}_t$ and a temporal horizon $\tau > 0$, the set of configurations reachable through admissible evolution is represented by Equation 9.

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$$\mathscr{G}_\tau\left(\mathfrak{S}_t\right) = \{\mathfrak{S}_{t+\tau} \mid \mathfrak{S}_{t+\tau} \text{ is generated through an admissible evolution from } \mathfrak{S}_t\}\,. \tag{9}$$

Equation 9 defines generativity in set-valued form. This representation preserves heterogeneity among possible future configurations and avoids imposing a single scalar ordering at the foundational level.

A domain-specific analysis may subsequently define observables or evaluative functionals over $\mathscr{G}_\tau(\mathfrak{S}_t)$. Such functionals can measure accessibility, diversity, persistence, participation, resource requirements, resilience, or other properties relevant to the governance problem. Their selection introduces additional descriptive or normative commitments and therefore occurs after the foundational definition of generativity.

Generativity also possesses temporal structure. A configuration that expands short-horizon possibilities can reduce longer-horizon generative capacity, and a configuration that temporarily constrains available action can preserve or create future possibilities. The temporal horizon associated with governance evaluation must therefore remain explicit.

This temporal orientation also permits generativity to be path-dependent. Future configurations can depend upon the sequence through which prior relations, rules, infrastructures, and institutional capacities were generated. The system representation developed below consequently allows its structural components to vary through time.

6.3 System Configuration and State Representation

This subsection defines the complete system configuration used in the Generative-Relational taxonomy. Its objective is to refine the preliminary representation introduced in the Discussion Paper Note by separating the state space from the currently realized state and by making temporal dependence explicit.

The formal system configuration is defined by Equation 10.

$$\mathfrak{S}_t = (X_t, x_t, R_t, F_t, C_t, \mathcal{B}_t)\,, \qquad x_t \in X_t. \tag{10}$$

In Equation 10, X_t denotes the space of admissible system configurations, x_t denotes the currently realized state, R_t denotes explicit rules and institutionally represented constraints, F_t denotes dynamical structure, C_t denotes relational and coupling structure, and $\mathcal{B}_t$ denotes the generative background.

The distinction between X_t and x_t is analytically important. Governance can alter the current state while leaving the wider possibility space approximately unchanged. Other interventions can change the set or geometry of configurations that are practically available. A licensing decision can change the legal state of one actor, for example, while a reform of institutional access can alter the range of configurations available to a larger class of actors.

The components of Equation 10 are analytical objects whose empirical representation depends upon the governance domain. A state can contain economic, institutional, informational, ecological, organizational, or symbolic variables. The state space can be finite, discrete, continuous, hybrid, network-valued, or manifold-valued according to the selected model.

When X_t possesses the required smooth structure, manifold and tangent-space language can be used in the standard mathematical sense [78]. Such a representation becomes important later for tangent-space governance, local vector fields, differential sensitivity, and background geometry.

6.4 Explicit Rules and Admissibility Structures

This subsection formalizes explicit rules as institutionally represented constraints on admissible action, transition, entitlement, or procedure. Its objective is to distinguish represented rule structures from the broader dynamics and conditions through which those rules acquire practical effects. The formalization permits rules to constrain both states and transitions.

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Let $\mathcal{A}$ denote a domain-dependent set of possible actions. A rule structure R_t can define the actions institutionally admissible at state x. One general representation of this admissibility relation is provided by Equation 11.

$$\mathcal{A}_{R_t}(x) = \{a \in \mathcal{A} \mid r_k(x, a, t) \leq 0, \quad k = 1, \ldots, m\}. \tag{11}$$

Equation 11 represents explicit rules through a family of constraint functions r_k. The representation can encode permissions, prohibitions, eligibility requirements, jurisdictional conditions, procedural prerequisites, or other institutionally represented constraints.

Rule structures can also define rights and institutional powers. A rule can authorize a decision maker, create an entitlement, allocate jurisdiction, specify a procedure, or determine the conditions under which another rule can be modified. The variable R_t therefore includes both conduct-directed and institution-directed rule structures.

The distinction between R_t and F_t is central to the taxonomy. A formally valid rule can possess different practical consequences under different enforcement capacities, incentive structures, relational configurations, and informational conditions. Rule content and effective dynamics therefore receive separate representations even when they interact strongly.

This separation permits state-and-rule governance to be analyzed without assuming that alteration of an explicit rule uniquely determines the system's subsequent trajectory. The transformation of R_t becomes one structural intervention whose effects propagate through the remaining components of $\mathfrak{S}_t$.

6.5 Dynamical Structure

This subsection defines the dynamical component of the Generative-Relational system. Its objective is to represent the processes through which system states evolve while preserving the influence of rules, relational structures, and generative backgrounds. The formulation provides the mathematical basis for feedback, event-based, perturbative, tangent-space, attractor-sensitive, criticality, and bifurcation-sensitive governance.

For a continuous-time representation on a smooth state space, the effective state evolution is represented by Equation 12.

$$\dot{x}_t = F_t\left(x_t; R_t, C_t, \mathcal{B}_t\right) + \eta_t. \tag{12}$$

In Equation 12, F_t denotes the effective vector field generated under the current rule, relational, and background structures, while η_t represents unresolved disturbance, stochasticity, exogenous forcing, or model discrepancy.

Standard dynamical-systems concepts including trajectories, invariant sets, stability, attractors, basins, and bifurcations can be introduced when the chosen model satisfies the relevant mathematical assumptions [76]. These concepts will be used selectively in the dynamical-process layer.

The dependence of F_t upon R_t, C_t, and $\mathcal{B}_t$ is deliberate. The same state can evolve differently under different legal constraints, network couplings, resource conditions, institutional environments, or informational structures. Dynamical behavior is therefore treated as relationally and institutionally embedded.

The disturbance term η_t also carries an epistemic function. Observed deviations from a model can arise from environmental disturbance, stochasticity, omitted variables, incorrect structural assumptions, or changing model parameters. Governance under uncertainty must therefore avoid interpreting every deviation as a known deterministic mechanism.

Discrete-time, stochastic, hybrid, agent-based, and event-driven models can be used where they better represent the empirical system. Equation 12 provides a common continuous-time reference model rather than a universal empirical specification.

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6.6 Relational and Coupling Structures

This subsection formalizes the relational architecture through which system components interact. Its objective is to separate relational topology and coupling from the local states of components and from the dynamical rules governing their evolution. Network, multilayer, hypergraph, institutional, and other relational representations can be incorporated according to the domain.

A general relational structure is represented by Equation 13.

$$C_t = (V_t, E_t, W_t, \Gamma_t)\,. \tag{13}$$

In Equation 13, V_t denotes the relevant system components, E_t denotes relations among them, W_t denotes weights or intensities associated with those relations, and Γ_t denotes rules or operators specifying how effects are transmitted through the relational structure.

Graph and network representations provide standard mathematical tools for encoding nodes, edges, weights, paths, connectivity, multilayer structures, and dynamic networks [89]. Governance systems may require directed, weighted, signed, bipartite, temporal, multiplex, or hypergraph extensions according to the type of relation being represented.

The relational variable C_t can encode authority, communication, dependency, resource transfer, contractual relations, institutional membership, jurisdictional overlap, recognition, influence, or other forms of coupling. Several relational structures can coexist within the same governed system.

The inclusion of Γ_t is important because connectivity alone does not determine propagation. Two actors can possess a formally identical relation while the mechanism governing information, resources, liability, authority, or behavioral influence differs. Relational topology and coupling law are therefore represented jointly.

Relational structures can also evolve endogenously. Collaboration can create new links, conflict can sever them, law can create institutional dependencies, market processes can concentrate network positions, and repeated interaction can modify coupling strength. Relational-structural governance consequently includes intervention into both topology and coupling mechanisms.

6.7 Generative Backgrounds

This subsection defines the deepest structural family in the proposed taxonomy. Its objective is to characterize background structures that shape the effective accessibility, cost, stability, propagation, and possibility of classes of future trajectories without specifying each trajectory individually. The definition remains intentionally general so that metric, field, symmetry, connection, structural-flow, resource, informational, and institutional representations can be developed later as distinct subtypes.

The generative background $\mathcal{B}_t$ denotes the structured conditions within which state evolution, rule operation, and relational interaction acquire their effective properties. A general decomposition of the background is represented by Equation 14.

$$\mathcal{B}_t = (\mathcal{Q}_t, \mathcal{I}_t, \mathcal{M}_t, \mathcal{G}_t, \mathcal{F}_t, \mathcal{K}_t, \ldots)\,. \tag{14}$$

In Equation 14, $\mathcal{Q}_t$ can represent resource and capacity conditions, $\mathcal{I}_t$ informational conditions, $\mathcal{M}_t$ metric or accessibility structures, $\mathcal{G}_t$ symmetry structures, $\mathcal{F}_t$ field-like background structures, and $\mathcal{K}_t$ connection or transport structures. The components serve as a family of possible representations and need not all be present in a single empirical model.

The background differs analytically from an immediate state because its governance relevance concerns a range of possible subsequent processes. Access to education, judicial remedies, finance, communication infrastructure, translation, technical standards, or institutional recognition can alter future possibilities for many actors across extended temporal horizons.

The background also differs from explicit rules. Two actors subject to the same formal entitlement can possess different effective access when resource, informational, geographic, linguistic, or institu-

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tional conditions differ. The rule structure and the generative background can therefore produce distinct forms of inequality.

The background concept also permits formal development through geometry. Riemannian metrics, for example, provide a mathematical representation of length, distance, and geodesic structure on an appropriate smooth manifold [79]. A governance model can use an effective metric when institutionally meaningful notions of distance, accessibility, or path cost can be defined. The later background-governance section develops the conditions required for such a correspondence.

Generative-background governance therefore concerns changes in the structures through which classes of future processes become easier, harder, more stable, more fragile, more connected, or more accessible. The category remains descriptive at this stage. Normative evaluation depends upon which capacities are affected, for whom, over which temporal horizon, and through which relations.

6.8 Endogenous Background Formation

This subsection extends the background concept by allowing the effective background to emerge from earlier relations, states, rules, and flows. Its objective is to represent recursive historical formation within the same formal architecture. The resulting model permits governance to act upon a background while also participating in the processes through which future backgrounds are generated.

An endogenous background is generated through a background-formation operator. This recursive process is represented by Equation 15.

$$\mathcal{B}_{t+\Delta t} = \mathcal{E}_{\Delta t}\left(\mathcal{B}_t, x_{\leq t}, R_{\leq t}, F_{\leq t}, C_{\leq t}\right). \tag{15}$$

In Equation 15, $\mathcal{E}_{\Delta t}$ denotes a background-emergence operator and the subscript $\leq t$ indicates that historically accumulated trajectories can contribute to the effective background at a later time.

This representation accommodates several familiar institutional processes. Repeated investment can create infrastructure. Repeated exclusion can produce persistent inequalities of access. Recurrent organizational interaction can generate trust or dependency. Long-standing legal practice can create institutional expectations and interpretive conventions. Accumulated technical standards can produce interoperability structures that shape later innovation.

The recursive formulation also makes structural effects path-dependent. Similar present states can possess different future possibilities because they were generated through different histories whose residues remain encoded in institutions, relations, resources, knowledge, or infrastructure.

Governance therefore participates in background formation even when an intervention is initially directed toward another layer. A rule can alter relations; repeated relational effects can generate institutional infrastructure; that infrastructure can later reshape the dynamics of actors who were absent when the original rule was adopted.

Endogenous background formation provides the formal connection between GR historicity and the later concept of background-emergence governance. The governance object can be an existing background structure or the process $\mathcal{E}_{\Delta t}$ through which that structure is continually generated.

6.9 Governance Operators and Structural Support

This subsection defines governance intervention as an operator acting upon the formal system configuration. Its objective is to establish the principal classification criterion of the paper: the structural support of an intervention. The formalism allows one intervention to act upon one or several components of the system.

A governance intervention at time t is represented by Equation 16.

$$\mathcal{U}_t : \mathfrak{S}_t \longrightarrow \mathfrak{S}_t^{+}, \tag{16}$$

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where $\mathfrak{S}_t^+$ denotes the configuration immediately following the intervention represented by $\mathcal{U}_t$. Equation 16 separates the intervention event from the subsequent endogenous evolution of the governed system.

The structural support of a governance intervention identifies the components directly transformed by the intervention. This support is defined by Equation 17.

$$\text{supp}_{\text{GR}}\left(\mathcal{U}_t\right) = \{Z \in \{x, R, F, C, \mathcal{B}\} \mid \mathcal{U}_t \text{ directly transforms } Z\}. \tag{17}$$

Equation 17 provides the foundational classification rule. An intervention with support on x or R belongs to the state-and-rule family. Support on F identifies dynamical-process intervention. Support on C identifies relational-structural intervention. Support on $\mathcal{B}$ identifies generative-background intervention.

The state space X_t requires contextual classification. A change in X_t produced through an explicit legal prohibition can arise from state-and-rule governance, while a change in effective accessibility produced through metric, infrastructural, or capacity structures can arise from generative-background governance. The classification therefore follows the mechanism producing the change rather than the mathematical symbol alone.

The structural-support criterion also distinguishes direct intervention from propagated effect. A rule reform may directly transform R_t, after which the resulting system evolution changes F_t, C_t, and $\mathcal{B}_t$. Those propagated changes remain analytically distinct from the initial structural support of the governance intervention.

This distinction prevents every consequential intervention from being classified simultaneously at every layer. Multilayer classification is reserved for interventions whose institutional mechanism directly operates upon several structural objects.

6.10 Layer-Specific Intervention Families

This subsection maps the structural-support criterion onto the four principal families of governance. Its objective is to establish the formal taxonomic architecture used throughout the remainder of the paper. The four layers are defined analytically and can occur independently or in combination.

The layer assignment associated with an intervention is represented by Equation 18.

$$\Lambda\left(\mathcal{U}_t\right) \subseteq \{\mathsf{SR}, \mathsf{D}, \mathsf{REL}, \mathsf{B}\}. \tag{18}$$

In Equation 18, SR denotes state-and-rule governance, D denotes dynamical-process governance, REL denotes relational-structural governance, and B denotes generative-background governance.

State-and-rule governance acts directly upon represented states, explicit constraints, permissions, duties, institutional competences, entitlements, or other codified structures. Dynamical-process governance acts upon the law, direction, triggering condition, sensitivity, or regime of system evolution. Relational-structural governance acts upon topology, coupling, interfaces, dependencies, modular structures, or relations among decision centers. Generative-background governance acts upon the conditions through which ranges of states, relations, and trajectories acquire their effective accessibility and stability.

An intervention can receive a multilayer assignment when its operative mechanism directly transforms several of these structures. A regulatory programme can, for example, combine a legal prohibition, continuous feedback, network restructuring, and subsidized access infrastructure.

The assignment in Equation 18 therefore produces a set-valued classification. The taxonomy permits hybrid mechanisms while retaining the capacity to identify the structural components from which the hybrid is formed.

6.11 Structural Depth

This subsection defines structural depth as an analytical property of the location through which governance enters generative processes. Its objective is to provide an ordered vocabulary for comparing

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interventions while separating depth from normative desirability, coerciveness, institutional scale, and practical effectiveness.

The four principal layers are assigned an ordinal structural-depth index by Equation 19.

$$d(\mathsf{SR}) = 1, \qquad d(\mathsf{D}) = 2, \qquad d(\mathsf{REL}) = 3, \qquad d(\mathsf{B}) = 4. \tag{19}$$

Equation 19 represents analytical depth within the proposed generative architecture. The index expresses the distance between an intervention object and the directly represented state of the system.

A deeper intervention can influence a broader family of future trajectories because it modifies structures through which many subsequent processes are generated. This possibility creates wider propagation potential and can also increase uncertainty, delay, implementation difficulty, and exposure to unintended effects.

The ordinal index carries no normative ranking. A state-level emergency intervention can possess greater legitimacy and effectiveness than a background intervention. A rule can provide clarity, accountability, and reversibility that a diffuse structural intervention cannot provide. The selection of intervention depth therefore remains a governance judgment dependent upon the problem, available knowledge, urgency, institutional capacity, and normative constraints.

Structural depth also differs from institutional scale. A municipal government can alter a deep background structure within a local domain, while an international organization can issue a comparatively shallow explicit rule across a large jurisdictional scope. Depth and scale should therefore be represented as separate analytical coordinates.

6.12 Cross-Layer Propagation

This subsection formalizes the propagation of changes from one structural component into others. Its objective is to distinguish the immediate support of a governance intervention from its subsequent system-wide consequences. The analysis introduces a sensitivity representation that can later support comparisons of amplification, attenuation, delay, and cross-layer coupling.

Let Z_i and Z_j denote two components selected from x, R, F, C, and $\mathcal{B}$. A local measure of cross-component propagation over horizon τ is represented by Equation 20.

$$K_{ji}(\tau) = \frac{\partial Z_j(t+\tau)}{\partial Z_i(t^+)}. \tag{20}$$

Equation 20 represents a local sensitivity when the relevant objects admit differentiable parametrization. Discrete, set-valued, probabilistic, or simulation-based analogues can be used where a derivative is inappropriate.

The quantity $K_{ji}(\tau)$ separates intervention location from effect location. A governance action supported only on R can generate substantial later changes in C or $\mathcal{B}$. Such propagation does not transform the original intervention into direct relational or background governance.

Propagation can also be reciprocal. A background change can alter dynamics, those dynamics can reorganize relations, and the new relational structure can contribute to later background formation. Cross-layer governance therefore contains feedback among structural components.

The temporal parameter τ is important because propagation can occur at different rates. A rule change may affect administrative decisions rapidly and institutional trust slowly. A network reconfiguration may alter information flow immediately while producing organizational concentration only after repeated interaction.

Cross-layer analysis consequently requires both a structural and a temporal description of governance effects.

6.13 Recursive Generative Dynamics

This subsection integrates state evolution, relational evolution, and background formation into a recursive Generative-Relational system. Its objective is to represent governance within a system whose own

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generative architecture changes through time. The formulation provides the common basis for later discussions of historical materiality, institutional reproduction, and background emergence.

A recursive system update is represented by Equation 21.

$$\mathfrak{S}_{t+\Delta t} = \mathcal{T}_{\Delta t}\left(\mathfrak{S}_t^{+}, \eta_{[t,t+\Delta t]}\right), \qquad \mathfrak{S}_t^{+} = \mathcal{U}_t\left(\mathfrak{S}_t\right). \tag{21}$$

Equation 21 separates governance intervention $\mathcal{U}_t$ from subsequent system evolution $\mathcal{T}_{\Delta t}$. The distinction makes it possible to analyze an intervention according to its immediate structural support while examining longer-term consequences through the system evolution operator.

Repeated governance produces a historical sequence of intervention and evolution. Institutions can therefore become partly constituted by residues of earlier governance actions. Rules alter practices, practices alter relations, relations produce institutional expectations, and those expectations shape the environment in which later rules operate.

Recursive generation also permits governed actors to participate in the production of future governance structures. Citizens, organizations, communities, firms, professional groups, administrative agencies, and international actors can modify relations and institutional conditions through their own responses to governance.

This formulation places governance within the system's history. A governance operator is an intervention into ongoing generation whose consequences can become part of the background confronting later interventions.

6.14 Observability and Governance Information

This subsection introduces the informational representation available to governance. Its objective is to separate the underlying system configuration from the observations through which governing actors construct actionable knowledge. This distinction later becomes central to tangent-space, criticality, event-based, and background governance.

A governing actor typically observes a transformed and incomplete representation of the underlying system. The observational relation is represented by Equation 22.

$$y_t = \mathcal{O}_t\left(\mathfrak{S}_t\right) + \varepsilon_t. \tag{22}$$

In Equation 22, y_t denotes available observations, $\mathcal{O}_t$ denotes the observation or measurement process, and ε_t represents measurement error, reporting error, aggregation loss, or other observational disturbance.

Governance therefore acts through an epistemic interface. Administrative records, indicators, surveys, inspections, sensor systems, legal classifications, expert assessments, network measures, and public reports construct partial representations of the governed system.

Different governance mechanisms require different informational structures. Event-based governance requires an observable trigger. Tangent-space governance requires sufficiently reliable local directional information. Criticality governance requires evidence concerning changing sensitivity or transition risk. Relational-structural governance requires information about connections or dependencies. Background governance can require observation of slowly evolving structures whose effects are distributed across time.

The observation map also creates potential governance distortions. A measurement system can render some relations visible while excluding others. An administrative classification can change the practical treatment of the persons or organizations classified. Governance therefore depends upon both the governed system and the epistemic structures through which that system becomes actionable.

6.15 Taxonomic Criteria and Category Boundaries

This subsection consolidates the formal architecture into operational criteria for classifying governance mechanisms. Its objective is to specify the dimensions that should accompany structural-layer assign-

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Table 5: Analytical dimensions of the Generative-Relational governance taxonomy

Analytical dimension	**Formal or conceptual object**	**Taxonomic function**
Structural support	$\mathrm{supp}_{\mathrm{GR}}(\mathcal{U})$	Identifies the component directly transformed by governance
Structural depth	$d(\Lambda(\mathcal{U}))$	Locates intervention within the generative architecture
Activation structure	Time-, state-, event-, threshold-, or condition-dependent activation	Distinguishes intervention triggering mechanisms
Temporal horizon	Intervention duration and evaluation horizon τ	Separates immediate, medium-term, and background effects
Observation structure	$\mathcal{O}_t$ and available y_t	Specifies informational requirements and epistemic limits
Relational scope	Affected nodes, edges, couplings, modules, or jurisdictions	Identifies the relational extent of intervention
Propagation structure	$K_{ji}(\tau)$ or domain-specific analogue	Distinguishes direct support from propagated effects
Reversibility	Availability and cost of returning toward a prior configuration	Characterizes intervention persistence and correction capacity
Uncertainty	Disturbance, model error, parameter uncertainty, structural uncertainty	Characterizes confidence in predicted intervention effects
Institutional scale	Local, organizational, national, transnational, global, or cross-scale	Separates jurisdictional reach from structural depth
Background endogeneity	Dependence of $\mathcal{B}_{t+\Delta t}$ on prior system history	Identifies recursive background generation
Normative evaluation	Domain-specific procedural and generative criteria	Evaluates governance separately from structural classification

ment and to establish category boundaries before the four layer-specific taxonomies are developed. The criteria concern intervention object, activation, temporal structure, information, reversibility, propagation, scale, and background endogeneity.

Table 5 summarizes the principal dimensions used throughout the remainder of the paper.

Table 5 establishes structural support as the primary classificatory dimension and treats the remaining dimensions as properties required for a fuller characterization of a governance mechanism. Two interventions can occupy the same structural layer while differing in activation logic, temporal horizon, observability, reversibility, propagation, or institutional scale.

Category boundaries are therefore defined by the direct object and mechanism of intervention. Feedback governance and event-based governance both belong to the dynamical-process layer while possessing different activation structures. Network-topology governance and polycentric reconfiguration both belong primarily to the relational-structural layer while operating upon different forms of relational architecture. Metric governance and field governance belong to the generative-background layer while representing different background structures.

Established governance theories can occupy several locations within this formal space. Adaptive governance may combine rule revision, feedback, relational reorganization, and background transformation. Metagovernance can coordinate interventions across several layers. Algorithmic governance can combine explicit rules, continuous observation, automated dynamical response, network restructuring, and architectural conditioning.

The taxonomy therefore classifies mechanisms within governance arrangements and permits institutional theories to retain their established meanings. This distinction supplies the bridge between the governance scholarship reviewed earlier and the formal layer-specific analysis that follows.

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Table 6: Formal architecture of the four Generative-Relational governance layers

Governance layer	Direct object	Representative mechanisms	Characteristic propagation
State-and-rule governance	x_t, R_t	State correction, permission, prohibition, entitlement, sanction, rule revision, adjudicative determination	Immediate configuration and explicit institutional constraint
Dynamical-process governance	F_t	Feedback, event-based intervention, perturbative governance, tangent-space governance, attractor-sensitive governance, criticality and bifurcation governance	Trajectory, stability, transition, and temporal response
Relational-structural governance	C_t	Network reconfiguration, coupling governance, boundary governance, modularity, interface governance, distributed and polycentric restructuring	Interaction, dependency, transmission, and cascade structure
Generative-background governance	$\mathcal{B}_t$, $\mathcal{E}$	Generative conditions, structural flows, metric governance, field governance, symmetry governance, gauge-like connections, background-emergence governance	Accessibility, possibility structure, long-horizon generation, and endogenous structural formation

6.16 Formal Architecture of the Four-Layer Taxonomy

This subsection synthesizes the preceding definitions into the complete Generative-Relational architecture. Its objective is to provide a compact reference structure for Sections 7 through the later generative-background section and to specify the analytical relation among the four governance layers.

Table 6 summarizes the structural objects, representative mechanisms, and characteristic propagation paths associated with the four principal layers.

Table 6 provides the organizing structure for the remainder of the taxonomy. The four layers describe distinct structural locations of intervention and remain compatible with hybrid governance arrangements.

The architecture also clarifies the relation among structural depth and recursive generation. Background structures influence relational and dynamical processes, while repeated states, relations, and governance interventions can contribute to the formation of later backgrounds. The dependency structure therefore contains downward conditioning and upward emergence within the same historical system.

The Generative-Relational taxonomy consequently treats governance as a family of interventions embedded within an evolving, relationally constituted, and partially observable system. The principal taxonomic problem concerns the structural object through which an intervention enters this system. The subsequent analytical problem concerns the way that intervention propagates across structures and through time.

The following section begins the layer-specific analysis with state-and-rule governance. It examines direct state modification, command, permission, prohibition, sanctions, entitlements, constraint governance, formal rule revision, adjudicative intervention, and related mechanisms. Each governance subtype is developed through its theoretical lineage, formal representation, practical manifestations, information requirements, cross-layer effects, and analytical limits.

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7 State-and-Rule Governance

This section develops the first structural layer of the Generative-Relational governance taxonomy. Its role is to classify interventions whose direct objects are represented system states or explicit institutional rules. The analysis distinguishes direct state modification, commands and prohibitions, permissions and authorizations, entitlements and eligibility structures, sanctions, constraint-based governance, secondary rule governance, adjudicative determination, and rule-form design. Each subsection specifies the relevant governance object, develops a formal representation, relates the mechanism to established legal and regulatory theory, and identifies the principal pathways through which state-and-rule interventions propagate into deeper dynamical, relational, and background structures.

State-and-rule governance occupies the first structural layer because its immediate object is comparatively explicit within the selected system representation. A state can be directly assigned, restored, transferred, or otherwise altered. A rule can specify an admissible action, establish an institutional competence, create an entitlement, define a sanction, or govern the production of subsequent rules. The resulting intervention can have long-ranging and system-wide consequences while retaining x_t or R_t as its direct structural support.

The legal and regulatory traditions reviewed earlier provide established conceptual foundations for this layer. Hart's distinction between primary and secondary rules gives particular importance to rules governing conduct and rules governing recognition, change, and adjudication [56]. Black's analysis of regulatory rules emphasizes the formulation, interpretation, and practical use of rules within regulatory systems [19]. Baldwin, Cave, and Lodge situate rules within a wider repertoire of regulatory strategies and enforcement arrangements [14]. These traditions supply institutional and jurisprudential concepts that the present section reorganizes according to the direct structural object of intervention.

7.1 Direct State Modification

This subsection defines governance interventions whose direct object is the currently realized state x_t. Its objective is to distinguish direct state change from rule modification and from interventions that alter the process through which a later state emerges. The analysis covers assignment, transfer, restoration, removal, direct provision, and other interventions whose institutional operation immediately changes a represented component of the governed configuration.

A direct state intervention transforms the current system state while the governing operation is being executed. The generic transformation is represented by Equation 23.

$$x_t^+ = \mathcal{U}_t^x \left(x_t \right). \tag{23}$$

Equation 23 defines the immediate post-intervention state x_t^+ as the result of a state-directed governance operator $\mathcal{U}_t^x$. Other components of the system can subsequently change through propagation after this direct transformation.

Direct state modification appears in many institutional settings. A court can transfer legal title, annul an administrative decision, or order restoration of a legal position. An administrative body can issue a license, allocate a benefit, register an organization, assign a legal classification, or remove an existing administrative status. A public authority can directly provide a resource, close a facility, seize an asset under lawful authority, establish an emergency zone, or restore access to a public service.

The defining feature concerns the immediate governance object. A benefit payment directly changes a resource state. A decision establishing citizenship status directly changes an institutionally represented status. A judicial order restoring possession directly changes an authorized legal configuration. The later behavioral consequences of those changes belong to subsequent system evolution.

A useful distinction can also be made between state assignment and state restoration. State assignment establishes a configuration authorized by the governing institution. State restoration seeks to return a represented component toward a previously recognized or legally required configuration. The distinction can matter normatively while both mechanisms remain within the same structural layer.

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Direct state intervention can possess high immediacy and comparatively clear institutional traceability. The initiating act, authorized decision maker, affected state variable, and time of intervention can often be identified explicitly. These features can support accountability and reversibility where the relevant institutional system permits review.

The apparent shallowness of the intervention therefore carries no implication of weak effect. A state modification can initiate substantial downstream changes in incentives, relations, expectations, and future institutional conditions. The structural classification records the location of direct action, while cross-layer analysis records those subsequent effects.

7.2 Commands, Prohibitions, and Mandatory Rules

This subsection examines explicit rules that prescribe, require, or exclude classes of action. Its objective is to formalize command-oriented governance through changes in the institutionally admissible action set and to distinguish formal constraint from the later processes of compliance and enforcement.

Let $\mathcal{A}$ denote the underlying action domain and let $\mathcal{A}_{R_t}(x)$ denote the actions admissible under the current rule structure. A rule intervention that changes the admissible action set is represented by Equation 24.

$$\mathcal{A}_{R_t}(x) \longrightarrow \mathcal{A}_{R_t^+}(x). \tag{24}$$

Equation 24 represents a transformation of formal admissibility produced through a change in R_t. A prohibition can remove a class of actions from the institutionally authorized set, while a mandatory rule can identify actions required under specified conditions.

Regulatory scholarship commonly associates command-oriented regulation with the establishment of standards backed by institutional mechanisms of monitoring and enforcement [14]. The formal standard and the enforcement process remain analytically distinguishable in the present taxonomy. The rule belongs directly to R_t, while observation, detection, escalation, and behavioral response can involve the dynamical layer.

A prohibition can be represented through a predicate that excludes actions satisfying specified conditions. A command can similarly establish an obligatory subset of actions for a defined state or institutional role. The relevant rule can depend upon context, legal status, jurisdiction, time, or other represented variables.

Command governance has several institutional advantages. Explicit rules can provide public notice, define responsibility, support adjudication, and create a common reference for institutional action. Their effectiveness also depends upon interpretation, observability, implementation capacity, and the relational environment in which the governed actor operates.

Black's analysis of regulatory rules is relevant here because the practical operation of a rule depends upon its formulation and interpretive structure [19]. Rules can vary in specificity, generality, linguistic form, reliance upon standards, and the discretion left to implementing institutions.

The GR taxonomy consequently treats command and prohibition as formal transformations of admissibility. Their consequences for actual trajectories are analysed through the relation between rule structure and effective dynamics developed in later sections.

7.3 Permissions, Authorizations, and Institutional Competence

This subsection examines governance through explicit creation of authorized possibilities. Its objective is to distinguish permission from command and to include rules that constitute institutional powers as well as rules that regulate conduct. The discussion covers licenses, permissions, delegated competences, jurisdictional authority, and constitutive authorization.

A permission expands or clarifies the set of institutionally authorized actions. The resulting transformation of admissibility can be represented by Equation 25.

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$$\mathcal{A}_{R_t}(x) \subseteq \mathcal{A}_{R_t^+}(x). \tag{25}$$

Equation 25 represents the formal structure of an authorization that enlarges the set of recognized actions under the specified state. The inclusion relation concerns formal admissibility and carries no claim that every newly authorized action becomes practically accessible.

This distinction is important for Generative-Relational analysis. Legal permission can exist while material resources, information, geography, language, organizational capacity, or institutional access prevent effective exercise. Formal possibility and effective possibility therefore belong to different structural components.

Institutional competence represents a related rule form. Constitutions, statutes, treaties, organizational charters, administrative rules, and delegation instruments can identify who possesses authority to perform a legally consequential act. Such rules create institutional powers whose exercise can alter other states and rules.

Hart's treatment of secondary rules is important to this domain because legal systems include rules that identify valid legal acts and the institutional conditions for producing them [56]. Governance through authorization consequently participates in the constitution of governing capacity itself.

A licensing regime illustrates the multilayer implications. The license rule defines the conditions under which an activity receives formal authorization. The application procedure introduces temporal and informational processes. Relations among applicant, regulator, experts, and reviewing bodies create a relational structure. Fees, documentation requirements, language, and access to administrative support can affect the effective background of participation.

The initial classification follows the directly modified rule. Additional layers enter when the governance mechanism directly redesigns those procedures, relations, or conditions.

7.4 Entitlements, Eligibility, and Institutional Status

This subsection examines rules that establish claims, benefits, statuses, and conditions of eligibility. Its objective is to distinguish the formal constitution of an entitlement from the practical capacity to exercise it. The analysis connects rule-based governance with administrative classification and resource allocation.

An entitlement can be represented as a rule-dependent relation among a subject, a qualifying condition, and an institutionally recognized claim. The eligibility relation is represented by Equation 26.

$$E_{R_t}(i, b, x) = \begin{cases} 1, & \text{if actor } i \text{ possesses an institutional claim to } b \text{ under } R_t \text{ at } x, \\ 0, & \text{otherwise.} \end{cases} \tag{26}$$

Equation 26 provides a binary representation for clarity. Domain-specific models can use graded, conditional, probabilistic, or set-valued entitlement structures.

Entitlement governance includes welfare eligibility, voting rights, professional status, access rights, legal personhood, residency categories, educational qualifications, licenses, and other institutional classifications. A change in the relevant rule can alter the formal position of an individual or organization even before any material resource is transferred.

Administrative systems frequently translate general entitlement rules into large numbers of case-specific determinations. Mashaw's study of Social Security disability claims demonstrates the organizational and procedural complexity involved in producing administratively consistent and legitimate benefit decisions [86].

The distinction between entitlement and effective access is particularly important for GR. Two actors with an identical formal entitlement can possess different capacities to realize its value. Application complexity, information, geographic access, language, processing delay, legal assistance, and institutional trust can alter effective access without changing the entitlement rule itself.

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This distinction will later permit a separation between entitlement governance at the state-and-rule layer and access-oriented governance at the generative-background layer. The same policy field can contain both.

7.5 Sanctions and Formal Consequence Structures

This subsection examines sanctions as explicit rule structures connecting specified violations or conditions with institutionally authorized consequences. Its objective is to distinguish the formal sanction map from enforcement dynamics, deterrence, behavioral adaptation, and responsive escalation. The analysis therefore locates sanction specification within the state-and-rule layer while preserving its cross-layer effects.

A formal sanction structure associates a represented violation condition with an institutionally specified consequence. The sanction map is represented by Equation 27.

$$\Sigma_{R_t} : \mathcal{V}_{R_t} \longrightarrow \mathcal{C}_{R_t}, \tag{27}$$

where $\mathcal{V}_{R_t}$ denotes the set of institutionally defined violation classes and $\mathcal{C}_{R_t}$ denotes the set of authorized consequences. Equation 27 represents the formal relation between violation and consequence.

Sanctions can include fines, suspension, exclusion, loss of authorization, remedial obligations, administrative penalties, professional discipline, contractual consequences, or criminal penalties. Their legal form specifies which institution can impose a consequence, under which conditions, and through which procedure.

The behavioral effect of a sanction depends upon additional structures. Detection probability, expected enforcement, actor preferences, social norms, resource constraints, reputational effects, and opportunities for avoidance can influence the resulting trajectory. Formal sanction severity therefore does not uniquely determine behavioral response.

Responsive regulation makes this distinction especially clear. Ayres and Braithwaite develop an approach in which regulatory responses can escalate in relation to the conduct of regulated actors [12]. The existence and specification of the available sanctions belong to the rule structure. The conditional sequence through which a regulator selects among them belongs primarily to dynamical-process governance.

The GR taxonomy therefore separates a *sanction repertoire* from a *sanction activation process*. This distinction prevents a formal penalty schedule from being conflated with the temporal governance mechanism that decides when and how the penalty is applied.

7.6 Constraint-Based Governance

This subsection develops a general formal representation of governance through explicit constraints. Its objective is to integrate prohibitions, requirements, eligibility conditions, procedural prerequisites, resource limits, and institutional boundaries within a common rule-based structure. The formulation also prepares the comparison with later background constraints that arise through effective rather than formally codified conditions.

Let the represented feasible region under rule structure R_t be denoted by $\mathcal{X}_{R_t}$. A general constraint-based governance structure is represented by Equation 28.

$$\mathcal{X}_{R_t} = \{x \in X_t \mid c_k(x, R_t) \leq 0, \quad k = 1, \ldots, m\}. \tag{28}$$

Equation 28 represents the formally admissible region generated by a family of institutional constraints c_k. Equality, logical, discrete, and set-valued constraints can be incorporated in domain-specific models.

Constraint governance appears throughout law and administration. Building codes establish admissible design regions. Financial regulation establishes capital or exposure constraints. Environmental rules

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define emission limits. Procedural law establishes timing, standing, evidence, and filing conditions. Procurement rules define eligibility and evaluation requirements.

Constraint formulation can support predictability by defining explicit boundaries. It can also transfer substantial interpretive responsibility to the institutions that measure compliance and determine whether a case falls within the relevant region.

The distinction between formal and effective feasibility is again central. A formally admissible state can remain practically unreachable because of resource, information, relational, or infrastructural conditions. Conversely, an institutionally prohibited action can remain physically or technically possible. State-and-rule governance concerns the formal feasible region, while later layers analyze the dynamics and background conditions associated with actual reachability.

7.7 Secondary Rules and Rule-System Governance

This subsection examines governance directed toward the production, recognition, revision, and application of other rules. Its objective is to formalize recursive rule systems and to distinguish rule-system governance from ordinary conduct regulation. The discussion draws on Hart's secondary rules and extends the concept into the GR representation of rule evolution.

Hart's account of primary and secondary rules provides a foundational jurisprudential distinction [56]. Secondary rules concern the identification, alteration, and adjudication of primary rules and thereby provide institutional mechanisms through which a legal system can organize its own normative operations.

The GR representation treats rule-system governance as an intervention on the operator through which rule structures are generated or modified. A generic rule-update structure is represented by Equation 29.

$$R_{t+1} = \mathcal{J}_t\left(R_t, p_t, a_t\right), \tag{29}$$

where p_t represents the institutionally authorized procedure and a_t represents the legally competent act producing the update. Equation 29 represents the rule-generating operation itself as an institutionally structured process.

Constitutional amendment procedures, legislative competences, delegated rule-making, treaty amendment procedures, judicial precedent systems, and organizational bylaw revision all contain forms of rule-system governance. The relevant governance object concerns the conditions under which another rule acquires, changes, or loses institutional validity.

Rule-system governance can therefore create generativity within the rule layer. A constitution or statute can establish procedures capable of producing a large family of future rules. The immediate structural object remains R_t, while the intervention changes the generative capacity of the legal or institutional rule system.

This observation also reveals that structural depth and recursion are different properties. A rule governing future rule production is recursive while remaining located within the explicit-rule layer. Recursion alone does not place an intervention within the generative-background layer.

7.8 Adjudicative Determination

This subsection examines adjudication as governance through authoritative determination of institutional states and interpretation of applicable rules. Its objective is to separate case disposition, rule interpretation, and precedential rule development while locating their direct structural objects.

Shapiro's comparative analysis treats courts as institutions possessing distinct decision-making structures and political functions across legal systems [117]. Adjudication can resolve disputes, determine status, allocate remedies, review institutional action, and contribute to the interpretation and development of legal rules.

A case-level adjudicative operation can be represented as a mapping from the present case record and applicable rules to an authoritative institutional determination. This operation is represented by Equation 30.

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$$d_i = \mathcal{D}\left(e_i, R_t, P_t\right), \tag{30}$$

where e_i denotes the legally relevant record associated with case i, P_t denotes applicable adjudicative procedures, and d_i denotes the authoritative determination. Equation 30 represents the formal decision function without presuming that real adjudication is mechanically deterministic.

A judgment can directly alter x_t by determining legal status, liability, custody, entitlement, or remedy. Interpretive holdings can also alter the effective content of R_t, especially in institutional systems where precedent possesses rule-generating significance.

Administrative adjudication contains analogous structures. Mashaw's study of disability claims emphasizes the relation among bureaucratic organization, accuracy, procedural values, and mass administrative decision making [86]. The practical operation of adjudicative governance therefore depends upon organizational and informational conditions in addition to formal decisional rules.

The GR taxonomy records these distinctions through direct support. A case-specific order can be state-directed. A precedential interpretation can be rule-directed. A reform of adjudicative procedure can alter rule structure and, where it directly redesigns information flow or interaction, can receive a multilayer classification.

7.9 Rule Form, Precision, and Interpretive Discretion

This subsection examines the internal form of explicit rules. Its objective is to distinguish changes in rule content from changes in precision, generality, standardization, proceduralization, and interpretive openness. The discussion connects legal form with the distribution of discretion across institutional actors.

Rules vary in their degree of specificity and the extent to which implementation requires contextual judgment. Black's analysis emphasizes the relation among rule form, interpretation, and the regulatory process [19]. Baldwin, Cave, and Lodge similarly distinguish regulatory strategies using detailed rules, broader principles, and other forms of regulatory control [14].

A highly specified rule can constrain interpretive variation while requiring extensive ex ante categorization. A broad standard can preserve flexibility while transferring greater interpretive responsibility to administrators, courts, regulated actors, or professional communities.

This trade-off has a relational dimension. Rule form distributes decision-making capacity among legislatures, regulators, courts, firms, professionals, and affected persons. A shift from detailed prescription toward principles can therefore leave the nominal regulatory objective unchanged while reallocating practical authority.

Fuller's analysis of legality adds another dimension by emphasizing conditions such as generality, promulgation, intelligibility, consistency, practicability, relative stability, and congruence between announced rules and official action [46]. These properties concern the institutional operation of legal order and demonstrate that rule effectiveness depends upon structural qualities extending beyond substantive command.

Within the GR taxonomy, explicit modification of precision, interpretive scope, or procedural form remains rule governance. The resulting distribution of discretion can subsequently alter dynamics and relations. A rule-form reform can therefore possess a shallow direct support together with deeper propagated effects.

7.10 Rule Revision and Institutional Adaptation

This subsection examines deliberate changes to existing rule structures. Its objective is to distinguish ordinary rule application from institutional adaptation through amendment, repeal, replacement, exception, and periodic revision. The analysis also clarifies the relation between rule adaptation and adaptive governance.

A direct rule revision transforms the explicit rule structure according to Equation 31.

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$$R_t^+ = \mathcal{U}_t^R \left(R_t \right). \tag{31}$$

Equation 31 represents the immediate transformation of the rule structure. The operator can encode amendment, repeal, addition, consolidation, exception, reinterpretation, or replacement according to the institutional context.

Rule revision can respond to observed failure, changing social conditions, new knowledge, institutional conflict, judicial interpretation, or political change. The existence of a revision procedure gives formal institutions a capacity for temporal adaptation.

Adaptive governance remains broader than rule revision. An adaptive governance system can change relations, organizational structures, information processes, and resource conditions in addition to formal rules. Rule revision therefore constitutes one mechanism through which adaptation can occur.

The temporal pattern of revision can also vary. Some rules are revised at fixed intervals. Others contain sunset clauses, review requirements, emergency exceptions, or condition-dependent modification procedures. These temporal structures can introduce dynamical features into a rule system.

Classification follows the operative mechanism. A scheduled legal review is a rule governing future rule reconsideration. A change triggered automatically by an observed system event introduces an event-dependent mechanism and can therefore acquire a dynamical-process component.

7.11 Formal Legality and Operational Congruence

This subsection examines the relation between formally represented rules and their institutional enactment. Its objective is to identify congruence, publicity, intelligibility, procedural regularity, and implementation as conditions affecting the practical operation of state-and-rule governance. The discussion establishes a boundary between rule structure and the wider system through which rules become effective.

Fuller's account of legality identifies several conditions associated with a functioning legal order, including generality, promulgation, prospectivity, clarity, consistency, practicability, stability, and congruence between official action and declared rule [46]. These conditions show that rule governance possesses operational requirements extending beyond the existence of a formally encoded command.

Congruence is especially relevant to the GR framework. A declared rule and an implemented institutional process can diverge. Selective enforcement, administrative delay, inaccessible procedures, conflicting guidance, or inconsistent adjudication can alter the effective dynamics associated with the same formal rule.

The distinction can be represented through the relation between formal rule structure R_t and an implemented rule representation $\widehat{R}_t$. Their discrepancy is described by Equation 32.

$$\Delta_R(t) = D_R \left(R_t, \widehat{R}_t \right), \tag{32}$$

where D_R denotes a domain-specific discrepancy measure. Equation 32 provides a general representation of the distance between formally specified and operationally instantiated rule structures.

The discrepancy measure can be qualitative, categorical, statistical, or metric according to the application. The formal expression does not imply the existence of a universally valid scalar distance among legal rules.

Operational congruence also connects the rule layer with later governance layers. Recurrent discrepancies can arise from enforcement dynamics, organizational relations, resource constraints, information barriers, or background inequalities of institutional access.

The rule layer therefore remains analytically meaningful while its effective operation depends upon the wider Generative-Relational system.

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7.12 State-and-Rule Governance under Uncertainty

This subsection examines the epistemic requirements and limitations of state-and-rule governance. Its objective is to identify the information needed to specify states, categories, violations, eligibility conditions, and formal constraints and to clarify the consequences of classification error and rule mis-specification.

Rule governance commonly requires a mapping from heterogeneous empirical conditions into administratively recognized categories. Eligibility, liability, licensing, legal status, risk class, and violation determination all depend upon representations that compress aspects of a complex empirical world into legally actionable forms.

Classification creates epistemic vulnerability. An actor can be assigned to an inappropriate category. A rule can rely upon a proxy whose relation to the governance objective changes over time. An administratively convenient threshold can divide cases whose underlying conditions are highly similar. A general rule can encounter circumstances outside those anticipated during its formulation.

State-directed intervention encounters related problems. Direct correction requires sufficient knowledge of the present condition and of the state toward which the intervention should move the system. Uncertainty concerning either can increase the risk of inappropriate intervention.

Rule governance can respond through review procedures, exceptions, discretionary standards, appeals, sunset provisions, evidentiary requirements, and mechanisms for institutional learning. These mechanisms redistribute epistemic responsibility across actors and time.

The GR framework therefore treats explicitness as distinct from epistemic certainty. A rule can be highly explicit while its correspondence with the governed system remains uncertain. State-and-rule governance supplies formal clarity concerning institutional action while still operating through partial representations of the system.

7.13 Cross-Layer Propagation of State-and-Rule Intervention

This subsection examines the mechanisms through which state-and-rule interventions generate changes in deeper structural components. Its objective is to distinguish direct support on x_t or R_t from propagated effects on F_t, C_t, and $\mathcal{B}_t$. The analysis provides the bridge from the first governance layer to the dynamical, relational, and background layers developed in subsequent sections.

A rule change can alter effective dynamics by changing incentives, obligations, enforcement exposure, or available institutional actions. It can alter relational structure by creating agencies, delegating authority, changing contractual relations, or redefining jurisdiction. Repeated operation of a rule can alter background structures through accumulated resource distribution, institutional expectations, infrastructure, or patterns of access.

The generic propagation of a rule intervention is represented by Equation 33.

$$R_t^+ \longrightarrow (F_{t+\tau}, C_{t+\tau}, \mathcal{B}_{t+\tau}), \qquad \tau > 0. \tag{33}$$

Equation 33 represents the possibility that a rule-supported intervention produces later transformations outside its direct structural support. The arrow denotes causal or generative propagation whose specific mechanism must be established in the domain under analysis.

The distinction has practical significance. A scholarship entitlement is formally a rule and status structure. Its repeated operation can change educational access and resource distribution. An antitrust rule can formally prohibit specified conduct while its implementation affects market network structure. A transparency rule can create reporting obligations whose operation changes the information background available to other actors.

The original intervention retains its state-and-rule classification when those deeper effects arise through subsequent system evolution. A policy receives a multilayer classification when its operative design directly intervenes in several components, such as combining a legal entitlement with dedicated infrastructure, information provision, and institutional network reconfiguration.

This distinction preserves taxonomic resolution while allowing governance effects to propagate throughout the system.

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Table 7: Taxonomy of state-and-rule governance mechanisms

Governance mechanism	**Direct object**	**Institutional operation**	**Characteristic propagation**
Direct state modification	x_t	Assignment, transfer, restoration, removal, direct provision	Immediate state change followed by dynamical and relational effects
Command governance	R_t	Mandatory conduct and prescribed action	Compliance dynamics, enforcement, organizational adaptation
Prohibitory governance	R_t	Exclusion of institutionally admissible actions	Behavioral substitution, avoidance, enforcement dynamics
Permission and authorization	R_t	Expansion of formal admissibility and institutional competence	New trajectories, organizational capacities, relational changes
Entitlement governance	R_t, x_t	Creation or recognition of rights, claims, eligibility, status	Resource access, participation, background opportunity structure
Sanction governance	R_t	Specification of consequences associated with violations	Deterrence, behavioral adaptation, responsive enforcement
Constraint governance	R_t	Definition of formal feasible regions and institutional boundaries	Trajectory restriction and organizational adaptation
Secondary-rule governance	R_t	Recognition, production, amendment, and adjudication of rules	Recursive rule generation and institutional evolution
Adjudicative governance	x_t, R_t	Authoritative case determination and rule interpretation	State correction, precedent, procedural and institutional adaptation
Rule-form governance	R_t	Modification of precision, generality, standards, and interpretive scope	Redistribution of discretion and implementation dynamics
Rule-revision governance	R_t	Amendment, repeal, replacement, exception, scheduled review	Institutional adaptation and later structural propagation
Congruence governance	R_t and its institutional implementation	Alignment of formal rule and operational practice	Legitimacy, predictability, administrative and relational effects

7.14 State-and-Rule Governance Classification

This subsection consolidates the first governance layer into a comparative taxonomy. Its objective is to distinguish the principal state-and-rule mechanisms according to their direct object, institutional operation, and characteristic cross-layer effects. The synthesis provides the reference structure for subsequent comparison with dynamical-process governance.

Table 7 summarizes the state-and-rule governance mechanisms developed in this section.

Table 7 shows that the first governance layer contains substantial internal diversity. Direct state intervention, conduct regulation, constitutive authorization, entitlement, sanctions, constraint systems, secondary rules, adjudication, and rule-form design all operate through explicit institutional objects while employing different mechanisms.

The layer also demonstrates the importance of separating rule existence from rule effect. A prohibition alters formal admissibility. Enforcement determines how the rule is operationalized. Behavioral adaptation determines how actors respond. Network reconfiguration determines how responses propa-

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gate among actors. Resource and informational conditions determine whether formally permitted alternatives are effectively available.

State-and-rule governance therefore provides one component of a wider governance architecture. Its strengths include explicit authorization, institutional traceability, codification, public reference, and compatibility with formal review. Its limitations can arise from category error, implementation discrepancy, rapidly changing environments, limited observability, and the dependence of formal rules upon deeper relational and background conditions.

The next section develops dynamical-process governance. Its direct object is the system's evolution rather than a represented state or explicit rule. Feedback governance, event-based governance, perturbative governance, tangent-space governance, attractor-sensitive governance, criticality governance, bifurcation governance, finite-horizon intervention, and related mechanisms will be differentiated according to their activation structures, dynamical targets, information requirements, and temporal properties.

8 Dynamical-Process Governance

This section develops the second structural layer of the Generative-Relational governance taxonomy. Its role is to classify interventions whose direct object is the process through which system states evolve. The analysis distinguishes feedback governance, event-based governance, perturbative governance, tangent-space governance, viability and corridor governance, attractor and basin governance, bifurcation-sensitive governance, criticality governance, finite-horizon governance, and hybrid switching governance. Each mechanism is defined through its dynamical object, activation structure, information requirements, temporal horizon, and cross-layer effects. The section also establishes the boundary between dynamical-process intervention and interventions directed toward explicit rules, relational architecture, or generative backgrounds.

The dynamical layer begins from the effective system evolution introduced in Section 6. A governance process can modify the local evolution law while leaving the currently represented state unchanged at the instant of intervention. A controlled representation of this relation is given by Equation 34.

$$\dot{x}_t = F_t\left(x_t; R_t, C_t, \mathcal{B}_t\right) + G_t(x_t)u_t + \eta_t. \tag{34}$$

In Equation 34, u_t denotes a governance input, G_t describes the directions through which the input enters the effective dynamics, and η_t represents unresolved disturbance or model discrepancy. The control-theoretic representation provides a formal language for intervention into system evolution and carries no assumption that governance possesses complete control over the governed system.

8.1 Dynamical Intervention and Structural Support

This subsection establishes the defining boundary of dynamical-process governance. Its objective is to distinguish intervention into the evolution law from direct modification of a represented state and from alteration of deeper structures that generate the evolution law. The distinction is based on structural support and on the temporal mechanism through which an intervention produces its immediate effect.

A dynamical intervention directly transforms the effective evolution operator. The corresponding structural transformation is represented by Equation 35.

$$F_t \longrightarrow F_t^{+} = F_t + \Delta F_t. \tag{35}$$

Equation 35 identifies ΔF_t as the direct process-level intervention. The resulting change in $x_{t+\Delta t}$ occurs through subsequent evolution.

This distinction separates dynamical governance from direct state modification. An administrative decision that assigns a legal status directly changes x_t. A feedback rule that continuously changes an intervention according to the evolving state directly changes the effective process governing $\dot{x}_t$.

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The distinction also separates the dynamical layer from the generative background. A temporary adjustment to an effective transition rate can act on F_t. A reform of the institutional, informational, resource, or geometric conditions through which that transition rate is systematically generated can act on $\mathcal{B}_t$.

The same institutional instrument can therefore occupy different structural locations according to its operative mechanism. A tax rate encoded as a legal rule belongs initially to R_t. A continuously state-dependent fiscal adjustment can contain a dynamical component. A redesign of the economic infrastructure producing long-term accessibility and dependency patterns can extend into the generative-background layer.

8.2 Feedback Governance

This subsection develops feedback governance as state-dependent adjustment through repeated observation and intervention. Its objective is to connect established cybernetic and control-theoretic concepts with a formal governance mechanism while preserving the informational and institutional limits of social systems. The discussion focuses on closed-loop adjustment, observation, delay, gain, and stability.

Feedback systems use observed system information to determine subsequent control action. Modern control theory provides a systematic treatment of closed-loop systems, stability, robustness, and feedback design [10]. Political cybernetics and governance theory provide corresponding institutional lineages through information, communication, adjustment, and regulatory response.

A general output-feedback governance policy is represented by Equation 36.

$$u_t = \pi_t \left(y_{\leq t} \right), \qquad y_t = \mathcal{O}_t \left(\mathfrak{S}_t \right) + \varepsilon_t. \tag{36}$$

Equation 36 represents governance action as a function of available observations. The policy π_t can depend upon the current observation, a finite observation history, accumulated indicators, or an estimated latent state.

Feedback governance appears in monetary policy, adaptive regulation, automatic stabilization, administrative monitoring, public-health response, environmental management, platform moderation, and many other domains. Observed consequences alter subsequent intervention intensity or direction.

The quality of feedback governance depends upon the observation process. Measurement delay can produce intervention after the relevant system state has already changed. Aggregation can conceal heterogeneous local conditions. Measurement noise can produce unstable or excessive responses. Strong feedback can amplify oscillation when the governing model, delay structure, or response gain is poorly matched to the system.

Feedback therefore describes a temporal mechanism rather than a normative criterion. A feedback loop can support learning and adaptation while also supporting intrusive surveillance or unstable overcorrection. Structural classification and normative evaluation remain separate.

8.3 Event-Based Governance

This subsection develops event-based governance as intervention activated by the occurrence of specified system conditions. Its objective is to distinguish event-triggering from continuously active feedback and from fixed-time review. The discussion draws on event-triggered control as a formal source and extends the triggering logic into governance analysis.

Event-triggered control updates sensing or actuation when a defined condition is satisfied, allowing control activity to respond to system need rather than to a purely periodic schedule [126, 58]. The formal concept provides a useful model for governance systems in which observation continues while intervention remains dormant until a relevant event occurs.

Let $h(x_t, y_t, t)$ denote an event function. The sequence of intervention times is represented by Equation 37.

$$t_{k+1} = \inf \left\{ t > t_k \mid h(x_t, y_t, t) \geq 0 \right\}. \tag{37}$$

Equation 37 defines intervention times through the crossing of an event condition. The event can represent a threshold, institutional status change, detected violation, resource level, conflict indicator, market disturbance, public-health condition, or another domain-specific trigger.

Event-based governance can reduce continuous intervention and concentrate institutional capacity on states requiring attention. Its effectiveness depends upon the quality of the event definition, the observability of the triggering variable, the detection delay, and the availability of an appropriate response after activation.

The event surface can itself be established through a formal rule. In that case, the rule defining h belongs to the state-and-rule layer, while the conditional activation of intervention belongs to the dynamical-process layer. Event-based governance therefore provides a clear example of multilayer composition.

Event-triggered intervention also differs from criticality governance. An event trigger can be based on any specified condition. Criticality governance concerns changing system sensitivity and proximity to possible regime transition.

8.4 Perturbative Governance

This subsection develops perturbative governance as bounded modification of an existing dynamical process. Its objective is to distinguish the magnitude and locality of intervention from its directional or regime-level purpose. The formalization draws on nonlinear control and dynamical-systems traditions in which small interventions can modify trajectories or stabilize selected behavior [70, 97].

A perturbative intervention preserves the reference dynamics as the local baseline and introduces a bounded process modification. The perturbation condition is represented by Equation 38.

$$F_t^+ = F_t + \delta F_t, \qquad \|\delta F_t\| \leq \epsilon_t. \tag{38}$$

Equation 38 characterizes a governance intervention whose immediate dynamical magnitude is bounded by ϵ_t under a selected norm.

Perturbative governance is appropriate as an analytical category when the intervention seeks to redirect an existing process while retaining much of its current dynamical organization. Examples can include temporary liquidity support, limited regulatory correction, narrowly targeted incentives, short-duration traffic controls, or small changes in operational parameters.

The control of chaotic systems provides a particularly strong mathematical illustration. Ott, Grebogi, and Yorke demonstrate that small time-dependent parameter perturbations can stabilize selected periodic behavior embedded in a chaotic attractor [97]. The governance relevance lies in the general structural insight that intervention magnitude and dynamical effect can differ substantially in sensitive systems.

Perturbative governance therefore carries no general implication of weak effect. Near sensitive regions, a small intervention can produce large trajectory differences. Inside strongly stable regimes, substantially larger perturbations can decay with limited long-term effect.

8.5 Tangent-Space Governance

This subsection develops tangent-space governance as a proposed Generative-Relational mechanism for local directional intervention under limited knowledge of global system structure. Its objective is to formalize governance that operates through locally available directions of change while maintaining epistemic modesty concerning long-horizon system evolution. The construction uses standard differential-geometric tangent spaces [78] and nonlinear local dynamics as its mathematical basis.

Let the current state x_t lie on a smooth state manifold M. The uncontrolled local velocity and a governance modification then belong to the tangent space $T_{x_t}M$. The local intervention is represented by Equation 39.

$$F_t(x_t) \in T_{x_t}M, \qquad \delta v_t \in T_{x_t}M, \qquad \dot{x}_t^+ = F_t(x_t) + \delta v_t. \tag{39}$$

Equation 39 represents a local change in the instantaneous direction of system evolution. The construction requires local differentiable structure around x_t and does not require a complete global reconstruction of M.

Tangent-space governance is particularly relevant when governance possesses reliable local information and limited confidence concerning distant future states. Decision makers can sometimes estimate whether current trajectories are moving toward increasing conflict, financial stress, ecological degradation, administrative overload, or another locally identifiable direction while remaining uncertain about the complete global attractor structure.

The mechanism can support short, revisable interventions. A governance actor can modify the local direction, observe the resulting trajectory, reconstruct the local tangent information, and update intervention as new information arrives.

The distinction from perturbative governance concerns the taxonomic emphasis. Perturbative governance characterizes bounded intervention magnitude. Tangent-space governance characterizes the locality and directional structure of available knowledge. A governance action can belong to both categories.

The distinction from background governance is equally important. Tangent-space governance acts within the current local geometry. Metric or background-geometry governance changes the structure through which notions such as distance, accessibility, and natural path are themselves generated.

8.6 Viability and Corridor Governance

This subsection develops governance directed toward maintaining system trajectories within an admissible or viable region. Its objective is to formalize a governance logic concerned with preserving acceptable evolutionary possibilities without prescribing a unique terminal state. The discussion draws on viability theory and invariant-set control [11, 21].

Let $K \subseteq X$ denote a domain-specific viable region and let $\mathcal{F}_{\mathcal{U}}(x)$ denote the set of velocities available under admissible governance actions. The viability requirement is represented by Equation 40.

$$x(0) \in K \quad \Longrightarrow \quad x(t) \in K \ \text{ for all } t \geq 0 \text{ under at least one admissible governance trajectory.} \tag{40}$$

Equation 40 expresses governance as maintenance of evolutionary possibility within K. Viability theory develops rigorous methods for controlled systems subject to state and control constraints [11].

Aubin and Cellina's work on differential inclusions provides a mathematical language for systems in which multiple admissible velocities remain available. Blanchini's survey of set invariance similarly demonstrates the importance of invariant sets for constrained control, robustness, and control synthesis [21].

The term *corridor governance* is used here for a broader governance interpretation of this formal structure. A corridor specifies a region of acceptable evolution while allowing heterogeneous trajectories inside that region. Environmental limits, financial stability bands, constitutional constraints, conflict-escalation boundaries, and safety requirements can all be represented through domain-specific corridors where appropriate.

This mechanism is especially compatible with a generative orientation because it can preserve multiple future possibilities. The governance objective can be maintenance of viable evolution rather than convergence toward one fully specified terminal configuration.

The normative selection of K remains a separate problem. A mathematically viable region can embody unjust or undesirable institutional conditions. Viability provides a dynamical structure for governance and leaves the legitimacy of the viable set for later normative evaluation.

8.7 Attractor and Basin Governance

This subsection develops governance directed toward persistent dynamical regimes and their basins of attraction. Its objective is to distinguish trajectory-level correction from interventions concerned with

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the regime toward which trajectories tend over longer horizons. The discussion uses standard attractor and basin concepts from dynamical systems [76, 96].

Let $\mathcal{A} \subseteq X$ denote an attracting invariant set and let $\mathcal{B}(\mathcal{A})$ denote its basin of attraction. The basin is defined by Equation 41.

$$\mathcal{B}(\mathcal{A}) = \{x_0 \in X \mid \operatorname{dist}(\phi_t(x_0), \mathcal{A}) \to 0 \text{ as } t \to \infty\}. \tag{41}$$

Equation 41 identifies the set of initial conditions whose trajectories approach the attractor under the modeled dynamics.

Attractor governance concerns intervention into the effective dynamics so that a desirable persistent regime becomes more stable, reachable, or recoverable. Basin governance concerns the boundary structure separating long-term regimes and the conditions under which trajectories move among them.

Control of chaos provides a formal precedent for deliberate stabilization of selected dynamical behavior through small parameter perturbations [97, 22]. Governance applications require separate empirical models and institutional interpretation.

The attractor language is useful for systems exhibiting persistent patterns. Examples can include recurrent conflict configurations, institutional deadlocks, market regimes, ecological regimes, organizational routines, or patterns of platform interaction. Identification of a social attractor requires empirical evidence and a model capable of supporting the dynamical claim.

Attractor governance also requires normative caution. Dynamical stability describes persistence and provides no independent measure of justice, legitimacy, or desirability. A highly stable institutional regime can possess serious normative deficiencies.

8.8 Bifurcation-Sensitive Governance

This subsection develops governance for systems whose qualitative dynamical structure changes as parameters vary. Its objective is to distinguish parameter-sensitive regime change from ordinary trajectory correction and from criticality monitoring under incomplete model knowledge. The formal vocabulary draws on established bifurcation theory [76, 55].

Consider a parameterized family of dynamical systems with parameter μ. The family is represented by Equation 42.

$$\dot{x} = F(x; \mu). \tag{42}$$

Equation 42 permits qualitative changes in equilibria, periodic behavior, stability, or other invariant structures as μ crosses bifurcation regions.

Bifurcation-sensitive governance uses an identified or hypothesized dynamical model to examine how intervention can influence such regime changes. The relevant governance action can seek to delay a transition, accelerate a transition, select among available branches, or maintain system evolution within a parameter region associated with acceptable dynamics.

The classification of the intervention depends upon the meaning of μ. Direct adjustment of an operational parameter within the effective dynamical law can belong to the dynamical-process layer. Transformation of the institutional, resource, relational, or geometric structure from which μ emerges can belong to a deeper layer.

Bifurcation-sensitive governance therefore requires explicit model identification. The presence of abrupt social or institutional change alone does not establish a mathematical bifurcation. The terminology becomes appropriate when a dynamical representation supports a qualitative change in the relevant invariant structure.

8.9 Criticality Governance

This subsection develops criticality governance as intervention under changing evidence of dynamical sensitivity and transition risk. Its objective is to formalize governance regimes that alter observation,

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preparedness, response speed, or intervention strategy as a system approaches a region associated with possible qualitative transition. The discussion distinguishes criticality governance from exact prediction of a future regime.

Research on critical transitions identifies classes of systems in which approach to a transition can be accompanied by critical slowing down and associated changes in statistical indicators [113]. Proposed signals include changes in recovery rates, autocorrelation, variance, and related observables.

Let Σ_c denote a modeled critical region within an augmented state-parameter space. When an appropriate distance representation exists, a criticality indicator can be defined by Equation 43.

$$d_c(t) = \operatorname{dist}\left((x_t, \mu_t), \Sigma_c\right). \tag{43}$$

Equation 43 provides one possible representation of proximity to a critical region. Empirical governance can use statistical or qualitative indicators when a geometrically explicit Σ_c is unavailable.

Criticality governance can change the governing regime as evidence of sensitivity increases. Observation frequency can rise, decision latency can be reduced, coordination can become more intensive, precautionary measures can be activated, and intervention horizons can shorten.

The epistemic limitations of early-warning inference remain central. Boettiger and Hastings demonstrate the possibility of false-positive interpretation of warning statistics under particular analytical conditions [23]. Some abrupt transitions also arise through mechanisms that provide little useful critical-slowing-down signal.

Criticality governance therefore treats warning signals as evidence under uncertainty. The governance problem concerns changing sensitivity, information value, and transition risk. The framework leaves the destination of the transition, its desirability, and the appropriate response open to domain-specific analysis.

8.10 Finite-Horizon and Receding-Horizon Governance

This subsection develops governance based on bounded prediction horizons and repeated local re-evaluation. Its objective is to formalize decision processes suited to systems in which short-horizon dynamics are more reliable than long-horizon forecasts. The construction draws on model-predictive control as a formal analogue while allowing feasibility, safety, and institutional constraints to replace a purely optimizing objective.

Model-predictive control repeatedly solves a finite-horizon control problem from the currently observed state, implements an initial control action, and recomputes as new state information becomes available [87]. This structure provides a useful formal precedent for governance under model uncertainty and changing conditions.

A feasibility-oriented horizon-H governance set is represented by Equation 44.

$$\mathcal{U}_H(x_t) = \{u_{t:t+H-1} \mid x_{k+1} = F_k(x_k, u_k),\ x_k \in K_k,\ u_k \in U_k \text{ for } k = t, \ldots, t+H-1\}. \tag{44}$$

Equation 44 defines the set of intervention sequences that satisfy modeled dynamical and institutional constraints over a finite horizon.

Finite-horizon governance can select an admissible first action from this set, observe the resulting state, update the local model, and construct a new feasible set at the next decision point. Domain-specific formulations can add performance criteria where such criteria are normatively and empirically justified.

This mechanism is useful under severe epistemic limits. A governance actor can avoid reliance on long-horizon trajectories whose predictions deteriorate rapidly while still using local simulation to reject actions that produce immediate constraint violations or unacceptable short-term dynamics.

The receding horizon also supports revisability. Each intervention is selected within a limited temporal window and becomes subject to reassessment as new information appears. This feature aligns with the GR emphasis on local knowledge and iterative governance.

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8.11 Hybrid and Switching Governance

This subsection develops governance in systems whose evolution combines continuous processes with discrete changes in operating mode. Its objective is to formalize emergency regimes, staged regulatory systems, escalation structures, and other mechanisms in which governance switches among dynamical laws according to states, events, timers, or institutional conditions. The construction draws on hybrid dynamical-systems theory [48].

Let $q_t \in \mathcal{Q}$ denote the current governance mode. A mode-dependent continuous evolution is represented by Equation 45.

$$\dot{x}_t = F_{q_t}(x_t) \qquad \text{while } (x_t, q_t) \in \mathcal{C}, \tag{45}$$

where $\mathcal{C}$ denotes the set of states for which continuous evolution under the current mode remains active. Equation 45 represents the flow component of a hybrid governance system.

A discrete governance-mode transition is represented by Equation 46.

$$(x_t^+, q_t^+) = \mathcal{J}\,(x_t, q_t) \qquad \text{when } (x_t, q_t) \in \mathcal{D}, \tag{46}$$

where $\mathcal{D}$ denotes the jump set. Equation 46 represents an instantaneous transition into a different governance mode.

Hybrid governance can describe escalation ladders, emergency activation, staged regulatory regimes, temporary crisis procedures, automated circuit breakers, and institutional systems containing distinct operational states.

Event-based governance and hybrid governance can overlap. An event can trigger a discrete transition between governing modes. Hybrid governance adds the explicit representation of multiple dynamical regimes and the rules governing movement among them.

The boundary with state-and-rule governance again follows structural support. A statute defining emergency powers belongs to R_t. Activation of a new dynamical regime when emergency conditions are detected belongs to the dynamical layer. Changes in the institutional architecture that systematically generate vulnerability or resilience belong to deeper layers.

8.12 Dynamical Governance under Partial Observability

This subsection examines the informational requirements associated with dynamical-process governance. Its objective is to compare the forms of knowledge required by feedback, event-based, tangent-space, attractor, criticality, viability, and finite-horizon mechanisms. The discussion treats observability as an independent analytical dimension.

Feedback governance requires observations sufficiently related to the system variables used by the feedback policy. Event-based governance requires reliable identification of the triggering condition. Tangent-space governance requires local directional estimates. Viability governance requires knowledge of relevant constraints and accessible local velocities. Attractor governance requires evidence concerning persistent dynamical regimes. Criticality governance requires indicators informative about changing sensitivity or transition risk.

These requirements differ in informational depth. A local event detector can function with limited knowledge of the global system. Identification of an attractor basin can require substantially richer state-space information. A bifurcation model can require parameter estimation and structural assumptions concerning the dynamical family.

Partial observability therefore influences the appropriate governance mechanism. Increasing model complexity can provide richer intervention possibilities while increasing sensitivity to model error, unobserved variables, and structural change.

Tangent-space and finite-horizon governance are especially relevant under severe epistemic limitation because their formal logic can operate through local or short-horizon information. Their applicability still depends upon the quality of that local information.

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8.13 Temporal Resolution and Intervention Frequency

This subsection examines the timing properties of dynamical-process governance. Its objective is to distinguish continuous, periodic, event-triggered, episodic, and regime-dependent intervention frequencies and to connect temporal resolution with institutional cost and system sensitivity.

A governance system can update continuously, at predetermined intervals, when specific events occur, after detected changes in system sensitivity, or during temporary crisis periods. These temporal architectures impose different monitoring and coordination requirements.

High-frequency governance can respond rapidly to change while consuming substantial informational and organizational resources. Lower-frequency governance can preserve institutional autonomy and reduce intervention cost while allowing fast disturbances to develop between updates.

Event-triggered control research is motivated partly by this trade-off between control performance and communication or computational resources [58]. Governance applications possess analogous resource constraints in monitoring, expertise, administrative attention, and political coordination.

Criticality governance introduces variable temporal resolution. A system can operate under ordinary monitoring while far from a sensitive region and shift toward more intensive observation and shorter decision cycles as transition risk increases.

Temporal frequency therefore forms a secondary taxonomic dimension within the dynamical layer.

8.14 Cross-Layer Boundaries of Dynamical Intervention

This subsection clarifies the relationship between dynamical-process governance and the surrounding structural layers. Its objective is to prevent classification from depending on superficial institutional terminology and to identify the conditions under which one governance programme receives a multilayer assignment.

A rule specifying a feedback procedure belongs to R_t, while the state-dependent intervention generated by that procedure acts on F_t. A network of agencies implementing feedback can also involve relational-structural governance when the programme directly changes institutional couplings.

A parameter intervention belongs to the dynamical layer when the parameter is treated as part of the effective evolution law. The same empirical variable can belong to generative-background governance when the intervention changes the deeper structure through which a family of dynamical parameters is generated.

This distinction is especially important for bifurcation and attractor governance. Adjusting an operational control parameter can modify F_t directly. Altering resource distribution, infrastructural accessibility, institutional trust, or a field-like condition that systematically reshapes the entire dynamical family can operate through $\mathcal{B}_t$.

Dynamical interventions can also propagate upward. Repeated trajectory modification can change actor relations, institutional routines, expectations, and eventually background structures. The direct support remains dynamical when those deeper changes arise through subsequent endogenous evolution.

The layer boundary therefore follows the immediate generative mechanism rather than the eventual breadth of the intervention's effects.

8.15 Dynamical-Process Governance Classification

This subsection consolidates the mechanisms developed in this section into a comparative dynamical taxonomy. Its objective is to distinguish the mechanisms according to their immediate dynamical object, activation structure, information requirements, and characteristic temporal logic. The synthesis provides the reference structure for later comparison with relational-structural and generative-background governance.

Table 8 summarizes the principal dynamical-process governance mechanisms.

Table 8 shows that dynamical-process governance contains several independent classificatory dimensions. Feedback concerns informational closure. Event governance concerns activation. Perturba-

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Table 8: Taxonomy of dynamical-process governance mechanisms

Governance mechanism	**Dynamical object**	**Activation and information**	**Characteristic function**
Feedback governance	State-dependent evolution	Repeated observation and closed-loop adjustment	Correction, regulation, adaptation
Event-based governance	Activation time and process response	Event surface or triggering condition	Selective intervention at dynamically relevant events
Perturbative governance	Local vector field	Bounded process modification	Trajectory redirection with limited immediate intervention magnitude
Tangent-space governance	Local direction in T_xM	Local state and directional information	Short-horizon directional adjustment under limited global knowledge
Viability and corridor governance	Admissible trajectory region	State constraints and accessible local dynamics	Maintenance of heterogeneous trajectories within viable bounds
Attractor and basin governance	Persistent regime and basin structure	Longer-horizon dynamical identification	Regime stabilization, escape, targeting, or basin redirection
Bifurcation-sensitive governance	Parameterized dynamical family	Model of parameter-dependent qualitative change	Management of transitions among dynamical regimes
Criticality governance	Sensitivity and transition proximity	Early-warning indicators and transition-risk evidence	Adjustment of observation and intervention near sensitive regions
Finite-horizon governance	Short-horizon reachable trajectories	Local model, constraints, repeated re-estimation	Revisable action under bounded prediction horizons
Hybrid and switching governance	Mode-dependent dynamics	Event, state, timer, or institutional mode condition	Transition among distinct governing regimes

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tive governance concerns intervention magnitude. Tangent-space governance concerns local directional structure. Viability governance concerns admissible evolutionary regions. Attractor governance concerns persistent regimes. Bifurcation governance concerns qualitative changes in a parameterized dynamical family. Criticality governance concerns changing sensitivity and transition risk. Finite-horizon governance concerns prediction horizon. Hybrid governance concerns mode structure.

These mechanisms can be combined. A governance system can use event-triggered feedback, local perturbations inside a viable corridor, criticality-sensitive monitoring, and finite-horizon simulation within a hybrid emergency architecture. The taxonomy decomposes such combinations into their operative dynamical mechanisms.

The dynamical layer also reveals a central theme of the Generative-Relational framework: governance can influence system evolution without specifying a single desired terminal state. Viability governance can preserve a region of trajectories, tangent-space governance can modify only local direction, and finite-horizon governance can preserve revisability under limited prediction.

The following section develops relational-structural governance. Its direct object is C_t: the topology, coupling, boundaries, interfaces, dependencies, modules, decision centers, and transmission structures through which system components interact. Network reconfiguration, coupling governance, boundary governance, modular governance, dependency governance, distributed governance, polycentric restructuring, and cascade governance are developed as distinct relational mechanisms.

9 Relational-Structural Governance

This section develops the third structural layer of the Generative-Relational governance taxonomy. Its role is to classify interventions whose direct object is the relational architecture through which system components interact. The analysis distinguishes network-topology governance, tie and channel governance, coupling governance, boundary and membership governance, interface governance, modular governance, centrality and dependency governance, multilayer and interdependent-network governance, distributed and polycentric restructuring, relational controllability, cascade governance, and temporal network reconfiguration. Each mechanism is defined through the relational object transformed, its formal representation, its connection to established governance and network theories, and its principal dynamical and background consequences.

Relational-structural governance begins from the relational component C_t introduced in Section 6. The defining governance operation changes who or what can interact, through which relation, with what strength, through which direction, under which interface, or within which organizational architecture. The resulting intervention can profoundly alter system dynamics even when the local states and explicit rules of individual components remain unchanged.

Network analysis provides a mature mathematical language for representing relational structure across social, technological, biological, and other systems [89]. Social-network scholarship likewise demonstrates that relational position and network structure can possess explanatory significance beyond attributes attached to isolated actors [25]. Governance scholarship supplies corresponding institutional traditions through network governance, collaboration, polycentricity, multilevel governance, and metagovernance. The present section integrates these resources through the direct structural support of intervention.

9.1 Relational Structure and Structural Support

This subsection establishes the formal boundary of relational-structural governance. Its objective is to distinguish direct transformation of relational architecture from changes in local dynamics and from rule-based definitions that subsequently influence relations. The formalization treats topology, coupling, relation type, direction, and transmission mechanism as components of the relational object.

The general relational representation introduced earlier is refined through Equation 47.

$$C_t = (V_t, E_t, W_t, \Gamma_t, \mathcal{L}_t)\,. \tag{47}$$

In Equation 47, V_t denotes system components, E_t denotes relations, W_t denotes relation weights or intensities, Γ_t denotes transmission or coupling rules, and $\mathcal{L}_t$ denotes relation types or layers when heterogeneous relations are represented.

A relational governance intervention directly transforms this architecture. The generic transformation is represented by Equation 48.

$$C_t \longrightarrow C_t^{+} = \mathcal{U}_t^{C}\left(C_t\right). \tag{48}$$

Equation 48 defines relational-structural governance through direct support on C_t. Subsequent changes in trajectories, rules, or background conditions are treated as propagated effects unless the intervention directly transforms those components as well.

The distinction can be illustrated through institutional delegation. A statute authorizing delegation belongs initially to the explicit-rule layer. The creation of a new reporting, dependency, or authority relation among organizations directly changes C_t. A programme containing both operations therefore receives a multilayer classification.

The relational layer consequently concerns realized or institutionally operational connections among components. Formal authorization of a relation and the existence, strength, or organization of the resulting relation remain analytically distinguishable.

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9.2 Network-Topology Governance

This subsection develops governance directed toward the topology of a relational network. Its objective is to formalize changes in connectivity, direction, path structure, and network organization while separating topological intervention from changes in the dynamics transmitted across the network.

For a simple weighted network, relational structure can be represented through an adjacency matrix A_t. A topological governance operation is represented by Equation 49.

$$A_t \longrightarrow A_t^+ = A_t + \Delta A_t. \tag{49}$$

Equation 49 represents addition, removal, redirection, or restructuring of relations through the matrix ΔA_t. Discrete network models can interpret the entries as relation existence, while weighted models can encode intensity through the same or a separate matrix.

Network topology influences possible paths of communication, exchange, dependency, diffusion, coordination, and disturbance propagation [89]. Watts and Strogatz demonstrate that changes in network organization can produce substantial differences in path length and clustering even when the number of nodes and local connection scale remain comparable [131].

Governance can therefore operate through creation or removal of institutional links. An interagency coordination mechanism can create new communication paths. A regulatory separation requirement can remove dependencies. A regional organization can connect previously weakly linked jurisdictions. A platform can change which classes of users, organizations, or information sources are allowed to interact.

The topology itself carries no universal normative meaning. Increased connectivity can improve access and information circulation while also increasing exposure to contagion, surveillance, dependency, or coordinated harm. Reduced connectivity can contain cascades while also fragmenting knowledge and participation.

Network-topology governance therefore requires specification of the relation being represented and the function whose propagation depends upon that relation.

9.3 Tie, Channel, and Brokerage Governance

This subsection examines interventions directed toward individual relations and bridging channels within a larger network. Its objective is to distinguish local relational editing from system-wide topological redesign and to identify the significance of weak links, bridges, brokers, and transmission channels for cross-group interaction.

Granovetter's analysis of weak ties demonstrates the potential importance of relatively weak interpersonal connections for diffusion, mobility, and relations among otherwise separated social groups [50]. The broader structural lesson concerns the importance of a relation's position within a network in addition to its local intensity.

A local tie-governance intervention affecting the relation between nodes i and j is represented by Equation 50.

$$e_{ij,t} \longrightarrow e_{ij,t}^+, \qquad e_{ij,t} \in E_t. \tag{50}$$

Equation 50 can represent creation, termination, redirection, or institutional transformation of a particular relational channel.

Governance practices of this type include appointment of liaison offices, creation of interministerial communication channels, diplomatic contact mechanisms, cross-community forums, data-sharing links, referral systems, cross-sector partnerships, and institutional mediation structures.

Brokerage governance concerns nodes or organizations that connect otherwise weakly connected parts of a system. A bridging organization can facilitate translation, information transfer, negotiation, or resource circulation between relational domains that possess limited direct connectivity.

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The importance of brokerage also creates dependency risks. Concentrating cross-domain communication in one intermediary can create a bottleneck or single point of institutional failure. Relational design must therefore consider both connectivity benefits and dependency concentration.

9.4 Coupling Governance

This subsection develops governance directed toward the strength, direction, sign, and functional form of interaction among connected components. Its objective is to distinguish the existence of a relation from the dynamical intensity through which connected states influence one another.

Let $w_{ij,t}$ denote the effective coupling from component j to component i. A coupling-governance intervention is represented by Equation 51.

$$w_{ij,t} \longrightarrow w^{+}_{ij,t}. \tag{51}$$

Equation 51 changes the intensity or character of an existing relational dependence while preserving the possibility that the underlying edge remains present.

Coupling matters because identical network topology can support substantially different system dynamics under different interaction strengths. The theory of coupled dynamical systems provides formal examples in which stability and synchronization depend jointly upon network structure and coupling properties [98].

Governance examples include altering fiscal dependence among jurisdictions, changing voting weights within an institution, modifying information-sharing intensity, limiting financial exposure between institutions, changing contractual dependency, adjusting platform amplification, or changing the frequency with which organizations must coordinate.

Coupling can be asymmetric. One organization can depend strongly upon another while the reverse dependency remains weak. Directed and weighted representations are therefore often more appropriate than undirected binary networks for governance analysis.

Coupling governance also differs from dynamical-process governance. A temporary process correction can modify F_t while preserving the underlying relation. A change to the enduring relational coefficient through which one component influences another acts directly upon C_t. Empirical classification depends upon the modeled mechanism and its persistence.

9.5 Boundary and Membership Governance

This subsection examines governance directed toward the relational boundaries that organize participation, membership, access, and interaction among subsystems. Its objective is to distinguish formal eligibility rules from the realized relational architecture that determines which actors participate in which institutional domains.

Boundaries play a central role in commons governance. Ostrom's institutional analysis includes clearly defined user and resource boundaries among the design principles associated with enduring common-pool resource institutions [93]. Boundaries determine the domain within which particular relationships, obligations, monitoring practices, and collective decisions operate.

Let $V_t^{(m)} \subseteq V_t$ denote the membership of institutional domain m. A relational boundary intervention is represented by Equation 52.

$$V_t^{(m)} \longrightarrow V_t^{(m)+}. \tag{52}$$

Equation 52 represents a transformation of the realized relational membership of a governance domain.

The formal criteria for membership can be specified through R_t, while the actual organization of participants belongs to C_t. This distinction is important when formal eligibility and effective institutional inclusion diverge.

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Boundary governance can involve inclusion of new participants, separation of functions, establishment of protected spaces, jurisdictional reallocation, formation of firebreaks, creation of information partitions, or restructuring of organizational memberships.

Boundaries can support local autonomy and limit harmful propagation. They can also exclude affected actors from decision processes or restrict access to resources and knowledge. Their normative evaluation therefore depends upon the purpose, affected actors, procedural conditions, and cross-boundary effects.

9.6 Interface and Interoperability Governance

This subsection develops governance of interfaces through which heterogeneous subsystems exchange information, resources, decisions, or institutional recognition. Its objective is to distinguish connection from interoperability: two systems can be relationally adjacent while lacking an effective mechanism for translation or transport across their boundary.

Consider subsystems M_i and M_j whose internal representations differ. An interface map between their relevant relational states is represented by Equation 53.

$$\Psi_{ij} : \mathcal{Z}_i \longrightarrow \mathcal{Z}_j. \tag{53}$$

Equation 53 represents the translation, recognition, or transformation required for information or institutional objects produced in subsystem i to become actionable within subsystem j.

Governance interfaces appear in data standards, mutual recognition regimes, interagency referral procedures, translation services, cross-border payment systems, diplomatic protocols, professional credential recognition, and coordination procedures among jurisdictions.

Interface governance can preserve heterogeneity while enabling interaction. Each subsystem can retain its internal rules and representations while a defined interface makes cross-system action possible.

Poor interface design can generate friction even when formal cooperation exists. Incompatible data classifications, documentary standards, procedural timelines, terminology, technical protocols, or legal categories can impede cross-system coordination.

Interface governance therefore occupies an important position between relational-structural and generative-background governance. A concrete translation or transport relation belongs to C_t. A deeper structure that defines the general space of admissible transformations across many local representations can later be modeled through connection or gauge-like background structures.

9.7 Modular Governance

This subsection develops governance through the organization of systems into partially differentiated modules. Its objective is to formalize the relation among local autonomy, internal coupling, cross-module interaction, and disturbance containment. The discussion draws on Simon's account of complex architecture and contemporary network representations.

Simon emphasizes near decomposability as an important property of complex systems, with interactions within subsystems generally stronger than interactions among subsystems [119]. This structure provides a conceptual basis for governance arrangements in which local units retain substantial internal organization while interacting through selected interfaces.

Let the node set be partitioned into modules $V_t^{(1)}, \ldots, V_t^{(m)}$. A block representation of the adjacency or coupling structure is introduced by Equation 54.

$$A_t = \begin{pmatrix} A_{11} & A_{12} & \cdots & A_{1m} \\ A_{21} & A_{22} & \cdots & A_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ A_{m1} & A_{m2} & \cdots & A_{mm} \end{pmatrix}. \tag{54}$$

Equation 54 separates within-module relations A_{ii} from cross-module relations A_{ij}.

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Modular governance can adjust the relative strength or density of these blocks. Institutional examples include federal arrangements, semi-autonomous agencies, compartmentalized financial structures, modular technical systems, regional governance units, and organizational divisions with defined interfaces.

Modularity can support differentiated experimentation and local adaptation. It can also limit propagation of local failure. Excessive separation can produce fragmentation, duplicated capacity, coordination failure, or institutional incompatibility.

The governance problem therefore concerns the structure of selective coupling. The appropriate relation among autonomy, coordination, redundancy, and cross-module learning depends upon the system and disturbance environment.

9.8 Centrality and Dependency Governance

This subsection examines interventions directed toward concentrated relational positions and asymmetric dependencies. Its objective is to identify how network position can influence access, control, vulnerability, and propagation and to distinguish relational concentration from actor-level attributes.

Network analysis provides several centrality measures associated with different structural properties, including degree, path position, and eigenvector-based influence [89]. The appropriate measure depends upon the mechanism represented by the network.

Let $c_i(C_t)$ denote a domain-specific centrality or dependency measure for component i. A governance intervention directed toward relational concentration is represented by Equation 55.

$$c_i(C_t) \longrightarrow c_i(C_t^+). \tag{55}$$

Equation 55 represents transformation of a component's relational position through changes in C_t.

Governance applications include diversification of suppliers, reduction of institutional bottlenecks, decentralization of data infrastructure, redistribution of decision channels, creation of alternative payment routes, or reduction of dependence upon a single intermediary.

Network centrality and institutional power can be related while remaining analytically distinct. A formally powerful institution can occupy a peripheral position in one operational network, while an actor possessing limited formal authority can occupy a critical brokerage or dependency position.

Relational dependency therefore provides an additional vocabulary for power analysis. The later normative sections can examine whether concentrated dependencies obstruct participation, value circulation, revisability, or generative capacity.

9.9 Multilayer and Interdependent-Network Governance

This subsection develops governance for systems containing several types of relations or several interdependent networks. Its objective is to avoid collapsing heterogeneous institutional relations into one graph and to identify dependencies that propagate across relational layers.

Kivelä et al. develop a comprehensive framework for multilayer networks in which entities can participate in several types or layers of connectivity [72]. Such representations are particularly suitable for governance systems in which legal, financial, informational, organizational, social, and infrastructural relations coexist.

A multilayer relational system with layers $\alpha \in \{1, \ldots, L\}$ is represented by Equation 56.

$$C_t^{\text{multi}} = \left(\{V_t^{[\alpha]}\}_{\alpha=1}^{L}, \{E_t^{[\alpha]}\}_{\alpha=1}^{L}, E_t^{\text{inter}} \right). \tag{56}$$

Equation 56 distinguishes within-layer relations from interlayer relations E_t^{inter}.

Governance can act differently across relational layers. Two organizations can be strongly connected financially, weakly connected informationally, and formally separated administratively. Intervention into one relation can therefore leave other forms of dependency intact.

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Interdependence also creates possibilities for cross-network cascades. Buldyrev et al. demonstrate formally that dependencies among networks can produce cascading failures with behavior substantially different from that of isolated networks [27]. The governance significance lies in the need to identify dependencies across infrastructures and institutions, especially where failure in one system removes capacities required by another.

Multilayer governance therefore supports a more precise analysis of infrastructure dependency, supply chains, international institutions, digital platforms, public administration, and other systems whose relational architectures cannot be represented adequately through one relation type.

9.10 Distributed and Polycentric Restructuring

This subsection examines governance directed toward the distribution of decision centers and relational authority. Its objective is to connect the established theory of polycentric governance with the formal structural layer while preserving polycentricity as an institutional concept with its own literature.

Polycentric governance contains multiple decision centers possessing substantial domains of autonomy while participating in wider structures of interaction and coordination [95]. The relational object therefore includes both the centers themselves and the relations through which their decisions interact.

Let $D_t = \{d_1, \ldots, d_m\} \subseteq V_t$ denote decision centers and let E_t^D denote their institutional relations. A polycentric relational architecture is represented by Equation 57.

$$C_t^D = \left(D_t, E_t^D, W_t^D, \Gamma_t^D\right). \tag{57}$$

Equation 57 represents the distribution and interaction of governance centers without specifying one universal polycentric topology.

Relational restructuring can create new decision centers, consolidate existing centers, modify dependencies among them, change reporting relations, or create mechanisms for mutual adjustment and learning.

Distributed authority can increase access to local knowledge and permit institutional experimentation. It can also create coordination burdens, jurisdictional conflict, duplication, or gaps in responsibility. The effects depend upon the relational design among centers.

Polycentric governance can therefore possess additional mechanisms at other layers. Decision centers can create local rules, participate in feedback processes, and collectively generate background conditions. The relational layer identifies the architecture through which these centers coexist and interact.

9.11 Relational Controllability and Driver Structures

This subsection examines the relation between network structure and the locations through which dynamical intervention can influence a networked system. Its objective is to distinguish relational controllability from actor importance and to identify driver structures as a joint property of network topology and modeled dynamics.

Liu, Slotine, and Barabási develop a structural-controllability approach for complex directed networks and identify sets of driver nodes through which time-dependent control inputs can render a modeled linear network controllable [82]. Their results also demonstrate that highly connected nodes and control-relevant driver nodes need not coincide.

For a linear networked system, the relation between network dynamics and control inputs is represented by Equation 58.

$$\dot{x} = Ax + Bu. \tag{58}$$

Equation 58 uses A to represent the modeled interaction structure and B to represent the components through which control inputs enter the system.

Relational controllability is relevant to governance when an empirical system can support a defensible state-space and network-dynamics model. The formal concept should be applied with caution to

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political or institutional systems whose nonlinearities, adaptive actors, changing topology, and partial observability depart substantially from the assumptions of the selected control model.

The structural insight remains useful. Effective intervention points depend upon relational architecture and dynamical mechanism. Institutional prominence alone does not identify the nodes through which intervention can most effectively influence a modeled system.

Governance can therefore seek to modify the driver structure itself by creating alternative intervention channels, reducing dependence on scarce control points, or changing network architecture so that intervention capacity becomes more distributed.

9.12 Cascade and Containment Governance

This subsection develops governance directed toward relational propagation of failure, behavior, information, or other state changes. Its objective is to distinguish cascade governance from event governance: the former concerns the architecture of transmission across components, while the latter concerns the condition that activates intervention.

Watts demonstrates that global cascades can arise from interactions between network structure and local threshold behavior [130]. Buldyrev et al. show how dependencies across interacting networks can amplify failure through recursive cascades [27].

Let p_{ij} denote a domain-specific transmission probability or effective propagation coefficient from component j to component i. A relational containment intervention is represented by Equation 59.

$$P_t = [p_{ij,t}] \longrightarrow P_t^+. \tag{59}$$

Equation 59 represents direct modification of relational transmission conditions. The matrix can be deterministic, probabilistic, weighted, or state-dependent according to the empirical model.

Cascade governance can remove dependency edges, introduce redundancy, strengthen buffers, compartmentalize modules, slow transmission, diversify suppliers, or establish alternative communication and resource channels.

Albert, Jeong, and Barabási demonstrate that network robustness can depend strongly upon network topology and upon the pattern through which nodes are removed [3]. The result provides a formal illustration of the relation between structural heterogeneity and vulnerability.

Governance should therefore distinguish local failure probability from systemic propagation capacity. Reducing the probability of a local event and reducing its capacity to generate a cascade are separate intervention strategies that can operate at different structural locations.

9.13 Relational Robustness and Redundancy

This subsection examines governance of relational resilience through alternative paths, redundancy, diversity, and dependency reduction. Its objective is to identify structural mechanisms that preserve function after loss or degradation of particular relations.

A relational system can maintain function through multiple paths connecting important components. Redundancy can provide alternatives when one relation, node, organization, or infrastructure becomes unavailable.

Let $\kappa_{ij}(C_t)$ denote a domain-specific measure of independent or sufficiently distinct paths connecting components i and j. A redundancy intervention is represented by Equation 60.

$$\kappa_{ij}(C_t) \longrightarrow \kappa_{ij}(C_t^+). \tag{60}$$

Equation 60 represents a change in relational alternatives between system components.

Governance applications include diversified supply chains, backup communication channels, multiple dispute-resolution routes, alternative payment infrastructures, redundant administrative capacity, and overlapping institutional competence.

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Redundancy can increase robustness while imposing coordination, maintenance, and resource costs. Multiple pathways can also generate conflicting signals or unclear accountability. Relational robustness therefore requires analysis of both failure tolerance and governance complexity.

The appropriate degree of redundancy depends upon the consequence of failure, the correlation among alternative paths, the cost of maintaining capacity, and the temporal requirements of recovery.

9.14 Temporal Network Reconfiguration

This subsection examines relational structures whose topology and coupling change through time. Its objective is to extend relational governance beyond static network representations and to identify rewiring, relation formation, dissolution, and institutional adaptation as temporal structural processes.

Real governance networks evolve. Organizations enter and leave partnerships, jurisdictions merge or divide, contracts begin and terminate, dependencies strengthen, professional communities form, information channels migrate, and platform relations change through repeated interaction.

A temporal relational structure is represented by Equation 61.

$$C_{t+\Delta t} = \mathcal{R}_{\Delta t}\left(C_t, x_{\leq t}, R_{\leq t}, \mathcal{B}_{\leq t}\right), \tag{61}$$

where $\mathcal{R}_{\Delta t}$ denotes the endogenous relational-evolution operator. Equation 61 permits current states, rules, and background conditions to influence subsequent relational architecture.

Governance can intervene directly into $\mathcal{R}_{\Delta t}$ when the policy alters the process through which relations are formed or dissolved. Procurement rules affecting long-term supplier concentration, platform matching mechanisms, institutional partnership programmes, and rules for organizational entry can all influence relational evolution.

This case approaches the boundary with generative-background governance. Direct governance of a specific relation or network-formation process remains relational. Governance of deeper conditions through which broad families of relations repeatedly become likely will be developed in the following background section.

9.15 Relational Governance under Partial Observability

This subsection examines the epistemic requirements associated with relational-structural intervention. Its objective is to distinguish the observable network from the underlying relational system and to identify missing ties, hidden dependencies, multiplex relations, temporal change, and measurement error as governance constraints.

Governance networks are rarely observed completely. Formal organizational charts can omit informal communication. Contract records can omit operational dependencies. Financial exposures can be partially reported. Platform interaction graphs can omit off-platform relations. International institutional maps can conceal informal coordination and political influence.

Let $\widetilde{C}_t$ denote the observed relational representation. The relational observation process is represented by Equation 62.

$$\widetilde{C}_t = \mathcal{O}_t^C\left(C_t\right) + \varepsilon_t^C. \tag{62}$$

Equation 62 distinguishes the operationally available network from the underlying relational structure.

Intervention based on incomplete network information can remove apparently redundant links that in fact provide critical bridging capacity. A hidden dependency can undermine a diversification strategy. Aggregating several relation types into one graph can conceal that two institutions remain highly dependent through another layer.

Multilayer representations can reduce some forms of this distortion while increasing data and modeling requirements [72]. Relational depth therefore creates an epistemic trade-off analogous to the one identified for dynamical governance.

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The GR framework consequently treats relational observability as an explicit property of any structural intervention.

9.16 Cross-Layer Boundaries of Relational Intervention

This subsection clarifies the boundaries among relational-structural governance, state-and-rule governance, dynamical-process governance, and generative-background governance. Its objective is to preserve classification according to direct structural support when one institutional programme contains several interacting mechanisms.

A statute defining an institutional relation directly transforms R_t and can authorize a subsequent transformation of C_t. Creation of the relation itself constitutes relational intervention. Changes in the behavior flowing through that relation can arise through F_t.

A temporary change in interaction frequency can be modeled as a dynamical intervention when it acts as an operational control input. A persistent reorganization of dependency or communication architecture acts upon C_t.

The boundary between relational structure and generative background requires particular care. A realized network of institutional relations belongs to C_t. A metric, field, symmetry, resource environment, or connection structure that shapes a broad family of possible relations belongs to $\mathcal{B}_t$.

An interface between two named institutions can therefore constitute relational governance. A general translation architecture that determines how arbitrary local institutional representations can be transported among a class of domains can receive a deeper background representation.

The distinction is functional rather than terminological. Classification follows the modeled object through which the governance intervention directly changes system generation.

9.17 Relational-Structural Governance Classification

This subsection consolidates the relational mechanisms developed in this section into a comparative taxonomy. Its objective is to distinguish topology, ties, coupling, boundaries, interfaces, modules, dependency positions, multilayer structures, distributed decision centers, controllability, cascades, redundancy, and relational evolution while preserving their possible combinations.

Table 9 summarizes the principal relational-structural governance mechanisms.

Table 9 demonstrates that relational-structural governance contains several analytically distinct operations. Topology determines which relations exist. Coupling determines their effective strength and transmission structure. Boundaries organize participation. Interfaces permit interaction across heterogeneous domains. Modularity organizes subsystem structure. Centrality and dependency describe relational concentration. Multilayer models represent heterogeneous dependencies. Polycentricity distributes decision centers. Cascade and redundancy governance address propagation and failure tolerance.

Several mechanisms can operate simultaneously. A governance reform can create new regional decision centers, connect them through a shared information interface, reduce dependence on a central organization, preserve modular local autonomy, and introduce redundant cross-regional communication paths. The taxonomy decomposes this arrangement according to its direct relational operations.

The relational layer also clarifies the distinction between entities and the conditions through which entities can act. Governance can transform the effective capacity of an actor by changing its dependencies, interfaces, network position, or membership while leaving its internal state comparatively stable. Relational constitution therefore becomes operational within the taxonomy.

Relational structures themselves remain generated structures. Repeated interaction, historical rules, resource distributions, technological infrastructures, cultural classifications, and background fields can shape which relations emerge and persist. The relational layer consequently leads directly to the deepest category of the taxonomy.

The following section develops generative-background governance. It examines governance of the conditions through which ranges of states, trajectories, and relations acquire their effective possibilities.

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Table 9: Taxonomy of relational-structural governance mechanisms

Governance mechanism	Relational object	Structural operation	Characteristic function
Network-topology governance	E_t, A_t	Addition, removal, or redirection of relations	Modification of connectivity and path structure
Tie and channel governance	e_{ij}	Creation or transformation of selected relational channels	Bridging, mediation, communication, cross-group linkage
Coupling governance	W_t, Γ_t	Modification of relation strength, direction, sign, or transmission	Adjustment of dependency and interaction intensity
Boundary and membership governance	$V_t^{(m)}$, boundary relations	Reconfiguration of participation and subsystem membership	Inclusion, separation, compartmentalization, domain formation
Interface governance	Ψ_{ij}	Translation and transport across heterogeneous subsystems	Interoperability and cross-domain coordination
Modular governance	Block structure of C_t	Modification of within- and cross-module organization	Local autonomy, coordination, and disturbance containment
Centrality and dependency governance	Relational position	Redistribution of bottlenecks, brokerage, or dependency	Concentration reduction and alternative access
Multilayer governance	$\mathcal{L}_t$, interlayer relations	Coordination across heterogeneous relation types	Cross-domain dependency and multilayer propagation
Polycentric restructuring	Decision centers and their relations	Creation, consolidation, or recoupling of governance centers	Distributed authority and institutional diversity
Relational controllability	Driver and intervention structure	Modification of control-access relations	Distribution of effective intervention channels
Cascade governance	Transmission and dependency structure	Reduction, redirection, or containment of propagation	Systemic-risk and contagion management
Redundancy governance	Alternative relational paths	Creation or preservation of substitutable connections	Failure tolerance and continuity
Temporal network governance	$\mathcal{R}_{\Delta t}$	Intervention into relation formation and dissolution	Longitudinal restructuring and network adaptation

Generative-condition governance, structural-flow governance, metric and background-geometry governance, field governance, symmetry governance, gauge-like and connection governance, and governance of endogenous background emergence are developed as distinct formal mechanisms.

10 Generative-Background Governance

This section develops the fourth structural layer of the Generative-Relational governance taxonomy. Its role is to classify interventions directed toward structures that condition the generation of states, trajectories, relations, and institutional possibilities across extended domains and temporal horizons. The analysis develops generative conditions, effective possibility spaces, resource and information backgrounds, metric and accessibility governance, field and potential governance, symmetry governance, connection and gauge-like governance, structural-flow governance, historical memory, and endogenous background formation. Each mechanism is defined through the background object transformed, its relation to lower-layer structures, its formal representation, and the conditions required for empirical interpretation.

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Generative-background governance concerns structures represented collectively by $\mathcal{B}_t$. These structures influence families of possible dynamics and relations while remaining analytically distinguishable from the currently realized state, a particular explicit rule, an individual trajectory, or a realized network connection. Background structures can include resource and capacity conditions, information environments, effective accessibility, geometric structures, distributed fields, symmetry structures, transport connections, historically accumulated flows, and the mechanisms through which such structures reproduce themselves.

The concept has precedents in several established traditions. North treats institutions as historically evolving structures that shape incentives and subsequent economic and political development [90]. Ostrom's Institutional Analysis and Development framework places action situations within configurations of rules, biophysical conditions, and community attributes [94]. Sen's capability approach distinguishes resources and formal rights from substantive opportunities available to persons under heterogeneous conversion conditions [114, 115]. These theories possess distinct purposes and conceptual vocabularies. Their relevance here lies in the shared recognition that effective action depends upon conditions extending beyond a currently observed action or formal rule.

10.1 Background Structure and Structural Mediation

This subsection establishes the formal boundary of generative-background governance. Its objective is to distinguish intervention into a background structure from intervention into a currently realized state, an explicit rule, a dynamical vector field, or a realized relational architecture. The distinction is based on structural mediation: a background structure generates or conditions families of lower-layer structures through which subsequent system evolution proceeds.

A refined representation of the generative background is provided by Equation 63.

$$\mathcal{B}_t = (Q_t, I_t, g_t, \Phi_t, G_t, A_t^{\text{conn}}, J_t, \mathcal{E}_t, \ldots)\,. \tag{63}$$

In Equation 63, Q_t denotes resource and capacity conditions, I_t denotes informational conditions, g_t denotes an effective metric or geometric structure, Φ_t denotes a distributed field-like structure, G_t denotes a relevant symmetry structure, A_t^{conn} denotes a connection or transport structure, J_t denotes a structural flow, and $\mathcal{E}_t$ denotes an endogenous background-formation operator.

The role of a background can be represented through a structural-generation map. This relation is introduced by Equation 64.

$$\mathcal{H}_t : \mathcal{B}_t \longmapsto \left(X_t^{\text{eff}}, F_t, C_t\right). \tag{64}$$

Equation 64 represents the way a background can condition the effective possibility space X_t^{eff}, the effective dynamics F_t, and the relational structure C_t. The map $\mathcal{H}_t$ is domain-specific and can itself depend upon explicit rules, actor characteristics, and historical conditions.

A background intervention acts upstream within this mediation structure. The generic operation is represented by Equation 65.

$$\mathcal{B}_t \longrightarrow \mathcal{B}_t^{+} = \mathcal{U}_t^{\mathcal{B}}\left(\mathcal{B}_t\right). \tag{65}$$

Equation 65 identifies direct support on the background. Subsequent changes in F_t, C_t, and reachable states arise through the background-generation map.

This mediation criterion distinguishes background governance from ordinary parameter adjustment. A temporary change to a control coefficient inside an already specified vector field belongs to dynamical-process governance. A change to the institutional, infrastructural, informational, or geometric structure from which a family of such coefficients is generated can belong to generative-background governance.

Persistence and temporal scale provide useful secondary indicators. Background structures frequently evolve more slowly than individual states or operational controls. Structural mediation remains the pri-

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mary classificatory criterion because some background structures can change rapidly during war, technological disruption, institutional collapse, or major legal transformation.

10.2 Generative Conditions and Effective Possibility

This subsection develops generative-condition governance as the broadest mechanism within the fourth layer. Its objective is to formalize the distinction between formally admissible possibilities and effectively accessible possibilities under heterogeneous resource, informational, relational, and institutional conditions.

The state-and-rule layer defined formal admissibility through $\mathcal{A}_{R_t}(x)$. For actor i, the effectively accessible subset under background $\mathcal{B}_t$ is represented by Equation 66.

$$\mathcal{A}_i^{\text{eff}}(x_t \mid R_t, \mathcal{B}_t) = \{a \in \mathcal{A}_{R_t}(x_t) \mid \chi_i(a; \mathcal{B}_t) = 1\}. \tag{66}$$

In Equation 66, $\chi_i(a; \mathcal{B}_t)$ represents effective accessibility under the selected domain model. It can depend upon financial capacity, information, language, geographic access, technology, institutional recognition, physical ability, time, documentation, or other relevant conditions.

This distinction has a close conceptual relative in Sen's capability approach, which directs evaluation toward substantive opportunities and human capabilities and gives importance to the conversion of resources into effective possibilities [114, 115]. The GR formalism uses the distinction for a broader systems purpose. Its background objects can concern persons, organizations, communities, infrastructures, or other governed components.

A formal entitlement can therefore remain constant while the effective possibility set changes substantially. Construction of accessible transportation, provision of translation, reduction of application costs, creation of legal assistance, expansion of communication infrastructure, or improvement of institutional interoperability can alter effective possibilities through background conditions.

Generative-condition governance consequently focuses on the structures through which future action becomes possible. Its descriptive definition leaves the selection and evaluation of desirable possibilities for later normative analysis.

10.3 Resource and Capacity Backgrounds

This subsection examines material and institutional capacities that condition the generation of future action. Its objective is to distinguish direct resource transfer from governance of durable resource structures and capability-producing arrangements.

Let Q_t denote the distribution and organization of resources relevant to the governed process. An actor-specific capacity vector can be represented by $q_i(t)$, while the system-wide background includes relations governing access, replenishment, conversion, and accumulation.

A background-resource intervention is represented by Equation 67.

$$Q_t \longrightarrow Q_t^{+}. \tag{67}$$

Equation 67 receives a background classification when the intervention changes a durable resource condition through which families of future actions acquire feasibility.

The distinction from direct state governance is temporal and structural. Payment of a particular benefit can directly modify a present resource state. Creation of a durable financing institution, public transportation system, educational infrastructure, common research facility, or permanent access mechanism can change the conditions through which many future states become reachable.

North's account of institutions emphasizes the role of institutional structures in shaping incentives and long-run patterns of economic performance [90]. Ostrom similarly examines how institutional, community, and biophysical conditions structure recurrent action situations [94]. These traditions provide established institutional precedents for treating durable conditions as causally relevant to recurring action.

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Capacity backgrounds can also be self-reinforcing. Access to education can generate expertise, expertise can improve organizational capacity, and organizational capacity can increase access to future resources. Background governance therefore frequently concerns the reproduction structure of capacity in addition to its current distribution.

10.4 Informational Background Governance

This subsection develops governance of information environments whose structure conditions future perception, decision, coordination, and learning. Its objective is to distinguish delivery of a particular message from the construction of persistent informational conditions through which many later decisions occur.

Let I_t denote the informational background available to governed actors. The background can contain availability, discoverability, reliability, classification, interoperability, provenance, linguistic accessibility, and institutional channels through which information becomes usable.

A transformation of the information background is represented by Equation 68.

$$I_t \longrightarrow I_t^+ = \mathcal{U}_t^I(I_t). \tag{68}$$

Equation 68 describes intervention into persistent information conditions. Examples include creation of open-data infrastructure, public registries, interoperable scientific repositories, translation systems, persistent provenance architectures, public statistical systems, and institutional arrangements supporting access to reliable knowledge.

The boundary with state-and-rule governance remains clear. A disclosure rule creates a formal obligation in R_t. A persistent public information infrastructure through which disclosed information becomes searchable, comparable, and reusable changes I_t.

The boundary with dynamical feedback is similarly distinct. A current signal used to update an intervention belongs to the feedback process. The institutional architecture determining which signals can be generated, preserved, discovered, and trusted belongs to the information background.

Informational background governance is especially important under heterogeneity. Equal provision of raw information can generate unequal effective access where language, technical expertise, disability, documentation formats, or institutional interfaces differ. The background can therefore be actor-dependent even when the underlying information resource is shared.

10.5 Institutional Context and Action-Situation Conditions

This subsection connects generative-background governance with established institutional analysis. Its objective is to identify contextual structures that repeatedly condition action situations and to distinguish these structures from individual institutional decisions occurring within them.

Ostrom's Institutional Analysis and Development framework treats action situations within a broader configuration that includes rules, attributes of the community, and biophysical or material conditions [94]. Interactions generate outcomes, and repeated outcomes can contribute to later changes in contextual conditions.

This architecture is closely related to the recursive structure required by a Generative-Relational background. A focal interaction can be analysed locally, while the conditions under which similar interactions recur possess a distinct analytical level.

Let Z_t denote a focal action situation and Θ_t denote its contextual conditions. Their relation is represented by Equation 69.

$$Z_t = \mathcal{Z}\left(R_t, C_t, \Theta_t\right), \qquad \Theta_t \subseteq \mathcal{B}_t. \tag{69}$$

Equation 69 represents an action situation as conditioned by rules, realized relations, and a broader background context.

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Governance of the context can alter recurrent action situations without specifying their individual outcomes. Examples include changes in shared infrastructure, institutional knowledge, organizational capacity, baseline resource conditions, or common informational environments.

The GR background category extends this contextual intuition through formal families such as metrics, fields, connections, and structural flows. These additional representations become appropriate only where their mathematical objects can be mapped to observable or operational institutional structures.

10.6 Metric and Accessibility Governance

This subsection develops metric governance as intervention into the effective geometry through which distances, costs, accessibility, and path structures are represented. Its objective is to distinguish movement within a given possibility geometry from governance that changes the geometry itself. Riemannian geometry supplies the formal vocabulary when the modeled state space satisfies the required smoothness and metric assumptions [79].

Let M denote a smooth manifold representing an effective possibility space. A Riemannian metric g_t defines the local line element. This structure is represented by Equation 70.

$$ds^2 = g_{\mu\nu}(z,t)\, dz^\mu dz^\nu. \tag{70}$$

Equation 70 assigns local effective distances through the metric tensor $g_{\mu\nu}$.

The corresponding length of a path γ is introduced by Equation 71.

$$L_g(\gamma) = \int_\gamma \sqrt{g_{\mu\nu}\, dz^\mu dz^\nu}. \tag{71}$$

Equation 71 permits governance-relevant notions of distance to differ from physical geographic distance. A path can represent institutional transition, administrative effort, information acquisition, educational progression, organizational coordination, or another domain-specific process.

Metric governance directly changes the effective geometry. The transformation is represented by Equation 72.

$$g_t \longrightarrow g_t^+. \tag{72}$$

Equation 72 can represent an intervention that changes the cost or accessibility structure of classes of paths. Construction of transportation infrastructure, simplification of cross-institutional procedures, common credential systems, translation infrastructure, or interoperability standards can reduce effective distances among relevant states.

The metric can also be actor-dependent. Heterogeneous actors can experience different effective geometries under identical formal rules. An actor-specific metric is represented by Equation 73.

$$ds_i^2 = g_{\mu\nu}^{(i)}(z,t)\, dz^\mu dz^\nu. \tag{73}$$

Equation 73 makes differential accessibility formally visible. Institutional reforms can then be evaluated according to their effects on the geometries experienced by different participants.

Information geometry provides an additional rigorous example of geometry constructed on a non-physical space. Amari develops differential-geometric structures on statistical manifolds and applies them to inference, optimization, learning, and information processing [4]. A governance application of information geometry would require a defined statistical family and a meaningful interpretation of its geometric quantities.

Metric language therefore supplies a formal instrument rather than a metaphor alone. Its use requires identification of the modeled manifold, the meaning of distance or cost, the empirical construction of g_t, and the observable consequences associated with paths in that geometry.

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10.7 Field and Potential Governance

This subsection develops field governance as intervention into distributed conditions defined across a domain. Its objective is to represent background influences whose value varies with position in a state, institutional, geographic, relational, or other modeled space. Classical field theory supplies a precise mathematical precedent for fields defined over a base space [43]; the present use concerns a formal modeling language for governance.

Let Φ_t denote a field defined over a domain M. Its representation is given by Equation 74.

$$\Phi_t : M \longrightarrow \mathbb{R}^k. \tag{74}$$

Equation 74 allows background conditions to vary across locations in the modeled domain.

The field can condition local dynamics through a field-dependent evolution law. This dependence is represented by Equation 75.

$$\dot{x} = F\left(x; \Phi_t(x)\right). \tag{75}$$

Equation 75 distinguishes the field Φ_t from the resulting vector field of system evolution. Governance directed toward Φ_t acts on the background from which local dynamics are generated.

Possible governance fields include spatially distributed resource access, institutional support, informational visibility, regulatory burden, environmental exposure, risk, or service availability. Each application requires an empirically defined field and a mapping from field value to governed dynamics.

Some models can possess a scalar potential V from which a gradient-like dynamics is generated. When such a model is justified, the corresponding dynamics can be represented by Equation 76.

$$\dot{x} = -\operatorname{grad}_g V(x). \tag{76}$$

Equation 76 provides a special case in which modifying V reshapes a whole landscape of local directions. The existence of a potential requires structural assumptions and therefore cannot be inferred from the observation of social movement alone.

Field governance is classified within the background layer when the intervention changes the distributed condition from which a family of local dynamics is generated. Direct modification of one local trajectory remains dynamical-process governance.

10.8 Symmetry Governance

This subsection develops symmetry governance as intervention into transformation structures under which selected system properties remain invariant. Its objective is to formalize equivalence, representation independence, and structured differentiation in governance systems. Differential geometry and mathematical physics provide standard languages of Lie-group actions and invariance [127].

Let a group G act on a state manifold M. The action is represented by Equation 77.

$$G \times M \longrightarrow M, \qquad (g, x) \longmapsto g \cdot x. \tag{77}$$

Equation 77 supplies a formal representation of transformations treated as belonging to one symmetry family.

For a dynamical model, equivariance under the group action can be expressed by Equation 78.

$$F(g \cdot x) = Dg_x F(x). \tag{78}$$

Equation 78 states that the dynamics transform consistently under the specified group action.

In governance, a symmetry can represent a formally defined invariance across jurisdictions, representations, categories, coordinate systems, or institutional positions. A symmetry claim requires specification of the transformation group and the property preserved by that transformation.

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Symmetry governance can preserve an existing invariance, restore an institutionally relevant invariance, or deliberately modify a symmetry structure where differentiated treatment corresponds to relevant differences. The concept therefore carries no intrinsic requirement of uniform treatment.

This distinction is important for differential governance. Equality under a specified transformation and differentiated response under structurally different conditions can coexist. The mathematical model makes explicit which transformations are regarded as equivalent and which differences alter the governing mechanism.

Symmetry governance belongs to the background layer when the transformation structure organizes a family of states, rules, or relations. A single equal treatment rule remains state-and-rule governance; transformation of the underlying equivalence structure can operate at greater structural depth.

10.9 Connection and Transport Governance

This subsection develops connection governance as a formal mechanism for transporting information, norms, classifications, or other structured objects across heterogeneous local representations. Its objective is to distinguish a single interface relation from a general transport structure defined across a family of local frames. The formal language uses bundles and connections in their standard differential-geometric sense [127].

Suppose a base space M is covered by local domains $\{U_\alpha\}$, each carrying a local representation. On overlaps, transition functions relate the local representations. This structure is introduced by Equation 79.

$$g_{\alpha\beta} : U_\alpha \cap U_\beta \longrightarrow G. \tag{79}$$

Equation 79 represents a transformation between local frames through a group G.

A connection provides a rule for comparing or transporting local objects across neighboring regions. A connection one-form will be denoted by A^{conn} to distinguish it from the adjacency matrices used in Section 9.

Under a change of local frame, a standard connection transformation is represented by Equation 80.

$$A^{\text{conn}}_\beta = g^{-1}_{\alpha\beta} A^{\text{conn}}_\alpha g_{\alpha\beta} + g^{-1}_{\alpha\beta} dg_{\alpha\beta}. \tag{80}$$

Equation 80 expresses the compatibility of local connection representations under a change of frame.

For governance, the formal construction becomes meaningful where several local institutional or interpretive systems represent related objects through different local conventions and where a defined transport mechanism connects those representations. Potential applications include credential recognition, legal translation, data interoperability, cross-jurisdictional classification, or multilingual institutional systems.

The distinction from interface governance in the relational layer concerns scope. An interface Ψ_{ij} connects two identified systems. A connection provides a rule for transport across a family of local representations throughout a structured domain.

Connection governance can therefore modify how institutional objects are transported while allowing local representations to remain heterogeneous. This architecture provides one formal approach to preserving local variation while maintaining cross-system compatibility.

10.10 Gauge-Like Governance

This subsection establishes a restricted use of gauge language within the Generative-Relational framework. Its objective is to identify the mathematical conditions under which local representations, transformation groups, connections, and invariants justify a gauge-like description. The term is reserved for models containing these structures explicitly.

A gauge-like governance model requires at least four components: a family of local representations, a transformation group connecting those representations, quantities whose interpretation is invariant under

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admissible representation changes, and a connection or equivalent structure governing transport among local frames.

The curvature associated with a connection provides one measure of the failure of local transport to remain path-independent. Its standard local form is introduced by Equation 81.

$$\mathcal{F}_A = dA^{\text{conn}} + A^{\text{conn}} \wedge A^{\text{conn}}. \tag{81}$$

Equation 81 defines the curvature of the connection in a non-Abelian local representation.

A governance interpretation can use curvature where transport around institutionally meaningful loops produces residual discrepancy. For example, a credential translated across several jurisdictions and returned to its origin can acquire inconsistencies if the recognition system possesses path-dependent translation rules. A comparable structure can arise in cross-system data semantics or legal classification.

Gauge-like governance can then concern the design of transition functions, transport connections, invariant quantities, or curvature-reducing compatibility structures.

The mathematical requirements are substantive. Cultural difference, jurisdictional heterogeneity, or pluralism alone supplies insufficient structure for a gauge model. A formal gauge-like description requires identifiable local frames, transformations, invariants, and transport rules.

This restriction preserves the analytical value of gauge theory while avoiding a loose identification between social heterogeneity and physical gauge fields.

10.11 Structural Flows on Manifolds

This subsection develops Structural Flows on Manifolds as a proposed Generative-Relational representation of slowly accumulated distributions and flows that participate in the production of future background conditions. Its objective is to distinguish structural flow from the immediate trajectory field F_t of the dynamical-process layer. The formal construction combines a manifold, a background density, a structural current, and source or sink terms.

Let M denote the manifold on which a background quantity is distributed, let $\rho(z,t)$ denote its density, and let $J^\mu(z,t)$ denote the corresponding structural flow. A continuity-type relation is represented by Equation 82.

$$\frac{\partial \rho}{\partial t} + \nabla_\mu J^\mu = \sigma. \tag{82}$$

Equation 82 permits σ to represent generation, depletion, entry, exit, or transformation of the modeled background quantity.

Possible structural quantities include institutional capacity, accumulated knowledge, infrastructure, financial capacity, population distribution, recognition, or other persistent resources whose spatial or relational distribution changes through repeated flows.

Structural-flow governance can alter the source structure σ, the transport current J, the metric through which transport occurs, or the institutional mechanisms generating the flow. The classification belongs to the background layer when the flow produces or redistributes a persistent condition that subsequently shapes families of lower-layer dynamics.

The same mathematical appearance can arise at different structural layers. A continuity equation describing immediate movement of actors can belong to a dynamical model. A continuity equation describing accumulation of long-lived institutional capacity can represent background formation. The modeled object and its generative role determine the classification.

Structural flows also provide a mechanism for connecting history with geometry. Repeated flows can alter the distribution ρ, while accumulated distribution can influence effective metrics, fields, or future flows. Structural Flow on Manifold models can therefore support recursive background-generation processes.

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10.12 Timescale Separation and Slow Structural Variables

This subsection examines the temporal relation between fast system evolution and slower structural formation. Its objective is to provide a formal language for background variables whose cumulative evolution shapes lower-layer dynamics over extended periods.

A simple fast-slow representation is introduced by Equation 83.

$$\begin{aligned} \dot{x} &= F(x;\mathcal{B}), \\ \dot{\mathcal{B}} &= \epsilon H(\mathcal{B},x), \qquad 0<\epsilon\ll 1. \end{aligned} \tag{83}$$

Equation 83 represents a system in which $\mathcal{B}$ evolves on a slower characteristic timescale than x.

This representation can model gradual changes in infrastructure, institutional capacity, trust, demographic structure, knowledge systems, ecological conditions, or other slow variables. Fast processes repeatedly occur within a background that changes incrementally through their cumulative effects.

Governance can then act on either side of the coupled system. Short-horizon intervention into F belongs to the dynamical layer. Intervention into H, or into the structural variables whose accumulation changes the background, belongs to the background layer.

Timescale separation also explains why background intervention can produce limited immediate visible effect while substantially altering long-horizon system evolution. Evaluation based exclusively on short-horizon state variables can therefore miss structural changes whose consequences emerge later.

The parameter ϵ is model-dependent. Some institutional backgrounds can change abruptly, and several timescales can coexist. Structural mediation remains the primary taxonomic criterion.

10.13 Historical Memory and Path Formation

This subsection develops historical memory as a background structure through which earlier system states and interventions continue to affect current possibilities. Its objective is to formalize cumulative institutional effects and distinguish historical background from a memoryless dynamical state.

North emphasizes that institutional change connects past, present, and future and gives historical sequence an important role in economic and political development [90]. Path dependence similarly appears in the political analysis reviewed in Section 5.

A background with distributed historical memory can be represented through a memory kernel. This representation is introduced by Equation 84.

$$\mathcal{B}_t = \mathcal{B}_0 + \int_0^t K(t-s)\,\Xi\left(\mathfrak{S}_s\right)\,ds. \tag{84}$$

Equation 84 represents the accumulated contribution of past configurations through a kernel K and a domain-specific structural contribution map Ξ.

The kernel can encode persistence, decay, delayed influence, or multiple timescales of institutional memory. A recent event can have strong short-term influence and rapid decay, while infrastructure, law, social classification, or organizational practice can leave longer-lasting structural residues.

Memory governance can therefore intervene in preservation, decay, archival structure, institutional learning, repair, or mechanisms through which past events continue to influence future possibilities.

The normative meaning of memory remains context-dependent. Preservation can support accountability and institutional learning, while persistent historical structures can also reproduce exclusion or dependency. The formal model identifies persistence mechanisms and leaves their evaluation for later analysis.

10.14 Endogenous Background-Emergence Governance

This subsection develops governance directed toward the mechanism through which backgrounds themselves are produced. Its objective is to represent the deepest recursive form of the proposed taxonomy: intervention into the operator that transforms relational history into future generative conditions.

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The endogenous background relation introduced in Section 6 can be refined through a parameterized emergence operator. This representation is given by Equation 85.

$$\mathcal{B}_{t+\Delta t} = \mathcal{E}_{\theta_t}\left(\mathcal{B}_t, \mathfrak{S}_{[t-\tau,t]}\right). \tag{85}$$

Equation 85 represents the next background as a function of the current background and a finite or extended history of system configurations.

Background-emergence governance directly modifies the generative mechanism $\mathcal{E}_{\theta_t}$. The corresponding intervention is represented by Equation 86.

$$\mathcal{E}_{\theta_t} \longrightarrow \mathcal{E}^{+}_{\theta_t}. \tag{86}$$

Equation 86 represents governance of the process through which future structural conditions are reproduced.

Examples include reforms to financing systems that repeatedly generate institutional concentration, educational structures that reproduce access to future professional positions, procurement systems that continually regenerate supplier dependency, platform architectures that repeatedly generate visibility inequalities, or knowledge institutions that determine which contributions enter durable public records.

This mechanism differs from one-time correction of the resulting distribution. A state intervention can redistribute a current resource. Background-emergence governance changes the process through which subsequent distributions are continually produced.

The distinction provides a formal foundation for the GR principle of identifying obstacles to generativity, altering the conditions producing those obstacles, and creating processes capable of sustaining subsequent generation.

10.15 Recursive Background and Relation Formation

This subsection examines the recursive coupling between generative backgrounds and relational structures. Its objective is to represent the reciprocal process through which backgrounds shape relations and accumulated relations reshape backgrounds.

The coupled evolution is represented by Equation 87.

$$\begin{aligned} C_{t+\Delta t} &= \mathcal{R}_{\Delta t}\left(C_t; \mathcal{B}_t, x_t, R_t\right), \\ \mathcal{B}_{t+\Delta t} &= \mathcal{E}_{\Delta t}\left(\mathcal{B}_t; C_{\leq t}, x_{\leq t}, R_{\leq t}\right). \end{aligned} \tag{87}$$

Equation 87 represents bidirectional generation between relational architecture and generative background.

A transportation network can alter patterns of social and economic interaction; repeated interaction can subsequently generate new infrastructure. A research institution can create collaboration opportunities; repeated collaborations can create enduring disciplinary resources and standards. A legal framework can create organizational relations whose repeated operation eventually changes institutional expectations and administrative capacity.

This recursion explains why the relational and background layers remain distinct while strongly coupled. A realized relation constitutes C_t. The conditions repeatedly generating families of relations belong to $\mathcal{B}_t$.

Governance can therefore act on a current network, on the conditions generating future networks, or on both through a multilayer intervention.

10.16 Background Heterogeneity and Differential Governance

This subsection examines heterogeneity in the way common background structures affect different system components. Its objective is to formalize differential accessibility and response while preserving a shared system representation.

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Actors can possess different conversion functions between a common background resource and effective possibility. Let $\chi_i(\mathcal{B})$ denote the actor-specific conversion structure. The corresponding effective generative set is represented by Equation 88.

$$\mathscr{G}_\tau^{(i)} = \mathscr{G}_\tau \left(\mathfrak{S}_t; \chi_i(\mathcal{B}_t) \right). \tag{88}$$

Equation 88 permits two actors exposed to a nominally shared institutional environment to possess different effective future possibilities.

This heterogeneity is compatible with Sen's emphasis on variation in the conversion of resources into capabilities [114]. Within GR, the concept extends to organizations, communities, jurisdictions, and other heterogeneous components.

Differential governance can therefore use actor-specific or context-specific background models. Equal formal rules can coexist with differentiated infrastructural support where the relevant conversion conditions differ.

Such differentiation requires normative justification and empirical knowledge. The structural model identifies heterogeneous generative conditions, while the legitimacy and justice of differential intervention belong to the normative analysis developed later.

10.17 Background Governance under Partial Observability

This subsection examines the epistemic requirements of generative-background governance. Its objective is to identify the difficulties associated with observing slow variables, latent structures, effective geometry, distributed fields, and endogenous background-generation processes.

Background structures are often inferred indirectly. Effective accessibility can be estimated from observed paths, costs, failures, and barriers. A field can be reconstructed from distributed measurements. A metric can be inferred from empirical transition costs or statistical distinguishability. A background-emergence mechanism can be estimated from longitudinal data.

Let $\widetilde{\mathcal{B}}_t$ denote an estimated background. Its observational relation is represented by Equation 89.

$$\widetilde{\mathcal{B}}_t = \mathcal{O}_t^{\mathcal{B}} \left(\mathcal{B}_t \right) + \varepsilon_t^{\mathcal{B}}. \tag{89}$$

Equation 89 separates the effective background from the model available to governing actors.

Deep intervention can amplify the consequences of model error because a background can condition broad families of future trajectories. This feature creates strong requirements for model validation, staged implementation, monitoring, revisability, and preservation of alternative pathways.

Epistemic modesty is especially important for geometric and field-based models. A visually appealing manifold, metric, or field representation gains governance significance only through an empirically defensible mapping between formal objects and the system being governed.

Gauge-like models impose still stronger requirements because local representations, transformation groups, invariants, and connections must all be specified consistently.

Structural depth therefore increases the importance of explicit model assumptions and uncertainty analysis.

10.18 Cross-Layer Propagation from Generative Backgrounds

This subsection examines the downward propagation of background intervention into relational structures, effective dynamics, and reachable states. Its objective is to make explicit the generative pathway that motivates the designation of this layer as a background layer.

The generic propagation chain is represented by Equation 90.

$$\mathcal{B}_t^+ \xrightarrow{\mathcal{H}_t} \left(X_t^{\mathrm{eff}+}, C_t^+, F_t^+ \right) \xrightarrow{\mathcal{T}} x_{t+\tau}. \tag{90}$$

Equation 90 represents structural mediation from a background transformation to lower-layer structures and subsequent state evolution.

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A change in transportation infrastructure can modify effective distance, which alters possible relational connections and patterns of movement. A common data infrastructure can change institutional interoperability, which modifies network coordination and later administrative trajectories. Educational infrastructure can alter capacity distributions, which affect future occupational and organizational relations.

The chain can also run recursively upward. Repeated lower-layer processes can modify the background through the emergence operator $\mathcal{E}$. The complete system therefore contains both background conditioning and endogenous background regeneration.

This bidirectional structure supports the use of structural depth while preserving historical materiality. Backgrounds condition processes, and processes participate in producing later backgrounds.

10.19 Generative-Background Governance Classification

This subsection consolidates the fourth structural layer into a comparative taxonomy. Its objective is to distinguish generative conditions, resource and information backgrounds, metric structures, fields, symmetries, connections, structural flows, memory structures, and emergence mechanisms according to their direct objects and generative roles.

Table 10 summarizes the principal mechanisms developed in this section.

Table 10 demonstrates that generative-background governance contains several mathematically and institutionally distinct mechanisms. Generative-condition governance concerns effective possibility. Resource and information governance concern durable capacities. Metric governance concerns accessibility geometry. Field governance concerns distributed conditions. Symmetry governance concerns transformation invariance. Connection governance concerns transport among local representations. Structural flows concern persistent accumulation. Background-emergence governance concerns the production mechanism of the background itself.

These mechanisms can coexist within one intervention. A multilingual international educational programme can establish common recognition rules, translation infrastructure, financing, cross-jurisdictional connections, and durable knowledge repositories. The rule component belongs to state-and-rule governance, the institutional connections belong to relational-structural governance, and the translation, access, capacity, and knowledge infrastructures can constitute background components.

The fourth layer also completes the recursive architecture of the taxonomy. States evolve through dynamics; dynamics operate through relations and background conditions; repeated states and relations contribute to future background formation. Governance can enter this architecture at several structural depths.

Generative-background governance therefore provides a formal vocabulary for governance concerned with the conditions of future generation. Its aim is to make those conditions analytically explicit so that their structure, distribution, historical formation, uncertainty, and normative consequences can be examined.

The following section integrates the four layers through cross-layer governance composition. It examines simultaneous and sequential interventions, propagation matrices, intervention portfolios, recursive coupling, structural substitution, conflicts among layers, temporal coordination, and the relation between intervention depth and reversibility.

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Table 10: Taxonomy of generative-background governance mechanisms

Governance mechanism	**Background object**	**Structural operation**	**Generative function**
Generative-condition governance	$\mathcal{B}_t$	Modification of effective conditions of action	Expansion, contraction, or transformation of future possibilities
Resource and capacity governance	Q_t	Restructuring of durable resource and capacity conditions	Formation of future action capacity
Informational-background governance	I_t	Modification of persistent information availability and usability	Knowledge access, observability, learning, coordination
Institutional-context governance	Θ_t	Transformation of recurring action-situation conditions	Reconfiguration of recurrent institutional interaction
Metric governance	g_t	Modification of effective distance and path cost	Accessibility and feasible transition structure
Field governance	Φ_t	Modification of distributed background conditions	Spatial or relational conditioning of local dynamics
Potential governance	V_t	Reshaping of a modeled generative landscape	Modification of families of preferred or accessible trajectories
Symmetry governance	G_t and its action	Modification of invariance and equivalence structures	Structured consistency and differentiated transformation
Connection governance	A_t^{conn}	Modification of transport across local representations	Cross-context compatibility and institutional translation
Gauge-like governance	Local frames, transitions, invariants, connection	Coordination of heterogeneous local representations	Representation-compatible transport across plural systems
Structural-flow governance	ρ_t, J_t, σ_t	Modification of accumulation and persistent transport	Formation and redistribution of background structure
Historical-memory governance	K, Ξ	Modification of persistence and historical accumulation	Path formation and institutional memory
Background-emergence governance	$\mathcal{E}_t$	Transformation of the mechanism producing future backgrounds	Recursive reproduction or transformation of generative conditions

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11 Cross-Layer Governance Composition

This section integrates the four structural layers developed in the preceding sections into a theory of governance composition. Its role is to analyze governance arrangements whose operative mechanisms act through several structural objects, either simultaneously or through temporally ordered sequences. The section distinguishes multilayer intervention, simultaneous composition, sequential composition, order sensitivity, cross-layer propagation, reinforcement and interference, structural substitution, redundancy, temporal coordination, adaptive portfolios, scale composition, metagovernance, and recursive co-evolution. The resulting framework treats a governance arrangement as a structured composition of interventions whose effects depend upon both their individual mechanisms and their relations with one another.

The need for compositional analysis is already recognized within policy studies. Policy-mix research examines combinations and interactions among policy instruments and emphasizes properties such as consistency, coherence, and the historical development of instrument combinations [67]. Flanagan, Uyarra, and Laranja similarly argue for a dynamic and multi-level understanding of interactions among policies, actors, institutions, and instruments [40]. Rogge and Reichardt extend this perspective through a framework containing policy strategies, instrument mixes, policy processes, and characteristics of the resulting policy mix [108].

The Generative-Relational framework contributes an additional compositional dimension. Two instruments can interact while acting through the same structural layer, while another pair can interact across different structural layers. Composition therefore concerns both the combination of institutional instruments and the structural locations through which their effects enter the governed system.

11.1 Multilayer Intervention Representation

This subsection defines the representation of a governance intervention with components distributed across several structural layers. Its objective is to replace an exclusively single-layer description with a structured intervention profile while preserving the direct-support criterion established in Section 6.

A multilayer governance intervention is represented by Equation 91.

$$\mathbf{U}_t = \left(\mathcal{U}_t^{\mathrm{SR}}, \mathcal{U}_t^{\mathrm{D}}, \mathcal{U}_t^{\mathrm{REL}}, \mathcal{U}_t^{\mathrm{B}}\right). \tag{91}$$

In Equation 91, $\mathcal{U}_t^{\mathrm{SR}}$ denotes the state-and-rule component, $\mathcal{U}_t^{\mathrm{D}}$ denotes the dynamical-process component, $\mathcal{U}_t^{\mathrm{REL}}$ denotes the relational-structural component, and $\mathcal{U}_t^{\mathrm{B}}$ denotes the generative-background component. An inactive component can be represented by the identity transformation on its corresponding structural object.

The active layer set associated with an intervention is represented by Equation 92.

$$\mathcal{L}\left(\mathbf{U}_t\right) = \left\{ \ell \in \{\mathsf{SR}, \mathsf{D}, \mathsf{REL}, \mathsf{B}\} \;\middle|\; \mathcal{U}_t^{\ell} \neq \mathrm{Id}_{\ell} \right\}. \tag{92}$$

Equation 92 distinguishes a genuinely multilayer intervention from an intervention whose effects merely propagate into other layers.

A regulatory programme can illustrate the distinction. A statutory prohibition contributes a state-and-rule component. Continuous behavior-sensitive enforcement contributes a dynamical component. Creation of new reporting relations among agencies contributes a relational component. Construction of a persistent information infrastructure contributes a background component. The programme therefore possesses multilayer direct support.

A statute whose operation later changes social relations through endogenous behavioral adaptation remains directly state-and-rule governance when the relational change arises only through subsequent system evolution. The multilayer representation therefore preserves the distinction between composition and propagation.

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11.2 Simultaneous Composition

This subsection examines governance components activated within the same intervention period. Its objective is to represent coordinated action across structural layers while allowing interaction among the components during implementation.

A simultaneous composition operator acting upon the four layer-specific components is represented by Equation 93.

$$\mathcal{U}_t^{\text{joint}} = \mathcal{C}_t\left(\mathcal{U}_t^{\text{SR}}, \mathcal{U}_t^{\text{D}}, \mathcal{U}_t^{\text{REL}}, \mathcal{U}_t^{\text{B}}\right). \tag{93}$$

Equation 93 uses $\mathcal{C}_t$ as a general composition operator. Its form depends upon the institutional and mathematical structure of the application and therefore does not imply linear addition among layer-specific interventions.

Simultaneous composition is common in governance practice. A public-health programme can combine legal requirements, adaptive monitoring, coordination among hospitals and agencies, and durable testing or information infrastructure. An educational reform can combine entitlement rules, adaptive assessment, institutional partnerships, and financing or translation infrastructure.

The effectiveness of one component can depend upon another. A formal entitlement can produce limited effective access when informational or resource conditions remain unchanged. A sophisticated feedback mechanism can produce limited effect when the organizations required to act upon its signals lack functional connections.

The unit of analysis therefore becomes the composition as well as its components. Layer-specific classification identifies the mechanisms involved, while compositional analysis identifies their interaction.

11.3 Sequential Composition

This subsection examines governance interventions implemented in an ordered temporal sequence. Its objective is to formalize the possibility that the effect of a later intervention depends upon structural changes generated by an earlier intervention.

For interventions $\mathcal{U}_1, \ldots, \mathcal{U}_n$, the ordered composition is represented by Equation 94.

$$\mathcal{U}_{1:n} = \mathcal{U}_n \circ \mathcal{T}_{n-1} \circ \mathcal{U}_{n-1} \circ \cdots \circ \mathcal{T}_1 \circ \mathcal{U}_1, \tag{94}$$

where each $\mathcal{T}_k$ represents system evolution between governance interventions. Equation 94 makes the endogenous evolution occurring between policy actions part of the compositional structure.

Sequence can matter substantially. Construction of institutional capacity before delegation can produce a different trajectory from delegation before capacity exists. Creation of an information infrastructure before introducing adaptive regulation can produce different feedback quality from implementing the regulatory mechanism first.

Policy-design research similarly recognizes temporal dimensions of instrument mixes and the possibility that sequencing influences policy effects. The GR framework adds structural depth to this temporal analysis by specifying which system component is modified at each stage.

Sequential composition also permits staged governance. A programme can begin with information provision, proceed to voluntary coordination, introduce formal rules after institutional capacity develops, and activate stronger dynamical intervention when specified conditions emerge.

The resulting sequence can therefore move across structural layers without implying a progression from inferior to superior governance.

11.4 Order Sensitivity

This subsection develops order sensitivity as a property of governance composition. Its objective is to identify cases in which identical component interventions generate different results when implemented in different sequences.

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For two governance operators $\mathcal{U}_i$ and $\mathcal{U}_j$, an order-sensitivity measure is introduced by Equation 95.

$$\Omega_{ij}(\mathfrak{S}) = D_{\mathfrak{S}}\left[\mathcal{U}_j \circ \mathcal{U}_i(\mathfrak{S}), \mathcal{U}_i \circ \mathcal{U}_j(\mathfrak{S})\right], \tag{95}$$

where $D_{\mathfrak{S}}$ denotes a domain-specific distance or discrepancy measure between resulting system configurations. Equation 95 quantifies the significance of intervention order where such a measure can be defined.

Positive order sensitivity can arise through path dependence, threshold effects, institutional learning, irreversible investment, relation formation, or background accumulation. An early intervention can change the state upon which a later intervention operates.

The phenomenon is especially important across structural layers. A relational reform can alter the propagation of a later feedback mechanism. A background investment can change the effective accessibility of a later legal entitlement. A rule intervention can alter which relational structures subsequently become institutionally possible.

Order sensitivity therefore creates a governance-design problem distinct from selection of individual instruments.

11.5 Cross-Layer Propagation Structure

This subsection develops a system-wide representation of propagation among structural components. Its objective is to extend the pairwise sensitivity introduced in Section 6 into a block structure capable of representing cross-layer influence over time.

Let the structural state vector be ordered as $\mathbf{Z} = (x, R, F, C, \mathcal{B})$. A local cross-component propagation matrix over horizon τ is represented by Equation 96.

$$\mathbf{K}(\tau) = \begin{pmatrix} K_{xx} & K_{xR} & K_{xF} & K_{xC} & K_{x\mathcal{B}} \\ K_{Rx} & K_{RR} & K_{RF} & K_{RC} & K_{R\mathcal{B}} \\ K_{Fx} & K_{FR} & K_{FF} & K_{FC} & K_{F\mathcal{B}} \\ K_{Cx} & K_{CR} & K_{CF} & K_{CC} & K_{C\mathcal{B}} \\ K_{\mathcal{B}x} & K_{\mathcal{B}R} & K_{\mathcal{B}F} & K_{\mathcal{B}C} & K_{\mathcal{B}\mathcal{B}} \end{pmatrix}_{\tau}. \tag{96}$$

Each block $K_{ij}(\tau)$ in Equation 96 represents the local sensitivity of structural component i at horizon τ to a perturbation in component j at the intervention time.

The matrix need not be numerically estimable in every application. A qualitative block structure can identify known, hypothesized, weak, strong, or unobserved propagation channels.

Several governance properties become visible through this representation. Strong K_{CR} indicates substantial propagation from rules into relational structure. Strong $K_{F\mathcal{B}}$ indicates substantial background conditioning of effective dynamics. Strong $K_{\mathcal{B}C}$ indicates relational processes that contribute substantially to later background formation.

The matrix also permits asymmetry. Rules can strongly reorganize relations while current relations exert a weaker short-horizon effect on formal rules. The reverse influence can become substantial over longer horizons.

Cross-layer propagation is therefore temporally indexed and directionally structured.

11.6 Reinforcement, Interference, and Policy Interaction

This subsection examines interaction among governance components whose combined effects differ from the effects associated with their independent operation. Its objective is to connect structural-layer composition with established policy-mix concepts of coherence, consistency, and instrument interaction.

Howlett and Rayner emphasize cohesion and coherence in policy mixes and draw attention to the institutional history through which combinations of policy instruments develop [67]. Flanagan, Uyarra, and Laranja similarly emphasize interactions and tensions among policies across multiple dimensions

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[40]. Rogge and Reichardt treat consistency among policy-mix elements and coherence of policy processes as important characteristics of complex policy mixes [108].

Within the GR framework, interaction can arise through cross-layer propagation. A rule intervention and a background intervention can reinforce one another when the background supplies effective conditions for the formal rule to operate. They can interfere when one mechanism changes conditions in a direction that reduces the effectiveness of the other.

Let J denote a domain-specific evaluative functional applied at a selected horizon. The interaction effect of two interventions is represented by Equation 97.

$$\Delta_{ij}^{J} = J\left(\mathcal{U}_{ij}(\mathfrak{S})\right) - J\left(\mathcal{U}_{i}(\mathfrak{S})\right) - J\left(\mathcal{U}_{j}(\mathfrak{S})\right) + J\left(\mathfrak{S}\right). \tag{97}$$

Equation 97 provides one possible measure of non-additive intervention interaction. Its interpretation depends upon the selected functional J, which can be descriptive or normative according to the analysis.

A positive value can represent reinforcement under a functional whose larger values correspond to the relevant objective. A negative value can represent interference. The sign carries meaning only after the evaluative convention is defined.

The structural source of interaction can then be examined separately. The components may act upon the same state variable, alter different parts of a feedback loop, reshape the network through which another intervention propagates, or modify the background conditions required for implementation.

11.7 Structural Complementarity

This subsection develops complementarity among interventions operating at different structural depths. Its objective is to identify governance arrangements in which one layer supplies conditions required for another layer to function effectively.

A formal entitlement can require background accessibility. A feedback system can require relational channels capable of transmitting observations and responses. A polycentric architecture can require rules defining competences among decision centers. A common infrastructure can require governance rules for access and maintenance.

Structural complementarity can therefore be represented as dependence of one intervention's effect upon the presence of another intervention. A conditional effect is represented by Equation 98.

$$\mathcal{E}_{i}\left(\mathcal{U}_{i} \mid \mathcal{U}_{j}\right) \neq \mathcal{E}_{i}\left(\mathcal{U}_{i} \mid \mathrm{Id}\right), \tag{98}$$

where $\mathcal{E}_{i}$ denotes a domain-specific effect representation. Equation 98 identifies dependence of the effective operation of intervention i upon intervention j.

This concept is useful because apparent failure at one layer can arise from a missing complementary structure elsewhere. Repeated strengthening of a formal rule can have limited effect when the principal obstacle lies in information, institutional access, network connectivity, or administrative capacity.

Compositional diagnosis can therefore redirect governance attention from instrument intensity toward structural complementarity.

11.8 Structural Substitution and Outcome Equivalence

This subsection examines cases in which interventions at different structural layers produce similar values of a selected observable over a defined horizon. Its objective is to distinguish short-horizon outcome equivalence from structural equivalence and to provide a framework for comparing alternative governance pathways.

Let $\mathcal{O}$ denote a selected observation map. Two interventions are observationally equivalent to tolerance ϵ over horizon τ when the condition in Equation 99 holds.

$$D_{Y}\left[\mathcal{O}\left(\mathcal{T}_{\tau} \circ \mathcal{U}_{a}(\mathfrak{S})\right), \mathcal{O}\left(\mathcal{T}_{\tau} \circ \mathcal{U}_{b}(\mathfrak{S})\right)\right] \leq \epsilon. \tag{99}$$

Equation 99 defines equivalence relative to an observation space Y, a horizon, and a tolerance.

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A direct subsidy and a background reduction in access costs can produce similar short-term participation rates. A prohibition and a technical architecture can produce similar immediate reductions in an activity. A centralized directive and a relational coordination reform can produce similar short-term administrative outputs.

Their deeper consequences can differ substantially. The interventions can differ in reversibility, legitimacy, resource requirements, future generativity, relational concentration, resilience, and long-horizon propagation.

Structural substitution therefore expands the governance choice set while requiring comparison across more than one immediate observable.

11.9 Redundancy and Layered Safeguards

This subsection examines governance arrangements in which several mechanisms provide partially overlapping protection against the same class of failure. Its objective is to distinguish productive redundancy from unnecessary duplication and to connect multilayer design with robustness.

A governance system can protect an important condition through an explicit rule, monitoring feedback, distributed institutional oversight, and structural background safeguards. Failure of one mechanism can then be partially compensated by another.

Let q_k denote the availability of safeguard k. A simple reliability representation for independent safeguards is introduced by Equation 100.

$$P_{\text{available}} = 1 - \prod_{k=1}^{m} (1 - q_k) \,. \tag{100}$$

Equation 100 provides an illustrative reliability model under independence. Governance applications commonly involve correlated failures, shared dependencies, and endogenous behavior, requiring a more elaborate representation.

Cross-layer redundancy can be especially valuable when the failure modes of the mechanisms differ. A legal safeguard can remain available when a technical system fails. A distributed institutional network can preserve operational capacity when a central organization becomes unavailable. A durable background infrastructure can preserve access during temporary administrative disruption.

Redundancy can also increase complexity, cost, inconsistency, and uncertainty concerning responsibility. The relevant governance problem concerns the structure and diversity of safeguards as well as their number.

11.10 Temporal Coordination and Intervention Windows

This subsection examines the timing relations among layer-specific interventions. Its objective is to identify intervention windows, delays, duration, synchronization, and staged activation as compositional properties.

Different structural layers can operate on different timescales. A direct state intervention can take effect rapidly. Relational restructuring can require repeated interaction. Capacity-building and infrastructure can require longer formation periods. Background effects can persist after the initiating programme ends.

The timing of composition therefore influences effectiveness. A feedback mechanism introduced before reliable measurement infrastructure exists can operate on low-quality signals. A legal entitlement introduced before administrative capacity exists can generate queues and inaccessible rights. Background investment introduced early can enlarge the feasible set for later rule and dynamical interventions.

Finite-horizon and receding-horizon control provide one formal precedent for repeated planning under updated state information [87]. The corresponding governance principle is to coordinate short-horizon interventions with slower structural development while reassessing the composition as information changes.

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Temporal coordination therefore concerns both intervention order and the timescales over which each layer becomes effective.

11.11 Adaptive Governance Portfolios

This subsection develops a portfolio representation for governance systems whose composition can change in response to evolving evidence. Its objective is to combine multilayer intervention with revisability and finite-horizon decision making.

Let Π_t denote the set of admissible multilayer governance portfolios at time t. A portfolio contains an intervention profile and its associated institutional constraints. The admissible set is represented by Equation 101.

$$\Pi_t = \{\mathbf{U}_t \mid \mathbf{U}_t \text{ satisfies the legal, resource, informational, and operational constraints at } t\}. \quad (101)$$

Equation 101 permits governance design to select among combinations of mechanisms rather than among isolated interventions.

An adaptive portfolio can change as system conditions evolve. Monitoring can show that a direct rule is sufficient under ordinary conditions, while rising sensitivity activates stronger dynamical monitoring. Persistent access problems can motivate a background intervention. Increased concentration can motivate relational restructuring.

The portfolio approach is compatible with the adaptive and experimentalist governance traditions reviewed earlier. Its GR contribution lies in explicitly tracking the structural location of each intervention component.

Adaptive composition also permits intervention components to expire. A temporary crisis rule or intensive feedback regime can be withdrawn after its function is fulfilled while slower background or relational reforms remain in place.

11.12 Metagovernance and Compositional Steering

This subsection connects cross-layer composition with established metagovernance theory. Its objective is to distinguish governance of institutional arrangements from the formal decomposition of structural interventions while identifying their practical intersection.

Sørensen and Torfing analyze metagovernance through tools for shaping the effectiveness and democratic quality of governance networks [122]. Metagovernance can involve institutional design, framing, resource allocation, process management, and participation.

Within the GR framework, a metagovernance intervention can itself contain several structural components. Rules can define the competence of network participants. Relational interventions can alter membership or coordination structures. Dynamical mechanisms can introduce periodic review or performance-sensitive adjustment. Background interventions can provide shared information, resources, or interoperability infrastructure.

Metagovernance therefore operates at a higher institutional level while remaining decomposable according to structural support.

This distinction is important because higher-order governance does not automatically correspond to greater GR structural depth. A metagovernance rule defining who may participate remains an explicit-rule intervention. A shared infrastructure enabling a family of governance networks to coordinate can possess a background component.

Institutional order and structural depth consequently remain independent analytical coordinates.

11.13 Polycentric Composition and Distributed Portfolios

This subsection examines governance composition when different intervention components are distributed across multiple decision centers. Its objective is to combine polycentric architecture with multilayer

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structural intervention.

Ostrom's analysis of polycentric governance emphasizes multiple interacting centers operating across heterogeneous institutional settings [95]. A polycentric system can distribute different governance functions among different centers rather than replicating the same intervention at every location.

Let $D = \{d_1, \ldots, d_m\}$ denote governance centers. A distributed intervention profile is represented by Equation 102.

$$\mathbf{U}_t^{\text{poly}} = \left\{ \mathbf{U}_t^{(d_1)}, \ldots, \mathbf{U}_t^{(d_m)} \right\}. \tag{102}$$

Equation 102 permits each decision center to operate through a different combination of structural layers.

A central government can define common rights, local authorities can operate feedback systems adapted to local conditions, regional institutions can manage cross-boundary relations, and shared infrastructure can provide background support across the system.

Polycentric composition can increase institutional diversity and access to local knowledge. It can also create incompatibility, duplication, gaps, and conflicting cross-layer effects.

The relational architecture among decision centers therefore becomes part of the composition itself.

11.14 Cross-Scale Composition

This subsection examines governance portfolios distributed across spatial, organizational, jurisdictional, and temporal scales. Its objective is to separate scale from structural depth while analyzing interactions among interventions operating at different scales.

A local intervention can act deeply by transforming durable background conditions within a community. A global intervention can act shallowly by establishing a formal reporting rule. Structural depth and institutional scale therefore remain independent.

Cross-scale composition becomes important where processes propagate beyond the jurisdiction responsible for the initiating intervention. Environmental flows, financial networks, supply chains, digital platforms, migration, infectious disease, and communication systems can connect governance actions across scales.

A local relational intervention can depend upon national rule structures and international technical standards. A global background infrastructure can support locally differentiated dynamical governance.

Cross-scale composition therefore requires attention to both vertical and horizontal coupling among governance centers.

11.15 Recursive Policy and System Co-Evolution

This subsection develops the recursive relation between governance composition and the system being governed. Its objective is to formalize the possibility that governance portfolios change the environment from which subsequent governance choices emerge.

Policy-mix research increasingly recognizes the dynamic and co-evolutionary character of interactions among policies, actors, and wider socio-technical systems [40, 108]. The GR framework represents this relation through recursive system and portfolio updates.

The coupled update is represented by Equation 103.

$$\begin{aligned} \mathfrak{S}_{t+\Delta t} &= \mathcal{T}_{\Delta t}\left(\mathbf{U}_t(\mathfrak{S}_t)\right), \\ \mathbf{U}_{t+\Delta t} &= \mathcal{P}_{\Delta t}\left(\mathbf{U}_t, \mathcal{O}_{t+\Delta t}\left(\mathfrak{S}_{t+\Delta t}\right)\right). \end{aligned} \tag{103}$$

In Equation 103, $\mathcal{P}_{\Delta t}$ denotes the governance-portfolio update mechanism. Governance changes the system, the changed system generates new observations, and those observations contribute to subsequent governance composition.

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Political feedback can also change the institutional feasibility of later intervention. Beneficiaries, affected organizations, administrative capacities, public expectations, and interest structures can evolve as a policy operates.

Governance composition therefore possesses its own history. A portfolio at time t can contain residues of earlier interventions, inherited institutions, accumulated infrastructure, and compromises generated by prior political processes.

11.16 Compositional Conflict and Constraint

This subsection examines conflicts among governance components. Its objective is to identify cases in which one intervention constrains the feasibility, operation, legitimacy, or generative effect of another.

A rule can prohibit a relational arrangement required by a collaborative programme. A background infrastructure can create technical lock-in that limits later policy alternatives. A high-frequency feedback regime can reduce the local autonomy required for experimentation. A decentralized network can produce coordination delays incompatible with an emergency-response horizon.

Let $\mathcal{F}(\mathbf{U})$ denote the feasible set generated by a governance portfolio. A compatibility condition for two intervention components is represented by Equation 104.

$$\mathcal{F}\left(\mathcal{U}_i\right) \cap \mathcal{F}\left(\mathcal{U}_j\right) \neq \varnothing. \tag{104}$$

Equation 104 provides a minimal formal condition for simultaneous feasibility. Practical governance can require stronger conditions concerning resource compatibility, legal authority, temporal coordination, and normative acceptability.

Conflict can therefore occur even when each intervention is individually reasonable. Composition introduces constraints generated by the relations among interventions.

11.17 Reversibility and Layered Exit

This subsection examines the ability to withdraw, reverse, or modify governance components across structural layers. Its objective is to identify reversibility as a property of governance composition and to distinguish component-level exit from system-level restoration.

A rule can sometimes be repealed rapidly, while the relations or background structures generated during its operation can persist. Removal of a subsidy does not immediately remove an industry structure created through years of investment. Termination of an organizational partnership does not immediately erase accumulated trust, dependency, or knowledge.

Let $\mathcal{R}_\ell$ denote a reversal operator for layer ℓ. The residual effect after reversal is represented by Equation 105.

$$\mathcal{D}_{\text{res}} = D_{\mathfrak{S}}\left[\mathcal{R}_\ell \circ \mathcal{U}_\ell(\mathfrak{S}),\, \mathfrak{S}\right]. \tag{105}$$

Equation 105 measures the residual system difference after attempted reversal.

A large residual can arise from cross-layer propagation, path dependence, irreversible investment, relationship formation, or background accumulation. Reversibility therefore depends upon both the direct intervention and the history generated after it.

Layered exit strategies can address this problem by specifying which components expire automatically, which require active reversal, and which require longer-term structural repair.

11.18 Compositional Governance under Uncertainty

This subsection examines uncertainty associated with multilayer governance portfolios. Its objective is to distinguish uncertainty about individual mechanisms from uncertainty concerning their interactions and propagated effects.

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Each additional governance component introduces model assumptions, implementation requirements, and possible interactions with the remaining portfolio. Complexity of composition can therefore increase both intervention capacity and epistemic burden.

Interaction uncertainty is particularly important where mechanisms operate at different temporal scales. A background reform can generate effects after the evaluation horizon of a rule intervention. A relational change can alter the feedback properties of a dynamical mechanism after implementation.

Sequential and adaptive portfolio design can reduce some of this uncertainty. Finite-horizon methods provide one formal precedent for repeated re-evaluation under updated state information [87]. Hybrid-system theory similarly provides tools for systems combining continuous evolution with discrete mode changes [48].

The GR framework therefore favors explicit representation of assumptions, monitoring, revision conditions, and propagation channels when complex multilayer intervention is used.

11.19 Cross-Layer Governance Classification

This subsection consolidates the compositional mechanisms developed above. Its objective is to distinguish the principal ways in which layer-specific interventions can be assembled, coordinated, and transformed through time.

Table 11 summarizes the principal forms of cross-layer governance composition.

Table 11 establishes composition as a second level of analysis built upon the four structural layers. The layer taxonomy identifies where an intervention acts. The composition taxonomy identifies how several interventions coexist, interact, propagate, and evolve through time.

This distinction also clarifies the relation between GR and the policy-mix literature. Policy-mix research provides established concepts for instrument interaction, coherence, consistency, policy processes, and historical development [67, 40, 108]. The GR framework adds an explicit structural decomposition of the objects through which those instruments operate.

A coherent policy mix can therefore still possess several structural configurations. One mix may rely primarily upon explicit rules and feedback, while another combines relational restructuring and background investment to pursue a similar policy objective. Their immediate outputs can be comparable while their longer-term generative effects differ.

Cross-layer composition also makes clear that increasing structural depth is only one possible governance strategy. A practical system can require direct rules, rapid dynamical intervention, resilient relational structures, and durable generative backgrounds simultaneously. The analytical task concerns their fit with the system, their interaction, and their temporal coordination.

The following section examines the epistemic and operational conditions under which these interventions can be selected and implemented. Observability, identifiability, model uncertainty, decision time, computational burden, institutional capacity, reversibility, intervention horizon, and severe epistemic limitation are treated as dimensions that constrain the feasible governance architecture.

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Table 11: Taxonomy of cross-layer governance composition

Composition mechanism	**Compositional object**	**Structural operation**	**Analytical significance**
Multilayer intervention	$\mathbf{U}_t$	Direct intervention across several structural layers	Identification of genuine multilayer support
Simultaneous composition	$\mathcal{C}_t$	Concurrent operation of layer-specific mechanisms	Immediate complementarity and interference
Sequential composition	$\mathcal{U}_{1:n}$	Ordered interventions separated by system evolution	Path dependence and staged governance
Order-sensitive composition	Ω_{ij}	Variation of result under intervention ordering	Sequence-dependent governance effects
Cross-layer propagation	$\mathbf{K}(\tau)$	Transmission of structural effects among layers	Direct-effect and propagated-effect differentiation
Structural complementarity	Conditional intervention effects	Mutual support among mechanisms at different layers	Identification of missing enabling structures
Structural substitution	Alternative layer-specific interventions	Similar selected outcomes through different mechanisms	Comparison of governance pathways
Layered redundancy	Multiple safeguards	Overlapping protection through heterogeneous mechanisms	Robustness and failure tolerance
Temporal coordination	Intervention timing and duration	Synchronization, staging, delayed activation, expiration	Alignment of heterogeneous governance timescales
Adaptive portfolio governance	Π_t	Revision of the multilayer intervention portfolio	Revisability under changing evidence
Metagovernance	Governance arrangements	Design and steering of governance modes and institutions	Higher-order institutional composition
Polycentric composition	$\{\mathbf{U}^{(d)}\}$	Distribution of intervention components among decision centers	Local differentiation and distributed governance
Cross-scale composition	Scale-specific intervention profiles	Coordination across jurisdictional and functional scales	Scale-sensitive propagation and responsibility
Recursive co-evolution	$(\mathfrak{S}_t, \mathbf{U}_t)$	Mutual evolution of governance portfolios and governed systems	Historical formation of governance arrangements
Layered exit	$\mathcal{R}_\ell$	Withdrawal or reversal of intervention components	Reversibility and residual structural effects

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12 Epistemic and Operational Conditions of Governance

This section develops the epistemic and operational dimensions that constrain the governance mechanisms classified in the preceding sections. Its role is to distinguish structural availability from practical governability and to identify the information, model, computational, temporal, institutional, and revisional capacities required by different forms of intervention. The analysis proceeds through observation, state estimation, identifiability, model uncertainty, bounded rationality, problem formulation, prediction horizon, computational burden, decision time, naturalistic judgment, institutional capacity, distributed knowledge, reversibility, and severe epistemic and operational limitation. The section concludes with a comparative framework relating these conditions to intervention depth and governance selection.

The distinction is necessary because the existence of a formal governance operator does not establish the practical availability of that operator. Feedback governance requires usable observations. Event-based governance requires detectable triggering conditions. Tangent-space governance requires local directional information. Attractor and bifurcation governance require substantially richer dynamical knowledge. Relational restructuring requires knowledge of dependencies and propagation paths. Generative-background governance can require inference concerning slowly evolving structures whose effects are distributed across long temporal horizons.

Governance therefore takes place through a partial epistemic interface with an evolving system. Formal depth, epistemic depth, and operational capacity form distinct analytical dimensions.

12.1 Observation and State Estimation

This subsection examines the informational relation between the governed system and the representations available to governing actors. Its objective is to distinguish underlying system configuration, observation, and estimated state and to establish the informational foundation required by subsequent governance mechanisms.

The observation relation introduced in Section 6 maps the underlying system into an available measurement. Governance commonly requires an additional inferential step that constructs an estimated system state from a history of observations. This relation is represented by Equation 106.

$$\widehat{\mathfrak{S}}_t = \mathcal{E}_t^{\text{obs}} \left(y_{\leq t}, u_{<t}, \mathcal{M}_t \right), \tag{106}$$

where $\widehat{\mathfrak{S}}_t$ denotes the estimated system configuration, $y_{\leq t}$ denotes the available observation history, $u_{<t}$ denotes prior governance inputs, and $\mathcal{M}_t$ denotes the model used for inference.

Equation 106 separates the governed system from its governance representation. Administrative statistics, inspection reports, network data, expert assessments, surveys, legal classifications, sensor systems, and public reports all provide partial observation channels whose coverage and reliability differ.

Control theory provides a precise concept of observability for dynamical systems. Kalman's state-space formulation distinguishes internal state from input-output behavior and develops observability as a property concerning whether internal states can be reconstructed from available outputs [69]. The exact mathematical criterion depends upon the selected dynamical model.

Governance systems generally face a more heterogeneous observation problem. Important variables can be latent, socially constructed, strategically reported, temporally delayed, or observable only through proxies. Institutional categories can also determine which phenomena enter administrative records.

Observation design therefore constitutes part of governance capacity. Improving a governance mechanism can require improvement of the epistemic interface through which the relevant system variables become visible.

12.2 Observability and Governance Reach

This subsection develops observability as a constraint on governance reach. Its objective is to identify the relation between what a governance mechanism seeks to influence and what the governing institution can reliably infer about that object.

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Let Z denote a structural object of governance and let $\mathcal{O}_Z$ denote the available observation process. A domain-specific observability score is represented by Equation 107.

$$\mathfrak{o}_t(Z) = \mathfrak{O}\left(Z_t, \mathcal{O}_Z, y_{\leq t}\right), \tag{107}$$

where $\mathfrak{O}$ denotes an application-specific measure of inferential access to Z_t.

Equation 107 is intentionally general. A linear control system can use a rank-based observability criterion, while governance applications can require statistical, qualitative, network-based, or institutional measures.

The relevant object also changes across GR layers. State-and-rule governance can require observation of a current legal or administrative condition. Dynamical-process governance can require observation of rates of change, feedback variables, thresholds, or local direction. Relational governance can require reconstruction of connections and dependencies. Background governance can require inference concerning effective accessibility, institutional capacity, slow variables, or historical formation mechanisms.

The informational burden can therefore increase with the complexity of the structural claim being made. This relationship remains domain-dependent. Deep intervention does not automatically require complete knowledge of every lower-layer variable, and shallow intervention can itself require extensive information.

The practical criterion concerns epistemic adequacy for the specific intervention mechanism.

12.3 Identifiability and Model Discrimination

This subsection examines whether available observations can distinguish among alternative models of the governed system. Its objective is to separate state estimation from structural identification and to clarify why similar observed trajectories can support different causal or dynamical explanations.

System identification develops methods for constructing and validating dynamical models from observed input-output data [83]. The discipline distinguishes model structure, parameter estimation, experiment design, prediction error, and model validation.

Let Θ denote a family of candidate parameterizations or structural models. The set of models compatible with current evidence at tolerance ϵ is represented by Equation 108.

$$\Theta_t^\epsilon = \left\{ \theta \in \Theta \;\middle|\; D_Y\left(\widehat{Y}_\theta, Y_t^{\text{obs}}\right) \leq \epsilon \right\}. \tag{108}$$

Equation 108 represents a model-equivalence set under the selected observation and discrepancy structures.

A large set Θ_t^ϵ indicates that several models remain compatible with the available evidence. Governance decisions based on one selected model can then depend substantially upon unresolved structural assumptions.

This issue becomes especially important for attractor, bifurcation, and criticality governance. Observation of an abrupt transition does not uniquely identify the dynamical mechanism that generated it. Similar time series can arise from parameter drift, external shocks, structural change, stochastic forcing, or changes in the observation process.

Model discrimination therefore precedes strong structural claims. Governance can still operate under incomplete identification, while the intervention strategy should reflect the degree of model ambiguity.

12.4 Risk, Uncertainty, and Structural Ignorance

This subsection differentiates several forms of epistemic limitation relevant to governance. Its objective is to separate probabilistically represented risk, parameter uncertainty, structural uncertainty, observational uncertainty, and unknown mechanisms whose probability structure remains poorly specified.

Knight's classical analysis distinguishes risk from uncertainty and gives particular importance to situations in which probabilities themselves cannot be treated as known in the same manner as ordinary

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measurable risks [74]. Contemporary governance problems frequently contain several additional forms of uncertainty at once.

A compact uncertainty profile is introduced by Equation 109.

$$\square_t = \left(\Upsilon_t^{\text{obs}}, \Upsilon_t^{\text{state}}, \Upsilon_t^{\text{param}}, \Upsilon_t^{\text{struct}}, \Upsilon_t^{\text{exo}}, \Upsilon_t^{\text{norm}}\right). \tag{109}$$

In Equation 109, Υ^{obs} concerns measurement, Υ^{state} concerns the current latent state, Υ^{param} concerns model parameters, Υ^{struct} concerns model form, Υ^{exo} concerns future external forcing, and Υ^{norm} concerns uncertainty or disagreement regarding the evaluative criteria relevant to governance.

The final component is especially important in political systems. Uncertainty can concern both what the system will do and which outcome should be institutionally preferred. These dimensions require separate treatment.

Structural ignorance also includes mechanisms absent from the current model. A governance model can be internally precise while omitting a relation, institution, slow variable, or actor response that later becomes decisive.

The GR framework therefore treats uncertainty as structured and multidimensional. Governance design can respond differently to measurement noise, model ambiguity, future disturbance, and normative plurality.

12.5 Problem Formulation and Model Boundary

This subsection examines the construction of the governance problem itself. Its objective is to identify model boundaries, variable selection, actor classification, and objective specification as epistemically consequential choices preceding formal intervention.

Rittel and Webber's analysis of planning problems emphasizes the difficulty of definitive problem formulation in many domains of social policy [107]. Their account draws attention to the relation between problem description, values, institutional plurality, and the effects of attempted intervention.

Within GR, a governance model begins by selecting a system boundary. Let $\mathcal{P}$ denote the full domain of potentially relevant phenomena and let B_t denote the boundary operator selecting the represented system. This relation is introduced by Equation 110.

$$\mathfrak{S}_t^{\text{model}} = B_t\left(\mathcal{P}_t\right). \tag{110}$$

Equation 110 makes model inclusion explicit. Variables, relations, historical processes, and affected actors lying outside B_t can still influence the modeled system.

Boundary selection is especially consequential for background governance. A reform can appear generative within one institutional boundary while externalizing costs, dependencies, or constraints to another domain.

Model boundaries should therefore be documented together with the governance claim. Expansion of a model boundary can change both the apparent problem and the preferred intervention.

12.6 Bounded Rationality and Administrative Attention

This subsection examines cognitive and organizational limits on governance decision making. Its objective is to distinguish the complexity of the governed system from the information-processing capacity of the institution attempting to govern it.

Simon develops bounded rationality as an alternative to decision models that presume exhaustive information, unlimited computation, and complete optimization [118]. His work on administrative behavior places decision processes within organizational structures and emphasizes the practical limits affecting administrative choice [121].

Governance capacity therefore depends upon an attention and processing budget. A simple operational constraint is represented by Equation 111.

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$$\mathcal{C}\left(\pi_t\right) \leq B_t^{\text{cog}}, \tag{111}$$

where $\mathcal{C}(\pi_t)$ denotes the informational and computational burden of governance policy π_t, and B_t^{cog} denotes the available cognitive and organizational processing budget.

Equation 111 can be extended to several resources, including staff time, expertise, data processing, consultation capacity, legal review, political attention, and interorganizational coordination.

A governance mechanism can therefore fail through excessive epistemic demand even when its formal model is valid. Highly detailed state reconstruction can exceed available monitoring capacity. A large optimization problem can exceed the decision window. A governance architecture can require coordination among more organizations than the institution can effectively manage.

Bounded rationality consequently provides a bridge between epistemic and operational constraints.

12.7 Model Granularity and Representational Compression

This subsection examines the level of detail used to represent the governed system. Its objective is to identify the trade-off among descriptive resolution, computational tractability, data availability, and decision relevance.

A model can represent every observable actor individually, aggregate actors into classes, compress network structure into summary statistics, or represent a complex dynamical system through a smaller set of slow variables.

Let $M^{(r)}$ denote a model at resolution r. A model-selection problem can be represented through a pair of quantities describing approximation error and operational burden. This relation is introduced by Equation 112.

$$\mathbf{Q}\left(M^{(r)}\right) = \left(E_{\text{approx}}^{(r)}, C_{\text{oper}}^{(r)}\right). \tag{112}$$

Equation 112 makes explicit that increasing model resolution can reduce some forms of approximation error while increasing operational cost.

Simon emphasizes decomposition and representation as central strategies for dealing with complex designed systems [120]. Modular and hierarchical representation can reduce the amount of information that must be processed simultaneously.

Governance therefore requires fit between model granularity and decision purpose. A crisis decision can require a coarse but rapidly updated model. Long-term background reform can justify slower construction of a richer structural representation.

The relevant question concerns sufficient resolution for the decision at hand.

12.8 Prediction Horizon and Model Degradation

This subsection examines the temporal range over which governance models remain decision-relevant. Its objective is to distinguish local predictive adequacy from long-horizon structural confidence and to identify horizon selection as a governance parameter.

Dynamic complexity can produce substantial divergence between intended and realized consequences through feedback, delay, nonlinear response, and endogenous adaptation. Sterman's system-dynamics treatment emphasizes the importance of feedback structure, delays, and model-based learning in complex organizational and policy systems [123].

Let $E_{\text{pred}}(\tau)$ denote a domain-specific measure of prediction error at horizon τ. A governance prediction horizon at tolerance ϵ is represented by Equation 113.

$$\tau_\epsilon = \sup\left\{\tau \geq 0 \;\middle|\; E_{\text{pred}}(\tau) \leq \epsilon\right\}. \tag{113}$$

Equation 113 defines the horizon over which the selected model remains within the required predictive tolerance.

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The value of τ_ϵ depends upon the system, the observable of interest, the governance decision, and the selected tolerance. A model can support reliable short-horizon directional inference while providing weak long-horizon trajectory prediction.

This distinction supplies the epistemic foundation for tangent-space and finite-horizon governance. Governance can use the portion of the future for which current information has sufficient decision value and revise the model as the horizon advances.

Longer horizons can still be explored through scenarios and structural analysis. Their epistemic status should remain distinct from near-term prediction.

12.9 Decision Time and Operational Windows

This subsection examines the time available for observation, interpretation, coordination, and action. Its objective is to distinguish computational possibility from operational timeliness and to represent governance decisions under finite response windows.

Let Δ_t^{avail} denote the time remaining before the decision loses practical relevance. Let the total governance latency include observation, inference, deliberation, authorization, and implementation. The operational feasibility condition is represented by Equation 114.

$$\tau_{\text{obs}} + \tau_{\text{inf}} + \tau_{\text{delib}} + \tau_{\text{auth}} + \tau_{\text{impl}} \leq \Delta_t^{\text{avail}}. \tag{114}$$

Equation 114 represents a minimum temporal condition for an intervention to arrive within the relevant decision window.

Ordinary administrative settings can permit extended consultation and analysis. Crisis conditions can compress the available horizon sharply. Near critical transitions, the useful intervention window can also contract as system sensitivity increases.

Decision time therefore affects appropriate model complexity. A globally rich simulation whose computation finishes after the critical intervention window has passed possesses limited operational value for the immediate decision.

Temporal feasibility is consequently part of governance adequacy.

12.10 Naturalistic Judgment under Time Pressure

This subsection examines decision making in environments characterized by time pressure, high stakes, changing conditions, and incomplete information. Its objective is to identify experience-based recognition and mental simulation as possible governance resources when exhaustive comparative analysis is operationally unavailable.

Klein's naturalistic decision-making research studies professionals operating under real-world constraints including time pressure, uncertainty, changing conditions, high stakes, and personal responsibility [73]. His Recognition-Primed Decision framework gives an important role to pattern recognition and mental simulation grounded in experience.

The relevance to governance concerns emergency and operational environments in which decision makers possess insufficient time to enumerate and evaluate a large set of possible policies. Experienced actors can recognize a familiar configuration, construct a plausible course of action, simulate a short sequence of consequences, and modify the action when the simulation reveals a problem.

Within GR, this process can be represented as a bounded candidate-generation and simulation procedure. A candidate action set is represented by Equation 115.

$$\mathcal{U}_t^{\text{cand}} = \mathcal{R}^{\text{exp}}\left(\widehat{\mathfrak{S}}_t, \mathcal{H}_t\right), \tag{115}$$

where $\mathcal{R}^{\text{exp}}$ denotes an experience-based recognition process and $\mathcal{H}_t$ denotes relevant institutional history.

A short simulation can then examine one candidate over a limited horizon. This structure is represented by Equation 116.

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$$\widehat{\mathfrak{S}}_{t+k+1} = \widehat{\mathcal{T}}_k \left(\widehat{\mathfrak{S}}_{t+k}, u_{t+k} \right), \qquad k = 0, \ldots, H-1. \tag{116}$$

Equation 116 formalizes a finite sequence of mental or computational simulation without requiring a long-horizon global optimization.

Experience-based judgment has its own epistemic requirements. Reliable recognition depends upon the availability of relevant experience and a sufficiently meaningful relation between past and current environments. Governance institutions should therefore distinguish experienced recognition from unsupported intuition.

12.11 Computational Burden and Search Space

This subsection examines the computational limits associated with governance models and intervention selection. Its objective is to identify search-space growth, simulation cost, optimization burden, and data-processing requirements as operational constraints on formal governance methods.

A multilayer governance portfolio can contain many possible combinations of rules, intervention timings, relational configurations, and background changes. Exhaustive evaluation of these combinations can become infeasible even when each individual component is simple.

Let $\mathcal{P}_t$ denote the candidate governance portfolio space and let $C_{\text{eval}}(p)$ denote the cost of evaluating portfolio p. The computational burden of exhaustive comparison is represented by Equation 117.

$$C_{\text{total}} = \sum_{p \in \mathcal{P}_t} C_{\text{eval}}(p). \tag{117}$$

Equation 117 makes clear that the operational burden depends upon both the number of candidate interventions and the cost of evaluating each candidate.

This limitation becomes particularly severe when evaluation itself requires simulation across uncertain models, network configurations, and long temporal horizons.

Governance can respond through decomposition, heuristics, sampling, local search, scenario restriction, evolutionary search, or staged decision procedures. The selected computational strategy should preserve the distinction between a tractable approximation and a globally established optimum.

Optimization language therefore requires methodological restraint in heterogeneous governance systems. Computational maximization of a selected functional also remains separate from ethical or political justification.

12.12 Institutional Capacity and Requisite Variety

This subsection examines the organizational capacity required to implement a governance mechanism. Its objective is to connect informational complexity with personnel, expertise, authority, coordination, monitoring, and response capacity.

Ashby's concept of requisite variety provides a systems-theoretical basis for comparing environmental variety with regulatory response variety [9]. Governance institutions similarly require a sufficient repertoire of observation and response to address heterogeneous conditions.

A generic capacity profile is represented by Equation 118.

$$\mathbf{C}_t^{\text{inst}} = \left(C_t^{\text{obs}}, C_t^{\text{analytic}}, C_t^{\text{legal}}, C_t^{\text{coord}}, C_t^{\text{impl}}, C_t^{\text{learn}} \right). \tag{118}$$

In Equation 118, the components represent observational, analytical, legal, coordinative, implementation, and learning capacities.

Different GR mechanisms require different profiles. A simple explicit rule can require substantial enforcement capacity. Feedback governance can require continuous monitoring and rapid implementation. Relational restructuring can require coordination among multiple institutions. Background governance can require sustained financing, longitudinal observation, and maintenance across administrative cycles.

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Institutional capacity therefore belongs to the feasibility conditions of governance and can itself become an object of background governance.

12.13 Distributed Knowledge and Heterogeneous Observation

This subsection examines governance systems in which relevant knowledge is distributed among actors, organizations, jurisdictions, and communities. Its objective is to represent epistemic heterogeneity as a structural condition and to identify aggregation, translation, and preservation of local knowledge as governance problems.

Let actor i possess observation map $\mathcal{O}^{(i)}$. The collection of heterogeneous observations is represented by Equation 119.

$$\mathcal{Y}_t = \left\{ y_t^{(i)} = \mathcal{O}_t^{(i)} \left(\mathfrak{S}_t \right) + \varepsilon_t^{(i)} \right\}_{i=1}^{N}. \tag{119}$$

Equation 119 allows different actors to observe different slices of the same governed system.

Local officials can observe implementation details unavailable to central administrators. Communities can possess contextual knowledge absent from formal databases. Central institutions can observe cross-regional patterns that remain invisible locally. Technical experts can observe specialized variables whose interpretation requires domain knowledge.

The governance problem therefore includes epistemic integration. Aggregation can reveal system-wide structure while losing local detail. Decentralized decision making can preserve local knowledge while reducing cross-system coordination.

Relational interfaces and background information infrastructures can mediate this problem by supporting transmission without requiring complete homogenization of local representations.

12.14 Epistemic Delay and Information Aging

This subsection examines the temporal decay of governance information. Its objective is to identify situations in which an observation remains accurate about a past state while becoming less useful for current intervention.

Let observation $y_{t-\delta}$ arrive after delay δ. A domain-specific information-value function is represented by Equation 120.

$$V_{\text{info}} \left(\delta \right) = \mathcal{V} \left(y_{t-\delta}, \widehat{\mathfrak{S}}_t \right). \tag{120}$$

Equation 120 represents the decision value of delayed information relative to the current estimated system condition.

Information aging is especially important in rapidly changing regimes. Administrative data collected annually can remain useful for slow structural analysis while providing limited support for hour-scale crisis intervention. Real-time signals can be valuable for operational feedback while remaining too volatile for identifying long-run structural change.

Governance therefore requires alignment between information frequency and the timescale of the intervention mechanism.

12.15 Intervention Depth and Epistemic Demand

This subsection examines the relation between structural depth and the knowledge required for intervention. Its objective is to provide a comparative framework without imposing a universal monotonic relation between depth and epistemic burden.

For governance mechanism $\mathcal{U}$, an epistemic-demand vector is represented by Equation 121.

$$\mathbf{D}_{\text{epi}} \left(\mathcal{U} \right) = \left(D_{\text{obs}}, D_{\text{id}}, D_{\text{horizon}}, D_{\text{rel}}, D_{\text{background}}, D_{\text{compute}} \right). \tag{121}$$

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In Equation 121, the components represent observational, identification, horizon, relational, background, and computational demands.

A direct state intervention can have low dynamical-model demand while requiring high certainty concerning legal status or factual conditions. Tangent-space governance can require reliable local information while using limited global structure. Attractor governance can require substantial dynamical identification. Network restructuring can require relational information. Metric or background-emergence governance can require extensive evidence concerning persistent conditions and long-horizon propagation.

Structural depth therefore provides one predictor of epistemic complexity without determining it.

The practical design task is to match the intervention mechanism with the available epistemic profile.

12.16 Reversibility and Epistemic Exposure

This subsection examines reversibility as a response to uncertainty. Its objective is to identify the relation among epistemic confidence, intervention magnitude, persistence, and the ability to revise governance after new information appears.

Let $\mathfrak{R}(\mathcal{U})$ denote a domain-specific reversibility measure and let $\square(\mathcal{U})$ denote the uncertainty profile associated with the intervention. An epistemic-exposure representation is introduced by Equation 122.

$$\mathfrak{X}(\mathcal{U}) = \mathfrak{X}(\square(\mathcal{U}), 1 - \mathfrak{R}(\mathcal{U}), H_{\mathcal{U}}), \tag{122}$$

where $H_{\mathcal{U}}$ denotes the relevant temporal horizon of propagated effects.

Equation 122 expresses the conceptual relation among uncertainty, persistence, and long-horizon consequence. The function requires domain-specific definition for quantitative use.

Reversibility can be increased through pilot programmes, sunset clauses, staged implementation, modular architecture, limited initial scope, reversible technical choices, or preservation of alternative institutional pathways.

Some interventions contain persistent effects even after formal withdrawal. Background investment, ecological change, institutional trust, network concentration, and accumulated dependency can all generate residual structure.

Governance under uncertainty therefore benefits from analysis of both direct reversibility and propagated irreversibility.

12.17 Local Governance under Limited Global Knowledge

This subsection develops a governance orientation for systems whose global structure remains weakly identified while useful local information is available. Its objective is to integrate tangent-space reasoning, finite-horizon simulation, viability constraints, and iterative observation into a coherent epistemic strategy.

Let $\widehat{F}_{x_t}$ denote the locally estimated vector field and let H denote a short prediction horizon. The local admissible intervention set is represented by Equation 123.

$$\mathcal{U}_t^{\text{local}} = \{u \mid \widehat{x}_{t+k}(u) \in K_{t+k}, \quad k = 1, \ldots, H\}. \tag{123}$$

Equation 123 identifies interventions whose locally simulated trajectories remain within the selected viable corridor.

The structure combines three ideas developed earlier. Tangent-space governance uses locally available directional information. Viability governance preserves an admissible region. Finite-horizon governance restricts prediction to a temporal range in which the model retains sufficient value.

The resulting governance cycle is iterative. An intervention is selected, the system evolves, new observations become available, the local model is updated, and the next intervention is reconsidered.

This approach is especially relevant when long-horizon prediction is fragile and intervention remains revisable.

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12.18 Criticality and Compressed Decision Windows

This subsection examines epistemic and operational conditions near possible critical transitions. Its objective is to integrate changing sensitivity, observation frequency, intervention delay, and local simulation under compressed decision time.

Critical-transition research suggests that some systems display changing recovery properties before particular classes of regime shift [113]. The statistical interpretation of warning signals requires careful inference because false-positive and mechanism-specific limitations remain possible [23].

Let $d_c(t)$ represent the estimated distance to a modeled critical region. A decision-window function can be represented by Equation 124.

$$\Delta_t^{\text{avail}} = \Psi\left(d_c(t), \dot{d}_c(t), \Upsilon_t^{\text{struct}}\right). \tag{124}$$

Equation 124 represents the available intervention window as a domain-specific function of transition proximity, approach rate, and structural uncertainty.

As the estimated window contracts, governance can shift toward faster observation, shorter simulation horizons, predefined coordination channels, and interventions with comparatively clear local consequences.

A richly detailed global reconstruction can remain useful for preparation and post-event learning. Immediate operational decisions can require a smaller model whose computation and authorization fit the remaining window.

Criticality governance therefore connects system sensitivity with institutional decision architecture.

12.19 Severe Epistemic and Operational Limitation

This subsection consolidates the conditions under which governance operates with simultaneously restricted observation, model identification, prediction horizon, computational capacity, decision time, and institutional resources. Its objective is to define severe epistemic and operational limitation as a governance environment and to identify structurally modest intervention strategies suited to such environments.

A governance environment is represented through an epistemic-operational resource vector. This vector is introduced by Equation 125.

$$\mathbf{R}_t^{\text{gov}} = (O_t, I_t, P_t, C_t, T_t, A_t, V_t), \tag{125}$$

where O_t denotes observation capacity, I_t model-identification capacity, P_t predictive horizon, C_t computational capacity, T_t decision time, A_t institutional action capacity, and V_t revisability capacity.

A severely limited environment occurs when several of these capacities become binding simultaneously. The relevant condition is represented by Equation 126.

$$\mathbf{R}_t^{\text{gov}} \in \mathcal{R}_{\text{constrained}}, \tag{126}$$

where $\mathcal{R}_{\text{constrained}}$ denotes a domain-specific region of jointly binding governance constraints.

Under such conditions, elaborate intervention can exceed the available epistemic and operational budget. Governance can then emphasize observable local conditions, protection of viable corridors, limited intervention magnitude where possible, modular containment, preservation of options, predefined emergency procedures, and repeated reassessment.

This orientation also provides a formal setting for the distinction between active intervention and strategic restraint. Restraint can preserve revisability where available information provides weak support for broad structural transformation. Active intervention can become necessary when available evidence indicates imminent exit from a viable region.

The governance decision therefore concerns the relation among uncertainty, urgency, reversibility, and the cost of delayed action.

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12.20 Operational Restraint and Intervention Thresholds

This subsection examines restraint as an explicit governance strategy under limited knowledge. Its objective is to distinguish strategic preservation of system freedom from institutional inactivity and to formalize the conditions under which intervention is activated.

Let $L_t(u)$ denote the estimated loss associated with intervention u, including intervention error and propagated structural effects, and let $L_t(0)$ denote the estimated loss associated with maintaining the current governance regime over the relevant horizon. An intervention threshold is represented by Equation 127.

$$u_t^* \in \arg\min_{u \in \mathcal{U}_t^{\text{adm}}} \widehat{L}_t(u), \tag{127}$$

subject to domain-specific uncertainty, viability, legal, and temporal constraints.

Equation 127 provides a formal decision structure while leaving the evaluative functional open. The admissible set can include a zero or restraint action.

Restraint can be appropriate when intervention possesses substantial irreversibility and the available model provides weak evidence concerning its effects. Stronger intervention can become appropriate when continued evolution threatens exit from a viable region or when delayed action sharply reduces future options.

This formulation gives operational meaning to the GR interest in $wuwei$ and $wubuwei$ without translating Daoist concepts into a control algorithm. The philosophical lineage concerns governance through conditions, restraint, and non-coercive intervention, while the present formalism concerns decision under uncertainty and reversibility constraints.

12.21 Epistemic Learning and Governance Revision

This subsection examines governance as a process that can generate information for subsequent decisions. Its objective is to connect intervention, observation, model revision, and governance revision within one recursive learning architecture.

Let $\mathcal{M}_t$ denote the current model set and let $y_{t+\Delta t}$ denote observations generated after intervention. A model-update process is represented by Equation 128.

$$\mathcal{M}_{t+\Delta t} = \mathcal{L}\left(\mathcal{M}_t, \mathbf{U}_t, y_{t+\Delta t}\right). \tag{128}$$

Equation 128 represents learning from the relation among prior model, intervention, and subsequent observation.

Governance can therefore possess epistemic value in addition to immediate policy effects. A carefully bounded intervention can reveal causal structure, implementation barriers, relational dependencies, or background constraints.

Experimentalist and adaptive governance already institutionalize forms of iterative learning and revision. The GR formulation adds structural identification: learning can concern which layer actually carries the mechanism responsible for the observed effect.

A rule can appear ineffective because the principal constraint lies in the background. A relational intervention can reveal an unobserved dependency. A feedback mechanism can reveal that the assumed dynamical variable possesses limited predictive value.

Governance learning therefore includes revision of the model of governance itself.

12.22 Epistemic and Operational Classification

This subsection consolidates the dimensions developed above into a comparative framework. Its objective is to provide the criteria required for matching a governance mechanism to the knowledge and institutional capacity available in a specific decision environment.

Table 12 summarizes the principal epistemic and operational conditions.

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Table 12 demonstrates that the choice of governance mechanism depends upon more than structural depth. An intervention must also fit the observation system, model confidence, prediction horizon, computational budget, institutional capacity, and decision window available in the relevant setting.

The relationship between these dimensions can be represented through an epistemic-operational feasibility criterion. This criterion is introduced by Equation 129.

$$\mathcal{U} \in \mathfrak{F}_t^{\mathrm{gov}} \quad \Longleftrightarrow \quad \mathbf{D}_{\mathrm{epi}}\left(\mathcal{U}\right) \preceq \mathbf{R}_t^{\mathrm{gov}}, \tag{129}$$

where $\mathbf{D}_{\mathrm{epi}}(\mathcal{U})$ denotes the epistemic and operational demands of the intervention, $\mathbf{R}_t^{\mathrm{gov}}$ denotes available governance resources, and $\preceq$ denotes domain-specific satisfaction of the relevant capacity constraints.

Equation 129 provides a second filter after structural classification. The four-layer taxonomy identifies where governance acts. The feasibility condition identifies which interventions are supportable under the knowledge and capacity currently available.

This distinction has important consequences for severe epistemic and operational limitation. A sophisticated global model can remain outside the feasible governance set even when its conceptual architecture is attractive. A local, revisable, and comparatively modest intervention can remain feasible because its information and implementation requirements fit the available decision environment.

Governance quality therefore depends partly upon epistemic fit: the structural ambition of intervention should correspond to the reliability of the knowledge and institutional capacity supporting it.

The following section develops the normative implications of the taxonomy. Structural depth, dynamical sophistication, relational reach, and background generativity provide descriptive properties of governance. Their ethical and political evaluation requires additional criteria concerning procedural justice, asymmetry, participation, generative capacity, value circulation, non-destruction, sustainability, revisability, and the distribution of epistemic authority.

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Table 12: Epistemic and operational dimensions of governance

Governance condition	**Analytical object**	**Primary constraint**	**Governance relevance**
Observation	$\mathcal{O}_t$, y_t	Coverage, noise, delay, classification	Availability of decision-relevant evidence
State estimation	$\widehat{\mathfrak{S}}_t$	Latent-state reconstruction	Alignment between intervention and current system condition
Observability	$\mathfrak{o}_t(Z)$	Inferential access to the intervention object	Feasibility of state-, dynamic-, relational-, or background-sensitive action
Identifiability	Θ_t^{ϵ}	Multiplicity of models compatible with evidence	Confidence in causal and dynamical structure
Uncertainty	$\square_t$	Observation, parameter, structural, exogenous, and normative uncertainty	Calibration of intervention commitment
Problem formulation	B_t	System boundaries and variable selection	Scope of the governance representation
Bounded rationality	B_t^{cog}	Limited attention and information processing	Feasible administrative decision complexity
Model granularity	$M^{(r)}$	Resolution and operational cost	Fit between representation and decision purpose
Prediction horizon	τ_ϵ	Temporal degradation of predictive reliability	Selection of local, finite-horizon, or long-horizon mechanisms
Decision time	Δ_t^{avail}	Observation-to-action latency	Operational viability of governance response
Computational capacity	C_{total}	Search and simulation burden	Feasible intervention comparison
Institutional capacity	$\mathbf{C}_t^{\text{inst}}$	Expertise, authority, coordination, implementation	Practical execution of the governance mechanism
Distributed knowledge	$\{\mathcal{O}^{(i)}\}$	Heterogeneous epistemic access	Need for decentralization, aggregation, and interfaces
Reversibility	$\mathfrak{R}(\mathcal{U})$	Persistence and residual structural effects	Exposure to intervention error
Criticality	$d_c(t)$ and transition evidence	Changing sensitivity and compressed response windows	Adjustment of observation and intervention intensity
Governance learning	$\mathcal{L}$	Model revision through intervention and observation	Iterative improvement of structural understanding

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13 Normative Implications for Generative-Relational Governance

This section develops the normative interpretation of the Generative-Relational governance taxonomy. Its role is to distinguish structural classification from ethical and political evaluation and to identify the normative dimensions that become visible once governance is analyzed across states, processes, relations, and generative backgrounds. The discussion develops procedural legitimacy, inclusion, effective possibility, value circulation, generative asymmetry, dependency, subject preservation, minimum generative safeguards, revisability, epistemic justice, differential governance, temporal responsibility, and cross-scale framing. The section concludes with a plural evaluative architecture that preserves disagreement among normative criteria and supports comparative judgment across governance alternatives.

The four-layer taxonomy developed in the preceding sections is descriptive in its primary function. It identifies the structural object through which a governance intervention acts, the mechanisms through which that intervention propagates, and the epistemic and operational conditions required for its implementation. Structural depth supplies no independent judgment concerning justice, legitimacy, desirability, or moral worth.

This separation is essential because every structural layer can support governance of very different normative quality. Explicit rules can protect rights or institutionalize exclusion. Feedback can support responsive public services or pervasive surveillance. Relational restructuring can distribute authority or consolidate dependency. Background intervention can enlarge substantive opportunities or create durable structures of domination. Normative assessment therefore requires criteria additional to the structural taxonomy.

The Generative-Relational approach developed here treats those criteria as plural and revisable. Generativity supplies an important object of normative attention while remaining one consideration among others. Procedure, participation, dignity, effective freedom, value circulation, distribution, asymmetry, sustainability, epistemic conditions, and historical responsibility can all constrain the evaluation of governance.

13.1 Structural Classification and Normative Evaluation

This subsection establishes the formal separation between structural classification and normative evaluation. Its objective is to prevent descriptive properties such as structural depth, dynamical stability, controllability, resilience, or generative capacity from functioning as implicit normative rankings.

Let $\mathcal{U}$ denote a governance intervention and let $\Lambda(\mathcal{U})$ denote its structural-layer classification. A normative evaluation is represented separately by Equation 130.

$$\mathcal{N} : (\mathcal{U}, \mathfrak{S}, \mathcal{H}, \mathcal{P}) \longmapsto \mathbf{n}, \tag{130}$$

where $\mathcal{H}$ denotes the relevant historical context, $\mathcal{P}$ denotes the set of affected perspectives and institutional positions, and $\mathbf{n}$ denotes a multidimensional normative profile. Equation 130 keeps normative evaluation dependent upon the intervention, system, history, and affected relations.

The normative profile is represented by Equation 131.

$$\mathbf{n} = \left(n_{\text{proc}}, n_{\text{incl}}, n_{\text{gen}}, n_{\text{circ}}, n_{\text{asym}}, n_{\text{epi}}, n_{\text{rev}}, n_{\text{temp}}, \ldots\right). \tag{131}$$

In Equation 131, the components refer respectively to procedural quality, inclusion, generative conditions, value circulation, asymmetry, epistemic justice, revisability, temporal responsibility, and other domain-specific considerations.

The vector representation is deliberate. The foundational framework does not reduce all normative dimensions to a single cardinal utility. Two governance arrangements can display different profiles and require comparative political or ethical judgment concerning the importance of their competing properties.

This orientation has affinities with Sen's comparative approach to justice, which emphasizes reasoned comparison among realizable alternatives and gives substantial attention to actual lives, freedoms,

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capabilities, public reasoning, and plural grounds of judgment [116]. The present framework uses a related comparative orientation while retaining the specific Generative-Relational concern with evolving relational conditions.

13.2 Procedural Legitimacy and Institutional Treatment

This subsection examines the procedural conditions under which governance is formulated, applied, reviewed, and revised. Its objective is to establish that the structural effectiveness of an intervention remains normatively distinct from the legitimacy of the procedure through which it becomes authoritative.

Procedural justice research demonstrates that people's evaluations of legal authority depend substantially upon their experience of fairness, voice, respect, and legitimacy. Tyler's empirical work gives procedural justice a central role in explaining the legitimacy attributed to law and legal authorities [129].

Procedural evaluation in GR therefore concerns several stages of governance: problem formulation, representation of affected actors, production of evidence, decision procedures, implementation, opportunities for challenge, review, and later revision.

Habermas's discourse-theoretic account of law and democracy provides a philosophical foundation for treating legitimacy as connected to procedures of participation, communication, and justification [54]. Procedural structure determines whose reasons enter the process and how collectively binding decisions become institutionally justified.

A procedural profile can be represented conceptually through Equation 132.

$$\mathbf{p} = \left(p_{\text{voice}}, p_{\text{reason}}, p_{\text{trans}}, p_{\text{review}}, p_{\text{account}}, p_{\text{respect}}\right), \tag{132}$$

where the components denote voice, reason-giving, transparency, review, accountability, and respectful institutional treatment.

The purpose of Equation 132 is organizational. The components require domain-specific operationalization and can remain qualitative where numerical representation would create false precision.

Procedural legitimacy becomes relevant across every GR layer. A background intervention affecting future access can require broader participation than a routine operational adjustment because its consequences can persist across groups and generations. A high-frequency feedback system can require particularly strong accountability because many interventions occur outside ordinary case-by-case deliberation.

Structural depth can therefore change the procedural requirements appropriate to an intervention without supplying a procedural judgment by itself.

13.3 Inclusion, Participation, and Representational Access

This subsection examines the capacity of affected actors to enter governance processes as recognizable participants. Its objective is to distinguish formal availability of participation from the effective capacity to contribute knowledge, claims, reasons, narratives, and interests to collective decision-making.

Young's account of inclusion emphasizes that formal deliberative settings can contain internal forms of exclusion generated through communication norms, social position, and unequal power [136]. Her discussion of political communication broadens the recognized forms through which participants can contribute situated knowledge and perspectives.

This distinction corresponds closely to the GR separation between formal rule and effective generative background. A procedure can grant every actor a formal right to speak while background differences in language, time, expertise, institutional confidence, disability access, economic resources, or social recognition produce sharply unequal effective participation.

For participant i, formal participatory access can be represented by P_i^R, while effective participatory capacity depends upon the wider background. This relation is represented by Equation 133.

$$P_i^{\text{eff}} = \mathcal{C}_i\left(P_i^R, \mathcal{B}_t, C_t\right), \tag{133}$$

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where $\mathcal{C}_i$ denotes the actor-specific conversion of formal participatory access into effective participation.

Equation 133 makes participation a relationally and institutionally conditioned capacity.

Representation introduces an additional issue. Young treats representation as a relationship involving authorization, accountability, and social perspectives [136]. A governance system can therefore evaluate both direct participation and the relations through which absent, distributed, or marginalized perspectives enter institutional decision processes.

The GR principle of avoiding subject erasure begins from this problem. Governance models can aggregate actors into categories, averages, network nodes, or state variables for analytical purposes. Normative evaluation must retain awareness that such compression can remove perspectives that matter to the justice of the intervention.

13.4 Effective Possibility and Generative Capacity

This subsection examines the normative significance of effective possibility. Its objective is to connect the background concept of generativity with established concern for substantive freedom while preserving the distinction between expanding possible action and determining which possibilities possess ethical value.

Sen's capability approach directs attention toward substantive opportunities and the heterogeneous conversion of resources into effective freedoms [114, 115]. This provides an important conceptual resource for GR because identical rules or resource allocations can produce different effective possibility spaces across actors.

For actor i, the generative set $\mathscr{G}_\tau^{(i)}$ represents accessible future configurations over horizon τ. A governance intervention can change this set in several ways: it can enlarge accessible possibilities, remove possibilities, change their costs, alter their stability, or transform the relations through which they can be realized.

Set enlargement alone provides an incomplete normative criterion. Some newly accessible trajectories can involve domination, exploitation, violence, or destruction of others' generative conditions. Some constraints can protect persons or systems from severe harm and thereby preserve longer-horizon generativity.

The normative concern therefore lies in the *quality and relational compatibility of generative possibilities*. A domain-specific admissible generative set is represented by Equation 134.

$$\mathscr{G}_\tau^{(i),\mathrm{adm}} = \left\{ s \in \mathscr{G}_\tau^{(i)} \;\middle|\; s \text{ satisfies the applicable normative safeguards} \right\}. \tag{134}$$

Equation 134 places normative constraints around generativity while leaving the content of those safeguards open to institutional and ethical justification.

The GR normative orientation therefore values the preservation and development of meaningful generative capacities while resisting the identification of justice with unrestricted expansion of possibility.

13.5 Value Generation and Circulation

This subsection examines the relation between governance, value production, and the circulation of benefits generated through relational systems. Its objective is to connect the GR taxonomy with Eglash's theory of generative justice while preserving the broader scope of the present framework.

Eglash develops generative justice around the capacity of value generators to participate in the benefits and conditions of their own value production and around forms of circulation that return value to the human, ecological, and social systems through which it is generated [37]. Later work applies this orientation to technosocial systems and emphasizes unalienated circular value flows, participatory control, and restorative transformation [38].

This perspective adds a normative dimension that distribution at a single moment can miss. A system can redistribute some outputs while preserving a generative structure that repeatedly extracts value from

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the actors, communities, or environments producing it. Governance can therefore evaluate the circulation process as well as the resulting allocation.

Let $v_{ij}(t)$ denote a domain-specific flow of value from generator or location i toward recipient j. A value-flow structure is represented by Equation 135.

$$\mathcal{V}_t = [v_{ij}(t)]\,. \tag{135}$$

Equation 135 can represent material, informational, ecological, institutional, symbolic, or other forms of value when the relevant domain provides a defensible definition.

A circulation analysis asks how value generated through one set of relations returns to, bypasses, or is extracted from its generative sources. The normative analysis can therefore examine production, recognition, extraction, return, reinvestment, and the reproduction of future generative capacity.

The GR framework adopts this concern as *value-cycle justice*. Its focus extends beyond allocation toward the relational process through which value is generated, recognized, circulated, and capable of supporting subsequent generation.

13.6 Generative Asymmetry and Power

This subsection examines power through asymmetries in the capacity to initiate, redirect, constrain, appropriate, recognize, or reproduce generation. Its objective is to distinguish asymmetry from domination and to identify the conditions under which asymmetric generative capacities become normatively problematic.

Relations commonly contain asymmetries. A court possesses authority that an individual litigant lacks. A central bank possesses monetary capacities unavailable to ordinary firms. A teacher and student possess different institutional roles. An infrastructure operator can possess technical capabilities unavailable to individual users.

Asymmetry therefore carries no automatic normative verdict. The relevant questions concern the origin, scope, accountability, revisability, effects, and circulation structure associated with the asymmetry.

A relational generative asymmetry between actors i and j can be represented conceptually by Equation 136.

$$\Delta_{ij}^{\text{gen}} = \mathbf{g}_i - \mathbf{g}_j, \tag{136}$$

where $\mathbf{g}_i$ and $\mathbf{g}_j$ denote domain-specific vectors of generative capacities.

The vectors can include capacities to create rules, alter relations, mobilize resources, define categories, control infrastructures, distribute knowledge, set agendas, or shape background conditions.

Young's analysis of domination and oppression is relevant because it directs justice analysis toward institutional processes and social relations extending beyond the distribution of discrete goods [135]. The GR framework similarly treats power as embedded within generative relations and institutional reproduction.

Normative concern becomes particularly strong where one actor can repeatedly appropriate another's generation, restrict the other's capacity to revise the relationship, or define the background conditions through which the asymmetry reproduces itself.

Governance can therefore seek accountability and circulation mechanisms around power without assuming that all asymmetry should be eliminated.

13.7 Dependency and Generative Autonomy

This subsection examines dependencies that constrain the capacity of actors or institutions to sustain and revise their own generative processes. Its objective is to evaluate dependency as a relational structure whose normative significance depends upon reciprocity, alternatives, exit capacity, and the distribution of control.

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Dependency is an ordinary feature of relational systems. Organizations depend upon suppliers, individuals depend upon public infrastructure, jurisdictions depend upon higher-level institutions, and governance centers depend upon shared information and resources.

A dependency becomes normatively significant when alternatives are severely restricted and the dependent actor possesses limited capacity to contest, revise, or exit the relation.

Let d_{ij} denote the dependence of actor i upon actor j, and let a_i denote the availability of viable alternatives. A simple dependency profile is represented by Equation 137.

$$\mathbf{d}_i = (\{d_{ij}\}_j, a_i, r_i, e_i)\,, \tag{137}$$

where r_i denotes revisional capacity and e_i denotes exit capacity.

Equation 137 provides a relational description whose normative interpretation depends upon context.

Governance can respond by creating alternative pathways, distributing infrastructure, reducing bottlenecks, increasing procedural voice, or establishing protections around unavoidable dependencies. The relevant intervention can therefore occur through state-and-rule, relational, or background layers.

Generative autonomy in this framework refers to meaningful capacity to participate in and revise the processes through which one's future possibilities are generated. It remains a relational concept because autonomy itself commonly depends upon supportive institutions, resources, knowledge, and social relations.

13.8 Subject Preservation and Heterogeneous Generativity

This subsection develops the normative requirement that governance preserve the recognizability of heterogeneous subjects within processes of aggregation, modeling, and intervention. Its objective is to address subject erasure arising when governance reduces participants to interchangeable units within a single optimized system representation.

Governance requires abstraction. Administrative systems classify persons, network models represent actors as nodes, dynamical systems compress behavior into state variables, and policy evaluation aggregates outcomes. Such abstractions can be operationally necessary.

Normative difficulty arises when the abstraction eliminates distinctions that matter to the affected subjects themselves. Different actors can possess different histories, vulnerabilities, purposes, languages, social positions, or forms of generation that a common metric fails to represent.

Young's work on difference and inclusion provides an important resource for this problem because it treats differentiated social perspectives as relevant to democratic and justice analysis [135, 136]. Rawls's later political philosophy similarly takes enduring reasonable pluralism as a central condition of modern democratic society [105].

GR therefore treats heterogeneous generativity as a normative fact requiring institutional attention. A common governance framework can coordinate different actors while allowing their generative functions, evaluative vocabularies, and legitimate forms of life to remain heterogeneous.

The resulting concern can be expressed through a preservation condition. For a governance transformation $\mathcal{U}$, actor-relevant distinctions contained in representation ρ_i should remain available to the extent required for justified governance. This relation is represented by Equation 138.

$$\rho_i\left(\mathfrak{S}\right) \longrightarrow \rho_i\left(\mathcal{U}(\mathfrak{S})\right) \tag{138}$$

subject to preservation of normatively relevant distinctions defined through the applicable institutional process.

The condition does not require preservation of every existing identity, category, or relation. Governance can legitimately transform harmful structures. The requirement concerns justification for the distinctions preserved, transformed, or erased.

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13.9 Minimum Generative Safeguards

This subsection develops minimum safeguards around the generative capacities of affected actors and systems. Its objective is to establish a constraint-based normative structure suitable for governance under plural values and limited knowledge.

The foundational normative presumption is that governance should exercise particular caution toward interventions that severely and irreversibly destroy the conditions through which others can continue to act, relate, learn, contest, recover, or participate in future generation.

This presumption can be represented through a family of minimum generative constraints. The admissible governance set is introduced by Equation 139.

$$\mathcal{U}_t^{\text{norm}} = \left\{ \mathcal{U} \in \mathcal{U}_t^{\text{feas}} \;\middle|\; G_k\left(\mathcal{U}, \mathfrak{S}_t\right) \geq \underline{G}_k, \quad k = 1, \ldots, m \right\}. \tag{139}$$

Equation 139 represents a family of domain-specific lower safeguards $\underline{G}_k$ associated with relevant generative conditions.

The safeguarded dimensions can include physical security, legal agency, minimum institutional access, communicative capacity, ecological viability, basic resource access, opportunities for contestation, or other conditions required by the domain.

The formalism deliberately uses constraints rather than maximization. Governance can seek good outcomes inside an admissible region while avoiding the assumption that increasing a single quantity of generativity produces increasing justice.

Safeguards can conflict, and emergency conditions can create tragic choices. The framework therefore supplies a structure for identifying threatened generative conditions and making their sacrifice institutionally explicit, reviewable, and revisable where possible.

13.10 Revisability and Institutional Self-Correction

This subsection examines revisability as a normative property of governance under uncertainty and historical change. Its objective is to connect epistemic humility with institutional capacity for correction, challenge, learning, and reversal.

The preceding section showed that governance operates under partial observability, model uncertainty, bounded rationality, and changing system conditions. Normative governance therefore requires mechanisms through which decisions can be reconsidered when their assumptions or consequences change.

Revisability can include appeals, periodic review, sunset provisions, constitutional amendment, scientific reassessment, participatory monitoring, experimental implementation, modular design, and preservation of alternative institutional pathways.

A revisability profile is represented by Equation 140.

$$\mathbf{r} = \left(r_{\text{challenge}}, r_{\text{review}}, r_{\text{update}}, r_{\text{reverse}}, r_{\text{repair}}\right). \tag{140}$$

Equation 140 distinguishes capacities for challenge, review, updating, reversal, and repair.

Revisability also has distributive significance. The formal existence of an appeal mechanism provides limited justice where only well-resourced actors can use it effectively. Revision mechanisms therefore depend upon the generative-background conditions of access.

The GR commitment to revisability also applies to its own normative framework. The criteria developed in this section are proposed analytical resources whose interpretation should remain open to historical experience, affected perspectives, and later theoretical correction.

13.11 Epistemic Justice and Governance Knowledge

This subsection examines justice in the production, recognition, and preservation of governance knowledge. Its objective is to connect the observation structures developed earlier with the normative status of participants as contributors to knowledge.

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Fricker develops epistemic injustice through harms associated with a person's capacity as a knower, including testimonial and hermeneutical forms [45]. The concept is directly relevant to governance because institutional decisions frequently depend upon whose testimony, categories, expertise, and interpretive resources receive recognition.

A governance observation system can be technically accurate with respect to the variables it measures while remaining epistemically unjust in its selection of whose experience becomes visible.

The relevant governance process includes at least three stages: production of knowledge, institutional recognition of that knowledge, and preservation of the conditions under which the knowledge remains contestable and revisable.

A simplified epistemic participation profile is represented by Equation 141.

$$\mathbf{e}_i = \left(e_i^{\text{voice}}, e_i^{\text{cred}}, e_i^{\text{interp}}, e_i^{\text{record}}, e_i^{\text{revision}} \right). \tag{141}$$

In Equation 141, the components concern access to voice, credibility, interpretive resources, durable recording, and opportunities for revision.

The GR concern extends beyond consultation. Knowledge formed through shared experience can depend upon relations among participants and upon the conditions under which that experience occurred. Complete outsourcing of such knowledge to an external observer can remove part of the epistemic process through which the knowledge became possible.

Governance records can therefore preserve, where feasible, both substantive claims and relevant conditions of knowing. Such preservation supports later reinterpretation when categories, evidence, or institutional perspectives change.

13.12 Differential Governance and Equal Normative Concern

This subsection examines differentiated intervention under heterogeneous generative conditions. Its objective is to distinguish equal normative concern from mechanically identical treatment.

The background analysis showed that actors can experience different effective metrics, conversion functions, informational conditions, and relational dependencies under a shared formal rule. Identical intervention can therefore generate unequal practical effects.

Sen's capability approach provides an established account of heterogeneous conversion between resources and substantive opportunities [114]. Young's work similarly emphasizes that institutional justice can require attention to differentiated social positions [135].

Differential governance can be represented through actor- or context-dependent interventions. The generic structure is introduced by Equation 142.

$$\mathcal{U}_i = \Pi \left(\widehat{\mathfrak{S}}_i, \mathcal{B}_i, C_i, R \right). \tag{142}$$

Equation 142 permits the intervention to depend upon relevant differences in state, background, and relational position.

Differentiation requires justification because classification itself can produce exclusion, stigma, or arbitrary treatment. Procedural safeguards, review, evidentiary standards, and participation by affected groups therefore become especially important.

The normative objective concerns equality of concern for heterogeneous generative conditions, with the form of intervention determined through publicly justifiable distinctions.

13.13 Value Extraction and Generativity Exploitation

This subsection develops generativity exploitation as a relational pathology in which one component benefits systematically from another component's generation while weakening the conditions through which that generation can continue or return value to its source. Its objective is to extend value-circulation analysis into a general governance diagnostic.

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Eglash's generative-justice framework treats alienated extraction and unalienated value circulation as central normative distinctions [37, 38]. The GR extension focuses on the generative process producing the relevant value and on the conditions required for its reproduction.

Let $G_i(t)$ denote value-generating activity associated with component i, let $X_{ij}(t)$ denote extraction toward component j, and let $R_i(t)$ denote value returned toward the reproduction of i's generative conditions. A diagnostic extraction ratio is introduced by Equation 143.

$$\eta_i(t) = \frac{\sum_j X_{ij}(t)}{G_i(t) + \epsilon}, \qquad \epsilon > 0. \tag{143}$$

Equation 143 is a descriptive indicator and carries normative meaning only after the relevant value forms, legitimate transfers, and reproduction requirements are institutionally specified.

Generativity exploitation can occur through labor, knowledge production, platform participation, ecological extraction, unpaid care, organizational dependency, or other domains in which value production and value control become separated.

Extraction becomes especially problematic where the generating source loses the capacity to reproduce itself, participate in decisions concerning the generated value, receive recognition, or revise the relation.

The governance response can therefore concern distribution, procedure, ownership, relational architecture, or background conditions supporting self-sustaining value cycles.

13.14 Temporal Responsibility and Generative Sustainability

This subsection examines normative responsibility across temporal horizons. Its objective is to distinguish immediate welfare or output from the conditions required for continued generation by future participants.

Governance interventions can shift costs and capacities across time. A policy can increase present output while degrading infrastructure, institutional trust, ecological conditions, knowledge systems, or fiscal capacity required for later generation. A background investment can impose present costs while expanding future effective possibilities.

The relevant normative object is therefore temporally extended. Let $\mathbf{G}_t(\tau)$ denote a vector of generative conditions projected over horizon τ. A sustainability safeguard can be represented by Equation 144.

$$\mathbf{G}_{t+\tau} \in \mathcal{K}_{\text{gen}} \qquad \text{for relevant } \tau, \tag{144}$$

where $\mathcal{K}_{\text{gen}}$ denotes a domain-specific region of generatively viable conditions.

Equation 144 expresses sustainability as maintenance of conditions supporting continued generation across the selected horizon.

Temporal responsibility also concerns irreversibility. Destruction of a slowly generated background can impose constraints upon future participants who had no role in the originating decision.

Revisability therefore becomes more demanding as intervention effects become long-lived or difficult to repair. Background governance in particular requires explicit attention to temporal distribution of benefits, burdens, risks, and institutional options.

13.15 Normative Framing and the Scope of Affected Relations

This subsection examines the boundary defining who counts within the normative evaluation of governance. Its objective is to connect system-boundary selection with political representation and cross-border justice.

Fraser's analysis of justice under globalization emphasizes the political dimension of representation and the problem of framing the community within which claims of justice are considered [44]. Governance can generate injustice through the boundary of representation as well as through distributions or recognition within a fixed boundary.

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The GR framework encounters the same issue formally because every model selects a system boundary B_t. A policy can appear beneficial inside that boundary while transferring costs, extraction, environmental effects, or dependency outside it.

Let $\mathcal{A}_{\text{aff}}(\mathcal{U}, \tau)$ denote the set of actors and systems materially affected by intervention $\mathcal{U}$ over horizon τ. The normative frame is represented by Equation 145.

$$\mathcal{F}_{\text{norm}} = \mathcal{F}\left(\mathcal{A}_{\text{aff}}(\mathcal{U}, \tau)\right). \tag{145}$$

Equation 145 makes the normative frame dependent upon the intervention's relational and temporal reach.

Transnational supply chains, digital platforms, ecological systems, migration, financial networks, and international institutions make this issue particularly important because the jurisdiction making a decision can differ from the set bearing its consequences.

Cross-layer propagation therefore has a normative analogue: the scope of responsibility can expand when effects propagate beyond the institutional boundary of the initiating actor.

13.16 Pluralism and Cross-Context Governance

This subsection examines normative governance across heterogeneous cultural, institutional, and interpretive systems. Its objective is to preserve possibilities for coordination while avoiding premature reduction of plural normative vocabularies to one evaluative representation.

Rawls treats reasonable pluralism as a persistent feature of democratic political life [105]. Young emphasizes differentiated social perspectives and inclusive forms of communication [136]. Sen similarly gives central importance to public reasoning and plurality among defensible grounds of judgment [116].

GR extends this pluralism through the concept of heterogeneous generative systems. Different communities or institutions can employ different languages, categories, histories, and evaluative practices while participating in shared governance relations.

A common governance layer therefore need not require a complete common normative ontology. Interfaces, procedural agreements, shared safeguards, and locally interpreted standards can provide partial coordination.

The normative challenge concerns which structures must be shared for cooperation and which differences can remain locally generated. This problem is especially relevant to international governance, multicultural institutions, federal systems, and cross-jurisdictional standards.

The connection and gauge-like models developed earlier can provide formal representations of cross-context translation when the required mathematical structures exist. Normative pluralism itself remains a philosophical and political problem broader than those formalisms.

13.17 Normative Conflict and Comparative Judgment

This subsection examines governance decisions in which defensible normative criteria point toward different alternatives. Its objective is to preserve conflict among values within the formal framework and to avoid converting normative governance into a single optimization problem.

A governance intervention can improve procedural participation while reducing decision speed. Redundancy can improve resilience while increasing resource cost. Decentralization can improve local autonomy while weakening coordinated redistribution. Strong preservation of existing generative processes can protect communities while slowing institutional transformation sought by others.

Let $\mathbf{n}(\mathcal{U})$ denote the normative profile of intervention $\mathcal{U}$. Comparative judgment between interventions a and b therefore operates on vectors, as represented by Equation 146.

$$\mathbf{n}\left(\mathcal{U}_a\right) \;\leftrightsquigarrow\; \mathbf{n}\left(\mathcal{U}_b\right). \tag{146}$$

Equation 146 uses $\leftrightsquigarrow$ to indicate comparative deliberation among multidimensional profiles. It carries no assumption of a complete numerical ordering.

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Some comparisons can be straightforward when one intervention performs at least as well across all relevant criteria. Others require political judgment, ethical reasoning, bargaining, or procedural resolution because improvement along one dimension entails sacrifice along another.

Sen's comparative account of justice provides a useful philosophical resource for this orientation because practical justice can proceed through reasoned comparison without requiring a complete specification of a perfectly just social order [116].

The GR normative framework therefore supports incomplete ordering where reasonable disagreement or insufficient knowledge prevents a unique ranking.

13.18 Normative Evaluation across Structural Layers

This subsection applies the preceding normative dimensions to the four GR layers. Its objective is to identify characteristic normative questions associated with each structural location while preserving the possibility that every criterion can become relevant at every layer.

State-and-rule governance raises questions concerning authorization, generality, due process, equality before institutions, substantive rights, classification, review, and accessibility. A formally equal rule can operate through unequal background conditions, making cross-layer evaluation necessary.

Dynamical-process governance raises questions concerning surveillance, triggering criteria, intervention frequency, proportionality, automated response, temporal fairness, model uncertainty, and opportunities for human review. Feedback architectures also determine who becomes observable and who controls the response.

Relational-structural governance raises questions concerning participation, dependency, centrality, exclusion, representation, network power, institutional autonomy, interoperability, and distribution of decision authority.

Generative-background governance raises questions concerning substantive access, durable capacity, historical reproduction, path dependence, intergenerational effects, structural extraction, and the authority to redesign conditions that shape broad families of future possibilities.

Table 13 summarizes these characteristic normative concerns.

Table 13 provides characteristic orientations rather than exclusive assignments. Procedural justice matters in background governance, and generative capacity matters in rule governance. The table identifies the questions that become especially salient because of each layer's structural object.

13.19 Generative-Relational Normative Architecture

This subsection consolidates the normative framework developed throughout the section. Its objective is to define a process of governance evaluation that combines procedural justice, generative conditions, value circulation, asymmetry, epistemic justice, revisability, and temporal responsibility without reducing these criteria to a universal scalar objective.

Table 14 summarizes the principal normative dimensions.

Table 14 expresses a process-oriented conception of governance ethics. Justice concerns both the state produced and the relations and processes through which that state is generated, sustained, recognized, challenged, and transformed.

The resulting framework can be summarized through a sequence of normative tasks. Governance identifies affected subjects and relevant system boundaries, examines whether those subjects can participate in knowledge and decision formation, identifies the generative conditions affected by the intervention, traces value and dependency relations, evaluates minimum safeguards and long-horizon effects, preserves revision mechanisms, and compares remaining alternatives through plural public reasoning.

This sequence provides no final algorithm for justice. The absence of a universal scalar objective is substantive: ethical and political judgment contains plural values, heterogeneous subjects, uncertain futures, and contested interpretations whose reconciliation can remain incomplete.

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Table 13: Normative dimensions across Generative-Relational governance layers

Governance layer	**Characteristic concern**	**Normative dimensions**	**Cross-layer implication**
State-and-rule governance	Formal status, obligation, entitlement, institutional decision	Legality, due process, equality, review, accessible rights	Formal equality can depend upon background conditions for effective realization
Dynamical-process governance	Observation, triggering, response, trajectory intervention	Proportionality, surveillance, uncertainty, temporal fairness, review	Process design can redistribute visibility, risk, and intervention burden
Relational-structural governance	Connection, dependency, participation, authority distribution	Inclusion, autonomy, representation, power, redundancy, exit	Relational position can condition effective generativity across actors
Generative-background governance	Access, capacity, structural reproduction, future possibility	Substantive opportunity, sustainability, historical responsibility, value circulation, revisability	Background intervention can reshape broad families of later states, relations, and dynamics
Cross-layer composition	Interaction among mechanisms	Coherence, cumulative burden, complementarity, reversibility, framing	Normative effects can emerge through interaction among individually defensible interventions

The Generative-Relational contribution is therefore structural. It expands the object of normative governance from distributions and decisions toward the relations, dynamics, and backgrounds through which future possibilities are continually generated.

The normative framework also places limits upon generativity itself. Generation that systematically destroys the generative conditions of others, extracts value without sustaining its sources, removes meaningful revisability, or excludes affected subjects from the formation of governance cannot acquire justification merely from increased aggregate generative output.

Justice within the present framework therefore concerns the quality of generative relations and the processes through which those relations remain capable of recognition, contestation, repair, and transformation.

The following section develops the broader discussion of the taxonomy. It examines its relation to established governance classifications, the advantages and limits of structural depth as a taxonomic axis, the status of the mathematical formalism, empirical operationalization, category overlap, model validation, and the research programme required to evaluate the framework across governance domains.

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Table 14: Normative architecture for Generative-Relational governance

Normative dimension	Evaluative object	Governance significance
Procedural legitimacy	Decision and implementation process	Voice, justification, respect, accountability, and institutional legitimacy
Inclusion and representation	Participation structure	Effective access of heterogeneous perspectives to governance formation
Effective possibility	$\mathscr{G}_{\tau}^{(i),\mathrm{adm}}$	Substantive capacity for future action and development
Value-cycle justice	Generation and circulation of value	Relation among production, recognition, extraction, return, and regeneration
Generative asymmetry	Distribution of generative capacities	Power to initiate, constrain, redirect, appropriate, and reproduce generation
Dependency and autonomy	Relational alternatives and revisional capacity	Ability to participate in and revise consequential relationships
Subject preservation	Representational treatment of heterogeneous actors	Protection against unjustified erasure through aggregation and standardization
Minimum generative safeguards	Critical generative conditions	Protection of capacities required for continued participation and recovery
Revisability	Institutional self-correction	Challenge, review, updating, reversal, and repair
Epistemic justice	Conditions of knowing	Recognition, credibility, interpretive access, recording, and revision
Differential governance	Heterogeneous conversion conditions	Context-sensitive treatment under equal normative concern
Temporal responsibility	Long-horizon generative conditions	Sustainability, intertemporal burden, irreversibility, future options
Normative framing	Boundary of affected relations	Identification of relevant subjects across jurisdictions and scales
Plural judgment	Multidimensional normative profile	Comparative reasoning under value conflict and incomplete ordering

14 Discussion and Research Programme

This section evaluates the conceptual status, analytical contribution, limitations, and empirical research programme associated with the proposed Generative-Relational governance taxonomy. Its role is to relate the four-layer architecture to established methods of classification, clarify the status of structural depth as a model-relative analytical coordinate, examine category overlap and boundary cases, specify requirements for empirical operationalization, and identify conditions under which the framework would require revision. The discussion also considers the explanatory value of the taxonomy, the status of its mathematical representations, the empirical demands associated with the generative-background layer, and the research designs required for comparative application across governance domains.

14.1 Taxonomic Status and Concept Formation

This subsection clarifies the methodological status of the proposed taxonomy. Its objective is to distinguish the conceptual architecture established in the present paper from the empirical classification programme required for its subsequent validation.

Classification terminology possesses several established methodological uses. Bailey distinguishes conceptual typologies from taxonomies constructed through the classification of empirical entities and also discusses combinations of conceptual and empirical classification procedures [13]. Collier, LaPorte, and Seawright similarly emphasize the role of typologies in concept formation, dimensional analysis, measurement, and the organization of explanatory claims [30].

Under this narrower methodological vocabulary, the present framework begins as a theoretically constructed typological architecture. It defines a classification dimension, specifies category boundaries,

proposes formal representations, and develops mechanisms associated with each category. Empirical research must subsequently determine whether governance cases can be classified with sufficient reliability and whether the categories generate useful explanatory distinctions.

The term *taxonomy* is retained in the title because the project aims toward an empirically operational classification of governance mechanisms. The word *Towards* therefore has methodological significance. The present paper develops the conceptual coordinate system from which an empirical taxonomy can be constructed, revised, subdivided, or partially rejected.

This status also preserves revisability. Empirical applications can reveal that a proposed subtype combines several mechanisms, that a category boundary requires refinement, or that an additional structural object deserves independent representation. The taxonomy consequently functions as an organized research programme whose categories remain accountable to empirical use.

Sartori's analysis of concept formation provides an additional methodological caution concerning conceptual stretching and the relation between abstraction and empirical differentiation [112]. The Generative-Relational framework therefore requires explicit criteria for each category and domain-specific specification of the formal objects to which its terms refer.

14.2 Position within Governance Classification

This subsection positions the Generative-Relational framework within established governance scholarship. Its objective is to clarify the additional classification coordinate supplied by the paper and the relation of that coordinate to existing theories of institutional form, authority, coordination, scale, adaptation, and governance composition.

Governance scholarship already contains a rich multidimensional classificatory vocabulary. Rhodes identifies several meanings of governance and gives particular attention to self-organizing interorganizational networks [106]. Stoker develops governance through institutional interdependence, blurred boundaries, power dependence, self-governing networks, and collective action [124]. Kooiman develops modes and orders of governance within contexts characterized by diversity, complexity, and dynamism [75]. Ostrom develops polycentric governance around multiple interacting decision centers [95]. Duit and Galaz explicitly introduce nonlinear dynamics, thresholds, cascades, limited predictability, and adaptive capacity into governance analysis [35].

The present taxonomy adds the *structural object of intervention* to this existing multidimensional field. Institutional mode, authority distribution, jurisdictional scale, policy instrument, temporal orientation, and normative quality remain analytically available as separate coordinates.

A polycentric governance arrangement can therefore contain interventions at each GR layer. A network can be governed through explicit rules, adaptive feedback, modification of network topology, or shared background infrastructure. An international organization can use a shallow formal rule across a geographically extensive domain, while a municipality can alter a deep local accessibility structure.

The contribution consequently concerns dimensional decomposition. Governance arrangements described identically along one established dimension can differ substantially in the structural mechanism through which they influence future system evolution.

This additional coordinate is especially useful when comparing policies whose institutional labels conceal different mechanisms. Two regulatory programmes can both be described as adaptive governance while one relies principally upon state-dependent feedback and the other upon persistent restructuring of institutional capacities. The GR taxonomy makes this difference explicit.

14.3 Structural Object as a Cross-Cutting Coordinate

This subsection examines the analytical consequences of treating structural object as an independent governance coordinate. Its objective is to show how the four-layer architecture can cross-classify established governance forms without absorbing their disciplinary meanings.

The primary GR question concerns the component directly transformed by an intervention. State-and-rule governance acts upon represented states and explicit rules. Dynamical-process governance acts

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upon system evolution. Relational-structural governance acts upon connections, couplings, dependencies, interfaces, and organizational architecture. Generative-background governance acts upon structures conditioning families of future possibilities, relations, and dynamics.

This coordinate differs from the institutional identity of the governing actor. Courts, ministries, international organizations, private standards bodies, communities, and digital platforms can each operate through several structural layers.

The coordinate also differs from the substantive policy domain. Education, environmental governance, financial regulation, diplomacy, public health, digital governance, and urban planning can each contain all four structural forms.

Governance scale provides another independent dimension. Local, national, regional, transnational, and global systems can employ state-and-rule, dynamical, relational, and background interventions.

The resulting classification space is therefore multidimensional. A complete description of a governance intervention can combine institutional form, jurisdictional scale, instrument family, structural support, temporal architecture, information requirements, and normative profile.

The GR taxonomy supplies one coordinate within this larger descriptive space. Its analytical value depends upon whether that coordinate reveals differences in propagation, epistemic requirements, reversibility, or institutional effects that remain obscure under other classifications.

14.4 Structural Depth and Model Relativity

This subsection examines the status of structural depth as an ordered analytical concept. Its objective is to clarify the dependence of layer assignment upon the selected system representation and to prevent the ordinal depth index from acquiring an absolute ontological interpretation.

The depth ordering introduced earlier locates intervention progressively farther from the directly represented state of the system. Rules constrain states and actions, dynamics generate trajectories, relational structures mediate interactions, and background structures condition families of relations and dynamics.

This ordering is defined relative to a model of the governed system. Different scientific descriptions can choose different state variables, temporal scales, and explanatory boundaries. A quantity represented as an exogenous parameter in one model can become an endogenous state variable in another.

Structural classification therefore requires attention to the *generative role* assigned to the object within the selected model. A background variable acquires Layer IV status because it conditions a family of lower-layer possibilities or mechanisms within that representation. Its label alone provides insufficient grounds for classification.

This model relativity creates a requirement for representation robustness. An intervention classification becomes stronger when reasonable alternative representations of the same governance mechanism preserve its basic structural location.

For example, an information infrastructure can be represented at several levels of resolution. A detailed engineering model may treat its individual servers and transmission processes as dynamical states. A governance model can treat the functioning infrastructure as a background condition enabling a large family of institutional interactions. The appropriate classification depends upon the explanatory question and the mechanism under analysis.

Structural depth should therefore be understood as a model-relative analytical ordering constrained by explicit mechanism specification. The numerical indices introduced earlier serve as ordinal labels for this architecture and carry no cardinal interpretation.

14.5 Mechanism, Instrument, Institution, and Outcome

This subsection consolidates distinctions among governance mechanisms, institutional forms, policy instruments, and observed outcomes. Its objective is to prevent classification from shifting between analytical levels during empirical application.

An institution identifies an organizational or legal arrangement through which governance is authorized or performed. An instrument identifies a technique selected for intervention. A mechanism

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describes the process through which the instrument produces an effect. A structural object identifies the system component directly transformed by that mechanism. An outcome describes a later observed configuration.

These categories can diverge substantially. A subsidy is an economic instrument. Its legal authorization can belong to the rule layer. Its behavioral incentive can alter effective dynamics. Repeated investment generated by the subsidy can reshape relational structures. Durable infrastructure created through the programme can become part of the generative background.

Likewise, a digital platform is an institutional environment rather than one GR mechanism. It can use explicit rules, continuous feedback, network reconfiguration, and interface architecture simultaneously.

Observed outcome similarity also provides limited information about structural mechanism. Several governance pathways can produce similar short-horizon outputs while generating different relational and background consequences.

Empirical research should therefore code the intervention mechanism before classifying the resulting outcome. This ordering preserves the direct-support criterion developed throughout the paper.

14.6 Category Overlap and Polythetic Classification

This subsection examines overlap among governance categories. Its objective is to clarify the decompositional character of the framework and to distinguish multilayer interventions from mutually exclusive case classification.

Many governance arrangements contain several simultaneous mechanisms. Responsive regulation can combine formal sanctions with state-dependent activation. Polycentric governance can combine relational restructuring with locally differentiated rules. An infrastructure programme can combine direct resource transfers with durable background transformation.

The framework therefore permits set-valued classification. A governance programme can occupy several categories when its operative design contains several direct structural supports.

Overlap can also occur within one layer. An intervention can be event-triggered, perturbative, tangent-local, and finite-horizon at the same time. These terms describe different properties of the same dynamical intervention.

This feature makes the proposed classification polythetic in practical use. Cases can share several characteristics without requiring every member of a class to possess one identical list of properties. Bailey's treatment of relationships among typological and taxonomic classification methods provides a useful methodological reference for this flexibility [13].

The presence of overlap therefore represents a substantive property of complex governance mechanisms. Analytical usefulness depends upon whether the decomposition isolates properties that matter for explanation, comparison, or design.

Classification should become more granular where recurrent combinations conceal distinct causal structures. Conversely, categories whose distinctions produce little empirical or explanatory value can be consolidated in later versions of the framework.

14.7 Direct Support and Propagated Effect

This subsection evaluates the distinction between direct structural support and propagated effect. Its objective is to identify the role of this distinction in preserving taxonomic resolution and to clarify the empirical evidence required for its application.

Every consequential governance intervention can influence structures beyond its immediate target. A legal reform can alter behavior, behavior can alter relations, and repeated relational change can contribute to later background formation. Classification by eventual consequence would therefore assign a large share of governance interventions to every layer.

The direct-support criterion addresses this problem by locating the institutional mechanism at the point where governance first transforms the represented system. Cross-layer propagation is then analyzed separately.

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Empirical use requires evidence concerning this mechanism. Legal documents can identify direct changes in rules. Administrative procedures can identify state-dependent intervention. Organizational records can document reconfiguration of institutional relations. Infrastructure and resource data can reveal direct transformation of background conditions.

Temporal evidence can further distinguish support and propagation. An immediate formal transformation followed by gradual relational change supports a different mechanism description from an intervention whose institutional design directly creates the new relation.

Causal ambiguity remains possible. Several structures can change simultaneously, and implementation can depart from formal programme design. Empirical coding should therefore include both intended institutional support and observed operational support where sufficient evidence exists.

14.8 Generative-Background Category Boundaries

This subsection examines the conceptual risks associated with the generative-background layer. Its objective is to prevent the deepest category from becoming a residual container for broad, slow, indirect, or poorly understood causes.

Layer IV carries the greatest risk of conceptual expansion because many governance conditions can be described informally as structural, institutional, cultural, infrastructural, or historical. A useful background category therefore requires a stricter criterion.

The central criterion is structural mediation. A Layer IV object should condition a family of lower-layer possibilities, relations, or dynamics through an identifiable generative mechanism. Persistence, broad scope, or slow change can support this interpretation while remaining secondary properties.

A public database qualifies as background governance when its persistent availability changes the information conditions through which many future interactions become possible. A single disclosure event belongs more naturally to a state, rule, or process representation.

A transportation network can function as background geometry when it systematically shapes accessibility across a domain. A temporary change in traffic routing can belong to dynamical-process governance.

A shared recognition architecture across many jurisdictions can support a connection-like background model. A bilateral recognition agreement between two institutions can remain a relational interface.

This mechanism criterion should be applied conservatively. Cases with weak evidence concerning background mediation can remain provisionally classified at a shallower level or receive an explicitly uncertain multilayer coding.

The strength of Layer IV therefore depends upon disciplined exclusion as much as conceptual expansion.

14.9 Mathematical Formalism and Empirical Correspondence

This subsection evaluates the role of mathematical language within the taxonomy. Its objective is to distinguish formal analytical structure from empirical claims and to specify the correspondence requirements associated with dynamical, geometric, network, field, and gauge-like representations.

The mathematical formalisms used throughout the paper serve three purposes. They clarify category boundaries, expose hidden assumptions, and provide a language from which empirical models can later be constructed.

A dynamical-systems model requires specification of state variables, evolution laws, parameters, observation processes, and relevant temporal scales. Attractor or bifurcation language additionally requires evidence supporting the corresponding invariant or parameter-dependent structure.

A network model requires specification of nodes, relation types, edge direction, weights, and transmission mechanisms. A network diagram alone provides limited evidence concerning the dynamics that propagate through it.

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A metric model requires specification of the underlying space, the meaning of distance or cost, and an empirical procedure for constructing or estimating the metric.

A field model requires a defined base domain, field quantity, measurement procedure, and mechanism connecting field values with local system behavior.

A gauge-like model carries still stronger formal requirements. Local representations, admissible transformation groups, invariant quantities, and a transport structure must be explicitly identified before gauge language acquires analytical content.

These conditions preserve a disciplined relation between mathematical structure and governance interpretation. Formal similarity can generate hypotheses, while empirical correspondence determines whether a mathematical representation becomes an explanatory model of the selected governance system.

14.10 Formal Complexity and Analytical Economy

This subsection examines the trade-off between formal richness and analytical economy. Its objective is to prevent the taxonomy from requiring mathematical structures whose complexity exceeds the needs of the governance problem.

The four-layer framework supports representations ranging from qualitative classification to differential geometry. Empirical application can therefore select the simplest formalism capable of distinguishing the relevant mechanisms.

A licensing reform can be adequately described through rule and access structures without reconstructing a manifold. A network intervention can require graph analysis while possessing little need for field theory. A critical-transition problem can justify nonlinear dynamical analysis when the relevant time series and structural evidence exist.

Formal complexity should therefore follow empirical necessity. Richer mathematical structures become useful when they produce additional discrimination, explanation, prediction, or inferential discipline.

This principle is especially important for interdisciplinary work. Mathematical terminology can create an appearance of precision even when the empirical mapping remains weak. Explicit correspondence criteria and domain-specific measurement protect the framework from this form of pseudo-formalization.

Analytical economy also supports accessibility across governance disciplines. The conceptual taxonomy can be used qualitatively, while mathematically richer versions can be developed in domains where data and modeling assumptions support them.

14.11 Empirical Operationalization

This subsection develops a practical protocol for applying the taxonomy to empirical governance cases. Its objective is to transform the conceptual architecture into a reproducible coding procedure and to identify the evidence required at each stage.

Table 15 summarizes a preliminary operationalization sequence.

Table 15 treats classification as an empirical reconstruction of mechanism. The first stage specifies the unit of analysis because a broad policy programme and an individual instrument can receive different classifications.

The second stage constructs the minimum system representation needed for the governance question. The third stage identifies the operational pathway through which the intervention enters the system. Direct-support coding then assigns one or several GR layers.

Propagation receives separate coding because later effects can travel through structures outside the initial support. Temporal and epistemic coding adds information concerning activation, horizon, observability, and model confidence.

Empirical studies should also record uncertainty in layer assignment. A classification supported by explicit legal and implementation records deserves a different evidentiary status from one inferred indirectly from aggregate outcomes.

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Table 15: Preliminary operationalization protocol for Generative-Relational governance classification

Analytical stage	Empirical object	Evidence base	Coding output
Case delimitation	Governance intervention and temporal window	Legal documents, programme records, institutional descriptions	Defined unit of analysis
System representation	Relevant states, rules, dynamics, relations, and backgrounds	Domain literature, administrative data, expert and participant evidence	Preliminary $\mathfrak{S}$ representation
Mechanism identification	Operational pathway of intervention	Implementation records, procedures, observations, interviews	Mechanism description
Direct-support coding	Immediate transformed structural object	Temporal and institutional evidence	Layer assignment $\Lambda(\mathcal{U})$
Propagation coding	Subsequent cross-layer effects	Longitudinal, network, process, or causal evidence	Propagation structure
Temporal coding	Activation, duration, sequence, and horizon	Programme timelines and system observations	Temporal profile
Epistemic coding	Observation, model, and uncertainty conditions	Data systems, models, expert assessments	Epistemic-operational profile
Compositional coding	Interactions among intervention components	Policy documents and implementation evidence	Multilayer portfolio
Normative coding	Affected subjects and evaluative dimensions	Procedural records, distributional data, participant evidence	Normative profile
Confidence coding	Evidence supporting classification	Source triangulation and coder assessment	Classification confidence

Repeated independent coding can provide evidence concerning reliability. Disagreement among coders can reveal ambiguities in the category definitions and thereby contribute directly to revision of the taxonomy.

14.12 Comparative and Explanatory Value

This subsection examines the explanatory contribution that would justify use of the taxonomy beyond descriptive relabeling. Its objective is to identify the types of comparative inference that the structural categories are expected to support.

The first expected contribution concerns epistemic requirements. Governance mechanisms acting on different structural objects should exhibit different information demands. Feedback requires suitable observations, relational restructuring requires information concerning dependency architecture, and background governance can require knowledge concerning long-horizon structural mediation.

The second contribution concerns propagation. A direct rule change and a background intervention can produce similar immediate outcomes while generating different downstream effects.

The third contribution concerns reversibility. Interventions whose effects become embedded in relationships, infrastructures, or background reproduction mechanisms can generate residual structure after the initiating policy is withdrawn.

The fourth contribution concerns composition. Similar policy instruments can interact differently according to the structural layers through which they operate.

The fifth contribution concerns diagnosis. A governance failure observed at one layer can result from a missing complementary structure elsewhere. A formal entitlement can be institutionally valid while background access remains weak. A feedback system can possess adequate information while the relational architecture prevents coordinated action.

These propositions convert the taxonomy into an explanatory research programme. Empirical value

will depend upon whether structural classification improves analysis of such outcomes beyond classifications already available in governance scholarship.

14.13 Empirical Evaluation and Disconfirmation

This subsection specifies conditions under which empirical research would weaken, revise, or reject components of the proposed framework. Its objective is to make the taxonomy accountable to observable classification performance and explanatory usefulness.

Several forms of evidence would motivate substantial revision.

First, repeated empirical coding may produce low agreement even after clear training and adequate case information. Persistent disagreement would indicate that category boundaries lack sufficient operational precision.

Second, small and substantively irrelevant changes in system representation may repeatedly shift cases among layers. Such instability would indicate that structural depth is excessively dependent upon arbitrary modeling choices.

Third, direct-support coding may provide little additional explanatory value. If governance outcomes, information requirements, propagation patterns, and reversibility are explained equally well through established classifications, the additional structural coordinate would have limited analytical utility.

Fourth, the generative-background category may absorb heterogeneous residual causes without reproducible criteria. Evidence of this pattern would support division, restriction, or removal of background subcategories.

Fifth, proposed mathematical mappings may fail empirical validation. A system described through attractors can show little evidence of persistent regime structure. A proposed metric can fail to correspond to observed transition costs. A gauge-like model can lack stable transformation rules or empirically meaningful invariants.

Sixth, empirical cases may repeatedly reveal a structurally distinct intervention object that cannot be represented adequately through x, R, F, C, or $\mathcal{B}$. Such cases would motivate an extension or reorganization of the foundational decomposition.

Disconfirmation therefore operates at several levels: category definition, coding reliability, mechanism identification, explanatory contribution, and formal-model correspondence.

The framework becomes stronger through successful revision under such evidence because its stated purpose is generative classification rather than closure of the governance problem.

14.14 Causality, Endogeneity, and Recursive Governance

This subsection examines causal inference within a system whose governance structures and governed processes co-evolve. Its objective is to clarify the difficulty of assigning effects to isolated interventions and to identify recursive causation as a central empirical challenge.

Governance interventions frequently arise in response to the systems they later affect. A crisis can generate a new rule. The rule can reshape institutional relations. Those relations can change future crisis probability. The resulting system then influences later governance reform.

This endogeneity complicates simple comparisons between governed and ungoverned cases. Policy adoption itself can be correlated with system conditions that influence later outcomes.

Cross-layer propagation introduces additional causal pathways. A background reform can affect dynamics indirectly through changes in accessibility and relations. An observed outcome can therefore arise after several mediating steps.

Empirical work should reconstruct these pathways through designs suited to the domain. Longitudinal process tracing, comparative case analysis, network analysis, interrupted time-series designs, natural experiments, simulation, system identification, and mixed-method approaches can each contribute under appropriate assumptions.

The taxonomy supplies the causal objects to be investigated and leaves causal identification to research designs capable of supporting the relevant claims.

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Recursive causation also means that governance can change the parameters of its own future effectiveness. Institutional learning, political feedback, infrastructure, trust, dependency, and organizational capacity can alter the environment confronting subsequent interventions.

This recursive property is a substantive part of governance analysis rather than an error term to be removed from every model.

14.15 Reflexivity and Governance Classification

This subsection examines governance systems containing actors capable of interpreting and responding to the classifications applied to them. Its objective is to identify reflexivity as a limitation on static system representations and as a source of endogenous dynamical change.

Human and institutional actors can learn governance rules, anticipate enforcement, reorganize relations, alter reporting behavior, contest categories, and strategically change their conduct in response to measurement.

A governance classification can therefore become part of the environment it describes. Risk classifications can influence behavior. Performance measures can redirect organizational attention. Platform ranking systems can change content-production strategies. Legal categories can shape institutional identity and mobilization.

This reflexivity strengthens the case for separating rules, dynamics, relations, and backgrounds. A classification introduced at the rule layer can produce adaptive dynamics, relational reorganization, and long-term changes in institutional meaning.

It also constrains prediction. Models estimated from behavior under one governance regime can lose validity after actors learn and adapt to a new regime.

Iterative observation and model revision therefore become particularly important in reflexive governance systems.

14.16 Scale and Domain Transfer

This subsection examines the transfer of the taxonomy across governance domains and scales. Its objective is to specify which components of the framework are intended to remain general and which require reconstruction in each empirical application.

The structural distinction among states, rules, dynamics, relations, and backgrounds is proposed at a high level of abstraction. The empirical content of each object remains domain-specific.

In financial governance, x_t can contain liquidity and exposure states, C_t can represent interbank dependencies, and $\mathcal{B}_t$ can include payment infrastructure and institutional capacity.

In educational governance, states can contain enrolment or qualification conditions, relations can include institutional and pedagogical networks, and backgrounds can include language access, financing, information, infrastructure, and accumulated learning capacities.

In international governance, rules can include treaties and organizational decisions, relations can include diplomatic and institutional networks, and background structures can include interoperability, shared technical standards, communication infrastructures, and persistent distributions of institutional capacity.

Domain transfer therefore requires reconstruction of the system representation and empirical meaning of each formal object.

The taxonomy gains support when structurally similar mechanisms can be identified across domains without forcing domain-specific phenomena into artificially uniform substantive categories.

14.17 Scope Conditions

This subsection specifies the settings in which the taxonomy is expected to provide the greatest analytical value. Its objective is to delimit the scope of the framework according to system complexity, temporal evolution, relational interdependence, and governance heterogeneity.

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The taxonomy is especially suited to governance systems possessing several of the following properties: heterogeneous actors, multiple institutional forms, nonlinear or adaptive processes, changing relations, partial observability, cross-scale interaction, path dependence, and interventions operating through several mechanisms.

Simple governance settings can require only a subset of the architecture. A straightforward administrative status correction can be adequately represented at the state-and-rule layer. Additional structural decomposition adds value when the mechanism or propagated effects extend beyond that level.

The framework is also particularly relevant to governance problems in which similar institutional instruments produce different effects across contexts. Relational and background structures provide explicit places for representing such contextual variation.

Applications involving rapidly changing or reflexive systems can benefit from the separation between current state and dynamical mechanism. Applications involving persistent inequality of effective access can benefit from the distinction between formal rule and generative background.

The taxonomy therefore provides a variable-resolution framework. Analytical depth can increase with the complexity of the governance problem and the quality of evidence available.

14.18 Limitations of the Present Framework

This subsection consolidates the principal limitations of the present framework. Its objective is to define the boundaries of the contribution and identify the methodological work required before stronger empirical claims can be made.

The first limitation concerns conceptual breadth. The framework spans political theory, governance studies, cybernetics, dynamical systems, network theory, geometry, institutional analysis, and normative theory. Such breadth creates a persistent risk of flattening disciplinary distinctions. The paper therefore uses established concepts in their disciplinary senses and treats proposed GR terms as analytical extensions requiring independent validation.

The second limitation concerns model dependence. The decomposition of a system into x, R, F, C, and $\mathcal{B}$ depends upon modeling choices concerning temporal scale, variables, boundaries, and causal resolution.

The third limitation concerns category boundaries. Real governance interventions frequently possess multilayer support, and several proposed subtypes describe orthogonal properties of one intervention. Empirical coding must therefore preserve overlapping classifications.

The fourth limitation concerns measurement. Background structures, effective metrics, fields, generative sets, and historical emergence mechanisms can be difficult to observe directly.

The fifth limitation concerns causal identification. Governance and governed systems co-evolve, creating selection effects, feedback, and endogenous institutional change.

The sixth limitation concerns formal transfer. Mathematical structures drawn from physics, geometry, control theory, and network science require domain-specific interpretation. Their presence in the formal framework provides analytical possibilities whose empirical validity varies across applications.

The seventh limitation concerns normative plurality. The normative architecture developed in the preceding section provides several evaluative dimensions while leaving conflicts among them open to political and ethical reasoning.

The eighth limitation concerns empirical coverage. The present paper develops the foundational architecture and illustrative correspondences. Comparative case studies, coding exercises, simulations, and domain-specific empirical models remain required to establish the practical value of the taxonomy.

These limitations define the next phase of the research programme.

14.19 Empirical Research Programme

This subsection specifies a staged empirical programme for developing the proposed taxonomy. Its objective is to connect conceptual refinement with case-based validation, measurement, comparative explanation, and formal model testing.

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The first research stage concerns qualitative classification. A diverse set of governance interventions can be coded using the protocol in Table 15. Cases should include legal, administrative, regulatory, networked, international, digital, environmental, and infrastructural governance.

The second stage concerns reliability. Independent coders can classify the same interventions, record confidence, and document disagreement. Recurrent ambiguities can identify category boundaries requiring refinement.

The third stage concerns within-domain comparison. Governance interventions pursuing similar objectives can be compared according to structural support, propagation, information requirements, and reversibility.

The fourth stage concerns cross-domain comparison. Structurally similar mechanisms can be examined across domains to determine whether the taxonomy supports transferable explanatory propositions.

The fifth stage concerns formal operationalization. Selected domains with sufficient data can develop explicit dynamical, network, metric, field, or background-emergence models.

The sixth stage concerns predictive and explanatory comparison. Models including GR structural variables can be compared with models using existing institutional or instrument classifications.

The seventh stage concerns normative and participatory evaluation. Affected actors can contribute to the identification of generative conditions, dependencies, epistemic exclusions, and value-circulation structures that remain poorly represented through administrative data alone.

The eighth stage concerns longitudinal revision. Classification results, failures, and domain-specific extensions can be used to revise the conceptual architecture itself.

This staged programme turns the proposed taxonomy into a cumulative process of concept formation, empirical classification, formalization, and revision.

14.20 Research Programme for Generative-Background Models

This subsection identifies the specific research programme required by the generative-background layer. Its objective is to give the most speculative part of the framework stronger empirical discipline and to separate immediately operational concepts from longer-term mathematical developments.

Generative-condition governance can be studied first through comparatively direct empirical variables such as institutional access, resource availability, information, infrastructure, and capability constraints.

Metric governance requires empirical reconstruction of effective distances. Observed transition costs, travel times, administrative burdens, transaction costs, information requirements, or empirically estimated transition probabilities can provide candidate data depending upon the domain.

Field governance requires spatial, institutional, or relationally indexed measurements of a background quantity and evidence connecting that quantity to local behavior.

Structural-flow models require longitudinal data concerning accumulation, movement, source, depletion, and persistence of the selected background quantity.

Connection models require multiple local representational systems and observed translation or transport rules among them.

Gauge-like governance requires the strongest formal evidence. Research should identify local frames, transformation functions, invariant quantities, and path-dependent transport effects before applying the gauge construction.

Background-emergence governance requires longitudinal evidence concerning the process through which current interactions contribute to later institutional conditions.

This progression permits empirical development from comparatively observable generative conditions toward mathematically richer background structures. Different domains can stop at the level supported by their data and explanatory needs.

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Table 16: Analytical status and validation requirements of the Generative-Relational governance framework

Framework component	Current status	Validation requirement	Revision pathway
Four structural layers	Conceptual classification	Reliable empirical mechanism coding	Boundary refinement or structural reorganization
Structural depth	Model-relative ordinal coordinate	Representation robustness and explanatory value	Domain-specific ordering or qualification
Direct-support criterion	Mechanism-based classification rule	Temporal and institutional evidence	Refined support and propagation criteria
Dynamical subtypes	Formal mechanism family	Dynamical-system identification where mathematical claims are used	Subtype consolidation or expansion
Relational subtypes	Network and institutional mechanism family	Observed relational structure and propagation	Domain-specific relational refinement
Generative-background layer	Proposed structural family	Evidence of lower-layer structural mediation	Restriction, subdivision, or extension
Metric and field models	Conditional mathematical representations	Empirical construction of geometric or field quantities	Domain-specific formal revision
Gauge-like governance	Exploratory formal extension	Local frames, transformations, invariants, and transport structure	Retention in domains satisfying formal requirements
Cross-layer composition	Conceptual and formal integration	Policy-process and longitudinal evidence	Interaction-specific refinement
Epistemic-operational framework	Feasibility coordinate	Observed information and institutional requirements	Domain-specific capacity models
Normative architecture	Plural evaluative framework	Procedural, participatory, and domain-specific justification	Ongoing normative revision

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14.21 Integrated Status of the Framework

This subsection synthesizes the status of the proposed framework after the conceptual, methodological, empirical, and normative qualifications developed throughout the discussion. Its objective is to provide a compact statement of what the taxonomy currently establishes and what remains subject to future research.

Table 16 summarizes the principal components of the research programme.

Table 16 makes explicit the heterogeneous epistemic status of the framework's components. The four-layer decomposition functions as the foundational conceptual proposal. Several dynamical and relational mechanisms possess strong precedents in established mathematical and governance literatures. The generative-background mechanisms range from comparatively direct institutional concepts, such as access and capacity conditions, toward more exploratory geometric and gauge-like formalisms.

The framework should therefore be evaluated component by component. Empirical support for state-and-rule, dynamical, or relational distinctions does not automatically validate every background formalism. Failure of one formal extension likewise leaves the wider structural-object classification open to independent evaluation.

This modular epistemic architecture is consistent with the paper's Generative-Relational orientation. The taxonomy can evolve through selective retention, refinement, subdivision, and removal of components as empirical research accumulates.

The central proposal remains comparatively simple: governance interventions can be classified according to the structural objects through which they enter an evolving relational system. States and explicit rules, dynamical processes, relational structures, and generative backgrounds provide four provisional families of such objects. Cross-layer composition describes their interaction; epistemic-operational analysis constrains their feasible use; normative analysis evaluates their legitimacy and effects.

The research programme therefore shifts the question of governance classification from the institutional name of an intervention toward the mechanism through which that intervention participates in subsequent system generation.

The final section summarizes this contribution, states the scope of the four-layer taxonomy, and identifies its principal implications for governance theory and future empirical research.

15 Conclusion

This paper has developed a Generative-Relational framework for classifying governance according to the structural object through which an intervention enters an evolving relational system. Its objective has been to add a cross-cutting analytical coordinate to established governance classifications organized around institutional forms, modes of coordination, jurisdictional levels, policy instruments, adaptive capacities, and normative traditions. The resulting framework distinguishes four provisional structural layers: state-and-rule governance, dynamical-process governance, relational-structural governance, and generative-background governance. It then extends this architecture through cross-layer composition, epistemic-operational conditions, and plural normative evaluation.

The point of departure was a simple classificatory difficulty. Governance interventions bearing similar institutional labels can operate through substantially different mechanisms, while interventions located in different institutional settings can act upon structurally similar objects. A regulatory programme can change an explicit rule, introduce state-dependent feedback, reconfigure relations among institutions, or alter persistent informational and infrastructural conditions. Network governance can similarly contain rules, feedback mechanisms, relational restructuring, and background infrastructures. Institutional vocabulary therefore identifies one important dimension of governance while leaving room for a complementary account of the structural location through which governing activity affects subsequent generation.

The first layer, state-and-rule governance, concerns direct modification of represented states and explicit institutional structures. Commands, prohibitions, permissions, entitlements, sanctions, constraints, adjudicative determinations, secondary rules, and rule revision belong to this family when their direct structural support lies in the current state or codified rule system. This layer preserves the analytical importance of law, administration, authorization, and institutional status while separating the formal rule from the dynamics through which actors subsequently respond.

The second layer, dynamical-process governance, concerns intervention into system evolution. Feedback governance, event-based governance, perturbative governance, tangent-space governance, viability and corridor governance, attractor-sensitive governance, bifurcation-sensitive governance, criticality governance, finite-horizon governance, and hybrid switching governance identify different properties of intervention into evolving processes. These categories distinguish activation, direction, magnitude, locality, regime structure, prediction horizon, and sensitivity. Their combination provides a vocabulary for governance under nonlinear, state-dependent, and partially observable conditions.

The third layer, relational-structural governance, concerns the architecture through which system components interact. Network topology, tie structure, coupling, boundaries, interfaces, modularity, dependency, multilayer relations, polycentric organization, cascade pathways, redundancy, and temporal network formation become direct objects of governance within this layer. This perspective makes relational constitution operational. An actor's effective capacity can change through its position, dependen-

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cies, interfaces, and available relations even while its internally represented state remains comparatively stable.

The fourth layer, generative-background governance, extends the taxonomy to conditions that shape families of future states, relations, and trajectories. Resource and capacity structures, informational environments, effective accessibility, metrics, fields, symmetry structures, connections, structural flows, historical memory, and endogenous background-formation mechanisms provide several possible representations of this deeper generative context. The central classificatory criterion is structural mediation. A background belongs to this layer when it conditions the generation or accessibility of a family of lower-layer possibilities, relations, or dynamics through an identifiable mechanism.

This fourth layer also provides the most exploratory part of the framework. Generative conditions such as institutional access, information, infrastructure, and capacity can be operationalized comparatively directly in many governance domains. Metric, field, connection, and gauge-like models require increasingly specific mathematical and empirical structures. Geometric or physical vocabulary acquires analytical force only when the modeled space, transformation, invariant, connection, field, or distance has a defensible empirical correspondence. The paper therefore treats these formalisms as conditional research directions whose validity must be established separately in each application.

The distinction between direct structural support and propagated effect is central to the architecture. A governance intervention can begin at one layer and generate consequences throughout the remaining system. A rule can change behavior; behavioral change can reorganize relations; repeated relational change can contribute to future background formation. Classification follows the structural object directly transformed by the intervention, while cross-layer propagation describes the subsequent movement of effects through the system. This distinction preserves taxonomic discrimination in systems where nearly every consequential intervention eventually affects several structures.

The framework also permits genuinely multilayer governance. A programme can directly combine legal rules, feedback mechanisms, relational reconfiguration, and durable background infrastructure. Cross-layer composition therefore forms a second analytical level concerned with simultaneous and sequential intervention, order sensitivity, complementarity, interference, substitution, redundancy, temporal coordination, metagovernance, polycentric distribution, and recursive policy–system co-evolution. Governance arrangements become portfolios of mechanisms whose combined effects depend upon their composition as well as their individual properties.

Structural depth supplies an ordinal description of intervention location within this generative architecture. It carries no independent implication of institutional sophistication, effectiveness, legitimacy, or ethical quality. A direct state intervention can be appropriate during an emergency. An explicit rule can provide clarity and accountability. A relational reform can fail through unrecognized dependencies. A background intervention can create persistent unintended effects. The appropriate depth depends upon the governance problem, available knowledge, temporal window, institutional capacity, reversibility, and normative constraints.

The epistemic-operational analysis therefore adds a necessary second coordinate. Governance mechanisms differ in their demands for observation, state estimation, model identification, prediction, computation, coordination, and implementation capacity. A formally sophisticated mechanism can exceed the information or decision time available to a governing institution. Under severe epistemic and operational limitation, locally supported and revisable strategies can possess particular value. Tangent-space reasoning, viable corridors, finite-horizon simulation, modular containment, event-sensitive intervention, and preservation of reversibility provide possible forms of governance under such conditions.

This perspective also changes the interpretation of restraint. Governance can include deliberate preservation of existing generative freedom when available knowledge provides weak grounds for broad intervention. Active intervention can become appropriate when evidence indicates imminent loss of viability, rapidly increasing sensitivity, or severe destruction of generative conditions. The relevant judgment concerns the relation among uncertainty, urgency, reversibility, and the costs associated with both intervention and continued evolution.

Normative analysis remains distinct from structural classification. The paper has therefore developed

a plural Generative-Relational normative architecture organized around procedural legitimacy, inclusion, effective possibility, value circulation, generative asymmetry, dependency, subject preservation, minimum generative safeguards, revisability, epistemic justice, differential governance, temporal responsibility, and the framing of affected relations. These dimensions place generativity within a wider structure of justice.

Generativity itself receives no universal maximization principle. Expansion of one actor's possibilities can damage the generative conditions of another. Stable generation can reproduce domination. Highly productive systems can extract value from the persons, communities, institutions, or environments through which that value is produced. Governance evaluation therefore concerns the quality of generative relations, the circulation and reproduction of value, the preservation of meaningful contestation and revision, and the conditions under which heterogeneous participants can continue to generate their own futures.

The resulting account also treats governance as historically recursive. States, rules, dynamics, relations, and backgrounds evolve together. Earlier governance interventions can become part of the environment confronting later actors. Repeated institutional processes can generate infrastructures, dependencies, expectations, knowledge systems, and patterns of access that outlive their initiating decisions. Governance therefore participates in the production of its own future conditions.

The proposed taxonomy remains a foundational and revisable architecture. Under a stricter methodological distinction between conceptual typology and empirical taxonomy, the present paper primarily constructs the conceptual structure from which an empirical taxonomy can develop. Comparative case classification, inter-coder reliability, longitudinal process analysis, formal model validation, network reconstruction, dynamical identification, and domain-specific measurement remain necessary for evaluating its empirical utility.

Future research should therefore proceed incrementally. Initial studies can classify well-documented governance interventions according to direct structural support and cross-layer propagation. Within-domain comparisons can then test whether the categories improve explanation of information requirements, reversibility, policy interaction, implementation failure, and long-horizon effects. Domains with sufficiently rich data can support explicit dynamical, network, metric, field, structural-flow, or background-emergence models. Components that repeatedly fail empirical classification or explanatory tests should be refined, consolidated, or removed.

The word *Towards* in the title reflects this status. The framework offers a coordinate system for investigating governance mechanisms and a research programme for revising that coordinate system through empirical and conceptual work. Its categories are intended to support further inquiry rather than close the classification of governance.

The central proposal can therefore be stated compactly. Governance acts within systems that continually generate subsequent states, relations, institutions, and possibilities. Governing interventions can enter that generation through explicit states and rules, through evolving processes, through relational structures, through the backgrounds conditioning future generation, or through compositions of these mechanisms. Identifying that structural location can clarify what an intervention changes directly, what knowledge it requires, how its effects propagate, which forms of reversibility remain available, and which normative relations become consequential.

A Generative-Relational taxonomy of governance thus shifts attention from the name of a governing arrangement toward the structure through which governance participates in the production of what can happen next.

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